Integrated Model for Project Risk & Uncertainty Management

Ilyas B. Alhassan
Tahir Mehmod

Degree of Master Thesis (1yr),
Royal Institute of Technology
Stockholm, Sweden

INTEGRATED MODEL FOR PROJECT RISK & UNCERTAINTY MANAGEMENT

Ilyas B. Alhassan
Tahir Mehmood

Master's Degree Thesis Project in Partial Fulfillment for the Award of Master of Science in Project Management and Operational Development (One Year)

The Royal Institute of Technology, KTH, Stockholm, Sweden

Royal Institute of Technology
School of Industrial Engineering and Management
Examiner: Roland Langhe
Internal Supervisor: Roland Langhe
External Supervisor(Elekta): Johannes Morelius

ABSTRACT

All projects taste unexpected events that can impact their objectives in the form of lost or gain, or even deviation from a required or planned outcome. Elekta as a product development organization is continuously developing innovative products through projects and product innovation. Projects development and execution naturally involve significant risks. This thesis project aimed at developing a prototype integrated quantitative and qualitative risk management model for handling project risks and uncertainties within Elekta. Interviews were first used to analyze the characteristics of the risk management process in Elekta with reference to ISO 31000. Eventually, it revealed that the process is not well structured, and thus provide insufficient support for managing project risks and uncertainties. The model was built in spread sheet (@ risk) and piloted on an ongoing project. The results have shown that the model can help improving the current schedule and cost risk analysis plus provide a means of analyzing risks at a good level of detail, that is, on the basis of the level of impact each risk may have on each specified project objectives. The model also provides a higher level and less rigorous approach for handing minor project risks. The demonstrations also showed that the model could also be applied to aggregate the individual risks to visualize project and portfolio level risks. We recommended that the model can be extended to consider opportunity management in good depth.

ACKNOWLEDGMENTS

We praise and thank God for His favors throughout this endeavor. We express our gratitude and appreciation to our supervisors; Roland Langhé (KTH) and Johannes Morelius (Elekta, Stockholm) for their support, guidance, suggestions, comments and encouragement. Their attention was central to the success of this study.

To all the project managers and other staff members of Elekta that we interacted with during our study, we appreciate your diverse support and we are grateful to Elekta for proving the funding for this study. To our colleague thesis students at Elekta, more grease and power to your elbows! It was nice meeting you.

Nonetheless, we wish to thank our families and friends for their indirect support. To all our course mates in the Project Management and Operational Development Program at KTH, thanks for making lectures and course work at KTH interesting and expedient.

Thank you all for being creditable part of our project.

Ilyas B. Alhassan & Tahir Mehmood

TABLE OF CONTENTS

TABLE OF FIGURES

Operational Definitions

Technical terms in this report are defined as in the ISO 31000 risk management standard.

CHAPTER 1

INTRODUCTION

A model has been proposed for handling project risks and uncertainties in this thesis. Here we intend to provide the general information requisite to understand more detailed information in rest of the report. That is, we introduce in general terms the concept and purpose of project risk and uncertainty analysis, the background of the research, the aim and objectives of the study, the research questions, the scope and limitations of the study as well as the description of the study unit.

Projects are normally created to achieve specific demands and benefits by means of producing a unique product or service within clearly specified objectives. These include but not limited to; scope, time and cost as well as the quality of the end product (PMBOK, 2008). Any event or occurrence that will affect these specified objectives positively or negatively constitutes a risk.

All Projects by definition are unique but beset with risks and uncertainties. A zero risk project is not worth undertaking. The extent of uncertainties and risks vary according to the size and complexity of projects. Risk and uncertainty analysis therefore helps decision makers to choose wisely under conditions of doubt. The analysis also assists project staff to discover things that can enhance the project objectives or things that can go wrong in the project process and offer ways to address them. Uncertainty, however, is an abstract and fuzzy concept and many project managers lack the suitable tool box to accurately define it for effective analysis.

Risk and uncertainty are related but different concepts and dealing with them in projects is a continual concern for project stakeholders (Martland, 2004). Chapman and Ward (2002) defined uncertainty as the *"lack of certainty, involving variability* *and ambiguity"*. They went further to defined Variability as *"uncertainty about the size of parameters which may result from lack of data, lack of detail, lack of definition, lack of experience and so on, which may be quantified if this is useful"* and finally, they defined ambiguity *as "the aspects of uncertainty not addressed in terms of variability*".

These definitions implied that the term uncertainty is a general term that has two parts; i.e. variability and ambiguity. This study focused more on the variability component of uncertainty as we have an objective to address variability in project cost and schedule estimations. For the purpose of convenience and clarity, uncertainty is defined in this study as the potential of different outcomes. That is, we are faced with uncertainty when the outcome of a given event is variable and this reflects the unknowns and randomness inbuilt in both natural and man-made systems. Uncertainty in this sense is therefore related to our inability to specify something with precision and this causes a major problem during decision making.

Risk on the other hand is a more precise term that refers to the effect of uncertainty on project objectives (ISO 31000). Thus, risk is an exposure to the consequences of uncertainty - the possibility that the outcome of an uncertainty will have positive or negative effects on the project objectives. Uncertainty thus evolves into risk and risk can either be favorable or unfavorable to the project objectives. Favorable future events or outcomes are called opportunities and unfavorable events are known as threats. The evolution process from uncertainty to risk can be iterative since the identified threats and opportunities can give birth to further uncertainties as summarized in Figure 1.1.

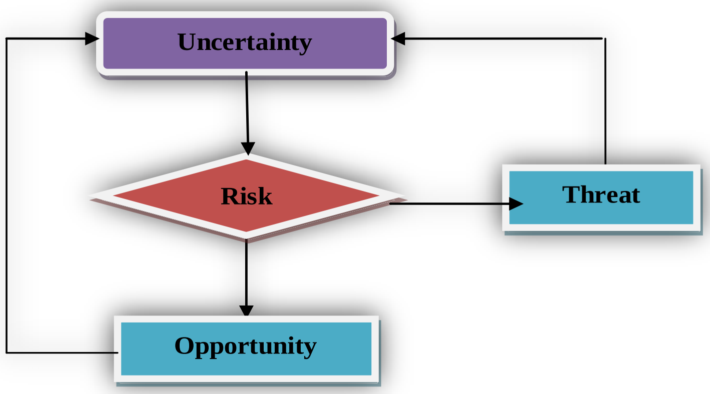


Figure 1.1 Relationship between uncertainty and risk

1.1 Background and the Research Problem

With about 3300 employees globally, Elekta is a global innovative medical technology related firm that provides unique clinical solutions for the treatment of cancer and brain disorders. Elekta uses well advanced tools and dose planning systems for the radiotherapy and radio surgery together with software systems. This enhances the efficiency of workflows all the way through the entire range of cancer care. The product business areas of Elekta includes; Elekta Neuroscience, Elekta Oncology, Elekta Software, and Elekta Brachytherapy solutions.

