RISK ANALYSIS FOR PROJECTS IN THE BUILDING INDUSTRY

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A research report submitted to the Faculty of Architecture, University of the Witwatersrand, in partial fulfillment of the requirements for the degree of Master of Science in Building in the specialised field of Project Management

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ABSTRACT

This research addresses the various risks and risk analysis techniques in the building industry in South Africa.

The principal objective of the research was to identify the risk analysis techniques used in the evaluation of building construction projects by project managers in the building industry in South Africa and determine the strengths and weaknesses of these techniques.

The literature review revealed a list of risks and twelve risk analysis techniques applicable to the construction industry. It also revealed the strengths and weaknesses of these techniques.

The descriptive survey method is used as the methodology for the research. A postal survey of sixty-eight project managers selected from the Professional and Projects Register 98 was conducted during November 1998. A response rate of 28% was achieved.

The survey showed that the risks that occur in building projects can be ranked on the basis of importance and frequency of occurrence. In addition, a visual comparison and Spearman's rank correlation coefficient showed a moderate positive relationship between the importance and frequency of occurrence of external predictable risks, internal non-technical risks, technical risks and legal risks. Analysis of the responses showed that the twelve risk analysis techniques are used in building construction projects but only to a very limited extent. Several reasons were indicated by the respondents for not using the techniques. The most predominant reason was that experience and judgement of management is perceived to be sufficient.

It was recommended that bodies such as the Project Management Institute, the Master Builders Association, the Council for Scientific Research in collaboration with tertiary institutions, should try and increase awareness on risk analysis, provide education on training on risks analysis and promote research on risk management.

DECLARATION

I declare that this research report is my own unaided work. It is being submitted in partial fulfilment of the requirements for the Degree of Master of Science (Building) in the specialised field of Project Management at University of the Witwatersrand, Johannesburg. It has not been submitted for any degree or examination in any other University.

....

LUCY W. CHEGE

27th day of February, 1999.

DEDICATION

To God and my beloved parents Mr. and Mrs. Chege for all the love and support they have given me.

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I also wish to express my gratitude to the Council for Scientific and Industrial Research (CSIR) – Boutek for their financial assistance.

All the respondents of the survey are acknowledged for their participation.

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CHAPTER ONE

INTRODUCTION

1.1 Background

Risk and uncertainty occur in all construction projects. In construction projects, there are four parameters within which the risks should be addressed. These are scope, quality, cost and time.

Large projects are particularly prone to cost and time overruns. One of the main reasons for this is that these risks may not have been properly assessed at inception of the project to ensure that either sufficient contingency is allowed or measures are taken at an early stage to entirely or partly prevent these risks from occurring.

The consequences of not carrying out a thorough risk analysis have been seen in some construction projects. Hall (1982) exemplifies this with the Humber bridge and the Barbican arts complex which suffered cost escalation of 400%, and the Sydney Opera House which finished over ten years late at a final cost of $A 102M compared to an original estimate of $A 7.2M. Lowe (1996) cites that The Bay Area Rapid Transit System in San Francisco, cost twice the original estimated price for half the original network. There are strong indications to suggest that if the risks inherent in these projects had been thoroughly analysed, these problems may have been minimised.

As seen in the examples above, projects require proper risk analysis because any deviation from the expected can lead to large financial losses. Risk analysis gives an insight into what happens if the project does not proceed according to plan.
Presently, the need for risk analysis cannot be overemphasized because the financial world, and hence project environments are more volatile now than they were years ago. Smithson *et al* (1995), concur with this, and stress that the financial world has become more risky.

A look at the price levels in England and the inflation rate in South Africa help to illustrate this point.

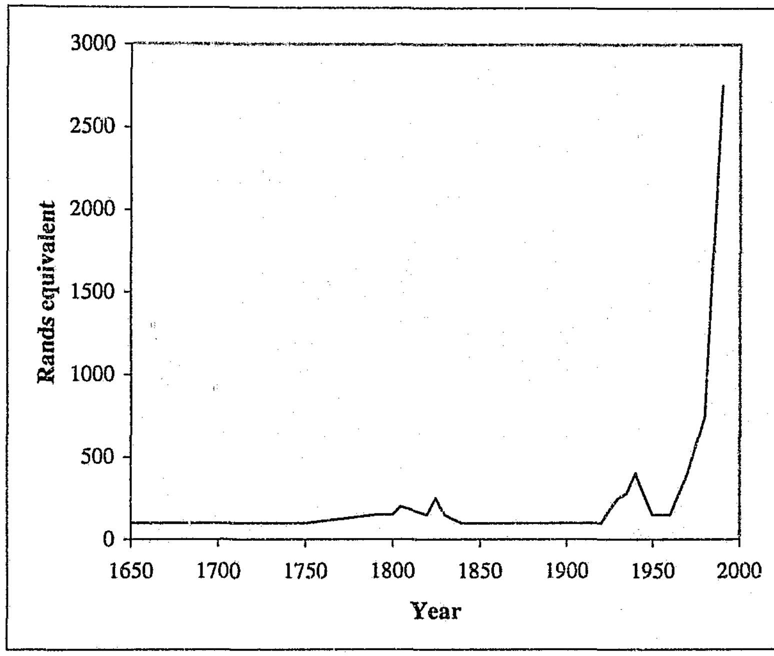


Figure 1.1 Long-term view of Price Levels for England (1850 = 100)
Source: Smithson *et al* (1995)

The price-level series shown begins in 1666 and runs through the mid-1980s. The remarkable fact revealed by this series is that for the first 250 years, prices changed very little (except in wartime). In contrast, in the last 30 or 40 years, prices have increased dramatically.

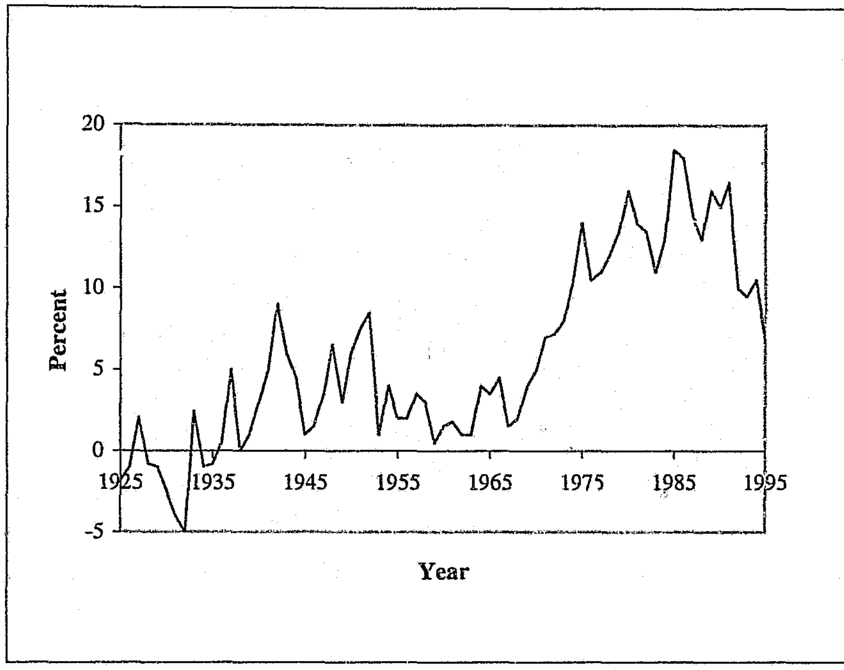


Figure 1.2 The Annual Rate of Inflation in South Africa from 1925 to 1995
Source: I-Net and Heather McLeod in Ross *et al* (1996)

What is clear is that not only have the prices been increasing, but also the rate of increase has been very volatile from year to year. This volatility has a large impact on project environments, and it means that firms must be equipped to handle the resultant financial risks.

Even if figure 1.2 shows that the rate of inflation in South Africa has declined, the uncertainty of future inflation remains.

This situation is not unique to the inflation rate, and other areas in South Africa where volatility has increased dramatically and uncertainty abounds are exchange rates and interest rates. It is imperative that South African firms utilise risk management techniques in order to shield themselves from this volatility.

According to Macnamara (1991) losses are incurred annually due to poor Project Risk Management. Further, Project Risk Management is a developing field and both descriptive and prescriptive research is needed to develop a better understanding and foundation for a contingency theory of project risk management for South Africa.

In the building and construction industries frequently projects run into problems or fail altogether. Co[illegible]ie (1991) states that "...one of the factors which is a cause of project failures is that the risks were not clearly identified and action was not taken to transfer or make contingency for these risks."

Hertz (1984) contends that risk analysis has an important role to play in the management of the strategic process through its input into such areas as: *forecasting and planning, risk positioning* for the firm, *scanning* of the uncertain business environment, *scenario development* in relation to potential social, political, economic and technological futures, and the *handling of risk and uncertainty,* which are increasingly stressed in modern strategic management paradigms.

Risk analysis is therefore a very important facet of project management and its importance cannot be overemphasized. It is important therefore to reassert that millions of Rands are being lost annually due to the lack of proper risk analysis in projects.

This research forms a basis from which a model for risk analysis for building construction projects in South Africa may be developed.

1.2 Objectives of the Research

1. To identify a comprehensive list of risks associated with building construction projects, and prioritise these risks in terms of importance and frequency of occurrence.
2. To identify the risk analysis techniques used in the evaluation of building construction projects in the building industry in South Africa, and determine the strengths and weaknesses of these techniques.
3. To establish to what extent risk analysis techniques are used in the building industry.

1.3 The Scope of the Research

1. The study will be confined to the building industry in South Africa.
2. The research will focus on responses of project managers.
   Project managers are the only professionals in the building industry that will be interviewed because risk management is one of the key functions of project management.
   This is justified by the PMI (1992) in their assertion that project and program risk management is inextricably tied into each of the other project management functions, especially the four basic project constraints of Scope, Quality, Time and Cost. The PMI (1996) also emphasize that Project Risk Management is one of the Project Management Knowledge Areas which describe project management knowledge and practice in terms of its component processes. All project managers should be fully aware of these knowledge areas.
3. The research is limited to Gauteng province. Gauteng is the principal focus of the study because it has the largest value of building construction activity out of all the provinces.
   According to the CSS (1998), of the total value of buildings completed in South Africa in 1997 (R 11, 311, 606, 000), Gauteng had the largest value of buildings completed (R 4, 598, 523, 000), out of all the provinces. This represents approximately forty one percent of the total value of buildings completed. (See Appendix 1.1.)

1.4 Definition of Terms

1.4.1 Risk

Risk has been defined by Chapman (1991) as " *...exposure to the possibility of economic and financial loss or gain, physical damage or injury, or delay as a consequence of the uncertainty associated with pursuing a particular course of action.*"

The PMI (1992) defines project risk in the context of project management as *"...the cumulative effect of the chances of uncertain occurrences adversely affecting project objectives."*

Kerzner (1995) defines risk as *"a measure of the probability and consequence of not achieving a defined project goal."*

This research adopts the definition of risk advanced by the PMI (1992).

1.4.2 Risk analysis

Flanagan and Norman (1993) have defined risk analysis as *"... the evaluation of the consequences associated with the type of risk, by using analytical techniques. It involves the assessment of the impact of risk by using various measurement techniques."*

Risk analysis is defined by Hertz and Thomas (1984) as *"...the methods which aim to develop a comprehensive understanding and awareness of the risk associated with a particular variable of interest."*

The definition of risk analysis advanced by Flanagan and Norman (1993) is used in this research.

1.4.3 Risk management

Risk management has been defined by the PMI (1996) as *"...the processes concerned with identifying, analyzing and responding to project risk; which includes maximizing the results of positive events and minimizing the consequences of adverse events."*

Carroll (1984) argues that risk management can be defined as *"...an element of management science concerned with identifying, controlling, and minimizing the adverse effects of untoward events."*

This research adopts the definition of risk management advanced by the PMI (1996).

1.4.4 Project

The PMI (1996) in a detailed discussion on project management, defines a project as *"...a temporary endeavour undertaken to create a unique product or service."*

The PMI also states that *"... temporary means that every project has a definite beginning and a definite end. Unique means that the product or service is different in some distinguishing way from all similar products or services."*

1.4.5 Building industry

The building industry has been defined by the National Property Education Committee (1993) as *"...that operational sector that provides buildings to the requirements of an employer by using the building professions, main contractors, subcontractors and a wide variety of associated resources."*

1.4.6 Construction industry

The National Property Education Committee (1993) also defines the construction industry as *" ...that operational sector that provides engineering structures (dams, roads, bridges, pipelines etc.) to the requirements of a client by using consulting engineers, main contractors, subcontractors and a wide range of associated resources."*

1.4.7 Uncertainty

Uncertainty has been defined by Raftery (1994) as *"a situation where it is not possible to attach a probability to the likelihood of occurrence of an event."*

This research is dealing with risk but this definition of uncertainty was viewed as important because the term has been used in a few isolated circumstances.

1.5 Assumptions

1. The risks identified from the literature review occur in all construction projects.
2. Risk analysis techniques are required for every major building construction project.

1.6 Organisation of the Research Report

Chapter One serves as the introductory chapter. In this chapter the background to the research, objectives, scope, and definitions of terms are discussed.

Chapter Two is the review of related literature. Risk identification, classification and analysis techniques are discussed in this chapter. This review will provide the necessary information required to develop the measuring instrument.

Chapter Three is the research methodology. The survey method, sampling method, data collection, and measurement techniques are discussed in this chapter.

Chapter Four presents the analysis of the data collected from the survey. This analysis is provided in the form of tables, graphs and written descriptions of observations.

Chapter Five discusses the conclusions and recommendations of the research. The main objectives are used as a base from which to conclude the research.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.1 Background to Risk and Decision Making

The growth and development of a business, an economy or an individual, require the exercise of judgement and the taking of decisions involving some uncertainty of outcome.

Bennett and Ormerod (1984) assert that there is a basic need to be able to quantify and access the impact that uncertainty can have on a project, and to incorporate this knowledge in the project and the management of the project. This expanded awareness of the project gives executive management and the client a more complete view of the project and a basis for decision making. Further, such awareness provides a much higher quality of information on which to base a decision, and allows an assessment of both uncertainty and risk while incorporating the manager's own value judgement into the decision.

Hertz and Thomas (1984) argue that to try to eliminate risk in business enterprise is futile. They continue to state that risk is inherent in the commitment of present resources to future expectations, and economic progress can be defined as the ability to take greater risk.

Raftery (1994) concurs with Hertz and Thomas (1984), and opines that to avoid all risks is to stagnate and ultimately be overtaken by events and die. He argues that in construction projects, the question is not whether to take risks but how to take reasonable risks. He emphasizes that the task is not how to avoid risks but how to recognize, assess, and manage risks. Latham (1994) agrees with this and states that risks can be managed, minimised, shared, transferred or accepted but not ignored.

Flanagan & Norman (1993) state that risk management is one aspect of management science. There are two broad categories of management science techniques: *deterministic,* and *probabilistic* or *stochastic.*

Flanagan & Norman (1993) argue that deterministic techniques assume that the values of the decision variables are known with 100% certainty, which is rarely the case with construction. Probabilistic or stochastic techniques on the other hand, are concerned with factors that cannot be estimated with certainty, such as most data associated with construction. The tools and techniques of risk management help us to determine a decision. Hertz (1984) points out that risk analysis adds a valuable contribution by providing strategic thinking input for the process of policy dialogue about the decision situation.

Birnie and Yates (1991) propose that the greater the risk and uncertainty in the financial outcome, the greater is the case for using the formal techniques of decision/risk analysis. Informal intuitive judgements should be combined formally in the decision/risk analysis procedure to assist us to make a wise decision to complete the problem.

Birnie and Yates (1991) criticize the nature of human judgement in decision making. They argue that judgements are made on the basis of information which has been processed by the individual and are therefore prone to biases. They support this argument by citing the research experiments by Hogarth and other cognitive psychologists, which have found these biases to exist in groups of people randomly sampled from differing social, academic and occupational backgrounds: for example Meehl (1954) on clinical predictions in medicine; Raiffa (1969) on probability assessment in MBA students; Slovic (1972, 1980) on risk assessment of investment, social and technological decisions.

This research supports the arguments of Birnie and Yates (1991). Formal decision making techniques can assist in management of risk and greatly reduce the probability of unfavourable outcomes in the project which may occur due to biases, human error, excessive optimism, and oversights (author's emphasis).

Flanagan and Norman (1993) state that the main purpose of a risk management system is to assist business to take the right risks. Further, an integral part of the system is risk analysis. The essence of risk analysis is that it attempts to capture all feasible options and to analyse the various outcomes of any decision.

2.2 Risk Management Framework

For clarity on risk analysis it is imperative that it is viewed in the light of the risk management framework.

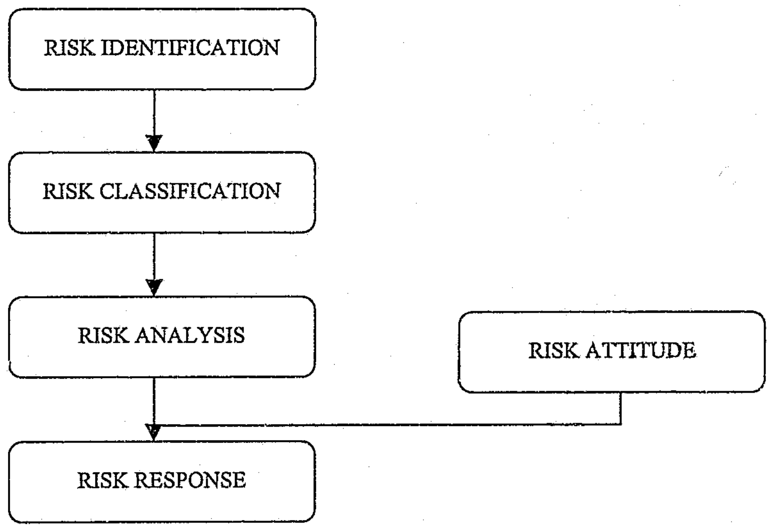


Figure 2.1 The Risk Management Framework
Source: Flanagan and Norman (1993)

These five stages form an integral part of the risk management system. However for purposes of this research, only literature relating to risk identification, risk classification and risk analysis shall be dealt with in sections 2.2.1, 2.2.2, 2.2.3 and 2.3. Risk attitude and risk response are beyond the scope of the research.

2.2.1 Risk identification

Kerzner (1994) points out that the first stage in risk management is the identification of potential risk and the determination of what could go wrong. Lowe and Whitworth (1996) highlight that risk identification deals with the source and type of risk.

Lowe and Whitworth (1996) present the various types of risk in sets as seen in figure 2.2.

