Rationalizing the Risk Quantification in Construction Projects: A Prospect Approach

A thesis submitted in partial fulfilment of the

requirements for the degree of

Masters of Science

in

Construction Engineering and Management

By

Muhammad Umer Farooq

(NUST201463351MSCEE15414F)

Department of Construction Engineering and Management
National Institute of Transportation (NIT)
School of Civil and Environmental Engineering (SCEE)
National University of Sciences and Technology (NUST),
Islamabad, Pakistan.

(November, 2016)

بِسمِ اللّٰهِ الرَّحمٰنِ الرَّحِیم

اللہ کے نام سے شروع جو بڑا مہربان، نہایت رحم کرنیوالا ہے۔

In the name of Allah, the most Merciful and Beneficent.

This is to certify that the

thesis titled

Rationalizing the Risk Quantification in Construction Projects: A Prospect Approach

Submitted by

Muhammad Umer Farooq

(NUST201463351MSCEE15414F)

has been accepted towards the partial fulfilment

of the requirements for the degree of

Masters of Science in Construction Engineering and Management

---

Dr. Muhammad Jamaluddin Thaheem

Supervisor,

Department of Construction Engineering and Management,

NIT-SCEE, NUST, Islamabad.

This thesis is dedicated to the People who kept me going when I wanted to give up!

ACKNOWLEDGEMENTS

In the name of Almighty Allah, the most Merciful, the Beneficent. All praise is only for Allah who created us and always planned the best for us. I am very much grateful to the Magnificent Almighty Allah for always helping me through the difficulties in my life and I seek His guidance and pray to Him for blessings and hope till I am alive! (آمین)

I am in debt of gratitude to my research supervisor Dr. Muhammad Jamaluddin Thaheem for his guidance and encouragement at every step of this journey. Furthermore, I would like to thank my mentor for introducing me to the topic as well for the support on the way. The door to Dr. Jamal office was always open whenever I ran into a trouble spot or had a question about my research or writing. He always steered me in the right direction whenever he thought I needed it. Indeed, he is the real meaning of a teacher and a spiritual father. His motivation, appreciation and time made this study possible. I am also grateful to my guidance committee members, Dr. Hamza Farooq Gabriel, Dr. Abdul Waheed and Dr. Ahsen Maqsoom for their genuine supervision.

Also, I like to thank the participants in my survey, who have willingly shared their precious time during the process of interviewing. I would like to thank my classmates who have supported me throughout the entire process, both by keeping me harmonious and helping me putting pieces together. Their love, respect, cheerfulness, and intellect were my support and lead. I thank to them for being there when I needed strong spirits and motivation. I am obliged for their contributions in this study as well as in other events.

Last but not the least; I would like to pay my earnest gratitude to my loved ones, my family, my parents, and my siblings, for their absolute support, encouragement, prayers and fortitude.

Thank you, Ammi, Abbu, Fatima and Adnan for being the best the world has to offer. You all are my life and will be the most beautiful thing ever.

ABSTRACT

Construction projects are prone to risk of unparalleled degree due to their size, complexity, resource utilization, safety hazard and dynamic nature. If not managed properly, risk may increase the possibility of project failure. For effective management, it is vigorously assessed using qualitative, quantitative and simulation-based methods. The metrological underpinning of risk is based on well-grounded Expected Utility Theory which stands as a de facto standard of risk quantification. This theory, however intuitive and logical, is a normative way of measuring risk and has been criticized for its averaging method. Also, it does not reflect the behavioural tendencies of decision makers into realistic risk quantification. To improve upon the state of art, Prospect Theory (PT) was proposed which better captures the intricacies of human nature into risk quantification. It uses the concept of probability weighting function to truly reflect the significance of risky prospect. It has been extensively used in financial decision making, giving birth to a new field of Behavioural Economics. However, the construction industry lacks the applications of PT and still resorts to conventional methods.

This study aims at investigating the prospect weights to better quantify risk in construction projects by rationalizing the over- and under-estimating pattern of decision makers in the face of threats and opportunities respectively. In doing so, a detailed scenario-driven, semi-structured, interview-based data collection is performed engaging senior project management professionals from construction industry of Pakistan. It is revealed that on average construction professionals underestimate the opportunities by 7.5% and overestimate the threats by 8%. Factoring these findings into the development of response strategies will result into realistic and effective contingencies, and justified resource allocation. The body of knowledge will benefit from this novel development of rationalizing factor which may trigger more research into better measurement of risk.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF EQUATIONS

LIST OF ABBREVIATIONS

PI	Probability and Impact
EMV	Expected Monetary Value
EUT	Expected Utility Theory
PT	Prospect Theory
DSS	Decision Support System
FST	Fuzzy Set Theory
AHP	Analytical Hierarchy Process
RV	Reference Value
EV	Expected Value
NUST	National University of Sciences and Technology
GM	General Manager
PM	Project Manager
RE	Resident Engineer
PD	Project Director
CEO	Chief Executive Officer

Chapter 1

INTRODUCTION

1.1 Overview

No construction projects are risk free. Project uncertainties may hinder the successful completion by causing time and budget over-run, and quality default (Ali et al., 2007). Performance of a construction project is compromised due to poor risk assessment at planning stage of the project which results in ineffective and flawed results. Construction industry has a poor reputation in risk analysis when compared with other industries such as finance or insurance (Laryea, 2008). Keeping construction projects within estimated costs and schedules requires sound strategies, good practices, and careful judgment (Enshassi et al., 2009). In this connection, effective risk management cannot be ensured without appropriate and balanced assessment. It is an established fact that what cannot be measured cannot be managed (Broadbent, 2007). Thus the realistic and rationalized quantification of risk would go a long way in ensuring project success (PMI, 2013).

1.2 Risk Assessment Techniques

There are many risk assessment and quantification techniques including probability and impact (PI) matrix, risk urgency assessment, sensitivity analysis, expected monetary value (EMV) analysis, modelling and simulation (e.g. Monte Carlo Simulation), etc. (PMI, 2013). These methodologies are often complicated to implement, involve complex mathematics that are beyond the reach of many decision makers and still result in a fairly wide dispersion of data (Conrow, 2003). For simplicity, decision makers mostly use Expected Monetary Value (EMV) technique to quantify the risk. One of the latest attempts to use probability analysis to a risk event can be traced back in the 20th century by Von Bortkiewicz (Campbell, 1980).

1.2.1 Expected Monetary Value (EMV)

Expected Monetary Value is a statistical concept that calculates the average outcome when the future includes scenarios that may or may not happen (PMI, 2013). It is a risk quantification technique consisted of two numbers; risk event probability and its consequences. The inputs of EMV are the values needed for its calculation. After risk identification, there are number of ways (e.g. expert judgement) for assessment of probability and value (impact) of risk. Basic EMV process consists of assigning a probability of occurrence, assigning monetary value of impact if the risk occurs, multiplying the probability with impact and adding all of them together as shown in Equation 1.1.

$$\mathbf{EMV = \sum_{i=1}^{n} Probability_i \times Impact_i} \qquad \textbf{Equation 1.1}$$

Output from EMV is generally used as input for other analyses for example Decision Tree Analysis. This technique can be implemented when probability and impact of a risk is quantifiable. It provides a way to figure out the amount of budget to be provided based on any risk contingency plan.

1.2.2 Drawbacks of using EMV

EMV is established based on Expected Utility Theory (EUT). There are many loopholes and errors in EUT due to which this technique is doubted upon. For example, irrational approach towards decision making, normative nature of EUT, linearity assumption of probability distribution and equal considerations for threats and opportunities, etc. And these problems have not been stated by the proponents of such tools/techniques nor adequately addressed in the literature (Conrow, 2003). This has been ignored till the evolution of Prospect Theory which states somehow rational approach towards decision making under uncertainty (Kahneman and Tversky, 1979). EMV technique contains several irrational assumptions on which it is based. For example,

1. EMV assigns equal weights to threats and opportunities which is not the case in reality (Kahneman and Tversky, 1979).
2. it assumes that the individual's behaviour should be risk neutral which implies that *no* criterion for risk is used (Haimes, 1993; Conrow, 2003). Contrary to this, people do not value gains and losses equally. Psychological perspective on risk focuses on personal preferences for probabilities and attempts to explain why individuals do not base their risk judgments on expected values (Lopes, 1983; Luce and Weber, 1986). Indeed, people in general are not risk-neutral. They are risk averse in case of gains and risk seeker when they come across losses (Kahneman and Tversky, 1979).
3. expected loss means that there is no distinction made between situations involving potential large consequences and associated small probabilities, and frequently occurring events with rather small consequences (Haimes, 1993; Haimes, 2004).
4. proper consideration of project risk requires consideration of both impact and probability instead of their average. Multiplying the impact and uncertainty to 'rank' risk is misleading, since the correct treatment of the risks requires both dimensions (Lowrance, 1976a; Williams, 1996; Andi, 2006; Taroun, 2014).
5. the concept works well to calculate the contingency reserve when more risks are identified. If fewer risks are identified, one will not get enough spread and reserve may dry up sooner (Usmani, 2015).

6. while making decision under uncertainty (risk), EMV calculated for risks is not the true reflection of reality. Resultantly the contingency cost for projects is not likely to be normal.
7. this approach has a limitation of being over-simplistic due to the assumption of independence between risk factors (Dikmen et al., 2004).

1.3 Problem Statement

In conventional risk quantification model, threats and opportunities are given equal weights. This model bases on the Expected Utility Theory (EUT) which is a normative model in nature. Later on, this theory was invalidated by Kahneman and Tversky (1979) due to observed *certainty effect*, *reflection effect*, *isolation effect*, Framing Manipulation and Nonlinear Probability Decision Weights in subjects' responses. These effects and decision weights reflect in the output of quantitative analysis which is not necessarily accurate all the times.

Although conventional PI-model apparently quantifies threats and opportunities equally, the prior assessed probability and impacts through subjective means are cognitively overestimated in case of threats and estimated in case of opportunities (Kahneman and Tversky, 1979). Losses loom twice larger than gains. Both upside and downside risks are equally important and can affect a project positively and negatively respectively. In this way, expected value of risk, which has until recently dominated most risk analysis in the field, is not only inadequate, but can lead to fallacious results and interpretations (Haimes, 1993); it is over simplistic with respect to threats and opportunities (Williams, 1996; Renn, 1998). To sum up, we require to see beyond expected values and irrational assessment when addressing risk. Thus, PI risk model should be extended to incorporate additional factor capable of reflecting realistic and balanced nature of risk by rationalizing for cognitive errors. Such an extension would provide the basis for a detailed and realistic risk assessment (Taroun, 2014).

Considering all this, there is a need to improve the existing PI-model by normalizing the threat and opportunity weight in the quantification process so that a realistic and rational approach could be devised to develop effective response strategies. Prospect Theory will form the foundation stone for calculating the weighting function to be incorporated in this model, which will further help in optimizing the cost calculation of risk in monetary term. It will improve the existing risk quantification model in an efficient and optimized way for effective risk management in construction industry. Adding a new dimension or a weighting function could be a possible solution to develop a more realistic, effective and accurate assessment model. A model that truly mimics the analytical state of threats and opportunities by calibrating for cognitive errors; which does not over- or underestimate the risk.

1.4 Research Objectives

This study will address the problem statement by figuring out the general risk behaviour of the decision maker. In the next step, this behaviour profile will be utilized to develop a rationalized weighting function for risk quantification with respect to opportunity and threat. Then this newly developed weighting function will be integrated into the existing conventional risk quantification model. Lastly, significance of the findings of this study will be checked with the help of a hypothetical or real-life case study if possible.

1.5 Significance of Study

This model will help in estimation of optimum contingency cost being a major challenge to construction industry, which is usually put into the project estimated cost in the form of a fixed percentage.

1.6 Relevance to National Needs

Risk management is a relatively new field in construction industry of Pakistan. A study by Choudhry and Iqbal (2012) reports current risk management techniques, status of risk management systems and barriers to effective risk management in the local construction industry. Risk management system and practices in most of the organizations are reactive, semi-permanent, informal, and unstructured with non-existent and limited committed resources. However, there is awareness about risk management and a desire to learn from past mistakes. Major barrier to effective risk management is the lack of formal and effective risk quantification technique/system. Quantitative analysis techniques, based on their sophisticated mathematical, statistical and scientific background, promise a detailed and thorough quantification and measurement of risk, which is very important for designing the response (Thaheem et al., 2012). This study will try to improve the conventional risk quantification model by following a realistic and rational approach. It will also figure out the risk behaviour of project management team in certain situations which will be further incorporated into the weighting function development. Such considerations will add fruitful outcomes to construction industry.

1.7 Thesis Outline

This thesis has been organized into five chapters. *Chapter 1* is '*Introduction*'. It includes an overview to the research, problem statement, objectives and scope of the study. It provides a general introduction to the research. *Chapter 2* is '*Literature Review*'. It explains the previous studies done concerning the research providing essential information and guidelines to cater the problems in risk quantification and management using the conventional methods. *Chapter 3* is '*Methodology*' of research. It explains how the research has been carried out to obtain our objectives. *Chapter 4* is '*Results and Discussion*' that covers the analysis of data after being collected, modelling and results according to our research objectives. It also discusses in detail how these objectives are achieved from using our analysed data. It explains how the collected and analysed data is interpreted to produce the results which interpret achievement of research objectives. Lastly, *Chapter 5* is '*Conclusions and Recommendations*' where final conclusions and recommendations have been drawn and summarized.

1.8 Summary

In this chapter, concept of risk and, its assessment and quantification has been discussed briefly. Further the issues with conventional risk quantification method are highlighted followed by a problem statement and research objectives. This study will help in better understanding and measurement of risk in construction industry and hence in setting response strategies.

Chapter 2

LITERATURE REVIEW

2.1 Background of Risk

Tracing back to the definition debate, the evolution of risk from likelihood of purely negative occurrence to a mix of threat and opportunity is marginally observed. However, the negative side still seems to dominate the risk spectrum. Initially, risk was defined as chance of damage or loss (Haynes, 1895). Even the substantial research work of 20th century continued looking at risk negatively; the only change was in the use of nomenclature such as measurable uncertainty (Knight, 1921), undesirable thing (Markowitz, 1952), possibility of bad happening (Riegel and Loman, 1966; Atheam and Pritchett, 1969) and combination of hazards and probability (Pfeffer, 1956; Lowrance, 1976b). In short, risk was inclined towards threat (Kaplan and Garrick, 1981; Henderson, 1987; Haimes, 1991; Giddens, 1999). But the literature has come a long way; in late 20^{th} and 21^{st} centuries, risk started to grow in its definition by incorporation of threat and opportunity (Chapman and Ward, 2000; Bunni, 2003; Rosa, 2003; PMI, 2013; Aven and Krohn, 2014). Today, risk is defined as "*an uncertain event or condition that, if it occurs, has a positive or negative effect on at least one project objective, such as time, cost, scope, or quality*" (PMI, 2013).

2.2 Risk – Recent Definition

Evolution of risk definition in various guidelines and standards shows that community of researchers and practitioners is moving towards a single term covering both subsets of 'threat' and 'opportunity' (Raz and Hillson, 2005). Threats and opportunities are not actually mathematically different: both involve uncertainty which may potentially affect the objectives. These can be managed by the same process with minor adjustments (Hillson, 2002). But the question is does this matter? As Shakespeare said about the sweetness of rose, *“that which we call a rose, by any other name would smell as sweet”*? The answer is yes; it matters since it points towards a clear statement of intent by integrating both opportunities and threats within a single definition. It is an attempt of recognition of its importance, influences over business and project success, and the need of proactive management (Hulett et al., 2002). As far as this study is concerned, we will consider risk definition given by PMI (2013).

2.3 Risk Perception in Different Fields

Risk has somehow same perception in different field with minor disparity. For example, in medical sciences, risk is observed as possibility of loss, injury, disease, or death (Oxford English Dictionary, 2016) and is considered as an objective phenomenon (Althaus, 2005). For example, lungs cancer is one of the major risks that affect smokers. In psychology, risk is rather seen as a function of subjectively perceived utilities and probabilities of their occurrence (Arrow, 1982; Renn, 1998). People show distinctive preferences for one situation or the other (Renn, 1990). In law, risk is the cost and loss of income caused by legal uncertainty (Tsui, 2013). Similarly, risk is considered as a problematic occurrence in philosophy (Althaus, 2005). Physical sciences define the term ‘risk’ as probability times consequences (Renn, 1998) which is similar to terrorism risk that is taken as expected consequences and expected utility (Aven and Guikema, 2015). The field of economics interprets risk as a decisional phenomenon, a mean of securing wealth or avoiding loss. In history and humanities, risk in not more than a story concept (Althaus, 2005). In engineering contexts, it is often linked to the expected loss (Lirer et al., 2001; Mandel, 2007; Verma and Verter, 2007; Willis, 2007).