The thesis project focuses on the Elekta's office in Stockholm, Sweden (business area Neuroscience), hereafter defined as Elekta. Some products of Elekta Neuroscience include; Leksell Gamma Knife® , Extend™ Program, Leksell Stereotactic System®, Elekta Neuromag®, SonoWand Invite™, etc.

Elekta Neuroscience is continuously developing innovative products through projects and product innovation projects naturally involve significant risks Many of these risks can however be identified in advance to plan response in order to effectively reduce their effect on the project objectives. Yet, the existing way of handling risk and uncertainty in Elekta is unable to effectively; identify the uncertain parameters in the activities of a given project, define or assign numerical or qualitative levels for these parameters to determine risk values and aggregate them to visualize project and portfolio risk levels. There are particular errors associated with the deterministic estimation of time and cost due the fact that projects are usually conducted in dynamic environments. This makes cost and schedule analysis difficult at the early stages of a project. This study therefore intended to improve Elekta's project risk and uncertainty management by developing a framework for dealing with risk and uncertainty. Special attention was given to stochastic quantification of activity duration and costs as well as quantification of project duration and cost. This can be helpful for identifying measures that can be taken to improve schedule and cost performance through the development of cost and schedule uncertainties (uncertainty of staying within budget and schedule).

1.2 Research Aim

The aim of the study was to develop a prototype project risk and uncertainty management model that can be applied at different levels of project aggregation- Project, program and portfolio levels, in Elekta, Stockholm. The following objectives were specified in order to achieve the research aim:

1. Assess and understand how project risks and uncertainties are currently managed in Elekta.
2. Establish the model functional logic or conceptual framework to systematically describe how the model will work.
3. Identify and specify the model contents
4. Develop and test the proposed model on some ongoing projects within Elekta.

1.3 Research Questions

The study seeks to address the following questions:

1. How are project risks and uncertainties managed in Elekta? What are weaknesses of this approach compare to best practices and what can be improved?
2. What models and frameworks are available and which of them are suitable to be applied in this case study?
3. What will be the structure and inputs to the model?
4. How will the suggested model be practically implemented at both project and portfolio levels?

1.4 Research Scope and Limitations

The scope of the study was limited to the development of a project risk and uncertainty model for the purpose of project risk management in Elekta, Stockholm and not a general kind of risk management model for Elekta. The study did not intend to analyze cause-effect relationships, but the focus was to explore, describe, understand, and suggest a model to improve the current risk model in Elekta. Also, given the time available for this thesis project, the study was not able to implement and monitor the performance of the proposed model in Elekta for further improvements. In addition, no software was developed to automate the prototype model since it was cost-effective, easy and efficient to adopt and existing appropriate software packages spreadsheet (@risk) for the implementation of the model.

The research strategy chosen for this project was case study strategy and it is therefore narrow in scope and cannot be used to make generalization about the characteristics of the process of risk and uncertainty management in similar organizations. Also, the empirical data collected for analyzing the present situation was designed to describe risk and uncertainty management in Elekta and this somehow puts a limit on how the study can explain why things were the way they were.

1.5 Outline of the Thesis Report

This report contains five chapters and the rest of the chapters are organized as follows: Chapter 2 is an overview of the relevant literature relating project risk and uncertainty management. Chapter 3 presents how the study was conducted. It discussed how the data was collected and the different steps used to develop the proposed model. Chapter 4 focuses on how the current situation was analyzed. Chapter 5 presents and discusses the proposed model and how the model was piloted and finally, Chapter 6 presents the conclusions and recommendations of the study.

CHAPTER 2

REVIEW OF LITERATURE

2.1 Overview of Project Risk and Uncertainty Management

This chapter presents a literature review on the concept of risk and uncertainty and how they are related to project management. The review showed that considerable research exists on the topic. Some of them related to the objectives of this study are prioritized and summarized in this chapter.

In project context, Cooper et al (2005) defined risk as *"the chance of something happening that will have an impact upon a project objectives and it include a possibility of loss or gain or variation from desired or planned outcome, as a consequence of the uncertainty associated with deciding on a particular course of action"* This definition is similar to the ISO/IEC Guide 73 and AS/NZS4360 (2004) definitions that risk in projects involves the perception of uncertainty and it is a measure of the probability and consequence of not achieving a project goal. It can be deduced from these definitions that the risk of a given event has two basic dimensions. One dimension is the probability of occurrence for that event and the other dimension is the impact of the event if it should occur. Hence, risk in this sense is a function of the likelihood and the impact of an outcome. That is, Risk = likelihood of uncertain event * Severity of the consequences ($\boldsymbol{Risk = f(Likelhood, Impact)}$). The higher the likelihood or impact of a given event, the higher the risk associated with that event (see figure 2.3). This implied that both impacts and likelihoods must be carefully analyzed in project risks management.

The cause of risk is another dimension of risk. A risky situation can be generated by something, or the lack of something, this source of danger is known as hazard. We can overcome some kinds of hazards to a good extent by knowing them and identifying ways to overcome them. This second concept leads to a second representation of risk as a function of hazard and safeguard- $\boldsymbol{Risk = f(Hazard, Safeguard)}$. Risk increases with hazard but decreases with safeguard. This second equation implies that project risk management needs to be structured to effectively and efficiently identify hazards and to allow safeguards to be develop to overcome them (Kerzner, 2001).