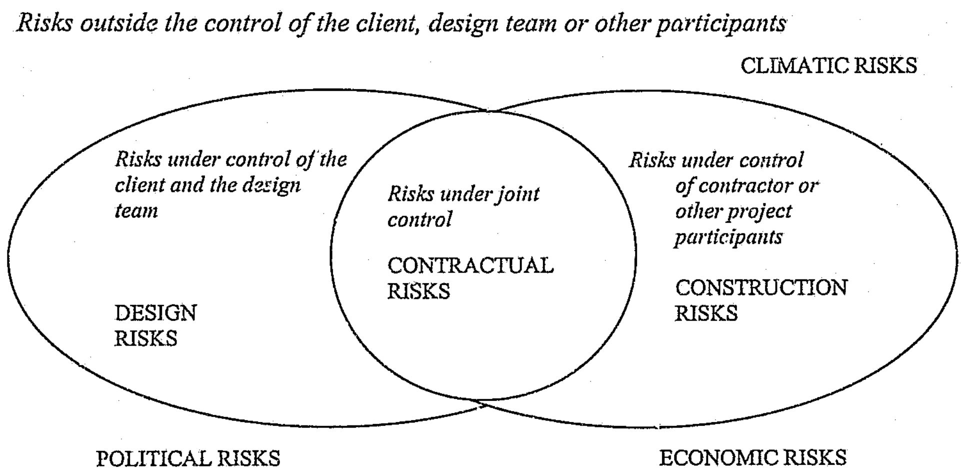


Figure 2.2 Total Project Risk

Source: adapted from CUP (1993)

Lowe and Whitworth (1996) state that the factors which occur at the intersection of the two sets are those which arise due to the contractual relationship between the project participants.

Flanagan and Norman (1993) suggest a risk identification system that broadly categorizes risks as controllable and uncontrollable risks. They define controllable risks as those risks which a decision-maker undertakes voluntarily and whose outcome is, in part, within our direct control; and uncontrollable risks as those risks which we cannot influence.

Perry and Hayes (1985) stress that this identification of risks provides a basis from which the appropriate organizational structure, tendering procedure, type of contract, and risk allocation through the contract documents can be formulated.

The risk identification system described by Flanagan and Norman (1993) has been adopted in this research.

2.2.2 Risk classification

Subsequent to risk identification, risks need to be classified in an appropriate manner. Tah, J.H.M. and Carr, V. (1998) argue that risk classification is an important step in the risk management process, as it attempts to structure the diverse risks which may affect a project.

There have been a number of approaches suggested for classifying risks:
Perry and Hayes (1985) give an extensive list of factors assembled from several sources, and classified in terms of risks retainable by contractors, consultants, and clients.

Tah et al (1994) use a risk breakdown structure to classify risks according to their origin and location of impact within a project.

Tah and Carr (1998) referring to the risk classification system by Cooper and Chapman (1987) and Wirba et al (1996) report that Cooper and Chapman (1987) classify risks according to their nature and magnitude, grouping risks into the two major groupings of primary and secondary risks; whereas Wirba et al (1996) adopt a synergistic approach which is a combination of that of Tah et al (1994) and Cooper and Chapman (1987), where the former is used to exhaustively classify risks, and the latter is used to sub-classify these as primary and secondary.

The PMI (1992) classify the types of project risk according to primary source (rather than effect). They categorize sources of risk as follows:

- External, unpredictable and uncontrollable

- External, predictable, but uncontrollable
- Internal non-technical but generally controllable
- Technical and generally controllable
- Legal and generally controllable

The PMI (1992) opines that this form of risk classification provides the opportunity to rank the various risk groupings according to their ability to manage effective response (that is, their relative controllability).

Flanagan and Norman (1993) state that there are three ways of classifying risks: by identifying the consequence, type and impact of risk.

Chicken (1996) classifies risk into two main categories; internal risks and external risks. He describes internal risks as those risks within the company or organization; and external risks as those factors that condition the environment in which an organization has to operate, and are outside the direct control of the firm.

This research adopts the risk classification system described by the PMI (1992) which appears to have features of the risk identification system described by Flanagan and Norman (1993) and the risk classification system adopted by Chicken (1996). This risk classification system has been used in the research questionnaire. (See Appendix 3.1)

2.2.3 Risk analysis

Risk analysis is a major part of this research and therefore it is dealt with in a separate section 2.3.

2.3 Review of Existing Risk Analysis Techniques

Flanagan and Norman (1993) describe in detail, four decision-making techniques dealing with risk analysis: decision analysis (includes algorithms, means-end analysis, decision trees and Bayesian theory), sensitivity analysis, Monte Carlo simulation, portfolio theory, and stochastic dominance. The PMI (1992) in their discussion of risk analysis techniques include the Delphi Method, Programme Evaluation and Review Technique (PERT), Expected Monetary Value (or Individual Risk Value), and Range Estimating as additional techniques. Raftery (1994) discusses a list of risk analysis techniques redolent with that of Flanagan and Norman (1993).

A discussion of these individual techniques and their strengths and weaknesses (where applicable) shall be the subject of the remainder of this chapter.

2.3.1 Decision analysis

Flanagan and Norman (1993) define decision analysis as a technique for making decisions in an uncertain environment that formally treats both risk exposure and risk attitude. They indicate that it provides a methodology to allow the decision-maker to include alternative outcomes, risk attitudes and subjective impressions.

Flanagan and Norman (1993) state that decision analysis deals with the process of making decisions, and it follows a number of steps:

- recognising and structuring the problem;
- assessment of the values and uncertainties of the possible outcomes;
- determining the optimal choice;
- implementation of the decision.

The decision techniques to be considered in this research are:

- algorithms;
- means-end chain;
- decision trees; and stochastic decision tree analysis;
- Bayesian theory.

Algorithms

Flanagan and Norman (1993) state that an algorithm contains a sequence of instructions for problem solving. These are the steps in a task and the responses determine the route to be followed. Algorithms have often been used as a prelude to computer programs as they are logical and easy to follow.

Means-end chain

Flanagan and Norman (1993) present this is as a method of clarifying a chain of objectives and therefore identifying a series of decision points. It relies on the fact that what is an objective to one decision-maker might be a means of achieving a higher objective to a higher level decision-maker. Most problems are multi-level and require a multi-level means-end chain as shown in the figure 2.3.

The means-end chain simply specifies the sequence, alongside this the risk should be considered by taking into account the most likely, the best and the worst eventualities. The means-end chain identifies gaps in the relationship between means and ends.

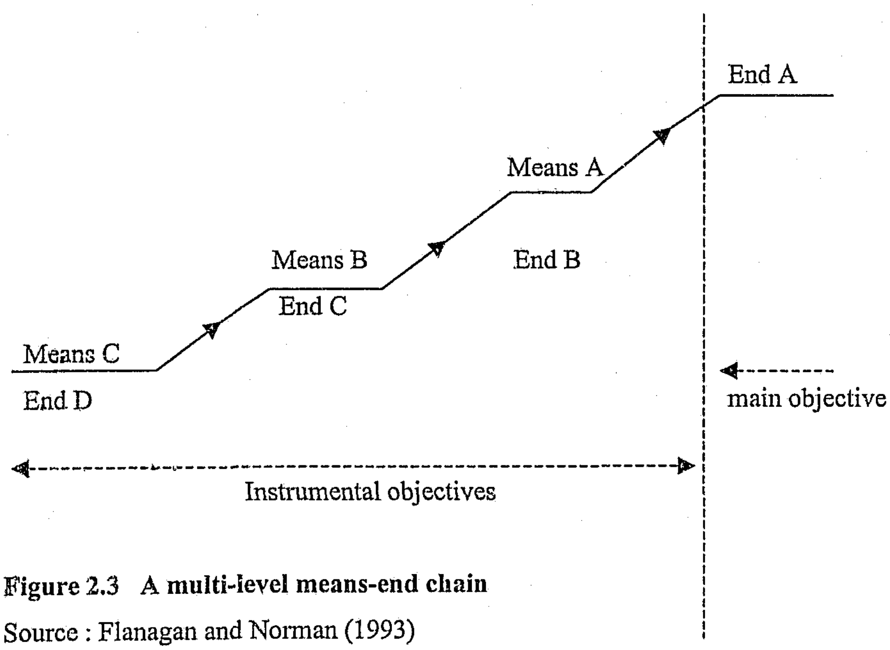


Figure 2.3 A multi-level means-end chain

Source : Flanagan and Norman (1993)

Decision trees

The PMI (1992) points out that a feature of project work is that a number of options are typically available in the course of reaching the final results. Perry and Hayes (1985) acknowledge that a decision tree provides a graphical means of bringing this information together.

Flanagan and Norman (1993) state that the decision trees show the sequence of decisions and the expected outcomes under each possible set of circumstances. They indicate that most decision problems, including those in the construction industry have some definable structure. By adopting an analytical approach such as a decision tree, the decision-maker is forced to recognise the existence of certain basic elements in the structure. There will be a set of objectives whose attainment depends on the decision-maker. The decision-maker has to keep an open mind to search for all the available options for any decision.

Flanagan and Norman (1993) indicate that the most frequently used measure of the value for each possible outcome in the decision tree is the expected monetary value (EMV), which is the sum of the payoffs (or values) weighted by their probabilities. The decision-maker has to place a probability on a particular outcome. The probabilities are likely to be rough assessments and hunches, but most importantly, the use of decision trees gives a structured approach to setting out a decision strategy.

Strengths

- Flanagan and Norman (1993) argue that the strong advantage of this technique is that the decision tree is a visual and easily understood means of representing the sequential, multi-stage logic of a decision problem. Provided the client has access to information on such matters as quality and cost, then he will have much to gain by structuring his investment decisions in terms of a decision tree.
- Perry and Hayes (1985) highlight that one advantage of this approach is that it forces the decision-maker to place some degree of probability on an outcome occurring. Future outcomes are considered, the likelihood of failure is quantified, and some value is placed on each decision.

Stochastic decision tree analysis

The stochastic decision tree approach, originally developed by Hespos and Strassman (1965) provides another method for analysing decision problems over time. Flanagan and Norman (1993) argue that it combines the logic of the decision tree analysis with the Monte Carlo simulation approach used in risk analysis. They state that risk evaluation typically treats investment decisions as if they were single-stage decision problems. However it is realistic to recognise that most decision problems have a large number of interrelated investment decisions over the time horizon of the project. Thus, if the two approaches can be combined, we have a potentially powerful technique for use in investment appraisal.

Flanagan and Norman (1993) have identified a number of features specific to the stochastic decision tree approach:

- instead of using the EMV principle, all factors, including chance events, can be represented by continuous, empirical probability distributions;
- the information about the results of decisions made at sequential points in time can be obtained in probabilistic form;
- the probability distribution of possible results from any particular combination of decisions can be analysed using the concepts of utility and risk.

Flanagan and Norman (1993) indicate that the stages of stochastic decision tree procedure are similar to the ones outlined for the traditional decision tree approach. They highlight that typically, the decision tree is used as a model for *forward-analysis*, and so each possible strategy path is evaluated in terms of a probability distribution based upon the NPV criterion. Such an approach has the particular advantage of being flexible. Flanagan and Norman (1993) continue to state that once the probabilistic output has been determined, a modified rollback principle can be used. Branches of the tree would then be eliminated on the basis of stochastic dominance principles rather than the decision analysis norm of EMV. For example, a branch might be eliminated if it had a higher variance than an alternative branch. The dominance procedure will reduce the decision set and allow the analysis to focus on the more relevant decision paths.

Bayesian theory

According to Levin and Rubin (1991), probabilities can be altered after obtaining additional information. These new probabilities are known as revised, or *posterior* probabilities.

Levin and Rubin (1991) state that this concept of obtaining posterior probabilities with limited information is attributable to the Reverend Thomas Bayes (1702 – 1761), and the basic formula (known as the *Bayes' theorem*) for conditional probability under dependence is:

$$P(B\backslash A) = \frac{P(BA)}{P(A)}$$

Flanagan and Norman (1993) stress that using decision trees, the accuracy of the method depends on the accuracy of the outcomes and the probabilities. They indicate that when further information is available, this can be incorporated with Bayesian analysis, and therefore the sensitivity of decisions can be examined.

2.3.2 Sensitivity analysis

Perry and Hayes (1985) state that sensitivity analysis seeks to place a value on the effect of change of a single variable within a project by analyzing that effect on the project plan. Uncertainty and risk are reflected by defining a likely range of variation for each component of the original base case estimate.

Perry and Hayes (1985) argue that in practice sensitivity analysis is only done for those variables which have a high impact on cost, time or economic return and to which the project will be most sensitive.

Flanagan and Norman (1993) highlight that sensitivity analysis is an interactive process which tells you what effects changes in a cost will have on the life cycle cost. By identifying the relative importance of risky cost variables, the decision-maker can adjust projects to reduce the risks and consider responses should the outcomes occur.

Spider diagram

Flanagan and Norman (1993) suggest that a spider diagram is an effective way of using sensitivity analysis. They discuss the steps involved in presenting a spider diagram as:

1. Calculate the expected total life cycle cost by using expected values.
2. Identify the variables subject to risk using a decision tree approach.
3. Select one risky variable, which we call 'parameter 1', and re-calculate the total life cycle cost using different assumptions about the value of this parameter. The life cycle chosen is recalculated assuming that the cost parameter changes by 1%, 2%, and so on.
4. Plot the resulting life cycle costs on the spider diagram, interpolating between the values. This generates the line labelled 'parameter 1' as shown in figure 2.4.
5. Repeat stages 3 and 4 for the other risky variables.

Each parameter on the spider diagram indicates the impact on the life cycle cost of varying the value attributed to a particular parameter within the defined range. The flatter the line, the more sensitive will be the life cycle costs to changes in that parameter 1 than it is to variation in parameter 2.

The spider diagram tends to appear to be more difficult to read when more variables are plotted. The practical answer is to have several spider diagrams.

In general, the spider diagram lines will not be linear, since if a running cost increases by *x* per cent it will be a relatively larger component of overall life cycle costs. Moreover individual cost parameters may vary in many different ways.

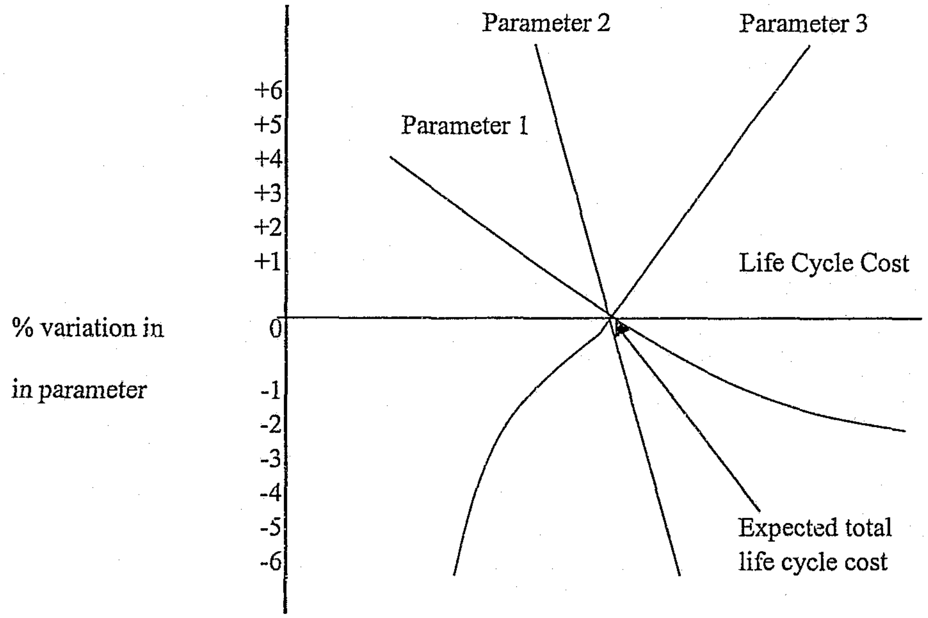


Figure 2.4 Non-linear spider diagram
Source : Flanagan and Norman (1993)

Sensitivity analysis shows the effect of a change to a risky variable. For each risky parameter, objective and subjective information can be used to identify the parameter's variance. This also gives an estimate of its standard deviation.
The sensitivity analysis shows the value of information regarding variables for a project, which of the parameters should be considered, and which might be expedient to ignore. Evidence has shown that the consideration of the eight largest risks will typically cover up to 90% of the total (Porter, 1981). Consequently, the identification of these risks by sensitivity analysis can yield savings in information requirements and costs.

Raftery (1994) indicates that sensitivity tests measure the impact on the project outcome of changes in the values of input variables about which there is some uncertainty.

Strengths

Raftery (1994) in his critique on sensitivity tests, contends that they have several advantages:

- They are quick and easy to use.
- They require little information.
- They can be carried out by hand.
- They fully recognise uncertainty in the input variables.
- They show how the output will be influenced by changes in the input variables either singly or in combination.

Perry and Hayes (1985) highlight the following additional strengths of sensitivity analysis:

- The powerful impact on management of the realization that there is a range of possible outcomes for a project.
- Decision-making is made more realistic although the information on which the decisions are made becomes more complex.

Flanagan and Norman (1993) argue that the major advantage of sensitivity analysis is:

- It explicitly shows the robustness of the ranking of alternative projects. Sensitivity analysis identifies the point at which a given variation in the expected value of a cost parameter changes a decision.

Weaknesses

Raftery (1994) argues that they have the following shortcomings:

- They take no account of the likelihood of the range of input or output. Therefore they do not give a probabilistic picture of risk exposure.
- There is no explicit method of allowing for risk attitude.
- They are ambiguous because they do not suggest how likely it is that their pessimistic or optimistic results will occur, for example.
- They are misleading when some analysts take a number of worst or best case values of input variables and calculate the effect on the output. Such combinations are extremely unlikely in the real world and this type of test would produce exaggerated results both on the optimistic and on the pessimistic bounds.

Perry and Hayes (1985) provide the following additional shortcomings:

- The variables are treated individually. This leads to severe limits on the extent to which combinations of variables can be assessed directly from the data.
- The sensitivity diagram gives no indication of the anticipated probability of occurrence of any event.

2.3.3 Monte Carlo Simulation

Flanagan and Norman (1993) define Monte Carlo Simulation as *"the art and science of designing a model which behaves in the same way as a real system. The model is used to determine how the system reacts to different inputs."* They state that it is called Monte Carlo because it makes use of random numbers to select outcomes, rather as a ball on a roulette wheel stops, theoretically at random, to select a winning number. These random numbers could be selected in a variety of ways such as picking a number out of a hat, or throwing a dice, but using a computer program is the most effective method of generating sets of random numbers.

Perry and Hayes (1985) state that the Monte Carlo Method, simulation by means of random numbers, provides a powerful yet simple method of incorporating probabilistic data.

Perry and Hayes (1985) indicate that the basic steps are:

1. Assess the range for the variables being considered and determine the probability distribution most suited to each.
2. For each variable within its specific range, select a value randomly chosen, taking account of the probability distribution for the occurrence of the variable. This may be achieved by generating the cumulative frequency curve for the variable and choosing a value from a random number table.
3. Run a deterministic analysis using the combination of values selected for each one of the variables.
4. Repeat steps 2 and 3 a number of times to obtain the probability distribution of the result. The number of iterations required depends on the number of variables and the degree of confidence required, but typically lies between 100 and 1000.