Among many other industries, construction and manufacturing industries are subjected to relatively more risk and uncertainty owing to their projected and innovative natures, respectively (Flanagan and Norman, 1993; El-Sayegh, 2008). Although risk concept in human life can be traced back to as far as 3200 BC (Baker et al., 1999), in construction field it did not appear until 1960s (Edwards and Bowen, 1998). Risk definition in this context is much like that of other disciplines. It is defined as likelihood of occurrence of a definite event (Faber, 1979), uncertainty associated with estimates of outcomes (Lifson and Shaifer, 1982), lack of predictability (Hertz and Thomas, 1983), exposure to economic loss or gain (Perry and Hayes, 1985; Paulson and Barrie, 1992), unexpected events which result in cost overrun or schedule delay (Wang and Chou, 2003; Kim et al., 2009), likelihood of a detrimental event occurrence (Ali et al., 2007) and variation in cost estimate (Barnes, 1983; Cooper et al., 1985; Beeston, 1986; Clark and Chapman, 1987).

2.4 Risk in Construction Industry

Construction is a fast-growing industry which imparts substantially in economic growth of a country. With the rapid advancement, an increased number of uncertainties are bound to occur (Thevendran and Mawdesley, 2004). This has become a serious problem; every new construction project is doubted upon regarding its success triangle. Due to poor management, several risks materialize like payment delays, defective design, inaccurate execution schedule, delay in material supply and accidents during construction, etc. Managers need to ensure delivery of projects to cost, schedule and performance requirements (Tah and Carr, 2001b). Risk is a possible, undesirable and unplanned event that could result in the project not meeting one or more of its objectives (Teneyuca, 2001). It is paramount for construction companies to be sensitive to the issue of embracing and managing uncertainty and risks.

2.5 Risk and Human Behaviour

Economic rationality implies that different risk attitudes are legitimate elements of decision making process (Luce and Weber, 1986). Theoretically, people are risk averse when potential losses are high and risk prone when potential gains are high. To them losses loom larger than gains (Kahneman and Tversky, 1979). The psychological perspective on risk focuses on personal preferences for probabilities and circumstantial constraints, and attempts to explain why individuals do not base their risk judgments on expected values (Lopes, 1983; Luce and Weber, 1986). For example, construction industry leaders, which are otherwise considered to be risk-avert, were found to seek risk when projects are running over budget (Fiolet et al., 2016), exhibiting a behaviour contrary to standard PT. This implies that when the profits start shrinking due to over expenditure in construction activities, decision makers tend to shift their behaviour from risk aversion to seeking (Han et al., 2005).

2.6 Risk Management Process

Risk management has been introduced to overcome the issues discussed in the above section. It is defined as a set of methods and activities intended to reduce the disturbances occurring during project delivery (Skorupka, 2003). It can also be defined as the structured set of processes designed to identify, analyse and respond to project risks. It includes maximizing the results of positive events and minimizing the consequences of negative events (PMI, 2013). According to Gray (2000), risk management is a proactive approach rather than reactive. It is a critical part of project management (Lyons and Skitmore, 2004). If a risk is not identified, it cannot be controlled, transferred or otherwise managed (Bajaj et al., 1997).

Based on consensus in the literature, it uses the following three-step approach i.e. risk identification, risk assessment and risk mitigation (Zayed et al., 2008).

Identification exposes the possible risks before they become problem for a project. Risk assessment estimates the probability of occurrence and its ultimate impact, if a risk materializes. While in risk mitigation, feasible possible proactive measures are taken to control it (KarimiAzari et al., 2011). Implementing risk management in construction industry may bring a number of useful outcomes and therefore it should be an integral part of management practices (Zou et al., 2009). It is not only trying to keep away bad results but also acting as a guide to maximize positive results (Monetti et al., 2006). There are number of reasons to implement risk management e.g. legal requirement, unique nature of project, stakeholder involvement, etc.

2.7 Risk Quantification

Risk may hinder the successful completion of an activity or a project which may cause cost and time overruns, and quality issues (Ali et al., 2007). One of the most significant steps in the risk management process is its quantification (Haimes, 1993).

2.7.1 Conventional Risk Quantification

In 1738, Daniel Bernoulli proposed a model for risk quantification based on utility of weighted averages of all outcomes in an uncertain scenario (Stearns, 2000). It was a de facto standard for risk quantification for almost two centuries. However, the concept was invalidated by Neumann and Morgenstern (1944) who proposed that the utility of risk is the probability-weighted average of the utilities of all outcomes as opposed to standalone utility of combined outcomes. Thus, a new model was proposed to quantify the risk, known as Expected Utility Theory (EUT).

A dominating and commonly used tool of risk assessment i.e. PI-model, is based on the expected utility theorem (Tversky and Kahneman, 1992). In this measurement system, the decision makers roughly assess the probability of occurrence and the degree of impact associated with a particular risk. Numerical scales are used to score each risk factor in terms of its impact and probability, and their product is often taken as the basis for rank ordering and quantification (El-Sayegh, 2008; Chan et al., 2011).

According to EUT, a risk event *i* can be estimated by multiplying its probability (P) of occurrence and its impact (I) in monetary terms (Campbell, 1980; Vose, 2008) as mathematically given in Equation 2.1 and theoretically known as PI-model.

$$\boldsymbol{Risk_i}\ (\boldsymbol{R_i}) = \boldsymbol{Probaility_i}\ (\boldsymbol{P_i}) \times \boldsymbol{Impact\ of\ the\ outcome_i}\ (\boldsymbol{I_i})$$ **Equation 2.1**

2.7.2 Flaws in Conventional Risk Quantification Method

Expected value behind the traditional PI-model does not adequately capture events with low probabilities and high consequences. Take as examples nuclear accidents and terrorism, where the possible consequences are disastrous but with relatively lower likelihood. The expected value can be very small due to the product of lower probability (e.g. 0.01) with number of fatalities. However, the scale of disaster needs special attention (Komljenovic et al., 2016). Thus, there is a need to see beyond expected values when addressing risk (Haimes, 2004). Some authors argue that multiplying the probability and impact values might be misleading (Williams, 1996; Andi, 2006). Further, the average estimates given by the traditional PI-model raise questions over its applicability. Manmade systems, be them in engineering, construction, infrastructure, production or services, are designed for optimal function (Williams, 1996), else imagine how the world would look if roads were designed for average traffic volume, telephone lines for average caller load, and pipelines for average fluid volumes (Haimes, 1993). Thus, it can be concluded that the expected value of risk may lead to unreliable results and erroneous interpretations (Edwards, 1995; Haimes, 2004). Indeed, people in general are not risk-neutral as envisaged by the traditional risk quantification model.

The case of expected values can be further explained by the current practices of risk assessment in construction, production and service industries which results into various risk response strategies for instance contingency reserves. One such reserve is cost contingency which is an additional amount allocated for accepted risks within the cost baseline. It is utilized for developing and deploying contingent or mitigating responses (PMI, 2013). Since existing risk quantification methods are affected by EUT anomalies, estimation of contingency amount has been a major budgeting challenge (Kangari and Riggs, 1989; Tah et al., 1993; Smith and Bohn, 1999; Cioffi and Khamooshi, 2009). In construction, the traditional estimation approach dictates allocating a fixed percentage of total project cost keeping in view project threats and ignoring opportunities (Kangari and Riggs, 1989).

2.7.3 Risk beyond Two Dimensions

Pertinent literature demonstrates that the intuitive understanding of risk is a multidimensional concept and cannot be reduced to mere product of probabilities and consequences (Renn, 1998). Although the two-dimensional PI-model of risk quantification is a bigger school of thought, its inability to capture the true nature of risk is also well-established (Williams, 1996; Haimes, 2004). Thus Charette (1989), Jannadi and Almishari (2003), Cervone (2006), Zeng et al. (2007), and Han et al. (2008) extended the model by incorporating additional dimensions of predictability, extent of exposure to risk, risk discrimination, factor index reflective of surrounding environment and risk significance respectively. But these qualitative dimensions are subjective, and case and criteria specific. Though the improvement introduced in PI-model can be argued, it has always been aimed at reflecting the complexity of risk assessment by incorporating the unique nature of risk and contextual influences. Among possible approaches to capture the complexity of risk, the notion of extending PI-model by additional explicit parameters has greater application and research appeal (Taroun, 2014).

This appeal has also been exploited by Kahneman and Tversky (1979) in the form of PT which, seemingly a two-dimensional construct, introduces a higher order semi-quantitative third dimension termed as ‘prospect’. The so-called prospect reflects pattern of preferences of decision makers when they come across different probabilities of occurrence varying from low to high. This new theory gave birth to a new branch of Economics naming “*Behavioural Economics*”.

2.8 Behavioural Economics

There has been carried a lot of research to reduce the project cost in construction sector. Quality of the material, the methods and techniques, and the management of construction project has continually been improved to increase the quality of work and to reduce the project cost. Due to this, most of the construction projects are well managed and well organized. In the meanwhile, there are uncertain situations that cannot be controlled efficiently. All the senior management professionals e.g. project managers, construction managers, foremen, etc. come across such type of uncertainties which are viewed as risks.

Some studies conducted in the field of Behavioural Economics have concluded that when people come across risky situations, their decision is not as simple as they think of it. People do not always consider only the expected monetary values; rather there are other parameters that affect their decision making under uncertainty. These could be relevant experience, knowledge of the area, geographical conditions, risk propensity, etc. These studies fall into a very specific field of economics known as “Behavioural Economics” which governs the psychological thought process that guides people when they have to make monetary decisions under uncertain situations. In behavioural economics, two type of processes take place while making decisions: 1) the *judgement process*, 2) the *choice process*. In *judgment process,* people anticipate the probabilities and in *choice* they select an action from several possible options. Hence this field of economics deals with the way in which people make decisions when they face risk i.e. Behavioural Economics is the combination of psychology and economics (Mullainathan and Thaler, 2000).

2.8.1 Influence of Experience on decision making

When there is a risky situation, two parameters must be considered: 1) the probability of risk, 2) monetary value of the outcome. These two factors are important as they are the main reasons towards decision making. Mostly statistical sampling is used to model the economic values of the outcomes. For example, *Bayes' Rule* in which greater influence is depicted due to last events instead of the older ones, can be used for updating the probabilities. But such type of sampling techniques and methods are difficult to use and people can misjudge the events without using these principles correctly.

Some researches in psychology state various mechanisms which differ from the above-mentioned principles. For example, according to Kahneman and Frederick (2002), the events that occur in actual are easy to imagine as compare to those which do not occur. Sometimes, the events that occur frequently are given prior consideration and people will decide on future events accordingly. For example, if a coin is tossed and appears as heads five times, people are more likely to bet on tails in the next toss: this biasness in the judgment is known as law of small numbers. Also, there could be another misjudgement leading towards opposite conclusion i.e. people may feel lucky or unlucky and decide on an option accordingly (Gilovich et al., 1985).

There is another problem associated with the judgment of probability that people can misunderstand a hypothesis. If a person has an idea about the probabilities from his previous experience, he will consider it while deciding on a choice (Rabin and Schrag, 1999).

2.8.2 Influence of the Work Environment and Context

After evaluating the probability of an event, choice is to be made on the presented options. Choices will be different depending upon the way in which they are presented for example, whether the problem is presented in a positive frame (in terms of gains) or in a negative frame (in terms of losses). This effect was named as "Framing Effect" by Twersky and Kahneman (1981). Moreover, the context also has a greater influence on the decision maker i.e. the choice among the options may depend on the other options available. This effect is known as "*Context Effect*" (Simonson and Tversky, 1992). From these effects, it can be concluded that the environment in which choice are presented to people can influence their decisions.

2.8.3 Loss Aversion

According to some economists, there are certain psychological effects that can create problem while making decisions in case of risky situation. One of these is that people dislike to lose an amount of money to a greater degree than they like earning the same amount (Tversky and Kahneman, 1991). Actually people give more worth to what they already have in hand as compared to that they are supposed to have in a deal. Knetsch (1992) called this "*reference dependence*". At the same time people would like to have something on a lower price than they would sell it (Kahneman et al., 1990). This is known as "*endowment effect*". One other aspect of this effect is that people do not consider the things which are for resale in the same way as they are to be utilized. One major contributor towards problems in decision making is loss aversion. People's tendency to strongly prefer avoid losses and acquire gains is referred to as *loss aversion* (Kahneman and Tversky, 1984).

Loss aversion relates to risk aversion directly. It is the risk aversion that weakens the validity of expected utility theory which states that the utility of a risky situation is the probability-weighted average of the utilities of the outcomes. This theory may seem logical but it fails due to the factor of risk aversion in actual behaviours of people. Hence expected utility theory is more valid on account of risk aversion in choices and judgments (Kahneman and Tversky, 1979). Although there are some studies which show that risk aversion is not always present in decision making, the main idea behind such researches is that when there is exchanging goods with goods, loss aversion effect is cancelled (Novemsky and Kahneman, 2005).

Conversely, some studies have concluded that loss aversion is sometimes reversed when it deals with small outcomes. In such cases, pattern of gains and losses is revered: losses appear smaller than gains. This can be explained in case of hedonic principle i.e. people like to minimize pain and maximize pleasure, as well as by the assumption that comparatively smaller losses are more easily discounted than bigger losses (Harinck et al., 2007).

2.9 Prospect Theory

In the face of above criticism, EUT was experimentally invalidated by Kahneman and Tversky (1979) with the introduction of Prospect Theory (PT). PT considers loss aversion and other behavioural tendencies such as effects of isolation, reflection and certainty. This theory explains decision making with the consideration of risk aversion phenomenon (Sun, 2009). It differs from EUT due to addition of probability weighting function $\pi(p)$ and a value function $v(x)$. These parameters capture risk aversion tendency in decision making. Presently, PT is considered as the basis of behavioural economics (Camerer et al., 2011).

Kahneman and Tversky (1979) figured out some problems with expected utility theory and proposed a new theory (Prospect Theory) to address these problems. Prospect theory considers loss/risk aversion and other behavioural tendencies such as isolation effect, reflection effect and certainty effect.

2.9.1 Behavioural Tendencies

The *Certainty Effect* explains that people overweight the outcomes that seem certain as compared to the outcomes that are probable in nature (Kahneman and Tversky, 1979). For example, if a person is asked to choose between 3000 for sure (100% chances) and 4000 with 90% chances, he will go for the option which is certain. Probable outcome is under weighted in such scenarios. Also, a difference between 100% and 90% will look more important than that is between 50% and 40%. When the probabilities are higher i.e. closer to 100%, the pattern of decision making changes and does not follow the one proposed by expected utility theory. This was also explained by Allais (1953a) and was the first behavioural effect pointed out by economists.

When a person is provided a situation in two perspectives: positive and negative but the outcomes remain same, his preference between positive prospects is the mirror image of the choice between negative prospects. This behavioural tendency is named as *Reflection Effect* (Kahneman and Tversky, 1979). From this, it is obvious that people will switch their choices when they are dealing with positive outcomes instead of negative ones. This change in preferences when the problem is inversed needs consideration. This shift in preferences is inconsistent with expected utility theory.

When the people come across a situation, they will try to simplify the outcomes by disregarding the common components and focus on the distinctive components. This effect was named as *Isolation Effect* by Kahneman and Tversky (1979). Hence an inconsistency between the preferences can be observed if a problem is presented in a different way. This also violates the basic postulates of expected utility theory.

2.9.2 Prospect Theory – Choice Process

Prospect theory distinguishes the choice process as 1) the *editing phase*, and 2) the *evaluation phase*. *Editing phase* involves different operations as preliminary analysis that yields simpler representations. Kahneman and Tversky (1979) defined this process as follows:

- *Coding:* People do not directly perceive the final states of the outcomes. Firstly, the outcomes are identified as gains and losses and these gains and losses are defined with respect to some neutral reference point. This reference point usually corresponds to the current asset position of a person.
- *Combination:* At this point, prospects are simplified by combining the probabilities associated with identical outcomes.
- *Segregation:* in this phase, the guaranteed components of a prospect are separated out from the risky component. For example, if a prospect has two components as 100 with a probability of 0.2 and 200 with a probability of 0.8, it is viewed as 100 for sure plus 100 with a probability of 0.8.
- *Cancellation:* Shared components in the offered gambles are discarded in this phase. This is the essence of Isolation Effect.
- *Simplification:* The probabilities and the outcomes are simplified by rounding off their values. For example, 100 with a probability of 0.4999 is perceived as 100 with 0.5 probability and 200.01 with 20% chances is perceived as 200 with 20% chances.
- *Detection of Dominance:* Lastly, only dominated prospect is considered by discarding the other option without further analysis.