Dealing with risks in projects can generally be achieved by means of either qualitative or quantitative approaches or by combining the two approaches depending on the purpose of the analysis. Qualitative risk analysis involves prioritizing risks on the basis of their probability and impact of occurrence (see figure 2.3). Quantitative risk analysis or uncertainty analysis involves obtaining numerical estimates of the effects of risk on project objectives. For instance, estimates of the uncertainty in project cost and schedule estimations are derived when the estimates are generated and represented as distributions. A better way to perform cost and schedule estimations is therefore by using stochastic (Monte Carlo) simulation. This provides detail information for decisions makers by evaluating the overall uncertainty in a project. In stochastic simulation, uncertain inputs are represented using ranges of possible values known as probability distributions. For example, inputs to a quantitative cost estimation model will include probabilities representing uncertainties in the occurrence of events, distributions of the model parameters, and the main correlations and other relationships between parameters. Probability distributions are thus a much more realistic way of describing uncertainty in a given estimation process (Cooper et al, 2005).

Risk exists in all aspects of life and this makes risk management a universal activity, although in most cases it is an unstructured activity, based on common sense, relevant knowledge, experience, and instinct (Chapman and Ward, 2003). Project risk management is considered as critical discipline by most organizations handling projects. This is confirmed by the Project Management Institute's project management guide and the other guides that represent the best practices in project management. Cooper et al (2005) pointed out that the main purpose of risk management is to reduce the dangers of not meeting the defined project objectives such as budget, schedule, and quality as well as to identify and take opportunities that can enhance these objectives. Project risk management therefore help project managers as well as staff to focus in the future where uncertainty exists and develop action plans for responding project risks. It is therefore to must to consider risk management at the early stages of the project planning and its management activities and it ought to be continued throughout the project life cycle. Dealing with project risk requires some form of structuring, leading to a number of related definitions of the risk management process. For example, the AS/NZS4360 (2004) defines the risk management process as "*The systematic process to understand the nature of and to deduce the level of risk, and the risk management process is the systematic application of management policies, procedures, and practices to the tasks of establishing the context, identifying, analyzing, evaluating, responding, monitoring, reviewing and communicating risk",* on the other hand, Project Management Institute (PMI, 2008) describes the risk management process to involve *"risk management planning, identification, analysis, response planning, and monitoring and control on the project"*.

Sub-processes in the Risk Management Process							
1	2	3	4	5	6	7	Source
Risk Identification	Risk Analysis	Risk Prioritization					Jurison (1999)
Risk Identification	Risk Analysis	Risk Monitoring					Bandyopadhyay et, al (1999)
Risk Identification	Risk Analysis	Risk Planning	Risk Monitoring				(Sommerville 2001)
Risk Identification	Risk Evaluation	Risk Control	Risk Monitoring				Beck et al., (2002)
Risk Identification	Risk Analysis	Risk Planning	Risk Tracking	Risk Control			Cornford (1998)
Review define goals	Identify and monitor	Analysis	Plan risk control	Control Risk			Kontio (1996)
Identify Risk	Analyze Risks	Prioritize & map risk	Resolve risks	Monitor Risks			Smith & Merritt (2002)
Goal Definition Review	Risk Identification	Risk Analysis	Risk Planning	Risk Tracking	Risk Control		Bruckner et, al (2001)
Risk Identification	Risk Analyze	Risk Plan	Risk Track	Risk Control	Risk Communication		Higuera and Haimes (1996)
Risk management mandate definition	Goal Review	Risk Identification	Analysis Risk	Risk control planning	Risk control	Monitor Risks	Boehm and Bose (1994)

Table 2.1: Risk Management Processes. Alhawari et al (2011).

Besides these definitions, various definitions of the risk management process have been used by different organizations. Table 2.1 summarizes some of the definitions. These definitions point out that the key word in project risk management is ***systematic***, because the more disciplined or structured a risk management approach, the more its ability to control and manage risks. On the other hand, uncertainty management according to Chapman and Ward (2003) goes beyond the management of perceived threats and opportunities, and their implications, it involves the identification and management of all the several sources of uncertainty that give rise to and shape the perception of threats and opportunities. It means exploring and understanding the sources of project uncertainty before attempting to manage it. With no predetermination about what is desirable and what is not. The central concerns are to understand where and why uncertainty is relevant in a specific project context, and where it is not.

2.2 Project Risk and Uncertainty Management Models and Frameworks

The attempt to systematize and improve best practice in risk and uncertainty management motivated global development of many but similar risk management approaches. However, these existing models and frameworks do not usually integrate both risk and uncertainty models together, the model developed in this study attempted to integrate both.

Examples of risk management frameworks include:

- PMBOK, *Project Management Body of Knowledge*, Project Management Institute (PMI), USA (2008);
- Association for Project Management, UK (1997), *PRAM Guide*;
- AS/NZS 4360 (2004), *Risk Management*, Standards Association of Australia;
- ISO 31000 (2009), *Risk Management- Principles and Guidelines*;
- ISO 10006 (2003), *Quality Management Systems-Guidelines for Quality Management in projects;*
- IEC 62198 (2001), *Project Risk Management—Application Guidelines*;
- Office of Government Commerce (OGC), UK (2002), *Management of Risk*; and
- Treasury Board of Canada (2001), *Integrated Risk Management Framework.*

Generally, these standards often outline the relevant areas of risk management. The basic structures of these standards according to Kutsch and Hall (2009) are similar. They offer very limited details on how to practically apply the risk management process, hence, the need to develop a customized and operational project risk management model for Elekta.

Although the PMBOK and AS/NZS 4360 have been consulted, the risk management framework that was adopted in this study is the ISO 31000. The ISO 31000 has therefore been review briefly in the following section.

2.3 ISO 31000

The International Organization for Standardization (ISO) is global federation of national standard bodies and the ISO 31000 was written by the ISO technical committee on risk management with the object of making risk management effective. The ISO 31000 risk management process is outlined in figure 2.1 below. The standard reveals that its proper implementation and maintenance can help an organization in improvements such as:

"– increase the likelihood of achieving objectives;
– encourage proactive management;
– be aware of the need to identify and respond risk throughout the organization;
– improve the identification of opportunities and threats;
– comply with relevant legal and regulatory requirements and international norms;
– improve mandatory and voluntary reporting;
– improve governance;
– improve stakeholder confidence and trust;
– establish a reliable basis for decision making and planning;
– improve controls;
– effectively allocate and use resources for risk response;
– improve operational effectiveness and efficiency;
– enhance health and safety performance, as well as environmental protection;
– improve loss prevention and incident management;
– minimize losses;
– improve organizational learning; and
– improve organizational resilience" (ISO 31000).