Flanagan and Norman (1993) indicate that simulation techniques are used extensively in industry, for instance, in construction; different weather patterns can be simulated to determine the impact they will have on the construction schedule. Equally, simulation techniques can be used in the evaluation of cost for construction projects. Simulation makes the assumption that parameters subject to uncertainty can be described by probability distributions.

Flanagan and Norman (1993) state that in Monte Carlo simulation a large number of hypothetical projects are generated to reflect the characteristics of the actual project. Further, statistical methods can then be used to calculate confidence intervals, and cumulative frequency curves are also usually presented as part of the results. From these it is a simple matter to read off the likelihood that a certain activity will not exceed a given time.

Strengths

Raftery (1994) highlights the following advantages of simulation:

- The resultant probability density and cumulative distribution functions are a powerful measure of risk exposure.
- The results allow for the incorporation of risk attitude by the decision-maker who has to decide the level of uncertainty to accept as part of a valid forecast.
- The method requires very little knowledge of mathematics and can cope with large number of types of input distribution, thus giving the flexibility to model precisely the perceptions of uncertainty surrounding all of the input variables.

Weaknesses

Curran (1989) highlights the following shortcomings of Monte Carlo technique:

- Initially the user must first identify each and every element which must be represented by a probability density function (PDF), but there are no quantitative guidelines for deciding whether any given element in the estimate is critical and thus demanding a PDF.

- In the output phase, a cost versus probability profile is produced. This profile clearly identifies the probability of overrunning the targe 1 bottom line cost of the project, but there is no way of determining why that probability is as high or as low as it is.

2.3.4 Portfolio Theory

Flanagan and Norman (1993) in a detailed discussion on portfolio theory and its application in the construction industry, point out that the aim of portfolio theory is to maintain the expected return and to minimise the risks of the portfolio. An investor holds a portfolio which consists of various types of investments such as gilts, stocks and properties. Individual investments in a portfolio have their own return and risks.

Flanagan and Norman (1993) indicate that in portfolio theory, while the total return is a weighted average of individual investments, the overall risk of the portfolio cannot be measured in the same way. A correlation coefficient indicates the relationship between each of the individual investment risks. The coefficient is within a range between +1 and –1; a correlation coefficient of +1 indicates that if the risk of an investment increases by one unit then the overall risk of the portfolio will increase by one unit. Zero correlation coefficient means there is no overall correlation between individual investments in a portfolio. The overall risk of the portfolio can be diversified if the correlation coefficient is less than +1.

Flanagan and Norman (1993) argue that it is not possible to totally eliminate the risks of a portfolio. There are two kinds of risks: specific risks which are associated only with a particular investment in the portfolio, and market risks which affect all individual investments. Market risks such as the economic climate or taxation policy cannot be diversified and hence the overall risk of the whole portfolio can never be zero.

The application of portfolio analysis in the construction industry

Building firms can create a project portfolio, in which each project has its own expected return and risk. The overall risk of the portfolio will be reduced because no two buildings are the same, that is, the correlation coefficient is less than +1.

Flanagan and Norman (1993) provide a useful illustration using housing and high technology commercial offices. Housing construction for public and private clients is less risky because it tends to use traditional materials and design. Since housing is relatively traditional and can be small scale with few barriers to entry into the market, tenders will become more competitive and the return likely to be lower. On the other hand office construction has a greater risk because high technology materials may be used with innovative design, but not all contractors are capable of handling such projects and so the market is less competitive and the expected return should be higher. These two types of construction are not perfectly correlated to each other, so the risk in the portfolio of a contractor who undertakes both housing and office construction is better diversified and a better combination of return and risk is achieved than is available from a concentrated portfolio. Of course such diversification is not without cost. In the investment world, an investor can maintain a balance between the return and risk of the portfolio by buying and selling assets. Such an active management method is not always applicable in the construction industry. Once a contractor enters into a contract, he has an obligation to complete the project.

Flanagan and Norman (1993) argue that building in different sectors of the property market diversifies risk only at the expense of expertise. A construction firm is willing to build in all property sectors only if it has sufficient expertise. Otherwise, diversification will slow down the output of the construction team and hence increase project cost and decrease competitiveness. A trade-off is necessary between the gain that diversification gives through improving the risk/return mix, and the loss of economies of scale and learning economies reducing the firm's exposure in any one project.

Flanagan and Norman (1993) opine that the moral of the portfolio theory story is, *'Don't put all your eggs in one basket'!*

2.3.5 Stochastic dominance

Flanagan and Norman (1993) describe stochastic dominance as the analysis of probability distributions without specifying whether the mean or the variance are the parameters to be considered. The whole of the distribution is considered, and the only assumption is that 'more is preferred to less'. The criterion strongly orders alternative projects precisely, because of the lack of restrictive assumptions. It classifies projects that are efficient and those projects that are dominated by a set of efficient projects. Flanagan and Norman (1993) illustrate this with two projects, F and G. Project F will first order stochastically dominate (FSD) G if the cumulative probability function of F is always below or equal to that of G. Although stronger orderings can be produced, the outcome is that of a set of efficient portfolios or projects.

Flanagan and Norman (1993) opine that in the future the criterion may be more widespread and certainly it can be used as a screening aid in comparisons of different cumulative distributions such as that used in Monte Carlo simulation.

Strengths

Raftery (1994) indicates that this technique has the following advantages:

- It offers a way of comparing probabilistic results.
- The results also allow for the informal incorporation of risk attitude by the decision-maker who has to decide the level of uncertainty to accept as part of a valid forecast.

Weaknesses

- Flanagan and Norman (1993) criticize this technique and argue that it tends to show the efficient frontier. Further, its applications have been fairly limited because it does not tell us how to choose between alternative projects that have different returns and different risks.

2.3.6 Delphi Method

Martin and McCormick (1983) opine that the basic concept of the Delphi Method is to derive a consensus using a panel of experts to arrive at a convergent solution. Raftery (1994) concurs with this and states that the Delphi peer group technique is designed to pool the expertise of many professionals in such a way as to gain access to their knowledge and technical skills while removing the influences of seniority, hierarchies and personalities on the derived forecast.

Martin and McCormick (1983) describe the steps in the Delphi Method as follows:

- The first and vital step is to select a panel of individuals, as participants, who have experience in the area at issue. For best results the panel members should not know each others identity, and the process should be conducted with each at separate locations.
- A scenario is established and each panelist is requested to reply a questionnaire. The responses, together with opinions and justifications, are evaluated and statistical feedback is furnished to each panel member in the next iteration.
- The process is continued until group responses converge to a specific solution. Should the responses diverge, the facilitator needs to review the wording of the questionnaire, the feedback, or the experience of the panelists to determine if there is a problem which needs to be corrected.

Strengths

Raftery (1994) argues that the Delphi Method has the following advantages:

- The physical separation of the experts is designed to nullify the effects of strong personalities and other undesirable consequences of personal interaction.
- It is a way of focusing on the task and ironing out the biases of poor metacognition and overconfidence which may encroach on the forecasts.
- It is also a powerful method of assessing important projects at the budget and feasibility stage.
- It can be easily conducted using electronic mail.

Weaknesses

Martin and McCormick (1983) report that social scientists are sometimes critical of the method on the grounds that:

- It has no predictive validity.
- The use of "experts" leads to manipulation of group suggestion rather than consensus.

2.3.7 Individual risk value

The individual risk value or the expected monetary value (EMV) involves the probability of the risk and the amount at stake.

Risk Value = Risk Probability x Amount at Stake

The PMI (1996) describe the risk event probability as an estimate of the probability that a given risk event will occur. Further, the risk event value is an estimate of the gain or loss that will be incurred if the risk event does occur.

The PMI (1992) highlight that some risk events are characterized by low probability and high severity, while others are the reverse. They insist that the most serious risks are those involving both high probability and high severity.

The PMI (1996) indicate that the EMV is generally used as an input to further analysis for example, in a decision tree, since risk events occur individually or in groups, in parallel or in sequence.

2.3.8 Range estimating

Curran (1989) describes range estimating as a decision technology which is used to evaluate a plan for the future. That plan may be a construction cost estimate or an estimate of the profit to be derived from the introduction of a new consumer product.

The PMI (1992) in their description of the technique indicate that an assessment is first made of the maximum tolerable variation in an estimate's bottom line total cost which might result from a variation in any single element of that estimate. This threshold value is called the critical variance. The critical elements in the estimate are then identified as those whose actual values could vary from the target by such a magnitude that the bottom-line cost of the project would change by an amount greater than the critical variance. At any given level of probability, the variations in the actual values will be either favourable or unfavourable and will range from highest to lowest.

The PMI (1992) stress that the deciding factor is not necessarily the magnitude of the element itself but its potential for variation. Consequently, the number of such elements in a typical estimate is not very large. Curran (1989) argues that the technique relies heavily on Pareto's law or what is variously described as "the law of the significant few and the insignificant many" or the "80/20 rule". This means that not everything is important: only a few things really make a difference. The application of Pareto's law leads to the identification of very few items which make a significant difference at the bottom line.

The PMI (1992) indicate that nevertheless, because of the large number of possible combinations, the number of potential outcomes in the actual bottom-line cost is indeed very large. The range of the resulting estimate is a simple but effective measure of its uncertainty.

Strengths

Curran (1989) indicates that range estimating has the following advantages:

- It provides specific and easily applied numerical guidelines to identify the critical elements in the problem.
- It removes the necessity to specify a classical Probability Density Function (PDF) for each critical element.
- It identifies, quantifies, and ranks the reasons why the probability of achieving the targeted bottom line is so high (or so low) and why the potential favourable and

unfavourable deviations from the targeted bottom line are the magnitudes that they are.

- The entire process requires only a modest amount of effort.

2.3.9 Programme Evaluation and Review Technique (PERT)

Kerzner (1994) in a detailed discussion of PERT states that it uses time as a common denominator to analyze those elements that directly influence the success of the project, namely, time, cost, and performance. The construction of the PERT network requires two inputs. Firstly, a selection must be made as to whether the events represent the start or completion of an activity. Secondly, define the sequence of events.

The PMI (1992) indicates that PERT uses three time estimates namely; optimistic (o), most likely (m), and pessimistic (p). If these three estimates are represented by time durations of o, m, and p, respectively, PERT allocates four times the weight to the most likely so that the expected time is given by:

$$\text{Expected time} = \frac{o + 4m + p}{6}$$

Kerzner (1994) presents PERT as a six-step process:

1. The project manager should lay out the list of activities.
2. Place these activities in order of precedence, thus identifying the interrelationships. These charts are known as logic charts, arrow diagrams, work flow or networks.
3. Review the arrow diagrams with line managers in order to obtain their assurance that neither too many nor too few activities are identified, and that the interrelationships are correct.
4. The functional manager converts the arrow diagram to a PERT chart by identifying the time duration for each activity (Note: The time estimates that the line managers provide are based on the *assumption of unlimited resources* because the calendar dates have not yet been defined).

5. This step is the first iteration on the critical path. The project manager looks at the calendar dates in the definition of the project's requirements. If the critical path does not satisfy calendar requirements, then the project manager must try to shorten the critical path.
6. The project manager places calendar dates on each event in the PERT chart, thus converting from planning under unlimited resources to planning with *limited resources*. This step is crucial because there is no guarantee that the correct resources will be available when needed.

Kerzner (1994) asserts that PERT replanning should be an ongoing function during project execution.

Strengths

Kerzner (1994) presents the following strengths of PERT:

- It is possible to evaluate the effect of changes in the program.
- It allows a large amount of sophisticated data to be presented in a well-organized diagram from which the contractor and customer can make joint decisions.
- The kind of planning required to create the PERT network. Network planning and critical path analysis reveal interdependencies and problem areas that are neither obvious nor well defined by other planning methods. The technique determines where the greatest effort should be made for a project to stay on schedule.
- One can determine the probability of meeting specified deadlines by development of alternative plans.

Weaknesses

Kerzner (1994) also indicates the following weaknesses of PERT:

- Unless the project is repetitive, there usually exists a lack of historical information on which to base the cost estimates of most optimistic, most pessimistic, and most likely times.
- Time and labour intensive effort is required.
- PERT is end-item oriented and as a result many upper-level managers feel that its adoption removes a good part of their power and ability to make decisions.
- There exists a lack of functional ownership in estimates.

- The assumption of unlimited resources may be inappropriate.
- There may exist the need for too much detail.

In a summary discussion of these techniques, Raftery (1994) argues that the choice of approach for dealing with the analysis depends on the size, type and general nature of the project or the problem being modelled, the amount of reliability of information available and the nature of the output required. The nature of the output will depend on the type of decisions to be made and on the particular needs of the client.

Raftery (1994) points out that there is some overlap among these approaches and some are unsuitable for particular situations; that is for any given decision on a particular project at a particular point in the project schedule, there may be quite a limited choice of approach to the analysis.

2.4 Summary

The review of related literature revealed that risks are present in all projects, and risk management assists decision-makers to take the right risks. The initial stage of risk management is risk identification. The review also showed that there are various styles of risk identification and classification.

A risk classification system and list of risks focusing on the source, is identified from the literature. Objective number one of the research study is to rank these risks in terms of importance and frequency of occurrence. This ranking is beneficial because there are numerous risks involved in any project, and as indicated in the literature review, the risks that should receive most attention are those that are likely to have high severity and the greatest probability of occurrence. (Please note that in the research survey, the words importance and frequency have been used in lieu of the words severity and probability respectively).

Risk analysis has been seen to be an invaluable aid to decision making. It provides management with information on which to base decisions. Several techniques of risk analysis relevant to the construction industry and their advantages and disadvantages have been presented in the literature. Objective two of the research study is to establish which techniques are being adopted in the South African building construction industry, and the strengths and weaknesses of these techniques. Objective three of the research study is to establish to what extent the risk analysis techniques are being utilised in South Africa. The fieldwork described next attempts to address these objectives.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter aims to describe the research methodology used in this research. The questionnaire and the sampling method are discussed.

3.2 Survey Methodology

Leedy (1993) defines methodology as "*an operational framework within which the facts are placed so that their meaning may be seen more clearly.*" He describes four principal research approaches (methodologies) namely, *the descriptive survey method, the historical method, the analytical survey method, and the experimental method.*

Leedy (1993) argues that the descriptive survey or the normative survey method is appropriate for data derived from simple observational situations whether these are actually physically observed or observed through benefit of questionnaire or poll techniques. Gill and Johnson (1991) point out that a descriptive survey is concerned primarily with addressing the particular characteristics of a specific population of subjects, either at a fixed point in time or at varying times for comparative purposes.

Due to the nature of the data required, the descriptive survey method was adopted in order to achieve the objectives of the research.

3.3 The Survey Population

Wegner (1995) describes a population as *"a collection of all the observations of a random variable under study about which one is trying to draw conclusions in practice."*

The building industry has a wide range of participants, each performing a different role. The project manager's role is becoming increasingly more significant as projects become more complex and diversified. It is the main responsibility of the project manager to ensure that the project constraints of time, scope, quality and cost are met. In order to perform this role, the project manager has to ensure that the risks are properly dealt with so that all goes according to plan. It is due to this reason that project managers are the chosen as the research population. Further justification on the use of project managers was discussed in Chapter One – Item No. 1.3 (2).

3.4 Sampling

Leedy (1993) states that sampling can be divided into two main categories: nonprobability and probability sampling. In probability sampling, the components of the sample are chosen from the larger population by a process known as *randomization.* This sample is known as the random sample.

Nkado (1991) referring to Ireland (1983) indicates the difficulty in obtaining data of a particular nature from an extensive enough set of cases to ensure a random sample and to be able to generalize to the population. Further, obtaining detailed information on confidential aspects is a difficult task and, with limited resources, one is not in a position to be selective enough with cases to build up a large random group.
Due to these limitations of probability sampling, the sampling technique used in this research is non-probability, convenience sampling. A convenience sample is an easily accessible sample.

The Professional and Projects Register 98 (Braby and Braby, 1998) was used to get a list of all the project managers in Gauteng. From this register, all the firms listed as project managers in Gauteng formed part of the survey. Sixty-eight project managers were surveyed.

This register, published by Avonwold, was used because it has been recognized as a valuable source of information and contacts. Avonwold has received several awards for publishing the Professional and Projects Register such as the SAPPI Fine Papers Annual Directory Award and The Philip Tyler Award. Avonwold has also published other useful registers such as the SAPOA Property Register, which is viewed as a valid source of information on property professionals in South Africa. Due to these reasons the Professionals and Projects Register 98 was viewed as a reliable directory for information on project managers.

3.5 The Survey Questionnaire

A questionnaire was developed and utilised to collect the data required from the respondent sample identified. The precise details of the questionnaire are described in the following sections.

3.5.1 Format of the survey questionnaire

A structured survey format was adopted for the research questionnaire. Mitchell and Jolley (1992) state that in a structured survey, all respondents are asked a standard list of questions in a standard order. This survey format has several advantages: Firstly, it ensures that each participant is asked the same questions and has the same response options. Secondly, by using a standard list of questions, the risk of interviewer bias is reduced. Thirdly, by controlling the questions and limiting the response range, you can obtain accurate and easily interpretable responses.

3.5.2 The design of the questionnaire

The questionnaire was in three multipart questions. The first part was aimed at describing the company profile. The second part was aimed at ranking the risks encountered in building projects in terms of their frequency of occurrence, and level of importance. The third part was aimed at identifying the risk analysis techniques used in South Africa, to what extent these techniques are used, and the usage of computer software programs to analyse risks.

Fellows and Liu (1997) state that questions occur in two primary forms – open or closed. They indicate that open questions are designed to enable the respondent to answer in full, to reply in whatever form, with whatever content and to whatever extent the respondent wishes, whereas closed questions have a set number of responses as determined by the researcher. They argue that responses to closed questions can be given more easily and quickly, as compared to open questions whereby the answer may never be full/complete and, often, the answers are difficult to analyse. It is because of these reasons that the questions posed were mainly closed-ended questions. In order to avoid rigidity of available responses, a response opportunity of 'other, please specify' was provided wherever possible. A few open-ended questions were used to obtain additional comments from the respondents.

The questionnaires were not coded in order to preserve anonymity of the respondents. The respondents were however asked to give their names and company details but the provision of this information was not mandatory.

The survey questionnaire is shown in Appendix 3.1.

3.5.3 Pilot study

According to Fellows and Liu (1997), all questionnaires should initially be piloted; completed by a small sample of respondents. The piloting will test whether the questions are intelligible, easy to answer, and unambiguous. It also provides an opportunity for improving the questionnaire, filling the gaps and determining the time required for, and ease of, completing the exercise

A pilot study was conducted with two companies to ensure that the questionnaire could bring about the results required to meet the objectives of the study.