These steps seem in line, what the people do but there is no specific order of applying these steps. Sometimes, this editing is possible without involving all the steps and some of these can also be performed collectively. This process varies from person to person.

Editing phase is followed by evaluation phase:

- *Probability Weighting Function:* The first scale π associates a decision weight with each probability which reflects the impact of probability p on the overall value of the prospect. π is not a probability measure and $\pi(p) + \pi(1-p) \leq 1$. Probability Weighting Function of PT is shown in Figure 2.1.

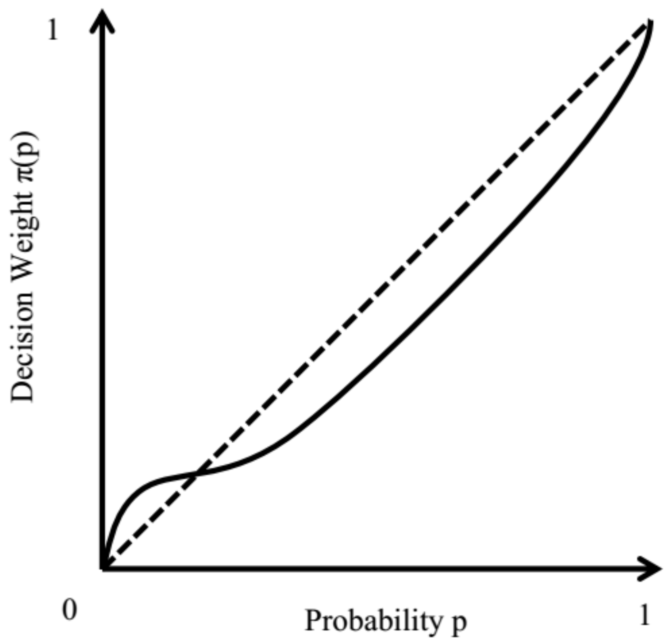

Figure 2.1: Probability Weighting Function of Prospect Theory

- *Value Function:* The outcome of a prospect is evaluated via a value function *v* as shown in in Figure 2.2 which reflects subjective value of the outcome. For examples a risk *R* can be overestimated as $R^{\uparrow}$ or underestimated as $R^{\downarrow}$ subject to its threatening or opportunistic nature. $R^{\uparrow}$ and $R^{\downarrow}$ are instinctive assessment under a risky situation *R* and are highly dependent upon personal characteristics. Among other attributes this value is perceived with respect to a reference or datum point which is usually the current wealth level. Hence, *v* is a measure of deviation from this reference point.

Though PT is widely accepted as a better reflection of human behaviour since it attempts to suitably gauge threats and opportunities, it has limitations in the form of a common probability weighting function for both sides of risk. Decision makers may not necessarily weigh threats and opportunities equally, and losses may not always loom twice larger than gains (Nwogugu, 2005). Furthermore, PT has not seen much action in risk quantification because a huge amount of research work is still being carried out to assess its developmental basis and application in real life scenarios (Fiolet and Haas, 2015).

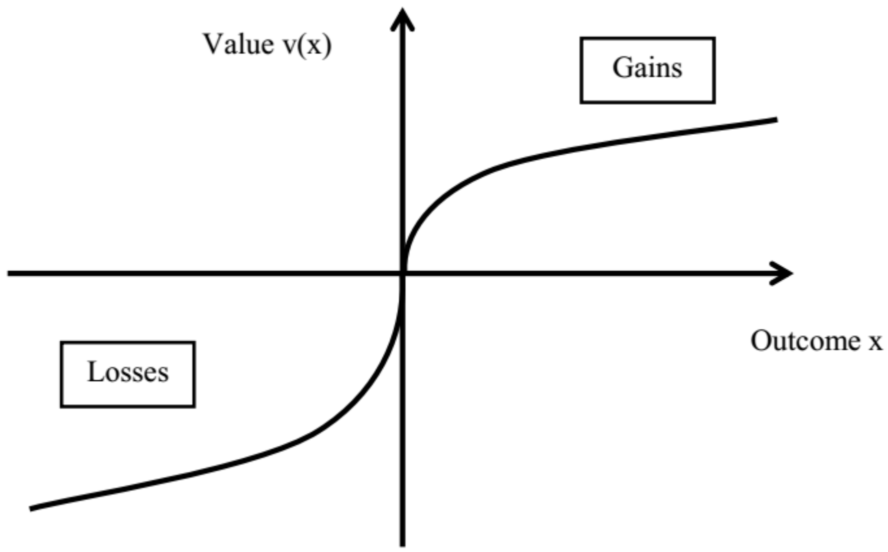

Figure 2.2: Value Function of Prospect Theory

2.10 Application to the Construction Sector

Construction industry is the backbone of economy of a country because it contributes towards GDP on larger scale as compared to other industries. At the same time there are a large number of uncertainties associated with a construction project (Flanagan and Norman, 1993). No construction project is risk free and these risks cause cost and time overrun (Wang and Chou, 2003). Risk management is the key to cope with uncertainties and in many developed countries of the world fruitful outcomes have been achieved by implementing it successfully. Conversely, the developing countries' construction industry has poor reputation due to inefficiently managing the risky situations that emerge during the on-site execution of the project (Ali et al., 2007). A perfect construction world is the one with no conflicts but there is no perfect construction world (Acharya et al., 2006). Hence there is a need to manage the uncertainties in construction properly and quantify them with a more rational way instead of averaging method of PI-model.

2.10.1 Factors Influencing Construction Decisions

Experience of a professional highly influences the decision making of a professional. It is easier to imagine the events that have occurred in actual as compared to the ones which have not yet occurred (Kahneman and Frederick, 2002). Several parameters can influence the decision made under risk. Experience is not the only one factor that influences the decision but also there are many other internal and external factors affecting the decision making.

Researches has been carried out to figure out the factors influencing the success of a construction project and these are the factors that affect the decision making of the professionals working on a project. For example, a study has summarized a set of critical success factors which affect the success of construction projects and if this set of conditions are met properly, successful completion of a project can be ensured (Sanvido et al., 1992). Following such studies, a list of factors supporting the success of a construction project can be created. These critical success factors depend on several things. For example, the country in which projects are being carried out, has a major role in the success of that project (Kaming et al., 1997). Culture of a certain country is different from the other countries and it has much influence on decision making while execution of the project. Weather conditions, economy, political situation, unemployment rate, market fluctuations, etc., are some prominent factors which are kept in mind while making certain on-site decisions (Chan et al., 2004b). There are some other studies which state the factors involved in partnering and bidding process (Chua and Li, 2000; Chan et al., 2004a).

To summarize such studies conducted on the questions of critical success factors, some researchers not only figured out the success factors but also grouped them into certain categories for example, external environment related factors, internal environment related factors, human related factors, project specific factors, etc. (Chan et al., 2004b). These factors which are considered critical to the success of a project are likely to influence the decision making of project management team when they make decisions under financial risks.

2.10.2 Tools for Decision-making

To cope with critical factors which affect the performance of a construction project, various tools has been developed to manage and model such risk factors. For modelling of risk management, Decision Support System (DSS) and Fuzzy Set Theory (FST) has been introduced by some authors (Baloi and Price, 2003). Potential use of FST in risk assessment was discussed by Kangari and Riggs (1989) in the late 1980's while Mustafa and Al-Bahar (1991) adopted Analytical Hierarchy Process (AHP) to assess the risks on a construction project. In short, there exist several multi-criteria-decision-making tools which can be applied in construction. These tools have their own strengths and weaknesses. Such tools have some limitations for example, these are applicable in certain project environments and decisions like bidding strategy (Chou et al., 2013). Furthermore, these tools are useful for complex and difficult situations of a project. They cannot be applied to smaller, frequent and quick decisions to be taken during on-site activities.

Certain parameters and factors can cause some risks around these small on-site decisions and construction project leaders must solve them on day to day basis. In such circumstances, behavioural economics can be applied for analysing the uncertain situations. In this way, it can be interpreted that how construction professionals are taking steps to figure out the solutions when they are to deal with risk.

2.11 Behavioural Economics in Construction

Application of behavioural economics in construction sector can be traced rarely. An important area of construction in which the application of behavioural economics can be seen in bidding process. This step of the project deals with large amounts of money and applying this knowledge can help understand that how project leaders make bidding decisions (Han et al., 2005; Chen et al., 2015).

Knowledge of behavioural economics can be applied to specific problems faced during construction. For example, if there is weather risk and it can cause delay in the project, it becomes a risk near construction project team. When they have to decide on such problem, certain behavioural patterns will influence their decision (Chan and Au, 2007).

2.12 Risk Measurement and Response Strategies

Due to reduced precision of conventional PI-model and existing tools, major risk decision making resorts to rules of thumb such as fixed percentages of cost or time contingency. Though some efforts have been deployed for improving PI-model (Cervone, 2006; Zeng et al., 2007; Han et al., 2008) and reflecting different aspects of uncertainty (Taroun, 2014), there is still a greater need to improve risk analysis tools especially the quantitative ones (El-Sayegh, 2014). Since an objective and rational model of risk quantification would reduce subjectivity in estimation (Ward, 1998), there is high incentive to direct research focus towards its development (Tang et al., 2007).

2.13 Prospect Theory and Risk Quantification

Although PT has some limitations and criticism for example contextual constraints, group decisions and methodological deficiencies, it can still produce better outcomes as compared to conventional PI-model. According to PT, losses loom twofold larger than gains (Tversky and Kahneman, 1992). In other words, it can be inferred that people overestimate a threat situation while underestimate an opportunistic one. This important deduction should also be incorporated in PI-model to rationalize the difference of prospect. The argument is also strengthened by PMI (2013) which establishes the objectives of project risk management for increasing the likelihood and impact of positive events, and decreasing those of negative events. Despite its psychological appeal and tendency to accurately capture human behaviour, PT has not been fully incorporated in improving the conventional risk quantification model.

Based on the above research gap, the main goal of this study is to rationalize the risk quantification in construction industry with respect to its opportunistic or threat prospect. In doing so, quantitative weighting function is developed with respect to opportunity and threat depending upon the risk behaviour of decision makers. Further it integrates the weighting function in the existing risk quantification model proposed by PT. The implication of this study deals with rationalized risk assessment which has the potential to ensure project success due to better response strategies. This study makes a unique contribution to project risk management body of knowledge and practice by improving quantitative risk assessment.

2.14 Summary

This chapter discussed a detailed review of published literature. It has been noted that risk is the part of every human endeavour and its management is an essential step for a project success. To properly manage and mitigate, risk quantification is of highest significance. Till present, conventional PI-model is being used as a foundation to quantify risk. This model contains a number of flaws and weaknesses. Therefore, Prospect Theory which captures more realistic picture of human behaviour should be incorporated into EUT based PI-model. In this way, a more rationalized assessment model can be developed that will result in realistic and effective response strategies.

Chapter 3

RESEARCH METHODOLOGY

3.1 Introduction

This chapter discusses a detailed methodology for this study. In the first step, a detailed literature review was conducted to get a wide introduction on the subject topic. A closed ended questionnaire survey involving day to day decisions on situation-based scenarios from construction industry, was used to collect data from decision makers. This data collection tool is more than a questionnaire survey and can be called a semi-structured, closed ended face to face interviews with the respondents. A detailed discussion was made on each scenario to get a better understanding of respondents' decision and the factors which they consider while making decision under a specific situation. Later, data was analysed for a detailed assessment of the respondents' behaviour under risky situations and the factors which they consider as reference when they make choices. A flowchart of research methodology is shown in Figure 3.1.

3.2 Research Design

With the goal to rationalize the risk quantification in construction industry, this study is performed in five phases. In the first phase a detailed literature review was conducted to figure out the deficiencies in existing risk quantification model. It was observed that the current tools do not allow rational evaluation of upside and downside risks. Therefore, a numerical method must be devised to rationalize the over- and under-estimating effects of threats and opportunities respectively. To achieve this purpose, a weighting function $\omega_{o|t}$ is proposed in second phase of research which is mathematically given in Equation 3.2.

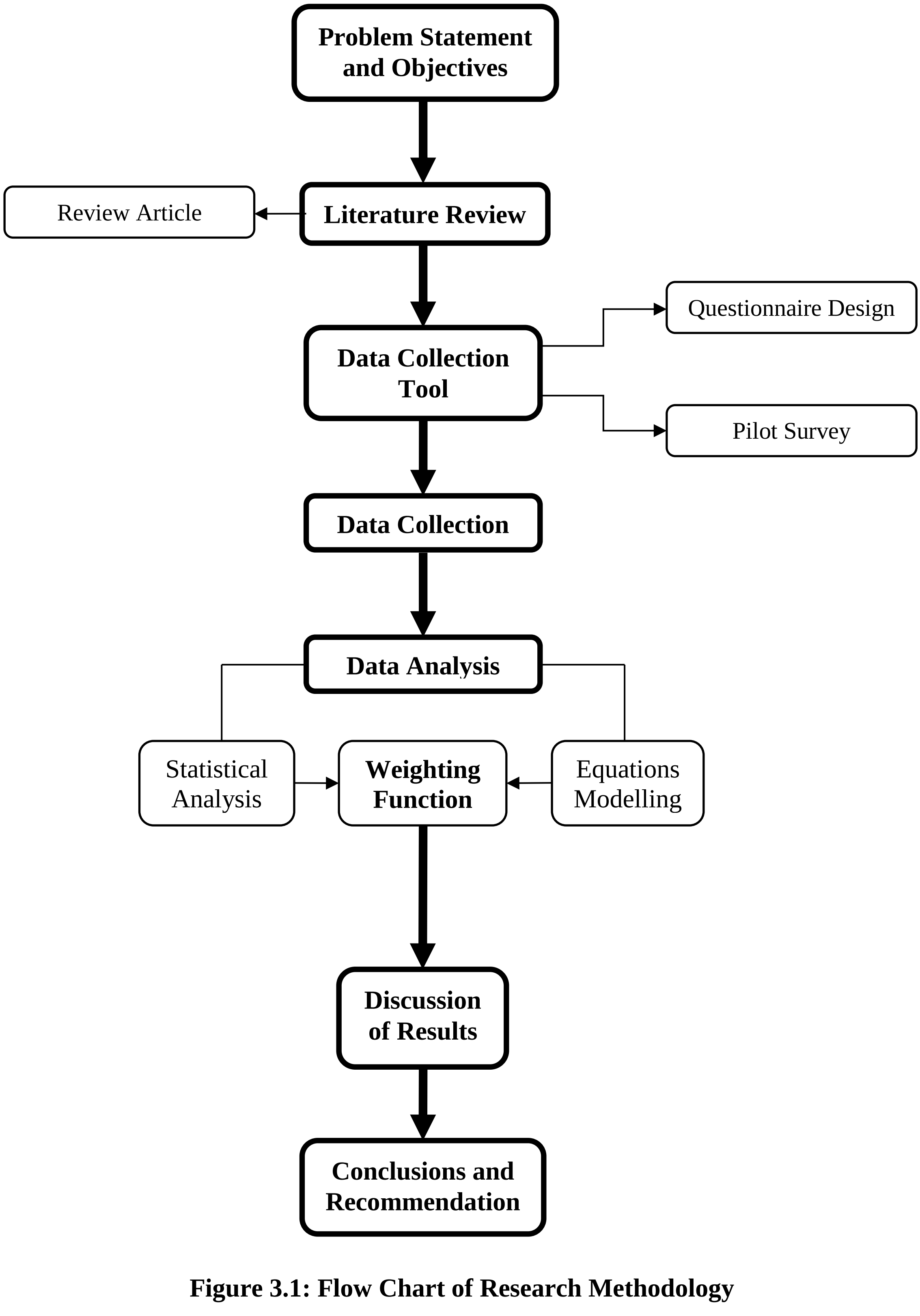

Figure 3.1: Flow Chart of Research Methodology

In the next phase, a data collection tool in the form of a closed-ended questionnaire was developed. In the fourth phase, data were collected by personally interviewing seasoned construction professionals occupying managerial and decision making positions. Every participant was briefed about the nature and scope of research to receive most realistic response. All data were collected in a single round of interviews and no feedback was considered to introduce any changes in the questionnaire. In the last phase, numerical analysis was performed on the collected data to attain the ranges of weighting function for both down- and up-side risks.