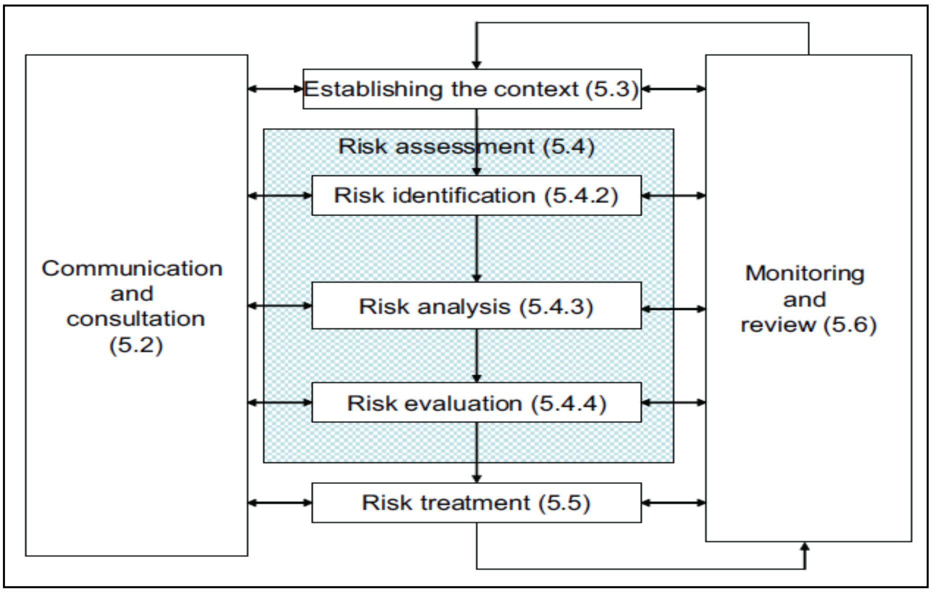


Figure 2.1 The Risk Management Process (ISO 31000, 2009).

These risk management processes are similar to those used by engineers to figure out potential safety and reliability problems in design. For instance, industries such as the automotive industry apply techniques like Fault Tree Analysis and Failure Mode and Effect Analysis (FMEA) (McDermott, 1996). Similarly, hazard analysis may be applied on new medical devices. Although these engineering techniques appear to be applicable to project risk management yet they are basically different as they cannot be applied until a design exists. Moreover, they are focused on finding errors in the design often in the form of safety and reliability. These analyses tools were therefore not suitable in this study. Project risk management rather focuses widely on the business success of the whole project including engineering (design) related aspects of the project and others that can hinder the project objectives.

The components of the ISO-31000 are described in following sections.

2.3.1 Communication and Consultation

This process focused on who should be involved in the specific risk management process. Good communication and consultation with team members and other stakeholder is crucial in the risk management process. The object of this process is to get all involved parties informed to avoid horrible surprises which can have far reaching consequences on future business deals. Thus, customers and owners can understand and appreciate the risks and trade-offs in projects. Regular reporting is an important form of communication where the risk register and the risk response plans form the basis. Risk reports summarize the projects risks and their response statuses.

2.3.2 Establishing the Context

This process answers the question, what are we intend to achieve? And involves setting up a structure to govern the risk management process. Thus, it is concern with: establishing the project environment within which the risk assessment will occur, specifying the objectives of the risk management, and identifying criteria for measuring the consequences of identified risks.

2.3.3 Risk Assessment

The risk assessment process according to ISO 31000 comprises of the processes of identifying risks, analyzing the identified risks and then evaluating them. Thus, the goals of the risk assessment process are; to determine the consequence of each risk if that risk should occur, to determine the likelihood of occurrence of the consequences, and to transform the consequence and likelihood ratings into risk levels and risk priorities. The three sub-processes that make up the risk assessment process are described in the following sections.

Risk Identification

The risk identification process answers the question what might happen in a given project? And it involves finding, recognizing and describing risks by using sources such as historical data, theoretical analysis, expert opinions, stakeholders, and so on. The objective of this process is to generate a comprehensive list of all the possible risks and other information needed to start creating a risk register, which is the set of all possible risks in a project. The standard recommends that an organization should apply risk identification tools and techniques that suitable for it objectives.

Risk Analysis

What is the meaning of the risks that has been indentified in terms of the project objectives? Risk analysis is the process of understanding the nature of the identified risks and determining their levels of risk (risk estimation). That is, using available and relevant information to determine in a structured manner how regularly specified events may occur and the size of their consequences. This kind of analysis provides inputs for risk evaluation and for making decisions about risk response such as if a given risk needs to be responded or not and selecting the suitable response technique.

Risk analysis often involves considerations of the consequences of risk (both negative and positive consequences) and the likelihood that those consequences can occur. The likelihood and the consequence can then be combined to determine the risk level.

The degree of risk analysis can vary depending on the nature of the risk, the data available and the purpose of the analysis. The analysis can qualitative, semi-qualitative or quantitative, or a combination of these depending on the specific situation. The model proposed in this study combined both qualitative and quantitative analysis methods.

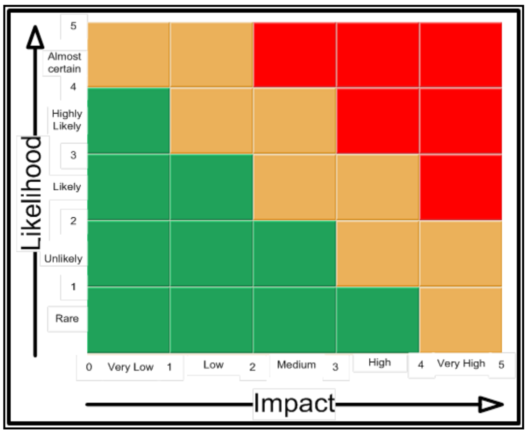


Figure 2.2: Probability - Impact Matrix.