On the basis of this pilot study, some of the response categories were altered. For example, some risk factors which were dealing with risk specific to project's technology were viewed as not appropriate to construction and were taken off the list of risks (See Appendix 3.1- Question 2.0). Aptitude was perceived to be an additional method of obtaining expertise on risk management (See Appendix 3.1- Question 3.3). From the pilot questionnaire it was also possible to discern that the respondents would require approximately 20 – 30 minutes to complete the questionnaire.

This pilot study was useful and on the basis of this pilot study, the questionnaire was modified in light of the suggestions from these two respondents.

3.5.4 Administration of the questionnaire

The data for this research was gathered through a postal survey. A postal survey was used because the respondents would have more time to consider their responses, it would allow contact with otherwise inaccessible respondents such as directors, a larger sample of respondents can be reached, it is relatively inexpensive to conduct, easily distributed, and it allows anonymity.

On the other hand, postal surveys also have some disadvantages. Firstly, they usually have a low return rate, and thus you may have a biased sample. Secondly, errors and oversights in the questionnaire cannot be corrected. Thirdly, you have no way of knowing whether the respondents object to your question format.

The respondents were provided with a stamped self-addressed envelope for return replies.

3.6 Measurement of Data

The nature of data collected dictates the level of measurement and the statistical procedure that can be used in processing it.

3.6.1 Levels of measurement

Kidder and Judd (1993) differentiate four types of measurement scale:

- Nominal scales

  With these type of scales, a variable is measured in terms of two or more qualitatively different categories, for example, 'male' and 'female'. The scale indicates differences of category but these have no arithmetic value.
- Ordinal scales

  This scale contains two or more categories that allow differentiation of variables in terms of categories. Some degree of ordering is involved as different points on the scale indicate the quantity being measured. Different points on the scale indicate greater or lesser amounts of the phenomena being measured relative to other points on the scale. This scale however says nothing about the distances between the points on the scale.
- Interval scales

  These have all the characteristics of an ordinal scale except the distances between the points on the scale (i.e. the intervals) represent equal quantities of the measured variable. However, interval scales do not have a true zero, rather, zero is arbitrary. Although we can add and subtract the numbers on an interval scale they cannot be multiplied or divided.
- Ratio scales

  These have characteristics of an interval scale except that they have a true zero. Multiplication and division of points on a ratio scale is therefore meaningful.

From the design of the questionnaire nominal, ordinal and ratio levels were used. The interval scale was not appropriate for any of the questions.

3.6.2 Statistical procedures

Using the nominal scales it was possible to determine the percentage values. The ordinal scales were used to find out the percentage, median, and rank correlation. Ratio scales were used to determine the arithmetic mean, weighted mean and median. Descriptive statistics such as tables and graphs was used to display the data.

3.7 Summary

The descriptive survey method was used as the methodology for the research. Project managers were identified as the research population, and a list of the project managers was obtained from the Avonwold Professions and Projects Register '98.

Non-probability, convenience sampling was used to determine the respondent sample. A questionnaire was adopted as the method of collection data from the sample. This questionnaire was sent by mail to the respondents of the survey.

Three measurement scales were used in the questionnaire – nominal, ordinal and ratio levels. Descriptive statistical measures were used to depict the data. (This is discussed in greater detail in the next chapter on data analysis).

CHAPTER FOUR

DATA ANALYSIS

4.1 Introduction

This chapter aims to analyze and interpret the data collected from the survey. The relevance and results of each question are discussed.

4.2 Response Information

Sixty-eight questionnaires were mailed to the respondents. Initially the response was poor and the respondents had to be contacted by telephone in order to request them to complete and return the questionnaire. Some of the companies had misplaced the questionnaire and requested for a new one. These companies were promptly sent another copy of the questionnaire to fill in.

19 completed questionnaires were returned. This represents a 28% return rate. Wegner (1993) indicates response rates for postal surveys are between 5% and 15%. Macnamara (1991) in his study stated that the response rate of 20.65% could be considered good. Fellows and Liu (1997) state that the response rate for postal surveys is between 25% - 35%. Based on these citations, 28% is perceived to be an acceptable response rate.

The reasons given for non-response were:

- The main reason given for non-response was lack of time (4 companies gave this reason).
- One company indicated that they dealt with building projects only when the building is part of a process plant project, in which case it is a relatively small part and thus does not receive any special attention as regards risk. They therefore indicated that they believed that the questionnaire was not appropriate for them.

4.3 Data Analysis

For purposes of clarity when analyzing the data, reference shall be given to the questions that were asked to the participants of the survey.

4.3.1 Administrative section

At the top of the first page of the questionnaire, there was an administrative section. This section was used to record the identity of the respondent, the company represented, position of the respondent in the company, and the postal address. The respondents had the option of filling in this section or not in order to allow them anonymity if they so wished. Notwithstanding this option, 79% of the respondents filled in this section. The rest preferred to remain anonymous.

The details filled in proved to be useful to the researcher, with special reference to the position of the respondents. This is reflected in Table 4.1.

Table 4.1 Position of respondents

Position	No	Percentage
Director	6	40%
Partner	4	27%
Executive Chairman	1	7%
Project Manager	1	7%
Business Development Manager	1	7%
Building Economist	1	7%
Cost Controller	1	7%
Total	15	100%

From this table, it is evident that senior personnel in the companies represented, who should be fully aware of the risk management practices in their companies, filled in the questionnaire. It can therefore be deduced that the questionnaire results can be relied on as being a fairly accurate reflection of risk analysis practices in these companies.

From the company details provided by these respondents it was also possible to discern that some of the major project management companies were represented. These companies included interalia Bovis Southern Africa (Pty) Ltd., Concor Building, CP de Leeuw, Farrow Laing, Murray and Roberts, and Turner and Townsend Project Management. These companies have handled some of the major contracts in Southern Africa, and can be viewed as giving an accurate reflection of some of the risk analysis practices by the major project management companies in South Africa.

4.3.2 Analysis of questions

Table 4.2 The respondents' main business activity (Question 1.1.)

Business Activity	No	Percentage
SINGLE ACTIVITIES		
Project Management	3	16%
Architecture	2	11%
Civil Engineering	1	5%
Construction (building)	1	5%
General Contracting	1	5%
Quantity Surveying	1	5%
MULTIPLE ACTIVITIES		
Project Management and Construction (building)	3	16%
Project Management and Civil Engineering	2	11%
Project Management, Construction (building) and Civil Engineering	1	5%
Project Management, Construction (civil) and Civil Engineering	1	5%
Project Management, Civil Engineering and Quantity Surveying	1	5%
Project Management, Construction Management, and Engineering Procurement	1	5%
Project Management, Viability Studies and Building Economics	1	5%
Total	19	100%

Table 4.2 shows that approximately 16% of the respondents' major business activity is project management. A further 52% have project management and another construction related activity as their major business activity. 11% of the respondents indicated that their major business activity was architecture. This is probably due to the fact that architects are in many instances appointed by the client to act as project managers on the project under the traditional procurement system. The balance of the respondents was equally spread between construction (building), general contracting, quantity surveying, and civil engineering.

From these results it can be deduced that majority respondents of the research survey were companies involved in project management as their main activity.

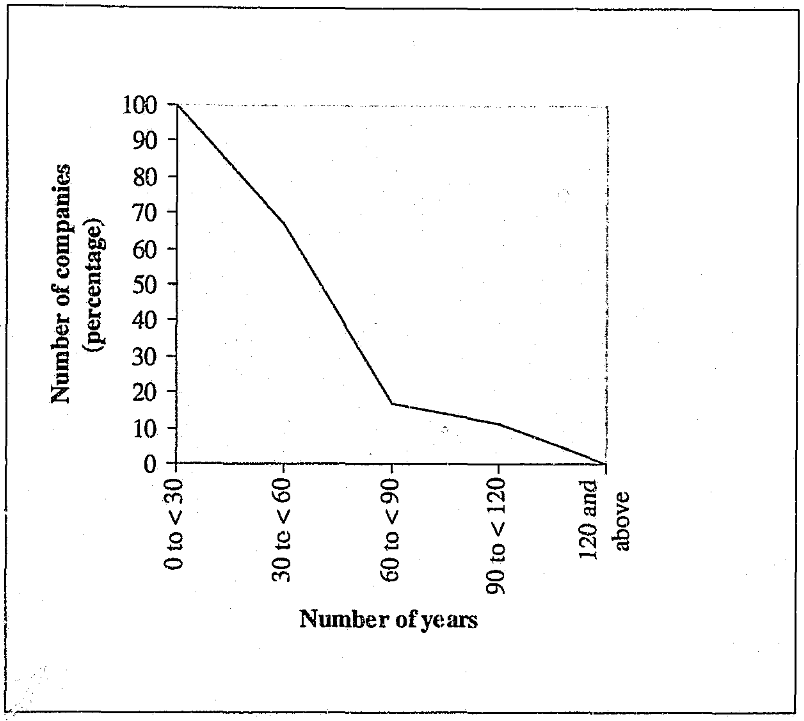


Figure 4.1 More than ogive for number of years the companies have been in existence (Question 1.2.)

The number of classes was calculated using *Sturges' Rule* as described by Wegner (1995). (See Appendix 4.1 for calculations)

From the more than ogive, it is evident that 67% of the companies have been in existence for more than 30 years. This indicates that these companies are fairly established and it can be deduced that they should have a fair idea of the concept of risk management.

Table 4.3 Average size of project handled by the companies (Question 1.3. and Question 1.4.)

Average size of project ('000,000 Rands)	No. of companies Absolute frequency
0 to < 20	8
20 to < 40	3
40 to < 60	0
60 to < 80	1
Data confidential	7
Total	19

Seven of the companies did not provide information on the total value of projects handled by the company per year and the average number of projects handled by the company per year. The reason given was that they were unable to disclose this information because it is of a confidential nature.

For the rest of the companies, the average size of project handled by each company per year was computed (See Appendix 4.2 for details). This data showing the average size of project was then grouped into classes using *Sturge's Rule* and presented in Table 4.3.

From the table, it can be seen that the average size of project handled by most of the companies that provided this information is less than 20 million Rands. It must be noted however the non-response from the seven respondents would affect the generalizations made using this data.

Risks (Question 2.0.)

Please indicate:

- The occurrence of the following risks in building construction projects.
- The level of importance of each of the risks

The aim of this question was to prioritise the risks identified from the literature review in terms of occurrence and importance. This was the first objective of the research study.

The mean score was computed for each of the risks to establish the relative occurrence and importance of each of the risks. The formula used for the mean score (MS) is the weighted mean as described by Chan and Kumaraswamy (1995):

$$MS = \frac{\Sigma (f \times s)}{N}$$

where	f	=	frequency of responses for each factor
	s	=	score given to each factor by the respondents
	N	=	total number of responses concerning that factor

For ease of reference, the risks were grouped and analysed according to five main categories as identified from the literature review. These categories are:

- External, unpredictable (and uncontrollable) risks
- External, predictable (but certain and uncontrollable) risks
- Internal, non-technical risks
- Technical risks
- Legal risks

The following tables depict the tabulated data.

- **External, unpredictable (and uncontrollable) risks**

Table 4.4 The mean scores for the frequency of occurrence of external, unpredictable (and uncontrollable) risks

Risk factors	Frequency of Responses 5	4	3	2	1	Total	Mean Score
(i) Government regulations and interventions:							
Local authority approvals	6	3	8	2	0	19	3.68
Site location issues	3	3	9	4	0	19	3.26
Change of standards	0	3	8	7	0	18	2.78
Supply of raw materials	1	2	4	12	0	19	2.58
(ii) Natural hazards	1	1	7	6	1	16	2.69
(iii) Deliberate causes:							
Theft	3	3	11	1	0	18	3.44
Vandalism	2	0	7	7	2	18	2.61
Sabotage	1	0	3	10	4	18	2.11
(iv) Indirect effects:							
Project environmental causes	1	3	9	5	0	18	3.00
Social causes	1	3	7	5	1	17	2.88
(v) Failure of completion, due to:							
Failure of others to provide infrastructure as agreed	2	2	9	5	1	19	2.95
Labour unrest	2	2	8	6	1	19	2.89
Political unrest	1	2	5	8	3	19	2.47
Bankruptcy of supplier(s)	1	1	5	10	2	19	2.42

Key: 1 = Never, 2 = Rarely, 3 = Sometimes, 4 = Often, 5 = Always

In terms of frequency of occurrence, local authority approvals had the highest mean score (3.68), followed by theft (3.44) and site location issues (3.26).

Local authority approvals and site location issues both fall under the category of government regulations and interventions. This suggests that these issues need to be expedited by the authorities concerned in order not to hinder progress of the projects.

Theft had the second highest mean score and this could probably be linked to the crime problem that South Africa is experiencing at present. The high crime rate is seen to be affecting several sectors of the economy and the results obtained imply that building projects are also being frequently affected by these criminal acts such as theft.

Sabotage had the lowest score of 2.11. This could probably mean that projects rarely suffer due to deliberate damage to productive capacity.

Table 4.5 The level of importance of external, unpredictable (and uncontrollable) risks

Risk factors	Frequency of Responses			Total	Mean Score
	3	2	1		
(i) Government regulations and interventions:					
Local authority approvals	7	11	0	18	2.39
Site location issues	8	10	1	19	2.37
Supply of raw materials	9	7	3	19	2.32
Change of standards	3	11	4	18	1.94
(ii) Natural hazards	6	8	1	15	2.33
(iii) Deliberate causes:					
Theft	4	12	1	17	2.18
Sabotage	1	12	5	18	1.78
Vandalism	1	12	5	18	1.78
(iv) Indirect effects:					
Project environmental causes	6	12	0	18	2.33
Social causes	5	11	1	17	2.24
(v) Failure of completion, due to:					
Labour unrest	12	7	0	19	2.63
Political unrest	9	10	0	19	2.47
Failure of others to provide infrastructure as agreed	10	7	2	19	2.42
Bankruptcy of supplier(s)	6	10	2	18	2.22

Key: 1 = Very Important, 2 = Important, 3 = Not Important

In the same category of external, unpredictable and uncontrollable risks, labour unrest had the highest mean score of 2.63, for level of importance. This indicates that majority of the respondents viewed this risk as very important. This is probably due to the fact that most of the building construction projects are labour intensive, and any sort of agitation from the workers could lead to a large disturbance to the progress of the works.

Political unrest had the second highest mean score of 2.47. Failure of others to provide infrastructure as agreed had the third highest mean score of 2.42. These risks were also viewed as important by the respondents and this strongly suggests that their occurrence causes serious disruptions to the works.

In contrast, vandalism and sabotage both had the lowest mean score of 1.78. This suggests that most of the projects are not plagued often by acts of vandalism and sabotage and thus they are not considered to be important.

- **External, predictable (but certain and uncontrollable) risks**

Table 4.6 The frequency of occurrence of external, predictable (but certain and uncontrollable) risks

Risk factors	Frequency of Responses					Total	Mean Score
	5	4	3	2	1		
(i) Market risks:							
Competition	4	7	3	4	1	19	3.47
Raw material cost	3	3	7	6	0	19	3.16
Change in demand	1	4	9	5	0	19	3.05
Raw material availability	2	2	9	5	1	19	2.95
(ii) Operational, e.g. safety and maintenance needs:							
Exchange rate fluctuations	3	7	6	2	1	19	3.47
Inflation changes	2	9	4	4	0	19	3.47
Safety needs	4	4	6	4	1	19	3.32
Environmental impacts	3	2	11	1	1	18	3.28
Maintenance needs	2	4	9	3	1	19	3.16
Social impacts	2	5	5	6	1	19	3.05
Taxation changes	1	1	10	6	1	19	2.74

Key: 1 = Never, 2 = Rarely, 3 = Sometimes, 4 = Often, 5 = Always

Overall, the risks in this category had quite high mean scores in terms of frequency of occurrence. Only two of the risks - taxation changes, and raw material availability had scores of less than 3.0 out of a maximum of 5.0.

Exchange rate fluctuations, inflation and competition had the highest mean score of 3.47. With reference to exchange rate fluctuations, the high mean score may be due to the fact that the exchange rate of the Rand within the last year was oscillating tremendously. The Asian financial crisis could also have been another factor contributing to the instab[illegible] [illegible]cial markets and other related currencies such as the Japanese Yen, [illegible] [illegible]stability in the exchange rate of the Rand.

With reference to competition, the high mean score is plausible due to the fact that the construction industry is rife with competition because there is a very large number of companies offering either contracting or professional services such as project management.

The fact that inflation changes had a high mean score infers that the inflation rate has also been changing considerably in South Africa. The instability of financial markets has probably also contributed to the frequency of inflation changes.

Safety needs also had a high frequency of occurrence and had a mean score of 3.32. This reaffirms the fact that in building construction projects, a lot of accidents occur on site.

Environmental impacts had a mean score of 3.28. This strongly suggests that construction activity has quite a huge effect on the environment.

Raw material cost had a mean score of 3.16. Raw material cost is perceived to have a high frequency of occurrence probably because the costs of raw materials are linked to factors such as inflation rate and exchange rate fluctuations. If the inflation rate fluctuates, the prices of the raw materials will also have to change to keep up with these fluctuations. Similarly, with exchange rate fluctuations, if the exchange rate fluctuates, then the cost of the raw material will keep changing especially if the raw materials are imported.

Taxation changes had the lowest mean score of 2.74. This indicates that the taxation levels in South Africa have been quite stable with very few changes, if any, over the years.

Table 4.7 The level of importance of external, predictable (but certain and uncontrollable) risks

Risk factors	Frequency of Responses			Total	Mean
	3	2	1		Score
(i) Market risks:					
Raw material availability	7	11	1	19	2.32
Competition	9	6	4	19	2.26
Raw material cost	6	11	2	19	2.21
Change in demand	3	12	4	19	1.95
(ii) Operational, e.g. safety and maintenance needs:					
Exchange rate fluctuations	11	7	1	19	2.53
Inflation changes	7	11	1	19	2.32
Safety needs	4	15	0	19	2.21
Environmental impacts	5	12	2	19	2.16
Maintenance needs	3	15	1	19	2.11
Social impacts	4	12	3	19	2.05
Taxation changes	1	16	2	19	1.95

Key: 1 = Very Important, 2 = Important, 3 = Not Important

From Table 4.7 it is evident that exchange rate fluctuations had the highest mean score of 2.53. It is speculated that the materials used in the construction process in South Africa are either imported or have a high content of imported material. If this is the situation, fluctuations in exchange rates would affect the projects' budgets especially if the exchange rate of the Rand falls against other major currencies such as the dollar.

Inflation changes and raw material availability both had a high mean score of 2.32. Inflation changes are considered to be important probably because changes in the rate of inflation affects the ultimate cost of the project. If the rate of inflation rises then the cost of the material and labour to be used in the project will also rise.

Raw material availability is also considered very important probably due to the fact that if the raw material is not available when required there can be dire consequences such as failure to complete the project timeously.

Change in demand and taxation changes both had the lowest mean score of 1.95. This implies that these two risks are considered to be of least importance in this category.