3.2.1 Sample Size

To ensure representativeness in data collection, it is critical that a random sample is selected from the known population. However, owing to the peculiarity of data collection, experts were selected based on *non-probability convenience sampling* technique. It is imperative to note that the convenience offered by this technique was not necessarily in the form of physical or logistic ease of access but the level of specialized knowledge and experience of professionals. Further, for statistical validation of collected data, quantitative reasoning behind sample size must be established. The number of people required to make an adequate sample for an interview-based qualitative research can vary from one to a hundred or more. Baker et al. (2012) suggested a sample of loosely around 30 individuals and Adler and Adler (2011) advised to sample between 12 and 60.

A recent study on similar lines used a sample size of 53 individuals (Fiolet et al., 2016) based on Cochran (2007) which uses a fixed confidence level, marginal error and sample mean. To compute the sample size, selection biases and sampling errors must be considered. The size of sample must be suitably selected to accurately reflect the true population size. The definitions for the *selection biases*, *sample mean* and *sampling errors* are:

- *Selection bias*: When the true selection probabilities differ from those assumed in calculating the results, it is not certain that the sample accurately represents the population. The confidence interval is the probability that the sample influenced the result. The most common value in academic research is 95%. This means that there is a 95% chance of obtaining the same result if the experiment is done a second time. If the sample does not consist of people selected randomly but rather people selected according to certain representative groups, then a factor needs to be added to the sample size.

- The *sample mean* is a point estimate. It is useful because the distribution is known. However, as a point estimate it has the undesirable property that its distance from the true population mean is unknown; it is unlikely to exactly equal it. So, a confidence interval is computed from the data derived from the questionnaire, which is an estimate that combines the variability and sample size. Usually, when a confidence interval is built, it is with a 95% confidence level. In this case, on repeated sampling from the population, 95% of the numerical intervals generated are expected to contain the population mean; by chance, 5% will not.
- *Random sampling error (or margin of error)*: This refers to random variation in the results due to the elements in the sample being selected at random. The common value for this is 5%. This means, for example, that if the value found is 80%, the real answer is between 75% and 85%.

The standard formula is given in Equation 3.1 (Cochran, 2007), where *n* shows the sample size, *m* the margin of error, *p* the sample mean and *t* the factor linked with confidence level.

$$n = \frac{t^2 p(1-p)}{m^2}$$ **Equation 3.1**

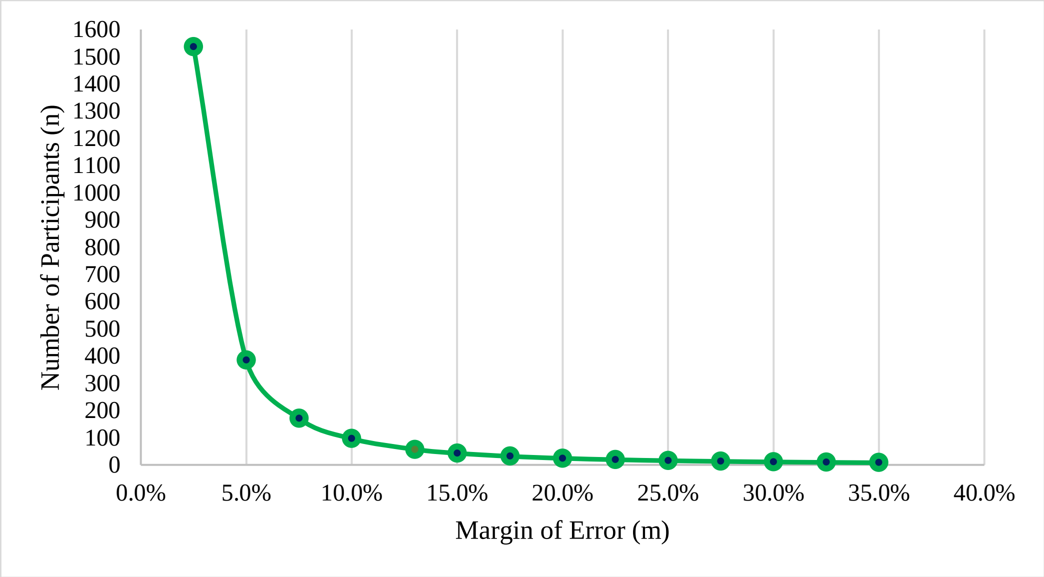

Figure 3.2: Confidence Interval vs Sample Size

In Figure 3.2, a graph is presented with a 95% confidence level for the confidence interval, linking the sample size (ordinate) and the margin of error (abscissa) by using the statistical formula introduced in Equation 3.1. Basing on the established logic, sample size for this study is 43 which is based on margin of error ±15%, confidence level 95% and sample mean 50%. This sample size is in the upper range as suggested by Adler and Adler (2011) and marginally larger than Fiolet et al. (2016) providing statistical validity and justification.

3.2.2 Questionnaire Design

In this phase, a data collection tool in the form of a closed-ended questionnaire was developed. This questionnaire consisted of two section. In the first section, demographics of the respondents were asked. Second section contained a series of relatable and realistic scenarios reported in English describing typical situations in construction projects focusing on three constraints of project success: time, cost and quality. Each scenario was presented with two possible options which were simple and easy to understand. Following the best practices of behavioural research (McFadden, 2001), scenarios were kept simple in order to minimize the influence of external factors and maximize the comprehension for respondents. In this context, detailed efforts were deployed, and internal and external experts were consulted to generate logically and physically appropriate questions. Also, to keep them closer to reality, local currency units and places were used. A currency conversion in US dollars is also provided. One scenario is given as an example below while rest of them are given in Appendix I.

"You are acting as Procurement Manager for your construction company. For a new project of 3 story commercial building located in Karachi, you have been tasked to purchase marble for flooring of 20,000 ft^2. The preparatory works for marble installation are underway and will be complete within 3 days. The approved lump sum cost for marble is Rs. 1.7 million ($16,150)). You have two options for marble purchasing.

a) *The local market in Pak Colony has given a rate of Rs. 80/ft^2 ($0.75) including the carriage and will deliver the material on site by next day.*

b) *While visiting the market, you get a news that a quarry in Baluchistan (a distant province known for marble production) has announced a clearance sale due to closing of its operations. Thus, they are giving a discount of Rs. 7/ft^2 ($0.07). However, the carriage charges will be Rs. 100,000 ($950). The normal delivery time is 2 days but due to travel risk, the on-time delivery of material is 75% certain.*

Which option will you select?"

Closed-ended questions can facilitate the respondents in answering faster and better. Such arrangement has been found useful for assessing the risk behaviour of respondents as reported by various studies (Allais, 1953b; Kahneman and Tversky, 1979). By design of options, participants were obligatory to choose between taking or avoiding risks which helped reach decisive conclusion.

3.2.3 Pilot Survey

In total, 16 risky but realistic scenarios were developed from construction industry. These questions were presented to 5 senior management professionals to detect any flaws, oversimplifications, or technical mistakes. The purpose of pilot survey was improvement of the designed questionnaire. In this activity, once scenario (#9) was discarded by the experts since it lacked realistic circumstances. Thus, the final version of the questionnaire contained 15 scenarios in total.

3.2.4 Details of the Final Questionnaire

As given in Table 3.1, these 15 scenarios were presented to the respondents to minimize the chance of detecting any patterns and structure of the experiment. Further, they were asked to make choices considering only explicitly described risky conditions as real and relevant construction risk behaviour to the decision. The experiment thus designed had two objectives: first to determine the sensitivity of construction management professionals to different typical risks during decision making process; second to study the impact of key project parameters on those decisions. It is evident that all three project success criteria were sufficiently addressed in the risk scenarios. Coincidentally, all outcomes under Option A were certain and those under Option B were probable with their corresponding prospect value as shown in Table 3.1. The negative sign in some scenarios shows the threat perspective of risk and the rest are associated with opportunity.

3.2.5 Developing Equations for Weighting Function ($\omega_{o|t}$)

To achieve this purpose of rationalization of opportunity and threat weight, a weighting function $\omega_{o|t}$ is proposed in second phase of research which is mathematically given in Equation 3.2, where $\omega_{o|t}$ is the weighting function for opportunity or threat, x

represents the PI-prospect and y is a limiting function that rationalizes the value function v proposed by Prospect Theory. In the case of opportunities, the value of ω_o will be a sum of unity and $f(x, y)$ and difference in case of threats.

Table 3.1: Details of risk scenarios

Scenario #	Affected Project Objective	Reference Value (RV)	Option A	Option B
1	**Cost**	PKR450,000 ($ 4,275)	(18,000) ($171)	(48,000, 0.5) ($456, 0.5)
2	**Quality**	PKR30,000,000 ($ 285,000)	(-1,000,000) (-$9,500)	(-4,000,000, 0.5) (-$38,000, 0.5)
3	**Cost**	PKR1,700,000 ($ 16,150)	(100,000) ($950)	(140,000, 0.75) ($1,330, 0.75)
4	**Time**	PKR2.5b ($ 233.75m)	(250m) ($2.375m)	(336m, 0.8) ($3.192m, 0.8)
5	**Time**	PKR30,000,000 ($ 285,000)	(-3,000,000) (-$28,500)	(-12,000,000, 0.33) (-$114,000, 0.33)
6	**Time**	PKR4,140,000 ($ 39,330)	(-1,350,000) (-$12,825)	(-17,880,000, 0.15) (-$169,860, 0.15)
7	**Cost**	PKR233b ($ 2.214b)	(100b) ($950m)	(133b, 0.8) ($1.263b, 0.8)
8	**Cost**	PKR4,400,000 ($ 41,800)	(88,000) ($836)	(264,000, 0.5) ($2,508, 0.5)
9	**Quality**	PKR30,000,000 ($ 285,000)	(-1,000,000) (-$9,500)	(-5,000,000, 0.2) (-$47,500, 0.2)
10	**Cost**	PKR36,000,000 ($ 342,000)	(3,000,000) ($28,500)	(6,624,000, 0.7) ($62,928, 0.7)
11	**Time**	PKR3,300,000 ($ 31,350)	(-1,350,000) (-$12,825)	(-2,300,000, 0.6) (-$21,850, 0.6)
12	**Cost**	PKR1,700,000 ($ 16,150)	(40,000) ($380)	(240,000, 0.25) ($2,280. 0.25)
13	**Cost**	PKR4,400,000 ($ 41,800)	(88,000) ($836)	(880,000, 0.1) ($8,360, 0.1)
14	**Time**	PKR30,000,000 ($ 285,000)	(-4,500,000) (-$42,750)	(-6,000,000, 0.9) ($57,000, 0.9)
15	**Cost**	PKR450,000 ($ 4,275)	(36,000) ($342)	(40,000,0.9) ($380, 0.9)

$$\boldsymbol{\omega_{o|t} = 1 \pm f(x, y)} \qquad \textbf{Equation 3.2}$$

Further, since *x* and *y* are context specific, they are mathematically expandable as given in Equation 3.3 and Equation 3.4. It is imperative to note that the mathematical operation between *x* and *y* depends upon the risk; in case of opportunities, the prescribed mathematical operation is multiplication and division when dealing with threat.

3.2.5.1 PI-prospect (*x*)

Equation 3.3 shows the newly developed 'PI-prospect' that resembles to conventional PI-model.

$$\boldsymbol{x = \frac{1}{2}\sum_{i=1}^{n}(\alpha_i . \mu_i)} \qquad \textbf{Equation 3.3}$$

α represents the normalized value of utility of option *i* with respect to reference value (RV) of scenario given in monetary terms, mathematically given by $\alpha_i = \frac{EV_i}{RV}$, and μ shows the proportion of respondents who opted for the option *i*, as given by $\mu_i = \frac{n_i}{N}$. Equation 3.3 is logically based on conventional risk quantification method. Such that α reflects the impact part of conventional PI-model and μ signifies the probability aspect. In this study, options are presented in the form of disjoint events. Thus, an average of the product of normalized value with the proportion of respondents opting for it is denoted by *x* i.e. PI-prospect.

3.2.5.2 Limiting Function (*y*)

Equation 3.4 represents the limiting function having a value of 1 and 2 depending upon the risk behaviour. This value of limiting function is in correspondence with PT suggesting that losses seem larger than gains by a proportion tending to 2.

$$y = \begin{cases} \mathbf{1} & \boldsymbol{for\ risk\ aversion} \\ \mathbf{2} & \boldsymbol{for\ risk\ seeking} \end{cases}$$ **Equation 3.4**

3.2.6 Data Collection

All the data were collected by personally interviewing seasoned construction professionals occupying managerial and decision making positions. Every participant was briefed about the nature and scope of research to receive most realistic response. All data were collected in a single round of interviews and no feedback was considered to introduce any changes in the questionnaire. However, the same has been incorporated to suggest future research recommendations. Lastly, numerical analysis was performed on the collected data to attain the ranges of weighting function for both down- and up-side risks. In doing so, the associated expected values (EV) for each question in the experiment were computed for both options.

3.3 Summary

This chapter discusses the research design for this study. Initially, sample size was finalized with the support of literature and statistical techniques. Then a closed-ended questionnaire comprising realistic scenarios of construction, was devised followed by development of equations to be used in analysis phase. Lastly, a debate on data collection has been done.

Chapter 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter describes a detailed analysis of the collected data. Results are drawn and a comprehensive discussion has been done on various findings in relevant sections.

4.2 Interviews and Demographics

This experiment was conducted in accordance with the ethical guidelines of the Research Office of National University of Sciences and Technology (NUST), Islamabad which are in line with the international best practices. In total, 57 senior construction professionals from major cities of Pakistan i.e. Islamabad, Lahore and Karachi as shown in Figure 4.1.

Figure 4.1: Respondents' City

Average experience of the respondents participated in this experiment, was above 20 years. Since more than half of the respondents aged over 40 years, as shown in Figure 4.2, and had experience greater than 20 years, as shown in Figure 4.3, the data received can be considered reliable and of high quality.

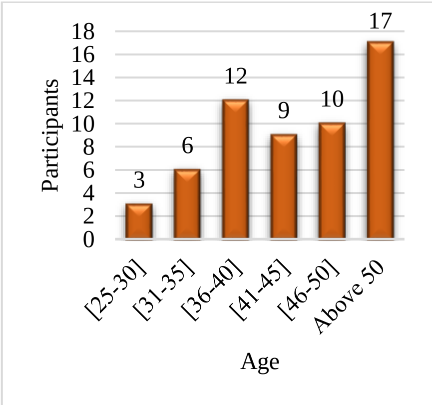

Figure 4.2: Distribution of the participants' age

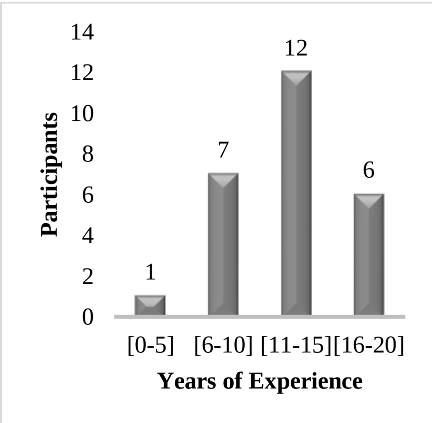

Figure 4.3: Distribution of the participants' experience

In terms of gender distribution, most of the respondents were male (93%) with a smaller portion of female (7%) project leaders. Though this is a typical representation of the male–female ratio in the industry (Fiolet et al., 2016), it raises the question for future research of whether higher proportion of female project managers will exhibit different behaviour under the same circumstances as their male counterparts. The participants held management positions at different levels under titles of General

Manager (GM), Project Manager (PM), Resident Engineer (RE), Project Director (PD) and Chief Executive (CEO) as shown in Figure 4.4.

The involvement of high ranking professionals ensures a holistic view of project activities and thus provides data which can be generalized for almost the entire lifecycle of construction project. Further, the organizational background of the participants has been so selected that all major stakeholders are sufficiently represented to generalize the findings for entire construction industry. In doing so, general contractors (24), consultants (14) and clients (12) form almost 90% of sample as shown in Figure 4.5.

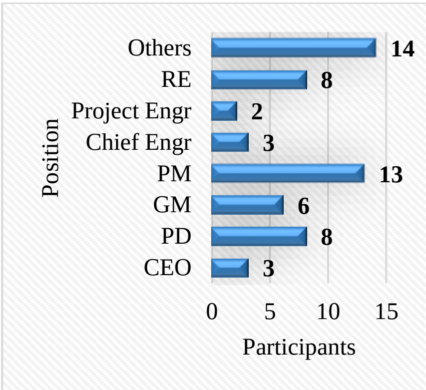

Figure 4.4: Distribution of the participants' position

Overall, this sample was as representative of global population of construction professionals as was possible keeping in view the resource constraints. Although the sample could be insufficient for some purposes, it is adequate to indicate few interesting and potentially important results discussed in greater details in the following sections.