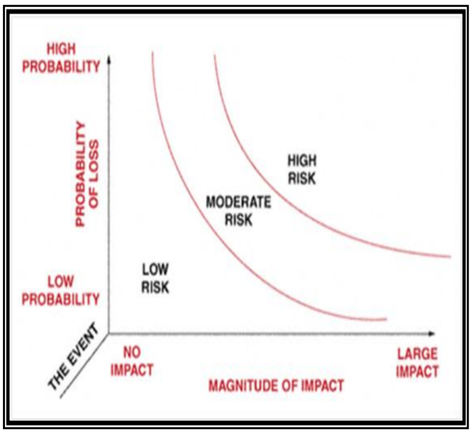


Figure 2.3: Overall risk as a function of its components (Kerzner, 2001**).**

Qualitative Risk Analysis – is built on the use of nominal or descriptive scales (e.g. Low, Medium, High) to describe the probabilities and impacts of risks. This initial assessment can then be extended to a semi-qualitative risk analysis by assigning numerical values to the descriptive scales. For example, 1 = Low, 2 = Medium and 3 = High, or similar suitable scales. The numbers are then used to calculate risk scores or factors. Thus, qualitative risk analysis involves assessing the impacts and likelihoods of the identified risk in order to determine their magnitude and priority. Qualitative analysis tools and techniques include: Probability/Impact Matrices, expert judgment, tracking of the top ten risk items, etc. A probability/impact matrix is a list of the relative probability of a risk occurring on one side and the relative impact of the risk occurring on the other side (as shown in figures 2.2 and 2.3). The risks are then grouped according to their risk value as low, medium or high risks. Consequently, analysis with qualitative methods is done without rigorous numerical calculations but rather rough estimates are made about the likelihood of occurrence. This means that the value of risk cannot be satisfactorily calculated with qualitative methods. However, it may be the most suitable way to do the analysis at hand.

Uncertainty or Quantitative Risk Analysis - Unlike the qualitative risk analysis described in the previous section, quantitative or uncertainty analysis apply numerical ratio scales rather than descriptive scales to estimate likelihoods and consequences. Analysis with quantitative methods is done with rigorous numerical calculations to obtain more accurate estimates of the likelihood of occurrence. This means that the value of risk can be satisfactorily calculated with quantitative methods. Quantitative analysis however has higher data requirements than qualitative analysis. The most popular uncertainty analysis (risk quantification) techniques are decision tree analysis and Monte Carlo (or stochastic) simulation.

Decision tree analysis involves the use of a tree-like structure drawn from left to right and branches out like a tree lying on it sides, to develop and document project managers understanding of the problem and to ease project team collaboration and communication. Thus, a decision tree is a diagram representation of expected value (EV) calculations and it is made up of three components (decision, chance and terminal or end nodes) connected by branches. Figure 2.4 illustrates a decision tree analysis. The expected Monetary Value (EMV) of result is given by the product of an outcome and the probability of the outcome. The Expected Monetary Value of a decision is the sum of all outcome generated by that decision. Hence, in this example, the aggressive schedule has expected the value of monetary $4,000 and is preferred over conservative schedule with the value of monetary $1,000.

Decision trees are suitable for analyzing sequential risks compounding over time and also for daily problems in which one desires to pick up the best alternative quickly and proceed, but not for multiple risks occurring simultaneously and this is one of the key strengths of the Monte Carlo Simulation. Shuyler (1950) confirms that the decision tree method also becomes difficult to use for solving certain kind of problems as it makes calculations impractical when there is combinatorial expulsion of branches, however, Monte Carlo technique easily handles many possible outcomes.

Monte Carlo simulation which was born during the development of atomic bomb in world war II models uncertain situations and has become a very useful tool for decision analysis in areas such as project management, transportation, engineering, environment, business, science, to mention but a few. That is, the method can be used in a huge range of industries; it could be in the economy department, planning and evaluation of data, life cycle analysis of products, projection of budget, maintenance service, warehousing, human resource allocation, queuing system at any service provider and so on.

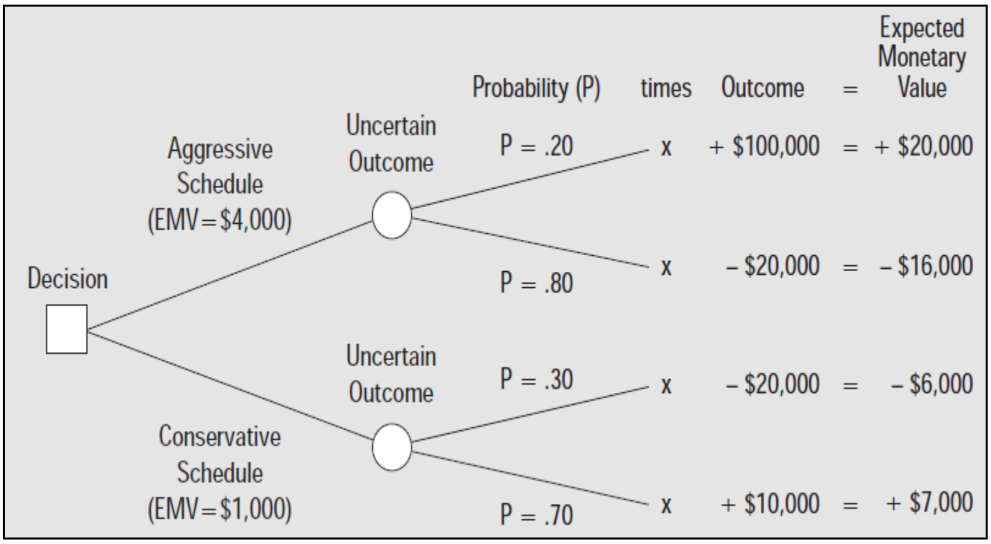


Figure 2.4 : Example of a decision tree. PMBOK, 1996.