- **Internal non-technical risks**

Table 4.8 The frequency of occurrence of internal, non-technical risks

Risk factors	Frequency of Responses					Total	Mean Score
	5	4	3	2	1		
(i) Management:							
Inadequate project management techniques	1	4	8	2	4	19	2.79
Insufficient or inadequate project planning	1	3	9	3	3	19	2.79
Frequent staff changes	0	3	8	8	0	19	2.74
Inadequacy in capacity	0	4	8	5	2	19	2.74
Wrong contract strategy	1	1	8	6	1	17	2.71
Lack of appropriate procedures	1	2	10	2	4	19	2.68
Poor organisational structures	1	4	6	3	5	19	2.63
Inadequacy in numbers	0	1	10	6	1	18	2.61
Lack of appropriate policies	1	1	10	3	4	19	2.58
(ii) Cost and time overruns due to:							
Scope changes	1	7	9	2	0	19	3.37
Contractor claims, etc.	1	4	10	4	0	19	3.11
Labour productivity	1	5	7	6	0	19	3.05
Unforeseen site conditions	1	3	10	5	0	19	3.00
Late deliveries	1	2	12	3	1	19	2.95
Under-estimating	1	2	8	8	0	19	2.79
Management problems	0	4	8	6	1	19	2.79
Manpower problems	1	1	10	4	3	19	2.63
Material shortages	0	1	10	8	0	19	2.63
Accidents	1	1	5	12	0	19	2.53
Poor procurement strategy	0	2	5	12	0	19	2.47
Pay negotiations	0	2	7	8	2	19	2.47
(iii) Cashflow due to:							
Programme changes	0	2	11	4	2	19	2.68
Inadequate programming	0	4	7	5	3	19	2.63
Inadequate quality control	0	2	10	5	2	19	2.63
Poor estimating	0	1	10	7	1	19	2.58
Inadequate cost control	0	2	8	7	2	19	2.53
Bankruptcy	0	1	3	11	4	19	2.05
(iv) Loss of potential :							
Removal of profit and benefits of the project	0	2	8	6	2	18	2.56

Key: 1 = Never, 2 = Rarely, 3 = Sometimes, 4 = Often, 5 = Always

The category of internal non-technical risks had a large number of risk factors. Most of these factors did not have very high scores in terms of frequency of occurrence. The risks which had the highest mean scores from Table 4.8 were scope changes (3.37), contractor claims (3.11), labour productivity (3.05), and unforeseen site conditions (3.00).

It is interesting to note that these four risks all fall under the sub-category of cost and time overruns. It can therefore be inferred that cost and time overruns occur frequently in projects due to these different risks.

Cost and time overruns due to scope changes had the highest mean score. This strongly suggests that in many instances, there are several issues not yet resolved when the construction team moves from the concept stage to the development and execution stages of the project.

Contractor claims also had a high mean score, and this also strongly suggests that the initial evaluation of the work to be performed in the project is usually not done thoroughly.

Labour productivity also had a high frequency of occurrence. This is probably due to the fact that when dealing with people there are several complex human and organizational issues which are not easily understood.

Bankruptcy does not occur frequently and received the lowest score of 2.05.

Table 4.9 The level of importance of internal, non-technical risks

Risk factors	Frequency of Responses			Total	Mean Score
	3	2	1		
(i) Management:					
Insufficient or inadequate project planning	13	6	0	19	2.68
Wrong contract strategy	10	7	0	17	2.59
Inadequate project management techniques	11	8	0	19	2.58
Inadequacy in capacity	8	11	0	19	2.42
Poor organisational structures	7	12	0	19	2.37
Lack of appropriate procedures	7	12	0	19	2.37
Lack of appropriate policies	6	13	0	19	2.32
Inadequacy in numbers	5	11	2	18	2.17
Frequent staff changes	4	14	1	19	2.16
(ii) Cost and time overruns due to:					
Scope changes	12	6	0	18	2.67
Management problems	12	7	0	19	2.63
Under-estimating	10	9	0	19	2.53
Contractor claims, etc.	9	9	0	18	2.50
Manpower problems	9	10	0	19	2.47
Unforeseen site conditions	8	10	0	18	2.44
Poor procurement strategy	7	11	0	18	2.39
Late deliveries	7	11	0	18	2.39
Labour productivity	6	11	1	18	2.28
Accidents	6	11	1	18	2.28
Material shortages	5	12	2	19	2.16
Pay negotiations	4	10	4	18	2.00
(iii) Cashflow due to:					
Inadequate quality control	10	6	1	17	2.53
Bankruptcy	7	10	0	17	2.41
Inadequate programming	8	8	1	17	2.41
Poor estimating	6	11	0	17	2.35
Inadequate cost control	7	9	1	17	2.35
Programme changes	4	13	0	17	2.24
(iv) Loss of potential :					
Removal of profit and benefits of the project	11	6	0	17	2.65

Key: 1 = Very Important, 2 = Important, 3 = Not Important

From Table 4.9 it can be perceived that insufficient or inadequate project planning received the highest mean score of 2.68. This reaffirms the fact that proper planning is

Table 4.9 The level of importance of internal, non-technical risks

Risk factors	Frequency of Responses 3	2	1	Total	Mean Score
(i) Management:					
Insufficient or inadequate project planning	13	6	0	19	2.68
Wrong contract strategy	10	7	0	17	2.59
Inadequate project management techniques	11	8	0	19	2.58
Inadequacy in capacity	8	11	0	19	2.42
Poor organisational structures	7	12	0	19	2.37
Lack of appropriate procedures	7	12	0	19	2.37
Lack of appropriate policies	6	13	0	19	2.32
Inadequacy in numbers	5	11	2	18	2.17
Frequent staff changes	4	14	1	19	2.16
(ii) Cost and time overruns due to:					
Scope changes	12	6	0	18	2.67
Management problems	12	7	0	19	2.63
Under-estimating	10	9	0	19	2.53
Contractor claims, etc.	9	9	0	18	2.50
Manpower problems	9	10	0	19	2.47
Unforeseen site conditions	8	10	0	18	2.44
Poor procurement strategy	7	11	0	18	2.39
Late deliveries	7	11	0	18	2.39
Labour productivity	6	11	1	18	2.28
Accidents	6	11	1	18	2.28
Material shortages	5	12	2	19	2.16
Pay negotiations	4	10	4	18	2.00
(iii) Cashflow due to:					
Inadequate quality control	10	6	1	17	2.53
Bankruptcy	7	10	0	17	2.41
Inadequate programming	8	8	1	17	2.41
Poor estimating	6	11	0	17	2.35
Inadequate cost control	7	9	1	17	2.35
Programme changes	4	13	0	17	2.24
(iv) Loss of potential :					
Removal of profit and benefits of the project	11	6	0	17	2.65

Key: 1 = Very Important, 2 = Important, 3 = Not Important

From Table 4.9 it can be perceived that insufficient or inadequate project planning received the highest mean score of 2.68. This reaffirms the fact that proper planning is one of the factors which lies at the core of a project and could determine its success or failure.

Scope changes had a mean score of 2.67. This is probably due to the fact that scope changes can affect the essential elements of the project, and need to be given very serious consideration before being ratified.

Removal of profit and benefits of the project is also viewed as very important and had a high mean score of 2.65. This indicates that companies view profit and benefits as a very important facet of the total project.

The other risks that were perceived as very important, and their corresponding mean scores were: management problems (2.63), wrong contract strategy (2.59) and inadequate project management techniques (2.58).

The risk factor that had the lowest score was pay negotiations (2.00). It can therefore be deduced that this factor does not have a very significant impact on the project and is therefore not very important.

- **Technical risks**

Table 4.10 The frequency of occurrence of technical risks

Risk factors	Frequency of Responses 5	4	3	2	1	Total	Mean Score
(i) Technology:							
Increase in complexity	0	1	11	4	2	18	2.61
Changes in technology	0	1	11	5	2	19	2.58
Obsolescence due to new or improved technology	0	0	9	8	2	19	2.37
(ii) Performance:							
Change in rate of production	0	1	12	5	1	19	2.68
Change in quality	0	1	10	7	1	19	2.58
Change in reliability	0	1	8	9	1	19	2.47
(iii) Design due to:							
Changes to specification	0	7	11	1	0	19	3.32
Changes to design	0	6	12	1	0	19	3.26
Changes to scope of work	0	6	11	2	0	19	3.21
Insufficient data	0	3	12	4	0	19	2.95
Detail and specification	0	5	7	7	0	19	2.89
Inadequacies	0	4	7	7	0	18	2.83
Designer experience	0	2	9	7	1	19	2.63
(iv) Size of project	0	2	6	5	0	13	2.77

Key: 1 = Never, 2 = Rarely, 3 = Sometimes, 4 = Often, 5 = Always

In this category of technical risks, the factors which occur most frequently are due to design problems. The respondents indicated that design risks due to changes to specification, changes to design, changes to scope of work, and insufficient data occur quite frequently.

The risk that had the highest frequency of occurrence was changes to specification (3.32). This was followed by changes to design which had a mean score of 3.26. The fact that these risk factors received a high mean score strongly suggests that there is often inadequate preparation in the conceptual stages of the project.

Design risks due to changes to scope of work received the third highest mean score of 3.21. It is important to reflect back to Table 4.8 whereby it was noted that cost and time overruns due to scope changes had the highest frequency of occurrence with a mean score of 3.[illegible]. This strongly suggests that scope changes are a major risk factor and have an exceptionally high frequency of occurrence. The project teams need to be very wary of this fact, and probably they need to readjust their *modus operandi* in order to reduce the occurrence of this risk.

Obsolescence due to new or improved technology had the lowest mean score of 2.37. This risk factor does not occur frequently. This indicates that construction does not rely very heavily on very highly sophisticated technology which would become obsolete quickly or require replacement often.

Table 4.11 The level of importance of technical risks

Risk factors	Frequency of Responses			Total	Mean Score
	3	2	1		
(i) Technology:					
Increase in complexity	5	10	1	16	2.25
Changes in technology	6	9	2	17	2.24
Obsolescence due to new or improved technology	3	13	1	17	2.12
(ii) Performance:					
Change in quality	5	12	0	17	2.29
Change in reliability	5	12	0	17	2.29
Change in rate of production	4	13	0	17	2.24
(iii) Design due to:					
Changes to scope of work	8	10	0	18	2.44
Changes to design	8	10	0	18	2.44
Designer experience	7	11	0	18	2.39
Changes to specification	7	11	0	18	2.39
Inadequacies	7	9	1	17	2.35
Insufficient data	6	12	0	18	2.33
Detail and specification	4	14	0	18	2.22
(iv) Size of project	6	2	4	12	2.17

Key: 1 = Very Important, 2 = Important, 3 = Not Important

Design risks due to changes to scope of work and changes to design both had the highest mean score of 2.44. This implies that the respondents consider these risks to be very important. Design risks due to designer experience and changes to specification both had a mean score of 2.39. This indicates that the overall accuracy and completeness of the design has a major impact on the project, and as a result is considered to be very important.

Obsolescence due to new or improved technology is not considered to be important and consequently received the lowest mean score was 2.12.

- **Legal risks**

Table 4.12 The frequency of occurrence of legal risks

Risk factors	Frequency of Responses					Total	Mean Score
	5	4	3	2	1		
(i) Licences	0	0	4	10	4	18	2.00
(ii) Patent rights	0	0	2	10	6	18	1.78
(iii) Contractual due to:							
Misunderstanding	0	2	9	8	0	19	2.68
Interpretation	0	1	10	8	0	19	2.63
Wrong contract type	0	2	5	11	1	19	2.42
(iv) Lawsuits	0	0	3	15	0	18	2.17
(v) Force majeure	1	1	1	12	2	17	2.24

Key: 1 = Never, 2 = Rarely, 3 = Sometimes, 4 = Often, 5 = Always

Contractual risks had the highest frequency of occurrence – misunderstanding (2.68), interpretation (2.63) and wrong contract type (2.42). This is probably because the parties involved in the construction project often choose the wrong contract procurement system and as a result end up with all these contractual problems.

Patent rights do not occur often and had the lowest mean score of 1.78.

Table 4.13 *The level of importance of legal risks*

Risk factors	Frequency of Responses 3	2	1	Total	Mean Score
(i) Licences	1	12	3	16	1.88
(ii) Patent rights	1	8	7	16	1.63
(iii) Contractual due to:					
Misunderstanding	9	7	1	17	2.47
Interpretation	8	9	0	17	2.47
Wrong contract type	8	10	0	18	2.44
(iv) Lawsuits	9	8	0	17	2.53
(v) Force majeure	7	6	3	16	2.25

Key: 1 = Very Important, 2 = Important, 3 = Not Important

From Table 4.13, lawsuits had the highest mean score of 2.53. This is probably due to the fact that lawsuits can be very costly and can damage severely the reputation of the company, amongst other things. Misunderstanding and interpretation are considered to be very important in the legal category and both had a mean score of 2.47.

Patent rights were considered to be the least important in this category and had a mean score of 1.63.

These risks are then ranked based on both their frequency of occurrence and level of importance in their various categories. This is presented in Tables 4.14 to 4.18.

Table 4.14 Ranking of external, unpredictable (and uncontrollable) risks

	Level of Importance		Frequency of Occurrence	
Risk Factor	Mean Score (Out of Three)	Rank	Mean Score (Out of Five)	Rank
Labour unrest	2.63	1	2.89	6
Political unrest	2.47	2	2.47	12
Failure of others to provide infrastructure as agreed	2.42	3	2.95	5
Local authority approvals	2.39	4	3.68	1
Site location issues	2.37	5	3.26	3
Natural hazards	2.33	6	2.69	9
Project environmental causes	2.33	6	3.00	4
Supply of raw materials	2.32	8	2.58	11
Social causes	2.24	9	2.88	7
Bankruptcy of supplier(s)	2.22	10	2.42	13
Theft	2.18	11	3.44	2
Change of standards	1.94	12	2.78	8
Sabotage	1.78	13	2.11	14
Vandalism	1.78	13	2.61	10

The risks ranked highly in both categories are failure of others to provide infrastructure as agreed, local authority approvals and site location issues. It can be seen that these three risk factors are both important and have a high frequency of occurrence.

Sabotage ranked second last in terms of importance and last in terms of frequency of occurrence. It can therefore be deduced that it is not important and hardly ever occurs in projects.

In contrast, political unrest was ranked number two for level of importance, but number twelve for frequency of occurrence. This implies that although this risk rarely occurs, it is viewed as important. It is presumed that political unrest can have very dire consequences to the progress of the project.

Similarly, labour unrest ranked number one in terms of level of importance and number six in terms of frequency of occurrence. This implies that even if this risk does not occur frequently, it is very important and should be not be taken lightly.

Table 4.15 Ranking of external, predictable (but certain and uncontrollable) risks

Risk Factor	Level of Importance		Frequency of Occurrence	
	Mean Score (Out of Three)	Rank	Mean Score (Out of Five)	Rank
Exchange rate fluctuations	2.53	1	3.47	1
Raw material availability	2.32	2	2.95	10
Inflation changes	2.32	2	3.47	1
Competition	2.26	4	3.47	1
Raw material cost	2.21	5	3.16	6
Safety needs	2.21	5	3.32	4
Environmental impacts	2.16	7	3.28	5
Maintenance needs	2.11	8	3.16	6
Social impacts	2.05	9	3.05	8
Change in demand	1.95	10	3.05	8
Taxation changes	1.95	10	2.74	11

Exchange rate fluctuations ranked number one for both level of importance and frequency of occurrence. Inflation changes ranked number two in terms of level of importance, and number one in terms of frequency of occurrence. It can be assumed that these two risk factors are both very important and have a high frequency of occurrence. The reason for this is probably due to the weakening of the Rand against other major currencies and instability of financial markets. (See discussions after Tables 4.6 and 4.7)

Social impacts, change in demand and taxation changes had low ranks in both categories, and thus are not viewed as important and have a low frequency of occurrence.

Raw material availability has a very low frequency of occurrence (ranked number ten) but is viewed to be very important (ranked number two).

Table 4.16 **Ranking of internal, non-technical risks**

Risk Factor	Level of Importance		Frequency of Occurrence	
	Mean Score (Out of Three)	Rank	Mean Score (Out of Five)	Rank
Insufficient or inadequate project planning	2.68	1	2.79	6
Scope changes	2.67	2	3.37	1
Removal of profit and benefits of the project	2.65	3	2.56	23
Management problems	2.63	4	2.79	6
Wrong contract strategy	2.59	5	2.71	12
Inadequate project management techniques	2.58	6	2.79	6
Inadequate quality control	2.53	7	2.63	15
Under-estimating	2.53	7	2.79	6
Contractor claims, etc.	2.50	9	3.11	2
Manpower problems	2.47	10	2.63	15
Unforeseen site conditions	2.44	11	3.00	4
Inadequacy in capacity	2.42	12	2.74	10
Bankruptcy	2.41	13	2.05	28
Inadequate programming	2.41	13	2.63	15
Poor procurement strategy	2.39	15	2.47	26
Late deliveries	2.39	15	2.95	5
Poor organisational structures	2.37	17	2.63	15
Lack of appropriate procedures	2.37	17	2.68	13
Poor estimating	2.35	19	2.58	21
Inadequate cost control	2.35	19	2.53	24
Lack of appropriate policies	2.32	21	2.58	21
Labour productivity	2.28	22	3.05	3
Accidents	2.28	22	2.53	24
Programme changes	2.24	24	2.68	13
Inadequacy in numbers	2.17	25	2.61	20
Frequent staff changes	2.16	26	2.74	10
Material shortages	2.16	26	2.63	15
Pay negotiations	2.00	28	2.47	26

From the table it is evident that scope changes are considered to be very important (ranked number 2) and have a high frequency of occurrence (ranked number 1).The other risk factor which was rated as quite important and had a high frequency of occurrence was management problems. This risk factor ranked number 4 and 6 for level of importance and frequency of occurrence respectively.

Removal of profits and benefits of the project ranked number 3 for level of importance, but in contrast ranked number 23 for frequency of occurrence. This indicates that whilst this risk is considered to be very important, it rarely occurs in projects.

Pay negotiations had low ranks in both categories and is deemed to be unimportant, with a low frequency of occurrence.

Table 4.17 Ranking of technical risks

Risk Factor	Level of Importance		Frequency of Occurrence	
	Mean Score (Out of Three)	Rank	Mean Score (Out of Five)	Rank
Changes to scope of work	2.44	1	3.21	3
Changes to design	2.44	1	3.26	2
Designer experience	2.39	3	2.63	9
Changes to specification	2.39	3	3.32	1
Inadequacies	2.35	5	2.83	6
Insufficient data	2.33	6	2.95	4
Change in quality	2.29	7	2.58	11
Change in reliability	2.29	7	2.47	13
Increase in complexity	2.25	9	2.61	10
Changes in technology	2.24	10	2.58	11
Change in rate of production	2.24	10	2.68	8
Detail and specification	2.22	12	2.89	5
Size of project	2.17	13	2.77	7
Obsolescence due to new or improved technology	2.12	14	2.37	14

Changes to scope of work ranked first in terms of level of importance and third in terms of frequency of occurrence. These results are compared to the results in Table 4.16 whereby it was noted that scope changes were ranked very highly in both categories as well. The other risk factors which ranked highly in terms of both level of importance and frequency of occurrence were changes to design and changes to specification.