4.3 Analysis for Weighting Function (*ω*)

In the next phase of the analysis, the range of weighting function ω is calculated for both threat (ω_t) and opportunity (ω_o) separately using Equation 3.2 so that it can be incorporated into risk quantification.

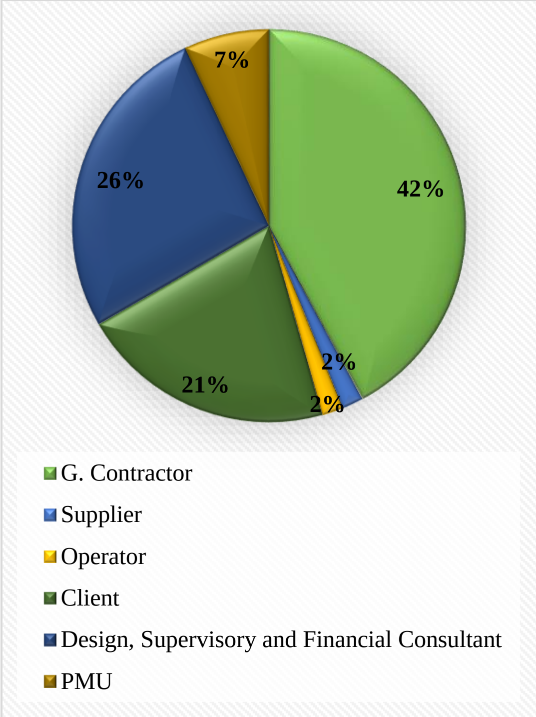

Figure 4.5: Distribution of the participants' organization

4.3.1 Calculating PI-prospect (x)

As explained in the methodology, the weighting function ω is a function of x and y. Therefore, to calculate the PI-prospect for each scenario, Equation 3.3 is used and results are given in Table 4.1. The expected value (EV) of various scenarios presented to the respondents is as per the prospect and reference values given in Table 3.1. It is intuitive to see larger prospect when stakes are large and vice versa in the form of α ranging between 0 and 1. The marginal difference of α between two scenarios is of no significance as the scenarios are context specific and bound by their independent reference values. Also, owing the mutual exclusivity of options A and B, the sum of α_A and α_B equates to unity.

Similar is the case with μ which represents the proportion of experts opting for a certain option in a scenario. It is interesting to note that in majority of scenarios, respondents are showing a conclusive behaviour either by chasing or avoiding the risk.

Further, keeping in view the larger proportion of respondents selecting Option A, it can be deduced that construction professionals maintain their traditional behaviour towards risk by actively avoiding it (Fiolet et al., 2016). However, the scenario 4 exhibits an opposite response where most of the participants agreed to take risk instead of avoiding it. It is important to note that the scenario presented a very costly infrastructure works in which the two options, though both were probable in accordance with Kahneman and Tversky (1979), were distinguished by use of advanced technology which positively reflected on quality. So, in case when quality was at stake, construction professionals seemed to choose any option that supported it regardless of their risk preference. Not only this came out in quantitative findings, the same was consistently reiterated by them during interviews owing to the overall impact of quality provision on organizational reputation

Most interestingly the scenarios 5 and 6 exhibit mixed behaviour where conclusive trend is hard to find since experts seemed indifferent towards seeking or escaping risk. Particularly scenario 5 where experts were asked to treat a procurement situation from contractor's perspective either purchasing from local or foreign supplier under strict contractual binding of time which could result into substantial liquated damages in case of late delivery. Upon a careful analysis, it is revealed though majority of experts chose to take risk in this situation by not altering their previous decision and sticking to it despite tighter schedule, a considerable proportion still chose to opt for a new way out. The last column of Table 4.1 reports average of the product of α and μ in the form of PI-prospect x. It can be observed that value of x for scenarios 6, 7 and 11 is larger as compared to rest due to higher outcomes of prospects with respect to their RV.

Table 4.1: PI-prospect value of risk scenarios

Scenario #	EV of A	EV of B	$\alpha_i = \frac{EV_i}{RV}$		n_i		$\mu_i = \frac{n_i}{N}$		x
			α_A	α_B	n_A	n_B	μ_A	μ_B	
1	18,000 ($171)	24,000 ($228)	0.0400	0.0533	52	4	0.929	0.071	0.0205
2	-1,000,000 (-$9,500)	-2,000,000 (-$19,000)	0.0333	0.0667	55	1	0.982	0.018	0.0170
3	100,000 ($950)	105,000 ($998)	0.0588	0.0618	41	15	0.732	0.268	0.0298
4	250m ($2.375m)	269m ($2.55)	0.1000	0.1076	7	49	0.125	0.875	0.0533
5	-3,000,000 (-$28,500)	-4,000,000 (-$38,000)	0.1000	0.1333	25	31	0.446	0.554	0.0592
6	-1,350,000 (-$12,825)	-2,682,000 (-$25,479)	0.3261	0.6478	36	20	0.643	0.357	0.2205
7	100b ($950m)	106b ($1b)	0.4292	0.4567	48	8	0.857	0.143	0.2166
8	88,000 ($836)	132,000 ($1,254)	0.0200	0.0300	42	14	0.750	0.250	0.0113
9	-1,000,000 (-$9,500)	-1,000,000 (-$9,500)	0.0333	0.0333	53	3	0.946	0.054	0.0167
10	3,000,000 ($28,500)	6,036,000 ($57,342)	0.0833	0.1677	41	15	0.732	0.268	0.0530
11	-1,350,000 (-$12,825)	-1,380,000 (-$13,110)	0.4091	0.4182	45	11	0.804	0.196	0.2054
12	40,000 ($380)	60,000 ($570)	0.0235	0.0353	51	5	0.911	0.089	0.0123
13	88,000 ($836)	88,000 ($836)	0.0200	0.0200	48	8	0.857	0.143	0.0100
14	-4,500,000 (-$42,750)	-5,400,000 (-$51,300)	0.1500	0.1800	51	5	0.911	0.089	0.0763
15	36,000 ($342)	36,000 ($342)	0.0800	0.0800	47	9	0.839	0.161	0.0400

However, the smaller values would suggest that a comparatively smaller stake with respect to RV is being presented. For example, the x values of scenarios 1, 2, 3 and so on. It is important to note that majority of scenarios are yielded with a very small PI-prospect value which reflects that a particular risk, however critical, has a marginal effect on the overall project as usually happens in construction endeavours. But put together, these risks have significant combined effect which demands a formal and effective management (Perera et al., 2009). Further, it is also imperative to notice that the prospect is a function of reference value. Therefore, comparable *x* values can be achieved despite larger variance of references values as evident in scenarios 4 and 5 since prospect outcomes are 10-13% of the reference values.

4.3.2 Ranges of Weighting Function (ω)

After calculating PI-prospect *x*, the range of weighting function ω is calculated for both upside and downside risks by selecting the value of limiting function *y* which is prospect-specific and discretely ranges between 1 and 2.

4.3.2.1 Ranges of ω for Threats (ω_t)

The general model for $\omega_{o|t}$ given in Equation 3.2 can be expanded for threats as shown in Equation 4.1.

$$\boldsymbol{\omega_t = 1 - \frac{\left[\frac{1}{2}\sum_{i=1}^{n}(\alpha_i . \mu_i)\right]}{[y]}}$$ **Equation 4.1**

As given in research methodology, some scenarios presented threatening prospect and some opportunistic as distinguished by a negative (-) sign in Table 3.1 and Table 4.1. Applying the weighting function model given in Equation 4.1 on scenarios with downside risks, individual values of ω_t for each scenario are reported in Table 4.2.

Since threats are overestimated, the value of ω as a mathematical counter-function comes out be less than unity. On average, the overestimation is quantified to range between 11% and 5% by taking a difference of average values at $y = 1$ and $y \rightarrow 2$ from unity. In terms of individual cases, such as in scenario 2, when limiting function is kept at 1, we rationalize the overestimation by 3% which reduces further to 1.5% when *y* is kept at 2. It is intuitive to figure out that with relaxed limiting function, the overestimation would tend to the conventional values. On average, with smaller value of *y*, 5% rationalization in overestimation of threat is achieved compared to that of upper value of *y*. Upon close observation of scenarios 6 and 12, it can be seen that the difference in optimization is 11% and 10% respectively which is substantially higher than average improvement. This is mainly due to higher stakes compared to reference value as presented in these scenarios. This particular situation has drastically influenced the intuitive risk assessment of experts in the form of greater anticipation of threat than usual circumstances. The similar trends have been previously reported in construction industry where experts were found more conscious of threats when the profit margin started to shrink (Han et al., 2005).

Table 4.2: Weighting Function for Threats (ω_t)

Scenario #	x	ω_t at y = 1	ω_t at y → 2
2	0.0283	0.972	0.986
5	0.0577	0.942	0.971
6	0.2226	0.777	0.889
10	0.0500	0.950	0.975
12	0.2055	0.795	0.897
15	0.0764	0.924	0.962
Average Range		**0.890**	**0.947**

4.3.2.2 Ranges of ω for Opportunities (ω_o)

In case of opportunities, the general form given in Equation 3.2 can be expanded as shown in Equation 4.2. Further, using the PI-prospect values of opportunistic scenarios, the range of weighting function ω_o at $y = 1$ and $y \to 2$ is reported in Table 4.3.

$$\omega_o = 1 + \left[\frac{1}{2}\sum_{i=1}^{n}(\alpha_i . \mu_i)\right] \times [y] \qquad \textbf{Equation 4.2}$$

Owing to the underestimating pattern for opportunities, the value of weighting function ω comes out to be greater than unity. On average the conventional methods underestimate the opportunities in the range of 5% to 10%. It is also important to note that for better rationalization, higher value of y is preferable in opportunistic scenarios. Such as in case of scenario 1, the improvement due to limiting function ranges between 2% to 4%. However, it is interesting to note that in case of threats, the maximum overestimation should not cross the logical and conventional threshold of unity. But same is not the case with opportunities where setting a limit not only requires in-depth research into human behaviour but will also be case-, context- and time-specific (Nwogugu, 2005).

Table 4.3: Weighting Function for Opportunities (ω_o)

Scenario #	***x***	**ω_o at $y = 1$**	**ω_o at $y \rightarrow 2$**
1	0.0204	1.020	1.041
3	0.0298	1.030	1.060
4	0.0533	1.053	1.107
7	0.2164	1.216	1.433
8	0.0112	1.011	1.022
11	0.0534	1.053	1.107
13	0.0123	1.012	1.025
14	0.0100	1.010	1.020
16	0.0400	1.040	1.080
Average Range		**1.050**	**1.099**

An anomalous condition occurs in scenario 7 where the range of ω is as large as 22% at different values of y. Upon closer observation, it is revealed that the stakes are 50% and 53% of reference value which represent significant amounts for a single risk. As amply established, the traditional PI-model does not have the capacity to reflect upon the value at stake. But the behavioural tendencies seem to take larger percentage of potential profit in view by significantly rationalizing the quantification of opportunity.

4.4 Discussion

With an aim to rationalize the risk assessment, this study has computed the over- and under-estimation factor when dealing with threats and opportunities respectively. To attain better risk quantities, the said factor should be incorporated to achieve reliable and defendable findings which can later be converted into suitable response strategies. As inferred in the previous section, a threat normally measured to unity has a more balanced value between the range 0.89 – 0.95, meaning that it is overestimated with a minimum factor of 5% and maximum of 11%. Actively underestimating within this range would allow to reach a more realistic value. Further, this may also reflect upon the individual risk behaviour such as risk prone individuals are suggested to opt for upper range of underestimate and lower range should be considered by comparatively less risk averse individuals (Gächter et al., 2007).

Similarly, an upside risk estimated at unity has a realistic value between a range of 1.05 – 1.10. This implies that an opportunity is usually underestimated to a minimum of 5% and maximum of 10%. Getting a balanced value would require overestimating them within the given range. Also, the behavioural implications hold equally significant in this case that individuals with higher propensity towards risk may select the upper range and those with relatively less liking for risk should go for lower range of weighting function. Thus, the trend for estimation bias due to limiting function follows a mirroring effect for threat and opportunity. In the case of opportunities, the behavioural influence in risk assessment at lower values of y is greater. However, the same is true for higher values of y in the case of threat.

4.4.1 Generalizing the Results

Since risk is a very personal behavioural trait and owing to the complexities of human nature, it is quite challenging to possibly generalize the quantities generated by the weighting function ω. So, to compare and validate the rationalizing factor, ranges are presented grouped by significant personal characteristics of respondents to find out the possible divergences between them. Literature on human behaviour suggests that risk propensity varies between younger and older individuals (Nicholson et al., 2002). So to investigate the behavioural variation, the age-wise classification of sample is performed keeping middle age (>45) as threshold as established by (Merriam-Webster Dictionary, 2016) and recently used by (Fiolet et al., 2016).

Following this logic, the younger group consists of 30 and older group of 27 respondents. As given in Table 4.4, the ranges for the two groups are so similar that a difference only occurs after third decimal place which nullifies any significance. However, statistical validation in the form of one-way ANOVA is performed to check any significant difference otherwise not noticeable. The p-value for difference between age groups in terms of opportunities is 5.0707E-06 and for threats is 1.75338E-05. It is deduced that such smaller p-values point towards insignificant difference of priorities between age groups and thus the findings can be generalized for individuals of almost all ages covered in the sample.

Table 4.4: Ranges of Weighting Function (ω)

Range of ω_o		**Range of ω_t**	
Over all	1.0496 - 1.0992	**Over all**	0.8932 - 0.9466
Age up to 45	1.0496 - 1.0993	**Age up to 45**	0.8930 - 0.9465
Age above 45	1.0495 - 1.0991	**Age above 45**	0.8934 - 0.9467
Experience up to 20	1.0497 - 1.0994	**Experience up to 20**	0.8934 - 0.9467
Experience above 20	1.0495 - 1.0991	**Experience above 20**	0.8930 - 0.9465

Further, it was hypothesized that the individual experience may affect risk perception and its treatment. Thus, to investigate it, the sample was divided based on the experience threshold of 20 years. The participants with experience up to 20 years counted to 25 and those with more experience were 31. A visual inspection of numbers given in Table 4.4 reveals a similar trend of difference after third decimal place. Likewise, statistical validation is performed using one-way ANOVA which reveals p-value in case of opportunities as 1.31837E-05 and for threats as 1.75338E-05. Owing to such low p-value, the hypothesis is rejected, generalizing the average ranges for all interviewed participants. Further, literature suggests a significant behavioural variation between male and female participants (Nicholson et al., 2002). However, owing to a smaller size of female participants in current study, this cannot be validated. Any future work which can investigate this phenomenon will highly benefit research as well as industry.

4.5 Practical Implications

The practical implications of this discussion translate into a generic weighting function $\omega_{o|t}$ which when incorporated with traditional PI-model, as shown in Equation 4.3, gives out a refined and rational measurement.

$$\boldsymbol{R = \omega_{o|t} \times PI} \qquad \textbf{Equation 4.3}$$

4.5.1 Rationalizing Conventional PI Matrix

Risk matrices are a valuable tool for quickly and effectively quantifying risks and evaluating in a practical way. They help rank and prioritize risk of (generally adverse) events and make decisions whether certain risks can be tolerated (Duijm, 2015). One of their forms is PI matrix which is a common and handy quantification tool mostly used in risk assessment (PMI, 2013). It takes the discrete values of probability and impact to return their linear product. It is said that a risk matrix should show logical compatibility with quantitative risks (Cox, 2008). It is worth mentioning that in addition to certain limitations as reported by Cox (2008), traditional PI matrix weighs threats and opportunities equally while categorizing them as shown in Figure 4.6.

	Threat					Opportunity					
5	5.0	10.0	15.0	20.00	25.00	25.00	20.00	15.0	10.0	5.0	**5**
4	4.0	8.0	12.0	16.0	20.00	20.00	16.0	12.0	8.0	4.0	**4**
3	3.0	6.0	9.0	12.0	15.0	15.0	12.0	9.0	6.0	3.0	**3**
2	2.0	4.0	6.0	8.0	10.0	10.0	8.0	6.0	4.0	2.0	**2**
1	1.0	2.0	3.0	4.0	5.0	5.0	4.0	3.0	2.0	1.0	**1**
I / P	**1**	**2**	**3**	**4**	**5**	**5**	**4**	**3**	**2**	**1**	**I / P**

Figure 4.6: Conventional PI Matrix

Using the ranges of weighting function $\omega_{o|t}$, a rationalized PI matrix is formulated as shown in Figure 4.7. The output values of threats are rounded down and opportunities are rounded up following the trend of weighting function.