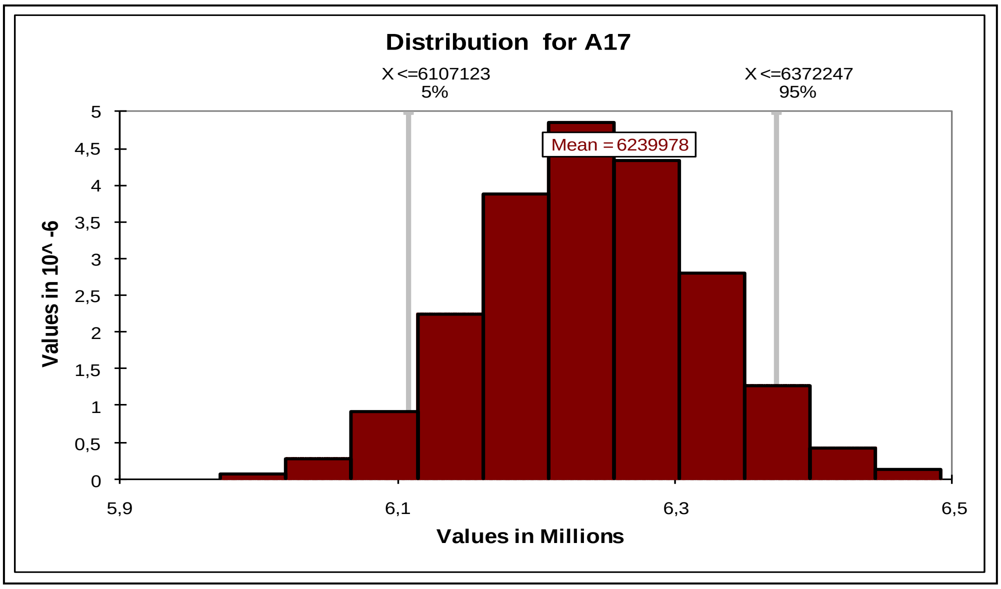


Figure 2.5 Simulation results visualizes in a Histogram (Lecture notes, 2010).

It is a very useful quantitative risk analysis method that uses a set of random inputs to iteratively evaluate a deterministic model (usually thousands of evaluations). It is thus, an improvement of the traditional single-valued deterministic model where we solve equations with probability distributions instead of just single values; therefore making Monte Carlo not just a calculation but the testing a situation several times with randomly generated inputs. Central to the application of Monte Carlo Simulation is the ability to select input distributions that closely fits the data or that represent the present state of knowledge. The outcome data from the simulation are usually visualized in graphs such as histograms (see figure 2.5), cumulative distribution, bars, confidence intervals etc.

How does Monte Carlo simulation works? Monte Carlo simulation is a highly iterative process. That is, it analyzes an uncertain situation by developing models of possible outcomes from a range of input values (a probability distribution). Figures 2.6 and 2.7 summarized the Monte Carlo simulation process. The following are the sequence of the typical four stages in a Monte Carlo simulation as outlined by (Schuyler, 1950; Sheel, 1995):

i. Build a mathematical model: the first step is to express the analysis situation into a mathematical model (equation). That is, first define the problem and determine all the input and output variables and determine the exact relationship among the variable. For example, to do a simple profit analysis, we can develop the simple model *'profit = selling price – cost price'*. Where profit is the output variable and selling/cost prices are the input variables.
ii. Identify the uncertain (stochastic) input variables in the mathematical expression developed in step (i). Uncertainty is modeled by specifying likely probability distributions to represent the uncertain input variables. In this step, a good knowledge of the characteristics of standard probability distributions such as normal, binomial, poison, weibull, exponential, triangular, uniform, beta, cumulative, pert, negative binomial distributions and so on can help us to select input distributions that best fit the random or uncertain variables we are dealing with.
iii. Simulate the stochastic model iteratively until the number of trials is enough to produce the expected level of precision (thousands of different combinations of the input variables) and obtain the possible outcome values and their probability distributions. That is, from the input distributions, we then

substitute the trial values of the stochastic variables into the deterministic model and run the model several times (> 1000).

iv. The last step involves analyzing the results and making decisions. The simulation results and the outcome probabilities can then be used to decide wisely on a desired course of action.

This Monte Carlo simulation process has been automated by several computer programs in the market including; @risk, Chrystal ball, Excel solver, XLSim, Abalone, BOSS, CompHEP, GEANT, MOCADI, Monte Carlo N-Particle Transport Code, Monte Carlo Universal, OpenBUGS, PYTHIA, WinBUGS.

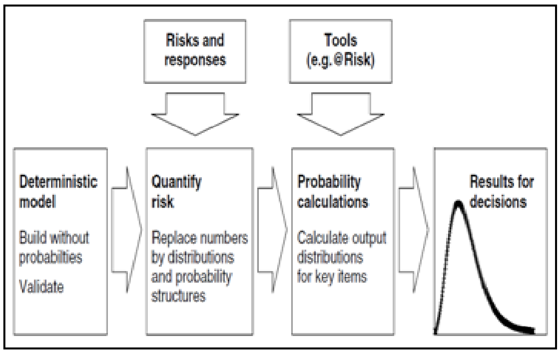


Figure 2.6 : Summary of the Quantitative Risk Analysis Approach (Cooper et al, 2005).

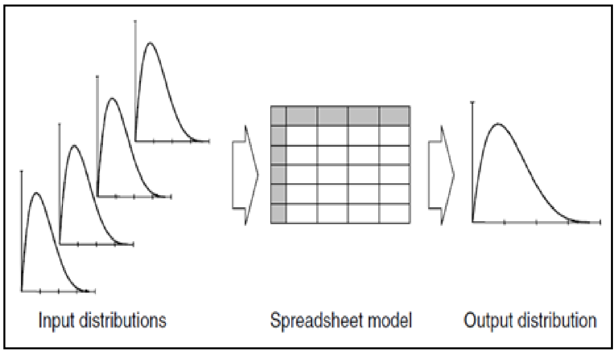


Figure 2.7: Quantitative Risk Analysis in Spreadsheet (Cooper et al, 2005).

2.3.4 Risk Evaluation

Risk evaluation is part of the risk assessment process that aimed at finding what the most important risks are. It is concerned with comparing the risks from the analysis results to determine their significant and to prioritize them for response.