Obsolescence due to new or improved technology is not perceived to be a very significant. This risk factor ranked last in terms of both level of importance and frequency of occurrence.

Table 4.18 Ranking of legal risks

	Level of Importance		Frequency of Occurrence	
Risk Factor	**Mean Score (Out of Three)**	**Rank**	**Mean Score (Out of Five)**	**Rank**
Lawsuits	2.53	1	2.17	5
Misunderstanding	2.47	2	2.68	1
Interpretation	2.47	2	2.63	2
Wrong contract type	2.44	4	2.42	3
Force majeure	2.25	5	2.24	4
Licences	1.88	6	2.00	6
Patent rights	1.63	7	1.78	7

Misunderstanding and interpretation can be viewed as ranking highly in both categories. This indicates that these two risks are very important and have a high frequency of occurrence.

Patent rights and licences were ranked the last and second last respectively in both categories. It can be deduced that these risk factors are not important and rarely occur.

A visual inspection of Tables 4.14 to 4.18 shows that there appears to be a correlation between the level of importance and the frequency of occurrence in Tables 4.15, and 4.18. In Tables 4.14, 4.16, and 4.17, this correlation was not evident by visual inspection and thus a scatterplot and *Spearman's rank correlation* as described by Wegner (1993) were used to find out if there is a measure of association between the two random variables.

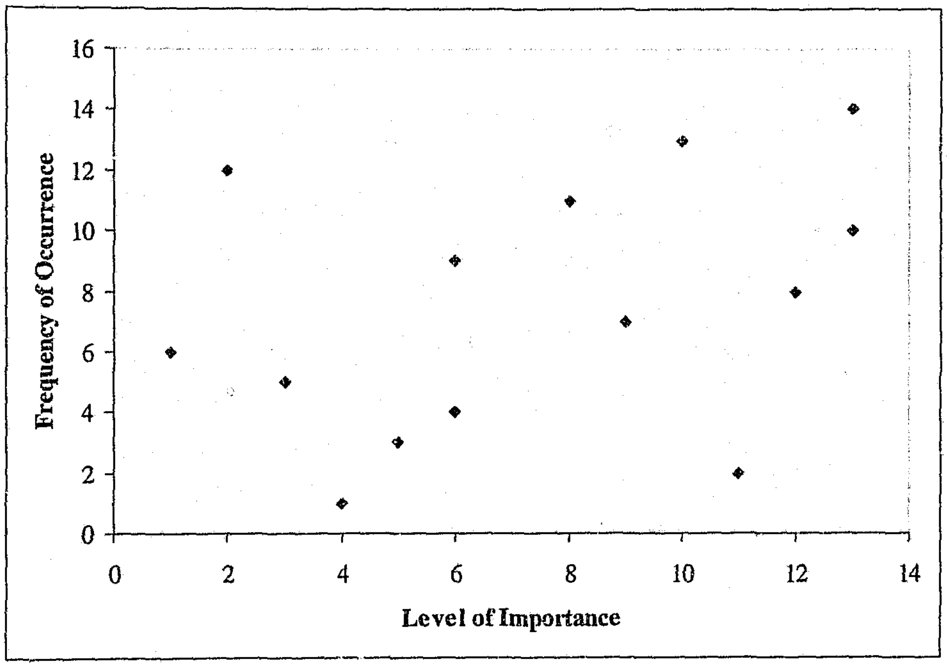


Figure 4.2 External unpredictable and uncontrollable risks – Relationship between the frequency of occurrence and the level of importance

From the scatterplot, the correlation between the variables appears to be positive. The calculated *Spearman's rank correlation* provides a value of 0.3621. The significance of this figure was tested using the t distribution and it was revealed that it is not significant at 10% significance level. (See Appendix 4.3 for calculations)

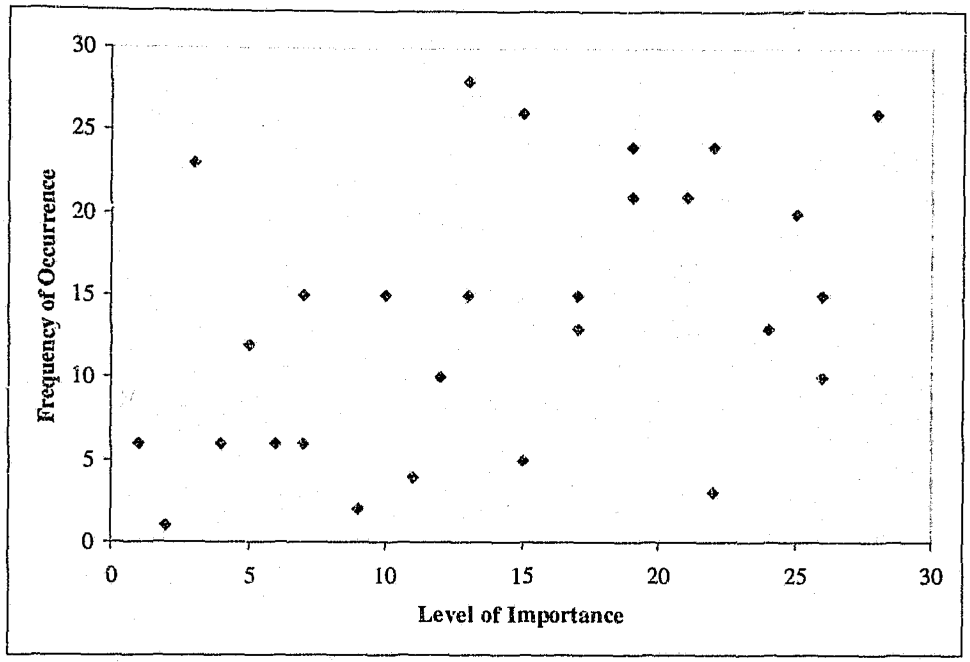


Figure 4.3 Internal non-technical risks – Relationship between the frequency of occurrence and the level of importance

From the scatterplot, the correlation between the variables appears to be positive. The calculated *Spearman's rank correlation* provides a value of 0.4283. This is significant at 5% significance level. Therefore it can be deduced that there is a moderate positive linear correlation between the variables.

(See Appendix 4.4 for calculations)

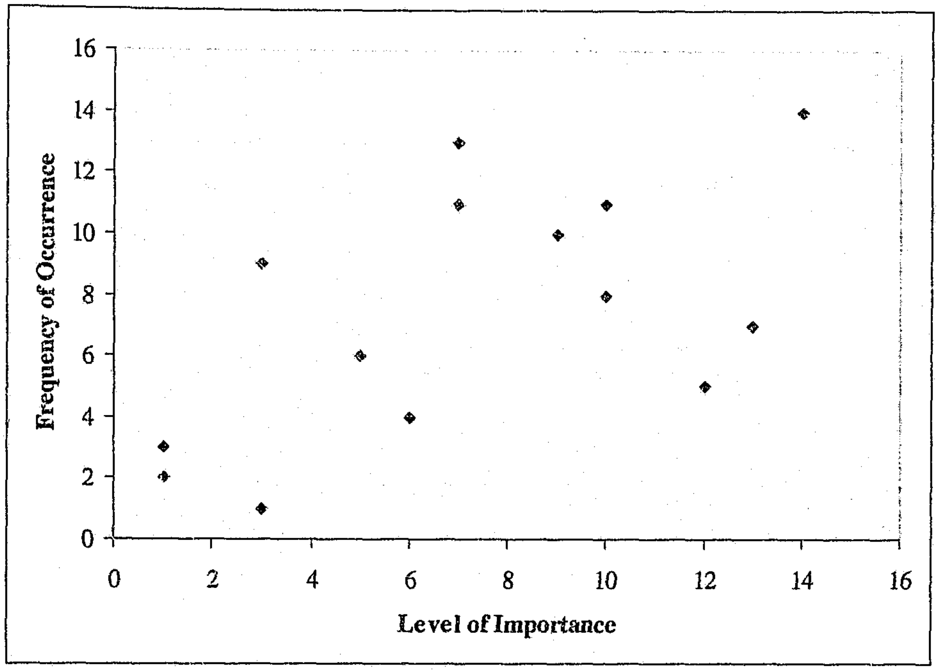


Figure 4.4 Technical risks – Relationship between the frequency of occurrence and the level of importance

The scatterplot also shows a certain degree of positive linear correlation between the two variables.

Spearman's rank correlation calculated produced a value of 0.5822. This is significant at 5% significance level (for 2-tailed test). Therefore it can be deduced that there is a moderately positive relationship between the level of importance and frequency of occurrence. (See Appendix 4.5 for calculations)

These results strongly suggest that for external predictable but certain and uncontrollable risks, internal non-technical risks, technical risks and legal risks there is a positive correlation between the level of importance attached to the risks and the frequency of occurrence of the risks.

Table 4.19 Number of companies with a risk management department (Question 3.1)

Response	Number	Percentage
Yes	4	21%
No	15	79%
Total	19	100%

The results of this question indicate that majority of the companies do not deal with risk management as a separate entity. This is interesting to note, especially when compared with results from question 1.2., it appears that even though 67% of the companies have been in existence for more than 30 years, only 21% have a separate risk management department.

Table 4.20 Personnel responsible for risk analysis (Question 3.2)

Category	No	Percentage
<u>PERSONNEL RESPONSIBLE</u>		
Managing Director	6	35%
Partner	2	12%
Projects Director	2	12%
<u>MULTIPLE PERSONNEL RESPONSIBLE</u>		
Projects Director, Contracts Manager and Partner	1	6%
Projects Director and Project Manager	1	6%
Managing Director and Projects Director	1	6%
Managing Director, Financial Director, Projects Director, Contracts Manager and Project Manager	1	6%
Managing Director, Financial Director, Projects Director, Contracts Manager, Project Manager and Chief Estimator	1	6%
Managing Director, Financial Director, Projects Director, Contracts Manager, Project Manager and Site Agent	1	6%
Managing Director, Financial Director, Projects Director, Commercial Director and Estimating Director	1	6%
Total	17	100%

This question revealed that most companies have more than one person responsible for risk analysis.

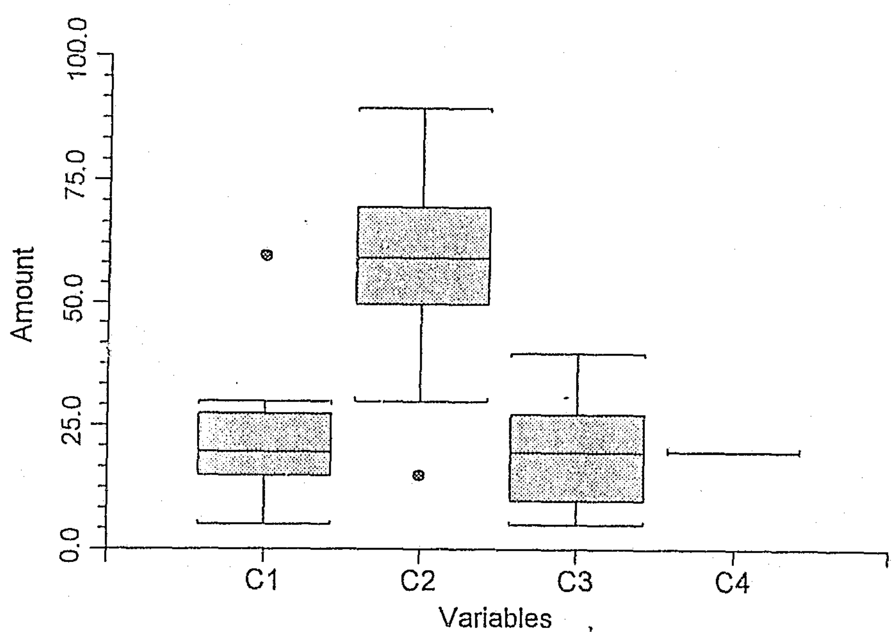
35% of the respondents indicated that risk analysis was the responsibility of the Managing Director. An additional 30% stated that it was the responsibility of the Managing Director and other personnel.

42% of the companies have multiple personnel responsible for risk analysis.

It is evident from the table that in all of the companies, risk analysis is viewed seriously and is the responsibility of senior personnel in the company.

Table 4.21 The points awarded to each method of acquiring risk management expertise (Question 3.3)

	Method of acquring expertise (Number of Points)				
	Specialized Training	Experience	Aptitude	Other	Total
	10	70	20		100
	20	70	10		100
	20	60	20		100
	20	60	20		100
	30	50	20		100
	5	90	5		100
	20	30	30	20	100
	10	50	40		100
	20	60	20		100
	20	50	30		100
	60	15	25		100
	20	50	30		100
	10	80	10		100
	20	60	20		100
	30	50	20		100
	30	60	10		100
	25	70	5		100
Mean	28	75	26	20	
Median	20	60	20	20	
Upper quartile	25	70	25	20	
Lower quartile	20	50	10	20	



Key: C1 = Specialized Training, C2 = Experience, C3 = Aptitude, C4 = Benchmarking

Figure 4.5 Box and Whisker representing the various methods of acquiring expertise (Question 3.3)

This question was aimed at finding out the current practices with respect training and education relating to risk management. The points awarded and the respective mean and median scores can be seen in Table 4.21 and in Figure 4.5.

From table and the graph it is evident that experience had the highest mean score (75) and the highest median score (60). This indicates that it is the most widely used method.

Experience had the highest range of 75. This was due to the fact that the highest score received was 90, and the lowest score received was 15. The company which gave a score of 90 relies almost solely on experience whilst the other company which presented a score of 15 relies less on experience. These two companies have distinctly different approaches to risk management.

One respondent indicated benchmarking as an additional method of acquiring expertise.

As an overview, it can be deduced from the figure 4.5 and the table 4.21 that experience is the most widely used method of acquiring expertise on risk management.

Risk analysis techniques used by the risk management practitioners (Question 3.4)

This was an open ended question aimed at the identifying the risk analysis techniques used by the companies. The techniques indicated were:

- Individual risk value
- Monte Carlo simulation
- Decision tree
- PERT
- Sensitivity analysis
- Experience and judgement of management

Table 4.22 Usage of risk analysis techniques (Question 3.5)

Risk analysis technique	f and %	Usage			Total
		Always	Sometimes	Never	
Individual risk value	f	4	7	3	14
	%	29	50	21	100
Decision trees	f	3	5	6	14
	%	21	36	43	100
Sensitivity analysis	f	4	6	4	14
	%	29	43	29	100
Range Estimates	f	1	9	5	15
	%	7	60	33	100
Pert	f	5	6	4	15
	%	33	40	27	100
Means-end analysis	f	0	4	9	13
	%	0	31	69	100
Algorithms	f	0	3	11	14
	%	0	21	79	100
Portfolio theory	f	1	0	11	12
	%	8	0	92	100
Delphi Method	f	0	3	10	13
	%	0	23	77	100
Bayesian theory	f	0	1	11	12
	%	0	8	92	100
Monte Carlo Simulation	f	0	8	5	13
	%	0	62	38	100
Stochastic dominance	f	0	4	9	13
	%	0	31	69	100

Key : f = absolute frequency, % = relative frequency

The respondents were asked to indicate the extent to which they use certain risk analysis techniques which were identified by the researcher from the literature review. This question was objective number 2 and 3 of the research study. The tabulated results are presented in Table 4.22.

In six out of the twelve techniques, more than 68% of the respondents indicated that they *never* use the particular technique. These techniques and the percentage of respondents that never use them are: Bayesian theory (92%), portfolio theory (92%), algorithms (79%), Delphi method (77%), stochastic dominance (69%), and means-end analysis (69%).

In contrast, six of the techniques are *always* used but by less than 34% of the respondents. These techniques and the percentage of respondents that always use them are: PERT (33%), individual risk value (29%), sensitivity analysis (29%), decision trees (21%), portfolio theory (8%), and range estimates (7%). As is evident these percentages are very low and it can be deduced that most of the companies do not always use these techniques.

It can be deduced from these responses that the risk analysis techniques identified from the literature review are used only to a very limited extent by a small fraction of the companies in South Africa.

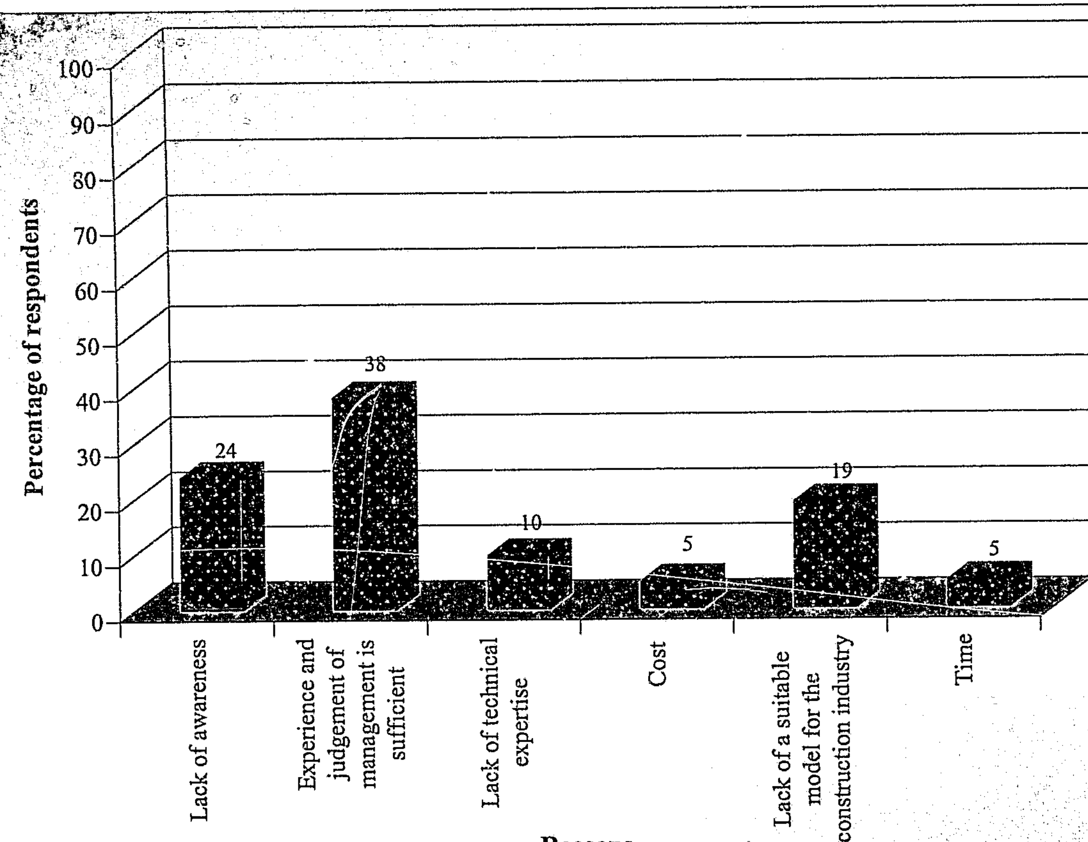


Figure 4.6 Reasons for not using risk analysis techniques (Question 3.6)

The reasons for not using the techniques can be seen in Figure 4.6. Most of the respondents provided more than one reason as to why they do not use any of the techniques identified from the literature review.