	Threat					Opportunity					
5	4.6	9.2	13.8	18.4	23.0	26.9	21.5	16.2	10.8	5.4	**5**
4	3.6	7.3	11.0	14.7	18.4	21.5	17.2	12.9	8.6	4.3	**4**
3	2.7	5.5	8.2	11.0	13.8	16.2	12.9	9.7	6.5	3.3	**3**
2	1.8	3.6	5.5	7.3	9.2	10.8	8.6	6.5	4.3	2.2	**2**
1	0.9	1.8	2.7	3.6	4.6	5.4	4.3	3.3	2.2	1.1	**1**
I / P	**1**	**2**	**3**	**4**	**5**	**5**	**4**	**3**	**2**	**1**	**I / P**

Figure 4.7: Rationalized PI Matrix

The practical implication of rationalized PI matrix suggests that a threat with probability and impact of 5 has a significance value of 23 instead of 25. Further, rationalized risk assessment of opportunities implies that a prospect with probability and potential impact of 5 will have a value almost 27 instead of 25. This indicates that the real value of opportunity seems considerably larger than that given by conventional methods and therefore suitable arrangements must be made to exploit it. Hence, deployment of resources to manage risk must keep in view the realistic value at stake and not the inflated or suppressed values which may be flawed due to indifferent treatment of risk prospect.

4.5.2 Risk Response Strategies

In a project scenario, where numerable threats and opportunities are attached to a project, a rationalized risk assessment will mean optimal resource allocation for response strategies. The point of risk analysis is to calculate cost, time and quality variations, and support the execution staff with necessary resources to effectively respond in case the variations exceed the acceptable ranges (PMI, 2013). It is surely obvious that to carry out such analyses, both threat and opportunity need to be given equal significance, as the effect of an upside risk will be quite different from that of a downside risk but it will characteristically counter the overall contingency reserve.

It is argued that the contingency-allocation approach is inevitably subjective and, largely judgmental and arbitrary (Yeo, 1990; Tah et al., 1993). Modern estimating textbooks usually represent the contractor's contingency as a fixed percentage of direct cost. Meredith and Mantel Jr (2011) suggested that the common way is to make an allowance for contingencies, usually 5% to 10% of the estimated cost. It is also assumed that contractors also have their own historical records to consider in setting contingency values (Smith and Bohn, 1999). Further, Moselhi (1997) argued that contingency expressed as a percentage of total project cost is not sufficient unless its level is linked with some probability (or confidence) at which cost overruns will not exceed the allocated limit.

Under low-bid, competitive tendering regimes, a contractor is less likely to win a bid if contingency is set too high. On the contrary, contingency set too low could result in significant financial losses. Therefore, contractors would be wise to consider the likelihood that a particular risk will occur, identify the potential financial impact and then determine the appropriate amount of contingency (Smith and Bohn, 1999) in the face of ever-straining client behaviour to allow for larger contingency amount.

In conclusion, the conventional method of contingency allocation may be argued to be too simplistic as it can easily reduce to a routine administrative procedure that requires little investigation and decision making by estimators and senior management (Tah et al., 1993). The proposed rationalizing approach will help project sponsors and managers in realistically measuring the effect of threats and opportunities on project objectives to come up with a defendable and justified contingent responses.

4.6 Results Significance

To validate the findings, five actuals bids for construction of a combined gas-steam power house were evaluated. Cost breakup was available from where the direct cost and contingency cost were observed. All the cost values are given in Euro (€) currency unit. Row 4 of Table 4.5 show the exposure that has been estimated by the bidders using traditional PI-model of risk quantification and the respective values of contingency budget are given in Row 3.

It is important to note that owing to their conventional mind-sets, only downside risks were identified and considered for contingency estimation and opportunities were ignored. When applied the rationalized quantification model using various rationalization values (in percentage), output values of risk exposure and contingency were reduced towards estimations based on rules of thumb as shown in Table 4.5

Table 4.5: Validation of Findings

Bid			Bid 1	Bid 2	Bid 3	Bid 4	Bid 5
Direct Cost (€)			19,743,367	19,585,575	26,851,000	26,388,413	26,234,186
Contingency Budget (€)			2,599,721	2,631,834	3,483,950	2,720,645	2,334,843
Risk Exposure			13.2%	13.4%	13.0%	10.3%	8.9%
Percentage Rationalization	**5.0%**	**Rationalized Contingency (€)**	2,469,735	2,500,243	3,309,752	2,584,613	2,218,100
		Rationalized Risk Exposure (%)	12.5%	12.8%	12.3%	9.8%	8.5%
		p-Value	0.001 < 0.05				
	6.0%	**Rationalized Contingency (€)**	2,443,738	2,473,924	3,274,913	2,557,407	2,194,752
		Rationalized Risk Exposure (%)	12.4%	12.6%	12.2%	9.7%	8.4%
		p-Value	0.002 < 0.05				
	7.5%	**Rationalized Contingency (€)**	2,404,742	2,434,447	3,222,653	2,516,597	2,159,729
		Rationalized Risk Exposure (%)	12.2%	12.4%	12.0%	9.5%	8.2%
		p-Value	0.005 < 0.05				
	9.0%	**Rationalized Contingency (€)**	2,365,746	2,394,969	3,170,394	2,475,787	2,124,707
		Rationalized Risk Exposure (%)	12.0%	12.2%	11.8%	9.4%	8.1%
		p-Value	0.011 < 0.05				
	10.0%	**Rationalized Contingency (€)**	2,339,749	2,368,651	3,135,555	2,448,581	2,101,358
		Rationalized Risk Exposure (%)	11.9%	12.1%	11.7%	9.3%	8.0%
		p-Value	0.018 < 0.05				

Percentage Rationalization	**11.0%**	**Rationalized Contingency (€)**	2,313,752	2,342,333	3,100,715	2,421,374	2,078,010
		Rationalized Risk Exposure (%)	11.7%	12.0%	11.5%	9.2%	7.9%
		p-Value	0.027 < 0.05				
	12.0%	**Rationalized Contingency (€)**	2,287,755	2,316,014	3,065,876	2,394,168	2,054,661
		Rationalized Risk Exposure (%)	11.6%	11.8%	11.4%	9.1%	7.8%
		p-Value	0.039 < 0.05				

4.6.1 Significance Test

To check whether the results of this study are significant as compared to the conventional PI-model, t- test has been performed on the values of contingency budget before and after rationalization as given in Table 4.5. At 8% rationalization, the p-value comes out to be 0.005 (< 0.05) which is within the acceptable range and thus the significance hypothesis is accepted. Upon further trials, it is observed that p-value remains significant if threats are rationalized up to a factor of 12%. It can be concluded that this difference due to findings of this study is significant.

4.7 Summary

This chapter includes a comprehensive debate on results followed by discussions. A rationalizing weighting function (ω) was developed for both threats and opportunities. Next, the practical implications of this study were discussed. Finally, the results were checked for significance with the help of a case study from construction industry.

Chapter 5

CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter concludes the research by stating and summarizing the inferences, findings, limitations, and recommendations. The insight helps us understand the crux of the study and parting ways for future endeavours related to this area of research.

5.2 Conclusion

No construction project is risk free. Risk can be managed, minimized, shared, transferred or accepted, but it cannot be ignored. For its better and effective management, risk must be quantified rationally. The quantitative risk assessment, despite demanding objective probabilities and frequencies, and complex methodologies, is considered reliable (Tah and Carr, 2001a). However, it is based on well-established but controversial PI-model proposed by Expected Utility Theory. Several studies have discussed the limitations of this model one of which is its oversimplifying tendency. Further, it does not incorporate the behavioural aspect of decision makers. Also, it weighs threats and opportunities equally which is contrary to the reality where losses have more weight as compared to gains as reported by Kahneman and Tversky (1979) in their Prospect Theory (PT). While some researches have argued that although losses loom larger than gains, this quantification cannot be generalized. Hence, rationalization of already existing risk quantification model is needed by applying PT in construction industry.

This study has tried to fill up the above-mentioned gap by following a logical methodology. A weighting function has been developed following a semi-structured interview-based data collection. Senior management professionals from construction industry of Pakistan were engaged to find that threats are overestimated by almost 5-12% and opportunities are underestimated by 5-10%. Based on these factors, a rationalized version of value function proposed by PT synthesized as graphically represented in Figure 5.1. The newly proposed rationalized model, when integrated into risk quantification, would result in formation of more realistic and efficient response strategies. One such example is estimation of a fitting contingency amount which will not only cover uncertain conditions effectively but also not seem too much to the client.

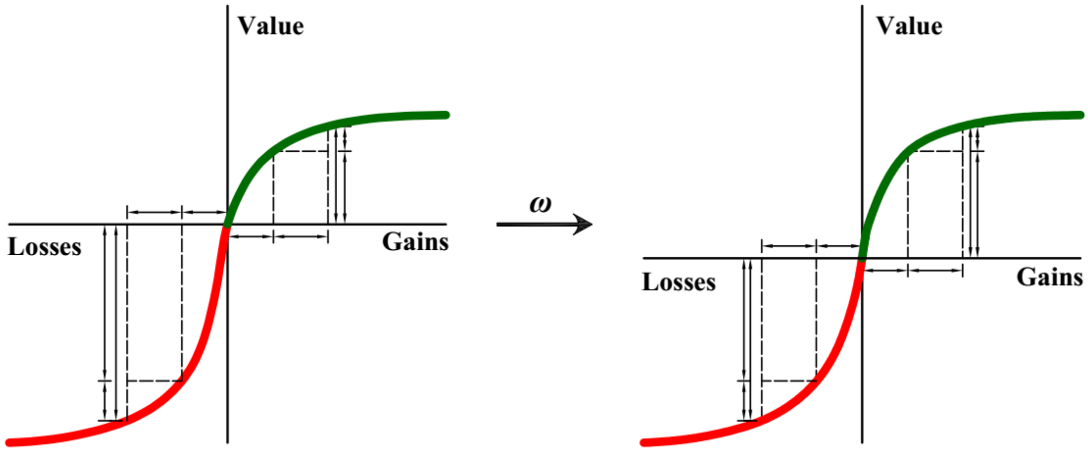

Figure 5.1: Rationalized Value Function

5.3 Limitations and Recommendations

This study is limited in its integration of probability weights given by Prospect Theory. Future research effort can be directed towards developing a more rationalized quantification model by synthesizing the probability weights into the proposed model. Also, integrating the additional dimension of risk explored by various studies (Jannadi and Almishari, 2003; Cervone, 2006; Zeng et al., 2007; Han et al., 2008) and introducing some newer ones would result in more holistic assessment model. Further, this study is restricted to the construction industry based on a limited number of risk scenarios which can be generalized by bringing inputs from other industries and opening the prospect into multinomial options. The body of knowledge will benefit from such novel development of rationalizing factor which may trigger even more research into better measurement of risk.

REFERENCES

Acharya, N. K., Dai Lee, Y., & Man Im, H. (2006). Conflicting factors in construction projects: Korean perspective. *Engineering, Construction and Architectural Management, 13*(6), 543-566.

Adler, P. A., & Adler, P. (2011). *The tender cut: Inside the hidden world of self-injury*: NYU Press.

Ali, T. H., Stewart, R. A., & Qureshi, S. (2007). *Evaluating risk management practices in the pakistani construction industry: The current state of play*. Paper presented at the Proceedings of the Fourth International Conference on Construction in the 21st Century: Accelerating Innovation in Engineering, Management and Technology.

Allais, M. (1953a). Le comportement de l'homme rationnel devant le risque: Critique des postulats et axiomes de l'ecole Americaine. *Econometrica*.

Allais, M. (1953b). Le comportement de l'homme rationnel devant le risque: Critique des postulats et axiomes de l'ecole americaine [Behavior of the rational man under risk: Critical assumptions and axioms from the American School]. *Econometrica, 21*(4), 503-546.

Althaus, C. E. (2005). A disciplinary perspective on the epistemological status of risk. *Risk analysis, 25*(3), 567-588.

Andi. (2006). The importance and allocation of risks in Indonesian construction projects. *Construction Management and Economics, 24*(1), 69-80.

Arrow, K. J. (1982). Risk perception in psychology and economics. *Economic inquiry, 20*(1), 1-9.

Atheam, J. L., & Pritchett, S. (1969). Risk and Insurance: St. Paul: West Publishing Company.

Aven, T., & Guikema, S. (2015). On the Concept and Definition of Terrorism Risk. *Risk analysis, 35*(12), 2162-2171.

Aven, T., & Krohn, B. S. (2014). A new perspective on how to understand, assess and manage risk and the unforeseen. *Reliability Engineering & System Safety, 121*, 1-10.

Bajaj, D., Oluwoye, J., & Lenard, D. (1997). An analysis of contractors' approaches to risk identification in New South Wales, Australia. *Construction Management & Economics, 15*(4), 363-369.

Baker, S., Ponniah, D., & Smith, S. (1999). Survey of risk management in major UK companies. *Journal of Professional Issues in Engineering Education and Practice, 125*(3), 94-102.

Baker, S. E., Edwards, R., & Doidge, M. (2012). How many qualitative interviews is enough?: Expert voices and early career reflections on sampling and cases in qualitative research.

Baloi, D., & Price, A. D. (2003). Modelling global risk factors affecting construction cost performance. *International Journal of Project Management, 21*(4), 261-269.

Barnes, M. (1983). How to allocate risks in construction contracts. *International Journal of Project Management, 1*(1), 24-28.

Beeston, D. (1986). Combining risks in estimating. *Construction Management and Economics, 4*(1), 75-79.

Broadbent, J. (2007). If you can't measure it, how can you manage it? Management and governance in higher educational institutions. *Public Money and Management, 27*(3), 193-198.

Bunni, N. G. (2003). *Risk and insurance in construction*: Routledge.

Camerer, C. F., Loewenstein, G., & Rabin, M. (2011). *Advances in behavioral economics*: Princeton University Press.

Campbell, I. B. (1980). *Accident Statistics and Significance: Their Practical Application in New Zealand*: Department of Business Studies, Faculty of Business, Massey University.

Cervone, H. F. (2006). Project risk management. *OCLC Systems & Services: International digital library perspectives, 22*(4), 256-262.

Chan, A. P., Chan, D. W., Chiang, Y., Tang, B., Chan, E. H., & Ho, K. S. (2004a). Exploring critical success factors for partnering in construction projects. *Journal of Construction Engineering and Management, 130*(2), 188-198.

Chan, A. P., Scott, D., & Chan, A. P. (2004b). Factors affecting the success of a construction project. *Journal of Construction Engineering and Management, 130*(1), 153-155.

Chan, D. W., Chan, A. P., Lam, P. T., Yeung, J. F., & Chan, J. H. (2011). Risk ranking and analysis in target cost contracts: Empirical evidence from the construction industry. *International Journal of Project Management, 29*(6), 751-763.

Chan, E. H., & Au, M. C. (2007). Building contractors' behavioural pattern in pricing weather risks. *International Journal of Project Management, 25*(6), 615-626.

Chapman, C., & Ward, S. (2000). Estimation and evaluation of uncertainty: a minimalist first pass approach. *International Journal of Project Management, 18*(6), 369-383.

Charette, R. N. (1989). *Software engineering risk analysis and management*: Intertext Publications New York.

Chen, Y. Q., Zhang, S. J., Liu, L. S., & Hu, J. (2015). Risk perception and propensity in bid/no-bid decision-making of construction projects. *Engineering, Construction and Architectural Management, 22*(1), 2-20.

Chou, J.-S., Pham, A.-D., & Wang, H. (2013). Bidding strategy to support decision-making by integrating fuzzy AHP and regression-based simulation. *Automation in Construction, 35*, 517-527.

Choudhry, R. M., & Iqbal, K. (2012). Identification of risk management system in construction industry in Pakistan. *Journal of Management in Engineering, 29*(1), 42-49.

Chua, D., & Li, D. (2000). Key factors in bid reasoning model. *Journal of Construction Engineering and Management, 126*(5), 349-357.

Cioffi, D. F., & Khamooshi, H. (2009). A practical method of determining project risk contingency budgets. *Journal of the Operational Research Society, 60*(4), 565-571.