2.3.5 Risk Response

What can be done about the risks we have assessed? Risk response consequently involves the selection and implementation of one or more options to modify the risks. Risk response thus involves: Finding options to change the likelihood or impacts of risks, assesses the cost and benefits of the selected response options and select the best for the project at hand and then, develop and implement risk response or action plan. Summaries of risk action plans are usually provided for high risks. Some of the most frequently used risk response options include:

i. Risk avoidance – avoids the risks by not starting or not continuing with the activity that can give rise to the risk.

ii. Risk transfer
iii. Explore the risk – involves taking the risk or increasing it so as to pursue the opportunity.
iv. Eliminating the risk source
v. Mitigating - Changing the likelihood or consequences of the risk occurring
vi. Risk sharing – involves sharing the risk with party or parties – including contracts and risk financing
vii. Accepting the risk

2.3.6 Monitoring and Review

How do we keep the risks under control? The purpose of this process is to consistently monitor and review the risk as the risk management plan is implemented. It facilitates the detection and management of risks. Developing risk watch list (the list of major risks in a project).

CHAPTER 3

RESEARCH METHODS

This chapter presents how the study was designed and conducted using a combination of research methods. Thus, it was to help achieve the research objectives and ultimately the research aim, the following research strategy, data collections techniques, framework for data analysis, Validity and reliability criteria were employed. Figure 3.1 below summarizes the study approach.

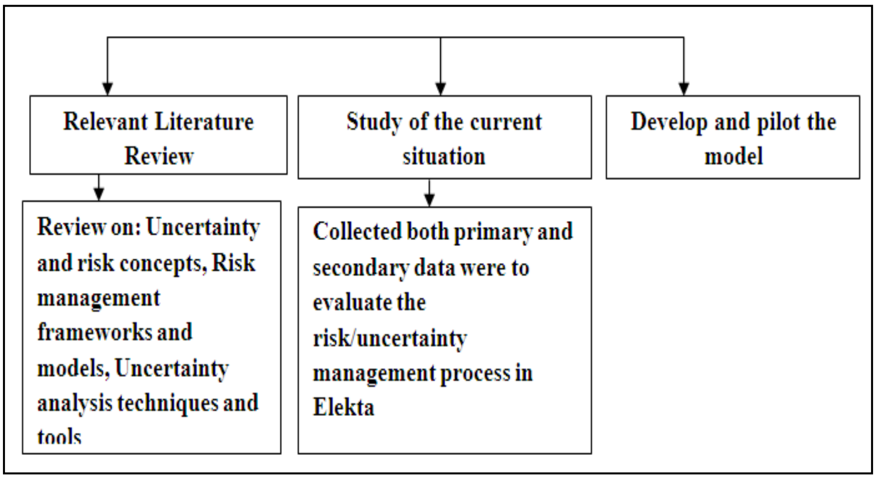


Figure 3.1 The research approach.

3.1 Literature Review

Literature review was used as the data collection method to gather information on risk/uncertainty management in general. The information obtained from this review was then used as an input to establish the model's conceptual framework. The results of the literature review are presented in chapter 2. To reduce the potential of ideas presented in no clear order, we focused the literature review on areas relevant to our study objectives. Thus, the study made use of several sources of literature such as relevant books, reports, journals of project management, as well as risk management standards and guides including PMBOK, UK PRAM Guide, AS/NZS 4360 guide, ISO 31000, IEC 62198, and Treasury Board of Canada's Integrated Risk Management Framework. Documented project risk management resources in the study area were also reviewed.

3.2 Research Strategy

Case study research strategy was the research strategy adopted in the study since its focus was a specific individual unit of an organization which has its specific challenges and unique working environment. Case study is a well accepted inductive research strategy well rooted in observation of empirical data for the study particular characteristics in particular setups. Thus, a case study usually explores present and past issues that affect one or more units such as organization, group, department or person (Adams et al, 2007). This definition coincides with Cohen and Manion's (1995) description of a case study research as a study that observes the characteristics of an individual unit such as a child, a class, a school, an organization, a community and so on, and the purpose of such observation is to investigate and analyze the unit of observation. It is particularly used for investigating organizations and for identifying best practice as intended in this study. Case study was therefore the appropriate strategy for this study because the study focuses on observing, analyzing, building a model and making suggestions for improving project risk management in Elekta, which is an individual unit of analysis.

3.3 Data collection

Secondary and primary data which were both qualitative and quantitative in nature were used in this study. The secondary data refers to the existing reports, templates, project schedules and similar documents available in Elekta as well as the other literature sources. The primary data refers to the interviews that were administered to help explore and understand risk and uncertainty management in Elekta base on the experience of the employees. One-to-one interviews were selected for the investigation on the basis of two reasons. First, access to all concerned project managers who have some experience in managing projects in Elekta and can share their experiences and feelings about project risk management. Second, this mode of research is cost effective as all employees that we are going to interview can be found in one office location. No extra travelling or phone calls or such things were required, thus making it data collection cost effective. The need for primary data collection was also relevant because no such previous data had been collected to describe or analyze project risk and uncertainty management in Elekta.

Thus, cross sectional data were collected on how projects risks are currently managed in Elekta so as to understand and suggest improvement without re-inventing the wheel. The target population was all project managers in PMO Elekta-Stockholm.

All these project managers were available at work during the data collection period, thus making the sampling strategy information based sampling (focused on project managers) instead of random based since the entire population was reachable. This made it easier to make a valid generalization of the responses within study unit. The data collection method was a mixture of exploratory (open ended) face-to-face interviews and closed ended questionnaire. By asking open ended questions, we got an overview of the current project risk management situation in Elekta. However, close ended questions helped us to prioritize and identify the model components.

The main steps in conducting the interview questions include; design of the draft questions, piloting the questions on one project manager, undertaking the main interview, data coding, punching, checking, analysis and reporting (Adams et al, 2007).

Exploratory (opened ended interviews)

A survey of literature reveals that the exploratory approach is the most popular method of data collection for describing reality as experience by the respondents. This approach does not seek to quantify or analyze numerical relationships or obtain statistical summaries of the responses (Fisher, 2007). It is chosen for this part of the investigation because it is a suitable method for collecting narrative responses to be able to achieve the first research objective of this study. The method is also justified for this part of the study because the researchers have very limited knowledge about how project risks are currently managed in Elekta and hence cannot set up closed ended questionnaire for the respondents. Also, the researchers could not guess with certainty the type of answers the respondents were likely to give and this approach was therefore both convenient and helpful in gathering the views, knowledge, and experiences of the individual respondents on the existing risk management process in good detail with minimized biases that could result from suggesting responses to the respondents. Face-to-face interviews were employed since the target population could be reached in persons at Elekta's office.