From Figure 4.6, it can be seen that 38% of the respondents indicated that the reason why they do not utilize risk analysis techniques is that the experience and judgement of management is sufficient. 24% indicted that lack of awareness was the reason, 19% indicated it was due to lack of a suitable model for the construction industry and 10% indicated lack of technical expertise as the reason. The rest of the reasons were evenly spread between cost (5%) and time (5%).

Table 4.23 The software packages used by the companies to determine risk on projects and the risk(s) which the package(s) cater for (Question 3.7)

Software Package	Respondents		Risks
	No	%	Catered for
Bovis in house Hummingbird Software	1	6	1
Primavera	1	6	2, 3, 5, 6
@risk	2	13	1
CA Superproject	1	6	5
Bespoke	1	6	1
Data Base	1	6	2,3,6
Pert	1	6	4
Autocad	1	6	5
Excel	1	6	3,5
Viabilty Program	1	6	2,3,4
PS7	1	6	2,3,5
Project Pro	1	6	No response
CCS	1	6	2,3
M/S Project Man	1	6	3,5
Sure Track	1	6	3,5
Total	16	100	

Key: 1 = All, 2 = External Unpredictable, 3 = External Predictable,
4 = Internal Non-technical, 5 = Technical, 6 = Legal

Most of the respondents who use software to determine risk on projects indicated that they use more than one software package to determine risk on projects. This is summarized in Table 4.23.

Only three of the six types of software used cater for all the five categories of risks. These are Bovis, @risk and Bespoke.

One respondent stated that Primavera does not adequately cater for internal non-technical risks. In particular, he mentioned that "it does not cater for commitment, perseverance and competent implementation".

Overall, it can be seen that software is not widely used to analyse risk in projects. Where software packages are being used by the companies, it is evident that most of the software packages do not cater for all the risks and need to be complemented with another type of software.

A comparison of the results of this question and questions 1.3. and 1.4. was done with an aim of establishing whether there is any relationship between the size of the projects handled by the companies and the use of computers in risk analysis.

One of the companies did not provide information on the use of computers in risk analysis. Table 4.3. shows a frequency distribution of the average size of project handled by the different companies.

Table 4.24 Average size of project handled compared with the use of computers for risk analysis by the different companies

Average size of project ('000,000 Rands)	No. of companies Absolute frequency	Use of computers		
		Yes	No	No response
0 to < 20	8	4	4	0
20 to < 40	3	3	0	0
40 to < 60	0	0	0	0
60 to < 80	1	0	0	1
Data confidential	7	1	5	1
Totals	19	8	9	2

It would appear that the companies that handle projects of 20 million and above use computers for risk analysis. This strongly suggests that companies that have projects of 20 million and above have realized the importance of information technology for risk analysis and utilise it in their business activities. The use of computer technology speeds up efficiency and effectiveness in an organisation, and this may be the reason why these companies are able to handle larger projects.

It is also interesting to note that the four companies that indicated that they do not use computers for risk analysis, handle projects of less than 20 million Rands (on average). It can be speculated that the reason for this is due to the fact that these companies have not kept abreast with technological improvements such as use of computers. As a result these companies do not have the capacity to compete with other firms for large projects. It is also possible that they do not have the financial resources to purchase sophisticated risk analysis software.

Table 4.25 The respondents views on five statements relating to risk analysis in South Africa (Question 3.8)

Statement	Frequency of Responses					Total	Mean Score
	5	4	3	2	1		
Due to the volatility of markets, risk analysis methods are required more today than ever before	3	9	6	0	0	18	3.83
The application of formal risk analysis techniques depends on the size of the project	3	11	1	3	0	18	3.78
Risk analysis techniques used in South Africa compare closely to those used in Western Europe, U.S.A. or South East Asia	1	1	8	6	0	16	2.81
Risk analysis methodologies in South Africa are highly sophisticated	0	1	8	7	2	18	2.44
There is widespread usage of formal risk analysis techniques in South Africa	1	2	2	9	4	18	2.28

Key : 5 = Strongly Agree, 4 = Agree, 3 = Neither agree nor disagree
2 = Disagree, 1 = Strongly Disagree

From Table 4.25 it is evident that there was a significant level of agreement with the following statements:

- *"Due to volatility of markets, risk analysis methods are required more today than ever before"*
  This statement received a high mean score of 3.83. 12 out of 18 respondents agreed with it. None of the respondents disagreed with it.

- *"The application of formal risk analysis techniques depends on the size of the project"*
  This statement received a mean score of 3.78. 14 out of 18 respondents agreed with it compared with only 3 respondents who disagreed with it.

In contrast there was a significant level of disagreement with the following statements:

- *"Risk analysis techniques used in South Africa compare closely to those used in Western Europe, U.S.A. or South East Asia"*
  This statement received a mean score of 2.81, with 6 out of 16 respondents disagreeing with it, and two respondents agreeing with it.

- *"Risk analysis methodologies in South Africa are highly sophisticated"*
  This statement received a mean score of 2.44, with 50% of the respondents disagreeing with it.

- *"There is widespread usage of formal risk analysis techniques in South Africa"*
  This statement received a mean score of 2.28. 13 out of 18 respondents disagreed with it.

Based on these results, the following can be deduced about risk analysis in South Africa:

- Risk analysis methodologies in South Africa have a low level of sophistication.
- Risk analysis techniques used in South Africa do not compare closely to those used in Western Europe, U.S.A. or South East Asia.
- Formal risk analysis techniques are not widely used in South Africa.
- The application of formal risk analysis techniques depends on the size of the project.
- Due to volatility of markets, risk analysis methods are required more today.

Steps that can be taken to improve risk analysis in South Africa (Question 3.9)

This was an open ended question aimed at establishing the respondents suggestions towards improvements of risk analysis in South Africa. Some of the major suggestions given were:

- Increase awareness in the construction industry.
- Individual companies should ensure that their risk analysis practices are up to standard.
- Increase formal training and education.
- The risk analysis methods should be presented in a practical usable manner.
- Increase *client* awareness.
- Clients should appoint a risk analysis team at the start of the design stage.
- Clients should be prepared to pay for the pre-commencement work by the project managers.

4.4 Summary

Out of all the risks that were identified from the literature review, it was found that the risks which had high mean scores and ranks in terms of *both* level of importance and frequency of occurrence were local authority approvals, failure of others to provide infrastructure as agreed, site location issues, exchange rate fluctuations, inflation changes, competition, scope changes, management problems, inadequate project management techniques, changes to design, changes to scope of work, changes to specification, misunderstanding, interpretation and wrong contract type (See tables 4.14 to 4.18). It can be surmised that these risks need to be taken seriously because they are important, and have a high frequency of occurrence.

From the survey it was evident that risk analysis is considered to be very important and it is the responsibility of senior personnel in the companies (See table 4.20). In support of this finding, the survey also showed that the main method of gaining risk management expertise was through experience (See table 4.21). Twelve techniques identified from the literature review are used for risk analysis: individual risk value, decision trees, sensitivity analysis, range estimates, pert, means-end analysis, decision trees, sensitivity analysis, range estimates, pert, means-end analysis, algorithms, portfolio theory, Delphi method, Monte Carlo Simulation, stochastic dominance and Bayesian theory.

It was also evident from the survey that six of the techniques are *never* used by more than 68% of the respondents. In contrast, six of the techniques are *always* used but by less than 34% of the respondents (See table 4.22). Even if the techniques are used, most of the companies indicated that they only use them occasionally, or never at all.

The respondents also indicated the reasons why they do not use the techniques. Of the six reasons given, the most prominent reason given was that experience and judgement of management is sufficient (38% of the respondents indicated this). The other two common reasons were lack of awareness (24%) and lack of a suitable model for the construction industry (19%). This can be seen in Figure 4.6.

The survey revealed that only 47% of the respondents use computer software packages to analyse risks (See table 4.24), and 79% of the computer packages used do not cater for all the risks (See table 4.23).

Many of the respondents expressed a need to increase awareness on risk analysis through education, training and development of suitable methods of risk analysis for the construction industry in South Africa.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

In chapter one the main objectives of the research study were indicated. Objective one was to identify a comprehensive list of risks associated with building construction projects, and prioritise these risks in terms of importance and frequency of occurrence. The literature review revealed a comprehensive list of risks. The research survey helped to prioritise these risks and establish which of these risks are *both* important and have a high frequency of occurrence (See tables 4.14 to 4.18). The survey also established that there is a moderate positive correlation between the importance and frequency of occurrence of the risks (See figures 4.2 to 4.4).

Objective two was to identify the risk analysis techniques used in the evaluation of building construction projects by project managers in the building industry in South Africa, and determine the strengths and weaknesses of these techniques. Once again the literature review helped to establish twelve risk analysis techniques which are *suitable for the construction industry.* These twelve risk analysis techniques are algorithms, means-end analysis, decision trees, Bayesian theory, sensitivity analysis, Monte Carlo simulation, portfolio theory, stochastic dominance, Delphi method, Programme Evaluation and Review Technique (PERT), individual risk value, and range estimating. The survey indicated that these twelve techniques are being used in the construction industry in South Africa. The review also showed the strengths and weaknesses of several of these techniques.

Objective three was to establish to what extent risk analysis techniques are used in the building industry. The survey showed that out of the twelve risk analysis techniques, individual risk value, PERT, and sensitivity analysis are the most widely used. It can be surmised that the type of technique to be used by the decision-maker will depend largely on factors such as the output required (some techniques are significantly more complex than others), time and cost.

It was however evident that there is very low level of usage of the risk analysis techniques in South Africa, with six of the techniques not being used by more than 68% of the respondents (See table 4.22).

The main reason indicated for non-utilisation of the techniques was that the experience and judgement of management is sufficient (See figure 4.6). This is in direct contradiction with the discussion in the literature review which indicated that the danger of relying solely on human judgement is that it can produce erroneous judgements. It was also pointed out in the literature review that risk analysis techniques are not a rigid rule to supplant or replace the decision-making process but they are an aid to decision-making.

Notwithstanding the above discussion, the survey results indicated that there is a desire for increased awareness on risk analysis in South Africa.

5.2 Recommendations

The construction industry in South Africa and in many other countries, has seen many major projects incurring substantial cost and time overruns. One of the plausible reasons for this may be that the project leaders were unable to cope with the risks.
In order for companies to be able to handle risks adequately, they need to improve the quality of decisions on risk. This can be done through incorporating informal intuitive judgements with formal risk analysis techniques.

It is recommended that the following steps should be taken by recognised bodies such as the Project Management Institute (PMI), the Master Builders Association (MBA), and the Council for Scientific and Industrial Research (CSIR) to improve risk analysis in South Africa:

- Increase awareness on the risk analysis through efficient dissemination of information to the practitioners in the construction industry.
- Provision of education and training on risk analysis in tertiary institutions.
- Research and development towards development of "best practice" guidelines on risk management.

5.3 Recommendations for Further Study

In pursuance to this study, further research could be done in the following areas:

1. The development of a risk analysis methodology suitable for implementation in the South African construction industry.
2. A strategy for expanding awareness of risk analysis in the South African construction industry.
3. Development of an integrated risk management system using information technology.
4. A methodology to help establish the probability of occurrence of the risk factors in construction projects.

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APPENDIX 1.1 – BUILDING STATISTICS FOR NOVEMBER 1998

(pp. 100-101)

TABLE 1.2 - BUILDINGS COMPLETED - PUBLIC AND PRIVATE SECTOR
TOTAL ACCORDING TO PROVINCES

ITEM		YEAR AND MONTH	TOTAL	PROVINCE								
				Western Cape	Eastern Cape	Northern Cape	Free State	KwaZulu-Natal	North West	Gauteng	Mpumalanga	Northern Province
TOTAL	Value (R1 000)	1996	10 423 821	2 105 254	513 307	130 920	354 199	1 856 904	322 947	4 597 495	323 545	219 240
		1997	11 311 606	2 558 779	554 041	124 254	346 963	2 053 778	403 943	4 598 523	423 183	248 141
		1997-Jan-Nov	10 321 797	2 345 966	513 860	116 260	320 736	1 961 138	387 567	4 043 092	392 027	241 151
		1998-Jan-Nov	10 772 159	2 553 233	582 847	123 929	332 181	1 912 747	508 109	4 195 851	363 120	200 143
		1997-Nov*	1 163 667	215 719	41 652	8 571	37 467	175 493	26 521	592 992	52 443	12 809
		1998-Oct	1 119 798	242 173	88 307	15 519	23 612	187 377	141 738	360 377	35 742	24 953
		1998-Nov	966 744	307 571	74 732	9 044	47 627	126 697	21 076	333 441	33 681	12 877
RESIDENTIAL BUILDINGS 1/	Value (R1 000)	1996	5 731 974	1 183 877	269 790	54 654	120 021	842 456	199 180	2 740 268	184 848	136 882
		1997	5 476 638	1 345 715	286 714	71 142	117 007	793 713	235 311	2 267 149	218 578	140 308
		1997-Jan-Nov	5 057 175	1 243 467	269 665	68 525	101 979	750 758	221 981	2 068 116	199 337	133 346
		1998-Jan-Nov	5 525 931	1 394 458	292 367	43 499	128 866	879 290	241 927	2 237 211	177 339	130 941
		1997-Nov*	631 643	116 261	13 814	3 143	15 724	71 195	18 819	365 097	19 494	8 095
		1998-Oct	485 533	127 088	45 736	7 931	11 093	76 172	31 981	157 391	20 014	8 127
		1998-Nov	509 606	161 184	32 693	4 303	12 761	75 200	16 936	181 942	15 058	9 529
Dwelling-houses	Number	1996	33 843	8 274	2 772	841	1 204	3 948	2 225	11 365	1 077	2 137
		1997	52 885	11 524	2 648	2 699	1 471	3 907	3 600	20 777	3 133	3 126
		1997-Jan-Nov	48 891	11 026	2 414	2 682	1 240	3 710	3 476	18 417	2 943	2 983
		1998-Jan-Nov	46 670	8 392	4 253	1 498	2 370	3 120	4 100	16 283	1 920	4 734
		1997-Nov*	8 962	1 558	167	102	279	374	214	5 810	221	237
		1998-Oct	4 572	946	619	204	130	266	572	1 488	138	209
		1998-Nov	4 602	1 422	754	196	161	421	222	997	206	223
	Value (R1 000)	1996	3 634 582	885 101	219 215	33 740	71 190	457 255	167 418	1 577 801	128 538	94 322
		1997	3 728 458	909 155	205 644	57 720	89 715	452 783	207 873	1 522 515	168 602	114 450
		1997-Jan-Nov	3 415 544	841 264	189 447	55 280	76 138	425 586	199 656	1 363 308	157 269	107 597
		1998-Jan-Nov	3 639 749	926 242	244 959	40 164	107 178	392 504	210 094	1 468 302	134 421	115 884
		1997-Nov*	442 544	98 657	9 801	3 020	15 344	39 089	15 417	240 415	12 826	7 975
		1998-Oct	379 883	95 920	29 158	7 331	8 403	46 293	26 865	143 406	16 207	6 298
		1998-Nov	385 301	141 291	30 923	3 828	11 588	41 031	14 022	119 524	14 429	8 665

1/ Residential buildings include: dwelling-houses, flats, townhouses and other residential buildings

TABLE 1.2 - BUILDINGS COMPLETED - PUBLIC AND PRIVATE SECTOR
TOTAL ACCORDING TO PROVINCES (concluded)

ITEM		YEAR AND MONTH	TOTAL	PROVINCE								
				Western Cape	Eastern Cape	Northern Cape	Free State	KwaZulu-Natal	North West	Gauteng	Mpuma-langa	Northern Province
Dwelling-houses smaller than 81 square metre	Number	1996	17 263	3 566	1 736	692	896	1 683	1 652	4 955	348	1 735
		1997	39 687	7 443	1 925	2 584	1 169	2 106	3 168	16 044	2 542	2 706
		1997-Jan-Nov	36 631	7 178	1 731	2 579	971	1 982	3 060	14 151	2 403	2 576
		1998-Jan-Nov	34 497	4 306	3 502	1 439	1 940	1 706	3 541	12 371	1 287	4 405
		1997-Nov*	7 554	1 047	142	94	247	245	173	5 221	167	218
		1998-Oct	3 273	560	544	200	90	105	514	1 015	58	187
		1998-Nov	3 429	967	678	195	111	297	177	675	124	205
	Value (R1 000)	1996	697 261	149 284	78 354	10 901	29 507	104 268	84 833	193 573	12 987	32 554
		1997	1 181 475	184 928	91 291	38 892	44 433	128 061	131 587	445 988	66 498	49 797
		1997-Jan-Nov	1 084 064	170 464	83 146	38 599	36 651	118 606	125 888	403 489	62 379	44 842
		1998-Jan-Nov	972 188	112 926	114 164	29 708	51 364	88 475	123 077	369 411	22 209	60 854
		1997-Nov*	178 422	26 612	5 971	1 588	10 795	12 900	9 669	103 155	2 810	4 922
		1998-Oct	97 534	12 257	16 130	6 545	4 341	6 867	16 739	32 249	688	1 718
		1998-Nov	89 516	18 302	16 857	3 730	2 884	11 484	7 455	20 451	3 579	4 774
NON-RESIDENTIAL	Number	1996	2 092	676	150	38	99	309	82	593	87	58
		1997	2 384	792	169	37	99	556	84	489	92	66
		1997-Jan-Nov	2 258	746	162	34	89	536	79	462	84	66
		1998-Jan-Nov	1 819	598	139	32	74	301	95	439	94	47
		1997-Nov*	219	79	13	3	15	31	4	59	8	7
		1998-Oct	219	60	24	3	14	47	13	44	10	4
		1998-Nov	133	36	18	2	9	13	3	35	14	3
	Value (R1 000)	1996	2 487 865	370 135	80 618	43 442	102 928	526 793	77 422	1 171 894	81 051	33 582
		1997	3 400 515	572 425	110 399	31 025	99 587	586 974	121 422	1 658 284	126 259	94 140
		1997-Jan-Nov	2 941 069	498 866	101 292	26 752	93 634	559 202	119 080	1 330 855	117 248	94 140
		1998-Jan-Nov	3 161 720	608 215	115 990	25 393	115 237	507 822	215 820	1 387 852	125 162	60 229
		1997-Nov*	312 597	54 786	22 974	4 014	14 841	57 720	4 308	127 332	23 938	2 684
		1998-Oct	436 119	56 011	24 437	1 272	7 560	67 406	105 877	151 900	5 905	15 752
		1998-Nov	288 342	100 347	11 298	710	27 563	13 194	1 570	116 692	14 524	2 443
ADDITIONS AND ALTERATIONS	Value (R1 000)	1996	2 203 981	551 252	162 899	32 825	131 250	487 655	46 345	685 333	57 647	48 777
		1997	2 434 454	639 639	156 929	22 087	130 369	673 091	47 210	673 089	78 346	13 693
		1997-Jan-Nov	2 323 553	503 632	142 903	20 983	125 123	651 177	46 506	644 121	75 441	13 664
		1998-Jan-Nov	2 084 508	550 550	174 490	55 037	88 055	525 635	50 362	570 788	60 619	8 973
		1997-Nov*	219 428	44 672	4 864	1 414	6 902	46 578	3 394	100 563	9 011	2 030
		1998-Oct	198 146	59 074	18 134	6 316	4 960	43 799	3 879	51 086	9 823	1 075
		1998-Nov	168 796	46 039	30 740	4 031	7 303	38 303	2 570	34 807	4 099	904

APPENDIX 3.1 SURVEY QUESTIONNAIRE

(pp. 102 – 112)

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

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Date: 29th October 1998

Dear Sir / Madam,

RE: RESEARCH SURVEY ON THE USE OF RISK ANALYSIS TECHNIQUES IN THE BUILDING INDUSTRY IN SOUTH AFRICA

Projects require appropriate risk analysis because deviations from the expected can lead to large financial losses. Project environments are now more volatile than they were years ago, reinforcing the need for stringent controls to ensure that everything goes according to the plan and that all the risks are catered for.