Clark, P., & Chapman, C. (1987). The development of computer software for risk analysis: A decision support system development case study. *European Journal of Operational Research, 29*(3), 252-261.

Cochran, W. G. (2007). *Sampling techniques*: John Wiley & Sons.

Conrow, E. H. (2003). *Effective risk management: Some keys to success*: Aiaa.

Cooper, D., MacDonald, D., & Chapman, C. (1985). Risk analysis of a construction cost estimate. *International Journal of Project Management*, *3*(3), 141-149.

Cox, L. A. T. (2008). What's wrong with risk matrices? *Risk analysis*, *28*(2), 497-512.

Dikmen, I., Birgonul, M. T., & Arikan, A. E. (2004). *A critical review of risk management support tools.* Paper presented at the 20th Annual Conference of Association of Researchers in Construction Management (ARCOM).

Duijm, N. J. (2015). Recommendations on the use and design of risk matrices. *Safety science, 76*, 21-31.

Edwards, L. (1995). *Practical risk management in the construction industry*: Thomas Telford.

Edwards, P. J., & Bowen, P. A. (1998). Risk and risk management in construction: a review and future directions for research. *Engineering, Construction and Architectural Management, 5*(4), 339-349.

El-Sayegh, S. M. (2008). Risk assessment and allocation in the UAE construction industry. *International Journal of Project Management*, *26*(4), 431-438.

El-Sayegh, S. M. (2014). Project risk management practices in the UAE construction industry. *International Journal of Project Organisation and Management, 6*(1-2), 121-137.

Enshassi, A., Al-Najjar, J., & Kumaraswamy, M. (2009). Delays and cost overruns in the construction projects in the Gaza Strip. *Journal of Financial Management of Property and Construction*, *14*(2), 126-151.

Faber, W. (1979). Protecting giant projects: A study of problems and solutions in the area of risk and insurance. *Willis Faber, England, Ipswich, UK.*

Fiolet, J.-C., Haas, C., & Hipel, K. (2016). Risk-chasing behaviour in on-site construction decisions. *Construction Management and Economics*, 1-14.

Fiolet, J.-C., & Haas, C. T. (2015). Application of prospect theory to management decisions under risk on construction projects.

Flanagan, R., & Norman, G. (1993). Risk management and construction.

Gächter, S., Johnson, E. J., & Herrmann, A. (2007). Individual-level loss aversion in riskless and risky choices.

Giddens, A. (1999). Runaway World: How Globalisation is Reshaping Our Lives: JSTOR.

Gilovich, T., Vallone, R., & Tversky, A. (1985). The hot hand in basketball: On the misperception of random sequences. *Cognitive psychology*, *17*(3), 295-314.

Gray, C. F. (2000). Project management: The management process.

Haimes, Y. (2004). Risk modeling, assessment and management. *Risk modeling, assessment and management*(Ed. 2).

Haimes, Y. Y. (1991). Total risk management. *Risk analysis, 11*(2), 169-171.

Haimes, Y. Y. (1993). Risk of extreme events and the fallacy of the expected value. *Control and Cybernetics, 22*(4), 7-31.

Han, S. H., Diekmann, J. E., & Ock, J. H. (2005). Contractor's risk attitudes in the selection of international construction projects. *Journal of Construction Engineering and Management, 131*(3), 283-292.

Han, S. H., Kim, D. Y., Kim, H., & Jang, W.-S. (2008). A web-based integrated system for international project risk management. *Automation in Construction, 17*(3), 342-356.

Harinck, F., Van Dijk, E., Van Beest, I., & Mersmann, P. (2007). When gains loom larger than losses reversed loss aversion for small amounts of money. *Psychological science, 18*(12), 1099-1105.

Haynes, J. (1895). Risk as an economic factor. *The Quarterly Journal of Economics, 9*(4), 409-449.

Henderson, M. (1987). *Living with Risk: The British Medical Assocation Guide*: John Wiley & Sons Incorporated.

Hertz, D. B., & Thomas, H. (1983). *Risk analysis and its applications*: Wiley Chichester etc.

Hillson, D. (2002). Extending the risk process to manage opportunities. *International Journal of Project Management, 20*(3), 235-240.

Hulett, D. T., Hillson, D., & Kohl, R. (2002). Defining risk: A debate. *Cutter IT Journal, 15*(2), 4-10.

Jannadi, O. A., & Almishari, S. (2003). Risk assessment in construction. *Journal of Construction Engineering and Management, 129*(5), 492-500.

Kahneman, D., & Frederick, S. (2002). Representativeness revisited: Attribute substitution in intuitive judgment. *Heuristics and biases: The psychology of intuitive judgment, 49*.

Kahneman, D., Knetsch, J. L., & Thaler, R. H. (1990). Experimental tests of the endowment effect and the Coase theorem. *Journal of political Economy*, 1325-1348.

Kahneman, D., & Tversky, A. (1979). Prospect theory: An analysis of decision under risk. *Econometrica: Journal of the Econometric Society*, 263-291.

Kahneman, D., & Tversky, A. (1984). Choices, values, and frames. *American psychologist, 39*(4), 341.

Kaming, P. F., Olomolaiye, P. O., Holt, G. D., & Harris, F. C. (1997). Factors influencing construction time and cost overruns on high-rise projects in Indonesia. *Construction Management & Economics, 15*(1), 83-94.

Kangari, R., & Riggs, L. S. (1989). Construction risk assessment by linguistics. *Engineering Management, IEEE Transactions on, 36*(2), 126-131.

Kaplan, S., & Garrick, B. J. (1981). On the quantitative definition of risk. *Risk analysis, 1*(1), 11-27.

KarimiAzari, A., Mousavi, N., Mousavi, S. F., & Hosseini, S. (2011). Risk assessment model selection in construction industry. *Expert Systems with Applications, 38*(8), 9105-9111.

Kim, S.-Y., Van Tuan, N., & Ogunlana, S. O. (2009). Quantifying schedule risk in construction projects using Bayesian belief networks. *International Journal of Project Management, 27*(1), 39-50.

Knetsch, J. L. (1992). Preferences and nonreversibility of indifference curves. *Journal of Economic Behavior & Organization, 17*(1), 131-139.

Knight, F. H. (1921). *Risk, uncertainty and profit*.

Komljenovic, D., Gaha, M., Abdul-Nour, G., Langheit, C., & Bourgeois, M. (2016). Risks of extreme and rare events in Asset Management. *Safety science, 88*, 129-145.

Laryea, S. (2008). Risk pricing practices in finance, insurance and construction.

Lifson, M. W., & Shaifer, E. F. (1982). Decision and Risk Analysis for Construction Management. *JOHN WILEY & SONS, INC., 605 THIRD AVE., NEW YORK, NY 10158. 1982.*

Lirer, L., Petrosino, P., & Alberico, I. (2001). Hazard assessment at volcanic fields: the Campi Flegrei case history. *Journal of volcanology and geothermal research, 112*(1), 53-73.

Lopes, L. L. (1983). Some thoughts on the psychological concept of risk. *Journal of Experimental Psychology: Human Perception and Performance, 9*(1), 137.

Lowrance, W. W. (1976a). Of Acceptable Risk.

Lowrance, W. W. (1976b). *Of Acceptable Risk: Science and the Determination of Safety*.

Luce, R. D., & Weber, E. U. (1986). An axiomatic theory of conjoint, expected risk. *Journal of Mathematical Psychology, 30*(2), 188-205.

Lyons, T., & Skitmore, M. (2004). Project risk management in the Queensland engineering construction industry: a survey. *International Journal of Project Management, 22*(1), 51-61.

Mandel, D. R. (2007). *Toward a concept of risk for effective military decision making*. Retrieved from

Markowitz, H. (1952). Portfolio selection. *The journal of finance, 7*(1), 77-91.

McFadden, D. (2001). Economic choices. *The American Economic Review, 91*(3), 351-378.

Meredith, J. R., & Mantel Jr, S. J. (2011). *Project management: a managerial approach*: John Wiley & Sons.

Merriam-Webster Dictionary. (2016). Retrieved from http://www.merriam-webster.com/dictionary

Monetti, E., Rosa, S., & Rocha, R. (2006). The practice of project risk management in government projects: A case study in Sao Paulo City. *Construction in Developing Economics: New Issues and Challenges. Santiago, Chile (18—20 January 2006).*

Moselhi, O. (1997). Risk assessment and contingency estimating. *AACE International Transactions*, 90.

Mullainathan, S., & Thaler, R. H. (2000). *Behavioral economics*. Retrieved from

Mustafa, M. A., & Al-Bahar, J. F. (1991). Project risk assessment using the analytic hierarchy process. *Engineering Management, IEEE Transactions on, 38*(1), 46-52.

Neumann, J. v., & Morgenstern, O. (1944). *Theory of games and economic behavior* (Vol. 60): Princeton university press Princeton.

Nicholson, N., Fenton-O'Creevy, M., Soane, E., & Willman, P. (2002). Risk propensity and personality. *London Business School, Open University Business School and Said Business School Oxford, London*.

Novemsky, N., & Kahneman, D. (2005). How do intentions affect loss aversion? *Journal of marketing research, 42*(2), 139-140.

Nwogugu, M. (2005). Towards multi-factor models of decision making and risk: A critique of Prospect Theory and related approaches, part I. *The Journal of Risk Finance, 6*(2), 150-162.

Oxford English Dictionary. (2016). Retrieved from http://www.oed.com/

Paulson, B. C., & Barrie, D. S. (1992). *Professional Construction Management*: Mcgraw-Hill International, Singapore.

Perera, B., Dhanasinghe, I., & Rameezdeen, R. (2009). Risk management in road construction: the case of Sri Lanka. *International Journal of Strategic Property Management, 13*(2), 87-102.

Perry, J. G., & Hayes, R. (1985). Risk and its management in construction projects. *Proceedings of the Institution of Civil Engineers, 78*(3), 499-521.

Pfeffer, I. (1956). *Insurance and economic theory*: Pub. for SS Huebner Foundation for Insurance Education, Univ. of Pennsylvania, by RD Irwin.

PMI. (2013). A Guide to Project Management Body of Knowledge (PMBOK® GUIDE). Pennsylvania, USA: Project Management Institute, Inc.

Rabin, M., & Schrag, J. L. (1999). First impressions matter: A model of confirmatory bias. *Quarterly journal of Economics*, 37-82.

Raz, T., & Hillson, D. (2005). A comparative review of risk management standards. *Risk Management*, 53-66.

Renn, O. (1990). The role of risk perception for risk management. *Reliability Engineering & System Safety, 59*(1), 49-62.

Renn, O. (1998). Three decades of risk research: accomplishments and new challenges. *Journal of risk research, 1*(1), 49-71.

Riegel, R., & Loman, H. J. (1966). *Insurance, principles and practices* (5th ed.): Prentice-Hall.

Rosa, E. A. (2003). The logical structure of the social amplification of risk framework (SARF): Aferatheoretical foundations and policy implications. *The social amplification of risk, 47*.

Sanvido, V., Grobler, F., Parfitt, K., Guvenis, M., & Coyle, M. (1992). Critical success factors for construction projects. *Journal of Construction Engineering and Management*, *118*(1), 94-111.

Simonson, I., & Tversky, A. (1992). Choice in context: Tradeoff contrast and extremeness aversion. *Journal of marketing research, 29*(3), 281.

Skorupka, D. (2003). Risk management in building projects. *AACE International Transactions*, RI191.

Smith, G. R., & Bohn, C. M. (1999). Small to medium contractor contingency and assumption of risk. *Journal of Construction Engineering and Management*, *125*(2), 101-108.

Stearns, S. C. (2000). Daniel Bernoulli (1738): evolution and economics under risk. *Journal of biosciences, 25*(3), 221-228.

Sun, L. (2009). Loss aversion in prospect theory.

Tah, J., & Carr, V. (2001a). Knowledge-based approach to construction project risk management. *Journal of computing in civil engineering, 15*(3), 170-177.

Tah, J., & Carr, V. (2001b). Towards a framework for project risk knowledge management in the construction supply chain. *Advances in Engineering Software, 32*(10), 835-846.

Tah, J. H., Thorpe, A., & McCaffer, R. (1993). Contractor project risks contingency allocation using linguistic approximation. *Computing systems in engineering*, *4*(2), 281-293.

Tang, W., Qiang, M., Duffield, C. F., Young, D. M., & Lu, Y. (2007). Risk management in the Chinese construction industry. *Journal of Construction Engineering and Management, 133*(12), 944-956.

Taroun, A. (2014). Towards a better modelling and assessment of construction risk: Insights from a literature review. *International Journal of Project Management, 32*(1), 101-115. doi:10.1016/j.ijproman.2013.03.004

Teneyuca, D. (2001). Organizational leader's use of risk management for information technology. *Information Security Technical Report, 6*(3), 54-59.

Thaheem, M. J., De Marco, A., & Barlish, K. (2012). *A review of quantitative analysis techniques for construction project risk management.* Paper presented at the Proceedings of the Creative Construct Conference.

Thevendran, V., & Mawdesley, M. (2004). Perception of human risk factors in construction projects: an exploratory study. *International Journal of Project Management, 22*(2), 131-137.

Tsui, T. C. (2013). Experience from the anti-monopoly law decision in China (Cost and Benefit of Rule of Law). *The Network: Business at Berkeley Law (Apr/May 2013)*.

Tversky, A., & Kahneman, D. (1991). Loss aversion in riskless choice: A reference-dependent model. *The Quarterly Journal of Economics*, 1039-1061.

Tversky, A., & Kahneman, D. (1992). Advances in prospect theory: Cumulative representation of uncertainty. *Journal of Risk and uncertainty, 5*(4), 297-323.

Twersky, A., & Kahneman, D. (1981). The framing of decisions and the psychology of choice. *Science, 211*, 453-458.

Usmani, F. (2015). A Short Guide to Expected Monetary Value (EMV). Retrieved from http://pmstudycircle.com/2015/01/a-short-guide-to-expected-monetary-value-emv/

Verma, M., & Verter, V. (2007). Railroad transportation of dangerous goods: Population exposure to airborne toxins. *Computers & operations research, 34*(5), 1287-1303.

Vose, D. (2008). *Risk analysis: a quantitative guide*: John Wiley & Sons.

Wang, M. T., & Chou, H. Y. (2003). Risk allocation and risk handling of highway projects in Taiwan. *Journal of Management in Engineering, 19*(2), 60-68.

Ward, S. C. (1998). Assessing and managing important risks. *International Journal of Project Management, 17*(6), 331-336.

Williams, T. (1996). The two-dimensionality of project risk. *International Journal of Project Management, 14*(3), 185-186.

Willis, H. H. (2007). Guiding resource allocations based on terrorism risk. *Risk analysis, 27*(3), 597-606.

Yeo, K. (1990). Risks, classification of estimates, and contingency management. *Journal of Management in Engineering, 6*(4), 458-470.

Zayed, T., Amer, M., & Pan, J. (2008). Assessing risk and uncertainty inherent in Chinese highway projects using AHP. *International Journal of Project Management, 26*(4), 408-419.

Zeng, J., An, M., & Smith, N. J. (2007). Application of a fuzzy based decision making methodology to construction project risk assessment. *International Journal of Project Management, 25*(6), 589-600.

Zou, P. X., Chen, Y., & Chan, T.-Y. (2009). Understanding and improving your risk management capability: assessment model for construction organizations. *Journal of Construction Engineering and Management, 136*(8), 854-863.

APPENDICES

Appendix I: Questionnaire

Section 1: Personal Details

1. Your Name: ______________________ **2.** Gender: **a.** Male **b.** Female

3. Your age (in years): ________________ **4.** Position: _________________

5. Your organization is:

a. Academia **b.** Main/General Contractor **c.** Subcontractor

d. Supplier **e.** Design Consultant **f.** Supervisory Consultant

g. Financial Consultant **h.** PM Unit **i.** Client

j. Operator

6. PEC Category of your organization (for contractors only):

a. C-A **b.** C-B **c.** C-1 **d.** C-2 **e.** C-3 **f.** C-4

g. C-5

7. Your working experience (in years)

a. 0-5 **b.** 6-10 **c.** 11-15 **d.** 16-20 **e.** Above 20

Section 2: Risk Response in Construction

1. To perform a concreting job on your newly acquired project, you have directed the Materials Engineer to prepare the required amount of concrete. He reports back that everything including materials and equipment are ready for the job scheduled for tomorrow. But late at night, Equipment In-charge at site calls you to inform about leakage in concrete mixer drum due to some accident. This has rendered your machine of 1014 m^3/hr productivity useless for the job. In the light of new information, it is not possible to carry out the task within the deadline. You now have two options to save a job worth Rs. 450,000 (Rs. 390,000 for concrete + overhead and profit).

- ⬭ You call your friend Engr. Syed M. Rizwan, Shift Manager at Exicrete Ltd., a commercial concrete plant. He informs you that due to prior commitment of supplying concrete to an industrial facility, it'll be extremely hard to provide the required 60 m^3 concrete by tomorrow. Even if he can manage, he'll charge an additional Rs. 200/m^3 on the usual rate of Rs. 7000/m^3 for 3000 psi concrete.

- You also call M. Ehsanullah Khan, proprietor of Marwat Construction Machinery, to arrange for a concrete mixer on rent. He informs you that currently only one old machine having an average productivity of 5.5 m^3/hr is available and can be sent over to your site within time. You estimate that it'll take a nonstop duration of 11 hours to be able to finish the task with this machine at an estimated success rate of 50%. This will require either paying overtime to the labour or arranging a second shift. In both cases, your cost will exceed Rs. 390,000, resulting into a reduction of Rs. 12,000 in total profit.

Which option will you select?

Under what conditions, you will go for the rejected option?

2. You are working as Project Manager for Chinese language black at NUML, Islamabad. The project has been funded by the Ministry of Culture, Government of China. NUML has provided land and other ancillary service. The total duration has been estimated at 2 years. NUML seeks a better quality of construction. You have following options.

- Hire a fulltime QA/QC Engineer who will cost total of Rs. 1 million during the 2 years.

- Do not maintain dedicated staff for QA/QC and run a risk of excessive Non-conformance Reports. Such quality performance will not go well with Quality Audit process and there is a 50% chance that due to bad quality, damages amounting to 4 million may be imposed.

Which option will you select?

Under what conditions, you will go for the rejected option?

3. You are acting as Procurement Manager for your construction company. For a new project of 3 story commercial building located in Karachi, you have been tasked to purchase marble for flooring of 20,000 ft2. The preparatory works for marble installation are underway and will be complete within 3 days. The approved lump sum cost for marble is Rs. 1.7 million. You have two options for marble purchasing.

- The local market in Pak Colony has given a rate of Rs. 80/ft2 including the carriage and will deliver the material on site by next day.

- While visiting the market, you get a news that a quarry in Baluchistan has announced a clearance sale due to closing of its operations. Thus, they are giving a discount of Rs. 7/ft2. However, the carriage charges will be Rs. 100,000. The normal delivery time is 2 days but due to travel risk, the on-time delivery of material is 75% certain.

Which option will you select?

Under what conditions, you will go for the rejected option?

4. You are acting as the Project Manager for expansion works of a major container terminal at Karachi port. One of the works is to provide pile foundation to a depth of 1422 meters in different sections depending upon the ground conditions. This is done to stabilize the existing quay wall of 450m whose current foundation will get exposed once capital dredging is done to increase the draft from 11m to 14m. The budgeted cost for this work is Rs. 2.5 billion and duration is 10 months. A corporate overhead of Rs. 7 million and job overhead of Rs. 3 million per month is estimated. Owing to disturbance of commercial activities at the port, this is a time sensitive project which is reflected by a large liquidated damage of Rs. 1,500,000 per day and an early completion bonus of Rs. 1,200,000 per day. The design team comes with following two options.

- To insitu construct the RCC end bearing piles using reverse rotary and auger bucket methods on different sites as per geological conditions. Success rate of this method is quite high (95%) due to previous experience of similar construction in the region. However, this method is primarily time intensive. A detailed ground investigation study has been conducted to ascertain the geological conditions and therefore the chance of delay due to uncertainty in ground conditions is 25%. The lump sum cost quoted by the piling subcontractor under ideal conditions is Rs. 2.25 billion.

- To drive steel tubular piles of varying diameter ranging from 80 cm to 200 cm using Movax vibro hammer. The average productivity for this hammer is 2 inch/hour. You approach a German subcontractor, Keller Group, working out of their Dubai office who are known for this kind of work. Though they have never worked in Pakistan, they feel comfortable due to several Pakistani employees in their Dubai office. Looking at the geotechnical site investigation report, they quote an amount of Rs. 2.3 billion and a duration of 7 months with a success rate of 80%.

Which option will you select?

Under what conditions, you will go for the rejected option?

5. Your organization is a well-known HVAC specialty contractor. The Project Manager for the New Sheraton Hotel in Bahria, Rawalpindi has invited you to install HVAC system. The budgeted cost of equipment is estimated at Rs. 30 million. You have been working with ROTRONIC AG, a reputed HVAC supplier from Germany, since a few years. You enjoy a good working relationship with them and get quality equipment within scheduled duration. For another project, you were procuring ducts and AHUs (air handling units). Taking advantage of that communication, you placed the order for Sheraton HVAC two months ago, before signing the contract, paying 10% of the total equipment cost in advance. Delivery time for the order is 30 ±10 days. After carefully reading the contract, it is revealed that the liquidated damage of Rs. 400,000 per day is imposed. It has already been 30 days and the shipment hasn't left the production facility in Germany yet. You are available with the following two options.

- Cancel the order by paying a penalty of 50% on the advance paid and purchase the equipment from the local supplier with an additional 5% cost. In this case you will get on time delivery and LDs can be avoided.

- Stick to the order already placed and pay LDs to the client in case of delay if it happens.

Which option will you select?

Under what conditions, you will go for the rejected option?

6. You are working as General Manager of south zone for construction operations of a major national construction company. Your current portfolio involves 3x road projects, 2x warehouse/storage facilities and 2x infrastructure works. You get a news that the Project Manager for one of your infrastructure projects has passed away of natural cause. As much you sympathize with the family of deceased PM, you are also concerned about the project whose deadline is fast approaching within 6 months. Your concern is genuine as a huge amount of Rs. 500,000 per day has been imposed as liquidated damage. You contact your Vice President and he authorizes you to take any suitable action to resolve this emergency. You have following options.

- You call Engr. Syed Mujtaba Sheeraz Mufti, a skilled and competent engineer who has managed several projects of this nature. Engr. Mufti's competence is surpassed by his emergency management skills. He happily agrees to join your projects. You are aware that Engr. Mufti will come at an additional 50% salary. The deceased PM was drawing Rs. 450,000 per month.

- You also consider promoting Engr. Haroon A. Chaudhry, currently working as Construction Manager, to the position of Project Manager. Though Haroon will only cost an additional 30% over his current salary of Rs. 240,000 per month, his current responsibilities combined with tight deadlines may create problems. It is probable that the project will delay by 1 month with a probability of 15%.

Which option will you select?

Under what conditions, you will go for the rejected option?

7. As a public private partnership (PPP) consultant hired by NHA, you have been tasked to evaluate build-operate-transfer (BOT) proposals for M35 project. A couple of concessionaires have submitted their expression of interest (EOI) statements: FWO, a leading contractor specializing in infrastructure projects, and BinaPuri holdings, a Malaysian BOT contractor.

- FWO has submitted a bid of Rs. 48 billion against a concession period of 35 years and construction period of 3 years. They have arranged finance at debt/equity ratio of 70:30 from a consortium of local commercial banks. Their revenue model shows a growth of 10% per year in revenue generation with a confidence level of 85%. The revenue for base year is estimated at Rs. 2.8 billion. FWO has agreed to pay a flat rate of Rs. 4 billion per year starting from 11th year of concession period. They have requested this flexibility as their main concern is debt servicing which is compounding against a rate of 8%. The revenue model further proposes a corporate overhead of Rs. 5 billion, recurrent expenses of Rs. 80 million and maintenance cost of Rs. 100 million per year. Inflation is taken at 5% per year. The net revenue sharing with NHA will be Rs. 100 billion.

- BinaPuri holdings has submitted a rather ambitious bid of Rs. 45 billion against a concession period of 30 years and construction period of 3 years. The finance is being arranged at 100% debt from a consortium of Malaysian and Turkish banks. The chances of successful financial close are 80%. The revenue model still shows a growth of 10% per year in revenue but the confidence level has gone up to 95%. It further proposes a corporate overhead of Rs. 4 billion, recurrent expenses of Rs. 100 million and maintenance cost of Rs. 150 million per year. The revenue for base year is estimated at Rs. 3.5 billion against an escalated toll of 25%. BinaPuri has attempted to attract NHA by offering a fee of Rs. 2 billion in base year increasing at an annual rate of 5%. Inflation is taken at 5% and discount rate is assumed as 6% per year. The net revenue sharing with NHA will be around Rs. 133 billion.

Which option will you select?

Under what conditions, you will go for the rejected option?

8. You are working as Accounts Manager for a construction organization. The invoice for Green Cement Ltd. for a purchase of 8000 bags of cement which was submitted 30 days ago right after delivery of cement has been processed and a total amount of Rs. 4,400,000 has been transferred to your account for further payment. As part of purchase agreement, a time of 60 days between delivery and payment was decided. You have two options.

- Make payment to Green Cement Ltd. who have promised a 2% discount for early payment.

- Invest this money in trade since current time coincides with harvest period. An average profit of 1012% has been suggested by the broker at 50% confidence with a return period of 25 30 days. However, the past trends suggest that a loss of 56% may occur with a probability of 50%.

Which option will you select?

Under what conditions, you will go for the rejected option?

9. You are working as Project Manager for Chinese language black at NUML, Islamabad. The project has been funded by the Ministry of Culture, Government of China. NUML has provided land and other ancillary service. The total duration has been estimated at 2 years. NUML seeks a better quality of construction. You have following options.

- Hire a fulltime QA/QC Engineer who will cost you a total of Rs. 1 million during the 2 years.

- Do not maintain dedicated staff for QA/QC and run a risk of excessive Non-conformance Reports. Such quality performance will not go well with Quality Audit process and there is a 20% chance that due to bad quality, damages amounting to 5 million may be imposed.

<u>Which option will you select?</u>

<u>Under what conditions, you will go for the rejected option?</u>

10. You are the chief procurement officer for Grand Hyatt construction supply chain on One Constitution Avenue, Islamabad. You have to decide which of two vendors will provide project's "signature" windows. Your marketing department has advertised the usage of triple glazed windows that are beautiful and provide even more thermal efficiency, sound reduction and security than double glazed units. Made up of three panels of glass with double argon filled cavities that throw radiated heat, these windows claim saving on heating/cooling bills. Part of the marketing appeal is in the "Gold" category of LEED certification that you have promised with the buyers. One major component of the credits for certification will be based on the energy efficiency of the building which will be significantly contributed by the selection of appropriate windows. Thus, three factors are important in this decision making: (1) quality of the product, (2) cost and (3) aftersales service by the vendor. In total 1500 windows of 2 sizes: 6' x 4' (900 windows) and 6' x 6' (600 windows) are to be procured. The two vendors are Everest Limited based in UK and Agha Safety Glass Co. based in Pakistan.

- Everest has quoted the price of one unit at Rs. 18,000 and Rs. 30,000 including shipping and duties for two window sizes. Their previous record suggests that these windows give better efficiency and not only for "Gold" category, but have also been successfully installed in "Platinum" category buildings.

- Agha will charge Rs. 10,000 and Rs. 16,000 per unit with additional shipment charges of Rs. 90,000 per shipment containing a maximum of 400 windows. They have never tested their product for LEED certification. However, their theoretical values are within 90% range of their British competitor. Your experience suggests that the theoretical values usually fall within 80% of practical range.

Which option will you select?

Under what conditions, you will go for the rejected option?

11. You are working as General Manager of south zone for construction operations of a major national construction company. Your current portfolio involves 3x road projects, 2x warehouse/storage facilities and 2x infrastructure works. You get a news that the Project Manager for one of your infrastructure projects has passed away of natural cause. As much you sympathize with the family of deceased PM, you are also concerned about the project whose deadline is fast approaching within 6 months. Your concern is genuine as a huge amount of Rs. 300,000 per day has been imposed as liquidated damage. You contact your Vice President and he authorizes you to take any suitable action to resolve this emergency. You have following options.

- You call Engr. Syed Mujtaba Sheeraz Mufti, a skilled and competent engineer who has managed several projects of this nature. Engr. Mufti's competence is surpassed by his emergency management skills. He happily agrees to join your projects. You are aware that Engr. Mufti will come at an additional 50% salary. The deceased PM was drawing Rs. 450,000 per month.

- You also consider promoting Engr. Haroon A. Chaudhry, currently working as Construction Manager, to the position of Project Manager. Though Haroon will only cost an additional 30% over his current salary of Rs. 200,000 per month, his current responsibilities combined with tight deadlines may create problems. It is probable that the project will delay by 20 days with a probability of 60%.

Which option will you select?

Under what conditions, you will go for the rejected option?

12. You are acting as Procurement Manager for your construction company. For a new project of 3 story commercial building located in Karachi, you have been tasked to purchase marble for flooring of 20,000 ft2. The preparatory works for marble installation are underway and will be complete within 3 days. The approved lump sum cost for marble is Rs. 1.7 million. You have two options for marble purchasing.

- The local market in Pak Colony has given a rate of Rs. 83/ft2 including the carriage and will deliver the material on site by next day.

- While visiting the market, you get a news that a quarry in Baluchistan has announced a clearance sale due to closing of its operations. As a result, they are giving a discount of Rs. 15/ft2. However, the carriage charges will be Rs. 100,000. The normal delivery time is 2 days but due to travel risk, the on-time delivery of material is 25% certain.

Which option will you select?

Under what conditions, you will go for the rejected option?

13. You are working as Accounts Manager for a construction organization. The invoice for Green Cement Ltd. for a purchase of 8000 bags of cement which was submitted 30 days ago right after delivery of cement has been processed and a total amount of Rs. 4,400,000 has been transferred to your account for further payment. As part of purchase agreement, a time of 60 days between delivery and payment was decided. You have two options.

- Make payment to Green Cement Ltd. who have promised a 2% discount for early payment.

- Invest this money in trade since current time coincides with harvest period. An average profit of 25% has been suggested by the broker at 10% confidence with a return period of 2530 days. However, the past trends suggest that a loss of 5% may occur with a probability of 10%.

Which option will you select?

Under what conditions, you will go for the rejected option?

14. Your organization is a well-known HVAC specialty contractor. The Project Manager for the New Sheraton Hotel in Bahria, Rawalpindi has invited you to install HVAC system. The budgeted cost of equipment is estimated at Rs. 30 million. You have good links with German reputed suppliers. While procuring ducts and AHUs (air handling units) for another project, you placed the order for Sheraton HVAC two months ago, before signing the contract, paying 10% of the total equipment cost in advance. Delivery time for the order is 30 days with 90% delay chances. After carefully reading the contract, it is revealed that the liquidated damage of Rs. 200,000 per day is imposed. It has already been 30 days and the shipment hasn't left the production facility in Germany yet. You are available with the following two options.

- Cancel the order by paying a penalty of 50% on the advance paid and purchase the equipment from the local supplier with an additional 10% cost. In this case, you will get on time delivery and LDs can be avoided.

- Stick to the order already placed and pay LDs to the client in case of delay (90% chances).

Which option will you select?

Under what conditions, you will go for the rejected option?

15. To perform a concreting job on your newly acquired project, you have directed the Materials Engineer to prepare the required amount of concrete. He reports back that everything including materials and equipment are ready for the job scheduled for tomorrow. But late at night, Equipment In-charge at site calls you to inform about leakage in concrete mixer drum due to some accident. This has rendered your machine of 1014 m^3/hr productivity useless for the job. In the light of new information, it is not possible to carry out the task within the deadline. You now have two options to save a job worth Rs. 450,000 (Rs. 390,000 for concrete + overhead and profit).

- You call your friend Engr. Syed M. Rizwan, Shift Manager at Exicrete Ltd., a commercial concrete plant. He informs you that due to prior commitment of supplying concrete to an industrial facility, it'll be extremely hard to provide the required 60 m^3 concrete by tomorrow. Even if he can manage, he'll charge an additional Rs. 100/m^3 on the usual rate of Rs. 6800/m^3 for 3000 psi concrete.

- You also call M. Ehsanullah Khan, proprietor of Marwat Construction Machinery, to arrange for a concrete mixer on rent. He informs you that currently only one old machine having an average productivity of 5.5 m^3/hr is available and can be sent over to your site within time. You estimate that it'll take a nonstop duration of 11 hours to be able to finish the task with this machine at an estimated success rate of 90%. This will require either paying overtime to the labour or arranging a second shift. In both cases, your cost will exceed Rs. 390,000, resulting into a reduction of Rs. 20,000 in total profit.

Which option will you select?

Under what conditions, you will go for the rejected option?