There is a need to investigate use of risk analysis within the context of:

- Identifying a comprehensive list of risks associated with major projects in South Africa.
- Determining what risk analysis techniques are utilised in the evaluation of building construction projects.
- Establishing to what extent risk analysis techniques are used in the building construction industry.

Enclosed herewith is a questionnaire constituting a survey with the above objectives.
The questionnaire is designed to take about 30 minutes of your time.
The completed questionnaires will be used only for research purposes, and all the replies will be treated as strictly confidential.
Kindly complete this questionnaire and post it using the self-addressed envelope provided, or preferably send it by fax to me at (012) 841-3539.

If you have any queries regarding the questionnaire please contact me at 083 7762 863.

Yours sincerely,

Lucy W. Chege.

Dr. R.N. Nkado
(Supervisor)

Name : .... (Optional)

Company: .... (Optional)

Position: .... (Optional)

Address: .... (Optional)

....

1.0. COMPANY PROFILE

1.1. Please indicate your company's major business activity

(a) Project Management ◯

(b) Construction (building) ◯

(c) Construction (civil) ◯

(d) Architecture ◯

(e) Civil Engineering ◯

(f) Quantity Surveying ◯

(g) Other - Please specify ◯

....

....

1.2. For how long has your company been in existence?
.... years

1.3. What is the average number of projects handled by your company per year?
(For the past 5 years)

Year	Number
1993	
1994	
1995	
1996	
1997	

1.4. What is the total value of projects undertaken by your company per year?
(For the past 5 years)

Year	Amount(in Rands)
1993	
1994	
1995	
1996	
1997	

2.0. RISKS

2.1. Please rank:

2.1.1. The occurrence of the following risks in building construction projects.

2.1.2. The level of importance of each of the risks.

	Always	Often	Sometimes	Rarely	Never	Very Important	Important	Not Important
	5	4	3	2	1	3	2	1
(a) External, unpredictable (and uncontrollable)								
(i) Government regulations and interventions:								
Site location issues...								
Change of standards..								
Local authority approvals..................................								
Supply of raw materials....................................								
(ii) Natural hazards..								
(iii) Deliberate causes:								
Vandalism..								
Sabotage..								
Theft...								
(iv) Indirect effects:								
Project environmental causes..............................								
Social causes...								
(v) Failure of completion, due to:								
Bankruptcy of supplier(s)..................................								
Political unrest...								
Labour unrest..								
Failure of others to provide infrastructure as agreed......								
(vi) Other (Please specify)								
....								
....								

	Always	Often	Sometimes	Rarely	Never	Very Important	Important	Not Important
	5	4	3	2	1	3	2	1
(b) External, predictable(but certain and uncontrollable)								
(i) Market risks:								
Raw material availability……………………………								
Raw material cost……………………………………								
Change in demand……………………………………								
Competition……………………………………………								
(ii) Operational, e.g. safety and maintenance needs:								
Safety needs……………………………………………								
Maintenance needs……………………………………								
Environmental impacts………………………………								
Social impacts…………………………………………								
Exchange rate fluctuations…………………………								
Inflation changes………………………………………								
Taxation changes………………………………………								
(iii) Other (Please specify)								
…………………………………………………………								
…………………………………………………………								
…………………………………………………………								
…………………………………………………………								
(c) Internal, Non-Technical								
(i) Management:								
Inadequacy in numbers………………………………								
Inadequacy in capacity………………………………								
Poor organisational structures……………………								
Lack of appropriate procedures……………………								
Lack of appropriate policies………………………								
Frequent staff changes………………………………								

	Always	Often	Sometimes	Rarely	Never	Very Important	Important	Not Important
	5	4	3	2	1	3	2	1
Inadequate project management techniques...........								
Insufficient or inadequate project planning...............								
Wrong contract strategy....................................								
(ii) ***Cost and time overruns due to:***								
Management problems....................................								
Manpower problems....................................								
Material shortages..								
Late deliveries..								
Scope changes..								
Accidents..								
Labour productivity..								
Unforeseen site conditions................................								
Pay negotiations..								
Poor procurement strategy................................								
Under-estimating..								
Contractor claims, etc......................................								
(iii) ***Cashflow due to:***								
Programme changes..								
Bankruptcy..								
Poor estimating..								
Inadequate programming..................................								
Inadequate cost control....................................								
Inadequate quality control................................								

	Always	Often	Sometimes	Rarely	Never	Very Important	Important	Not Important
	5	4	3	2	1	3	2	1
(iv) Loss of potential :								
Removal of profit and benefits of the project..............								
(v) Other (Please specify)								
....								
....								
....								
....								
(d) Technical								
(i) Technology:								
Changes in technology.......................................								
Obsolescence due to new or improved technology........								
Increase in complexity......................................								
(ii) Performance:								
Change in quality..								
Change in reliability...								
Change in rate of production................................								
(iii) Design due to:								
Inadequacies..								
Insufficient data...								
Designer experience...								
Detail and specification.....................................								
Changes to design...								
Changes to specification....................................								
Changes to scope of work..................................								

	Always	Often	Sometimes	Rarely	Never	Very Important	Important	Not Important
	5	4	3	2	1	3	2	1
(iv) Size of project...								
(v) Other (Please specify)								
....								
....								
....								
....								
(e) Legal								
(i) Licences..								
(ii) Patent rights...								
(iii) Contractual due to:								
Misunderstanding..								
Interpretation..								
Wrong contract type.......................................								
(iv) Lawsuits...								
(v) Force majeure...								
(vi) Other (Please specify)								
....								
....								
....								
....								

3.0. RISK ANALYSIS

3.1. Does your company have a risk management department?

Yes ◯ No ◯

3.2. Who is responsible for risk analysis in your firm?

(a) Managing Director ◯

(b) Financial Director ◯

(c) Projects Director ◯

(d) Contracts Manager ◯

(e) Project Manager ◯

(f) Other (Please specify) ◯

....

....

3.3. Below are methods through which risk management practitioners acquire expertise. Please allocate 100 points among the methods so that the allocation indicates how your risk management practitioners gain their expertise. (The total number of points allocated should not be more or less than 100).

	Number of Points
Specialized training	....
Experience	....
Aptitude	....
Other (Please specify)	....
....	....
....	....
	100

3.4. What risk analysis techniques do your risk management practitioners use?

....

....

....

....

....

3.5. Please indicate whether your firm uses the following techniques to quantify risk:

	Always	Sometimes	Never
(a) Individual risk value			
(b) Decision trees			
(c) Sensitivity analysis			
(d) Range Estimates			
(e) PERT			
(f) Means-end analysis			
(g) Algorithms			
(h) Portfolio theory			
(i) Delphi Method			
(j) Bayesian theory			
(k) Monte Carlo Simulation			
(l) Stochastic dominance			
Other (Please specify):			
....			
....			
....			
....			

3.6. If your company does not use any of the abovementioned techniques to quantify risk please indicate why.

Lack of awareness ◯

Experience and judgement of management is sufficient ◯

Lack of technical expertise ◯

Cost ◯

Lack of a suitable model for the construction industry ◯

Other (Please specify) ◯

....

....

....

3.7. Computers in Risk Analysis

3.7.1. Please indicate:

(a) The computer software package(s) you use to determine risk on projects.
(b) The risk(s) which the package(s) cater(s) for.

Software Package	Risk(s) Catered For				
	External, unpredictable (and uncontrollable)	**External, predictable (but certain and uncontrollable)**	**Internal, Non-Technical**	**Technical**	**Legal**
(i).					
(ii).					
(iii).					
(iv).					
(v).					

3.7.2. In your opinion which of the risk(s) does the computer software package not cater for?

(i). ....

(ii). ....

(iii). ....

(iv). ....

(v). ....

3.8. Please indicate your level of agreement with the following statements:

	Strongly Agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
Risk analysis methodologies in South Africa are highly sophisticated					
Risk analysis techniques used in South Africa compare closely to those used in Western Europe, U.S.A. or South East Asia					
There is widespread usage of formal risk analysis techniques in South Africa					
The application of formal risk analysis techniques depends on the size of the project					
Due to the volatility of markets, risk analysis methods are required more today than ever before					

3.9. What steps do you think should be taken to improve risk analysis in South Africa?

....

....

....

....

....

....

Please indicate if you would like to be furnished with feedback on the results of this research survey:

Yes ◯ No ◯

Please mail this questionnaire to me using the self-addressed envelope provided, or preferably send it by fax to me at (012) 841-3539.

If you have any queries, please contact me at 083 7762 863.

Thank you for your cooperation.

APPENDIX 4.1 : FREQUENCY DISTRIBUTION CALCULATIONS AND TABLES FOR QUESTION 1.2
(pp. 113 – 114)

APPENDIX 4.2 : CALCULATIONS FOR THE AVERAGE SIZE OF PROJECT HANDLED BY EACH COMPANY PER YEAR
(pp. 115 – 117)

APPENDIX 4.3 : CALCULATIONS OF SPEARMAN'S RANK CORRELATION COEFFICIENT FOR EXTERNAL UNPREDICTABLE AND UNCONTROLLABLE RISKS
(p.118)

APPENDIX 4.4 :CALCULATIONS OF SPEARMAN'S RANK CORRELATION COEFFICIENT FOR INTERNAL NON-TECHNICAL RISKS
(p. 119)

APPENDIX 4.5 : CALCULATIONS OF SPEARMAN'S RANK CORRELATION COEFFICIENT FOR TECHNICAL RISKS
(p.120)

Appendix 4.1

The data for question 1.2. was presented in the form of a frequency distribution.

Data Range:

Maximum 113

Minimum 8

Range = Maximum - Minimum = 113 - 8 = 105

The number of classes was calculated using *Sturges' Rule* as described by Wegner (1995).

$2k \geq n$, where:

n = the sample size = 18

k = the number of classes

To satisfy *Sturges' Rule* k = 5

Class width:

$$\text{Class width} = \frac{\text{Range}}{\text{No. of classes}} = \frac{105}{5}$$

$$= 21$$

Based on this, 30 is used as the class width.

The resultant class limits and absolute and relative frequency distributions are shown below.

Table A: Class limits

Lower limits	Upper limits
0	less than 30
30	less than 60
60	less than 90
90	less than 120

Table B: Absolute and relative frequency distribution

No. of years	No. of companies Absolute frequency	Relative frequency %
0 to < 30	6	33
30 to < 60	9	50
60 to < 90	1	6
90 to < 120	2	11
Totals	18	100

Table C: More than ogive (Absolute and relative frequencies)

No. of years	No. of companies	Cumulative frequency	
		%	Absolute
0 to < 30	6	100	18
30 to < 60	9	67	12
60 to < 90	1	17	3
90 to < 120	2	11	2
120 and above	0	0	0
Totals	18		

Appendix 4.2

Table D : The average size of project handled by each company per year

Company	Data Labels	Year					Totals	Average size of project ('000,000 Rands)
		1993	1994	1995	1996	1997		
1	Average no. of projects	24	21	28	37	50	160	12.91
	Total value of projects ('000,000 Rands)	105	108	403	600	850	2066	
2	Average no. of projects	75	70	75	85	70	375	0.31
	Total value of projects ('000,000 Rands)	20	18	22	25	30	115	
3	Average no. of projects	5	5	5	5	5	25	30.80
	Total value of projects ('000,000 Rands)	130	140	150	170	180	770	
4	Average no. of projects	40	40	40	40	40	40	12.50
	Total value of projects ('000,000 Rands)	500	500	500	500	500	500	
5	Average no. of projects	19	24	13	18	22	96	2.34
	Total value of projects ('000,000 Rands)	18	72	65	22	48	225	
6	Average no. of projects	18	26	20	6	10	80	8.05
	Total value of projects ('000,000 Rands)	130	143	130	96	145	644	

Table D contd. : The average size of project handled by each company per year

Company	Data Labels	Year					Totals	Average size of project ('000,000 Rands)
		1993	1994	1995	1996	1997		
7	Average no. of projects	15	15	15	15	15	75	13.33
	Total value of projects ('000,000 Rands)	200	200	200	200	200	1000	
8	Average no. of projects	12	10	9	9	13	53	37.55
	Total value of projects ('000,000 Rands)	450	380	400	320	440	1990	
9	Average no. of projects		3	10	6	8	27	26.00
	Total value of projects ('000,000 Rands)		20	80	202	400	702	
10	Average no. of projects	4	2	4	3	3	16	67.50
	Total value of projects ('000,000 Rands)	50	130	200	150	550	1080	
11	Average no. of projects	41	88	83	88	57	357	8.40
	Total value of projects ('000,000 Rands)	600	600	600	600	600	3000	
12	Average no. of projects	150	160	140	170	200	820	1.52
	Total value of projects ('000,000 Rands)	150	200	250	300	350	1250	

Data Range:

Maximum: 67.50

Minimum 0.31

Range = Maximum - Minimum = 67.50 - 0.31 = 67.19

Sturges' Rule as described earlier was used once again to calculate the number of classes.

$2k \geq n$, where:

n = the sample size = 12

k = the number of classes

Using *Sturges' Rule* therefore k = 4

$$\text{Class width} = \frac{\text{Range}}{\text{No. of classes}} = \frac{67.50}{4}$$

$$= 16.88$$

Based on this, 20 is used as the class width.

The class limits are shown below.

Table E: Class limits

Lower limits	Upper limits
0	less than 20
20	less than 40
40	less than 60
60	less than 80

Appendix 4.3 External unpredictable and uncontrollable risks

Risk Factor	Rank: Level of Importance	Rank: Frequency of Occurrence	d	d^2
Labour unrest	1	6	-5	25
Political unrest	2	12	-10	100
Failure of others to provide infrastructure as agreed	3	5	-2	4
Local authority approvals	4	1	3	9
Site location issues	5	3	2	4
Natural hazards	6	9	-3	9
Project environmental causes	6	4	2	4
Supply of raw materials	8	11	-3	9
Social causes	9	7	2	4
Bankruptcy of supplier(s)	10	13	-3	9
Theft	11	2	9	81
Change of standards	12	8	4	16
Sabotage	13	14	-1	1
Vandalism	13	10	3	9

Total d^2 = 284

$$R_s = 1 - \frac{6 \times 284}{14\,(14 \times 14) - 1}$$

$$= 0.3788$$

Using Microsoft Excel 0.3621 This is the figure which was adopted in the research

$S_r = \sqrt{((1-r^2)/(n-2))}$ $S_r = \sqrt{((1-0.3621^2)/(14-2))} = 0.26908$

$$t = \frac{R_s}{S_r} = \frac{0.3621}{0.26908} = 1.345$$

Degrees of freedom = n-2 = 14 -2 = 12

Appendix 4.4 **Internal non-technical risks**

Risk Factor	Rank: Level of Importance	Rank: Frequency of Occurrence	d	d^2
Insufficient or inadequate project planning	1	6	-5	25
Scope changes	2	1	1	1
Removal of profit and benefits of the project	3	23	-20	400
Management problems	4	6	-2	4
Wrong contract strategy	5	12	-7	49
Inadequate project management techniques	6	6	0	0
Inadequate quality control	7	15	-8	64
Under-estimating	7	6	1	1
Contractor claims, etc.	9	2	7	49
Manpower problems	10	15	-5	25
Unforeseen site conditions	11	4	7	49
Inadequacy in capacity	12	10	2	4
Bankruptcy	13	28	-15	225
Inadequate programming	13	15	-2	4
Poor procurement strategy	15	26	-11	121
Late deliveries	15	5	10	100
Poor organisational structures	17	15	2	4
Lack of appropriate procedures	17	13	4	16
Poor estimating	19	21	-2	4
Inadequate cost control	19	24	-5	25
Lack of appropriate policies	21	21	0	0
Labour productivity	22	3	19	361
Accidents	22	24	-2	4
Programme changes	24	13	11	121
Inadequacy in numbers	25	20	5	25
Frequent staff changes	26	10	16	256
Material shortages	26	15	11	121
Pay negotiations	28	26	2	4
			Total d^2 =	**2062**

$$R_s = 1 - \frac{6 \times 2062}{28\,(28 \times 28) - 1}$$

$$= 0.4364$$

Using Microsoft Excel 0.4283 This is the figure adopted

$S_r = \sqrt{(1-0.4283^2)/(28-2)} = 0.1772$ $t = 0.4283/0.1772 = 2.416$

Appendix 4.5 Technical risks

Risk Factor	Rank		d	d^2
	Level of Importance	Frequency of Occurrence		
Changes to scope of work	1	3	-2	4
Changes to design	1	2	-1	1
Designer experience	3	9	-6	36
Changes to specification	3	1	2	4
Inadequacies	5	6	-1	1
Insufficient data	6	4	2	4
Change in quality	7	11	-4	16
Change in reliability	7	13	-6	36
Increase in complexity	9	10	-1	1
Changes in technology	10	11	-1	1
Change in rate of production	10	8	2	4
Detail and specification	12	5	7	49
Size of project	13	7	6	36
Obsolescence due to new or improved technology	14	14	0	0

Total d^2 = 193

$$R_s = 1 - \frac{6 \times 193}{14\,(14 \times 14) - 1}$$

$= 0.5778$

Using Microsoft Excel 0.5822 This is the figure which was adopted in the research

$S_r = \sqrt{(1-0.5822^2)/(14-2)} = 0.2347$ $t = 0.5822/0.2347 = 2.48$