Collecting data through interviews can be achieved in three ways - unstructured, semi-structured or structure manner. In structured interviews, the interviewer read out a pre-set and similar set of questions in a manner that avoids influencing the outcome of the results. The interviewer prepares a set of questions in advance in the case of semi-structured interviews, but the flow of the conversation dictates which question will be chosen next. Unstructured interviews however involve casual conversations between the interviewer and the interviewee with the purpose of fully exploring a single topic. In this study, the structured interview format was selected since the ISO risk management framework which is already structured in nature as used as a standard for evaluation.

Closed ended questions

The closed ended questionnaire was relevant to identifying and prioritizing the components of the model. This method was appropriate for achieving the third research objective (specifying the model contents). Thus, the closed ended questions were instrumental for comparing the views of the respondents by obtaining statistical summaries for their responses on each variable

The Likert scale was used in assessing the value of the model variables with regards to Elekta's projects. This technique was quick and easy for collecting data and had the advantage of showing the strength of both individual and collective expert responses on what the components of the model should be. It also made it easy to analyze the results.

3.4 Framework for data analysis

The questions for the opened ended questions focused on how the generic risk management processes or themes including; identifying risks, analyzing risks, evaluating risks, responding risks, communicating risks, as well as monitoring and reviewing risks, were implemented in Elekta compared with those processes outlined in ISO 31000, which served as the framework for evaluating Elekta's project risk management procedures as revealed by the interviews. The information obtained from each question or theme was then used to asses and suggests improvement to the particular risk management process that question focused on.

The numerical and subjective data gathered by using closed ended questions will be described by using statistical summaries that will help in understanding the data.

3.5 Reliability and Validity of the Study

Validity is the extent to which a claim or conclusion is based on sound logic. A valid research according to Biggam (2008) is therefore a research that is acceptable by the research community (academics and practitioners who undertake research) and that validity is judged by the suitability of the selected research strategy, data collection and analysis techniques. Validity in this study was thus ensured by selecting tested and accepted: research strategy, data collection, and analysis techniques that were appropriate for the study.

CHAPTER 4

ANALYSIS OF PRESENT SITUATION

To understand the risk management process in Elekta as input for building the model, the ISO 31000 hypothesis of a standard risk management system was used to evaluate the risk management process in Elekta. The sections below summarize the characteristics of each of the main risk management processes as applied in Elekta.

In all, nine (9) interviewees were contacted to take part in the structured in the interview and the response rate was 100% (i.e. the number of responses suitable for analysis divided by the number of respondents approached). The interview questions are shown in appendix A. No female was interviewed since all members of the target population were males. Table 4.1 below summarizes some demographic information of the focus group.

Gender		**Experience (years)**		**Job Title**		
Male	Female	< =3	> =5	PM	PM/Consultant	PM/Product Mananeger
9	0	2	7	7	1	1

Table 4.1: Interview Respondents.

4.1 The Risk Identification Process

We found that appropriate approaches have been adopted identifying project risks. The results presented in Figure 4.2 confirmed that most of the project managers brainstorming session at the early stage of project, and the risk register is the next most used tool in the risk identification process. Also, the project managers used different techniques at different degrees. For example majority said that the project team figure out the project risks which are further documented. Few of them conduct a silence brainstorming session where everybody think and write at least 5 risks which are further discussed in meeting with smaller project group.

1 =Never
2 =Rarely
3 =Sometimes
4 =Very Often
5=Always

Figure 4.1: Key for subsequent graphs

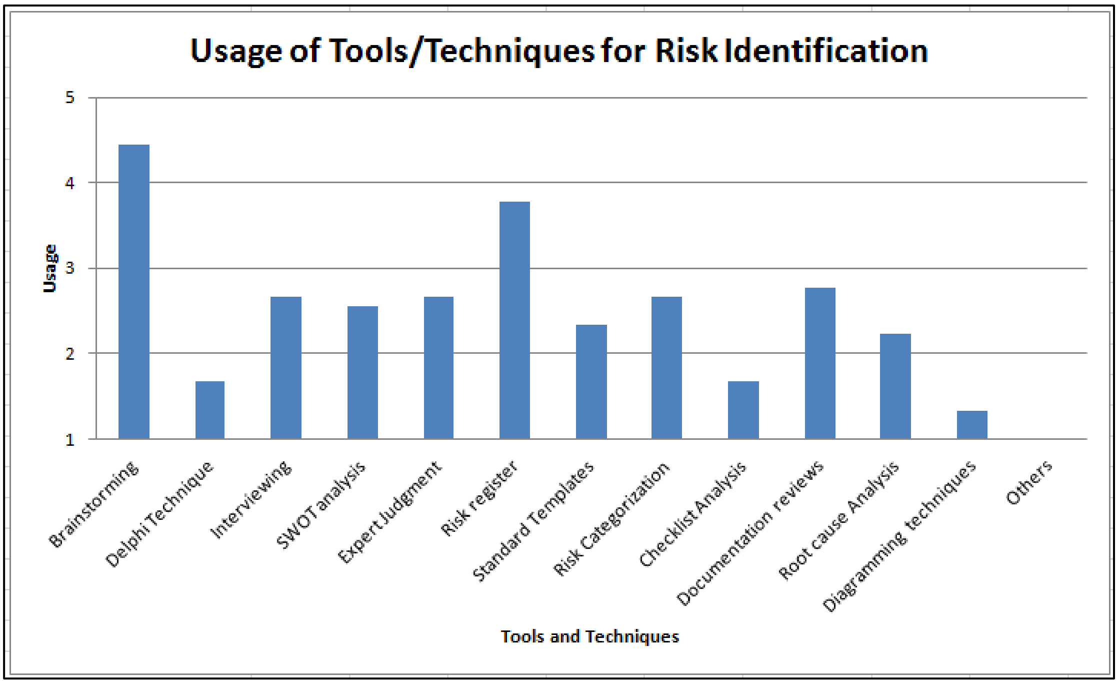


Figure 4.2: Present usage of tool/techniques for Risk Identification.

Lesson learnt from previous projects is not always the part of risk identification process. Some mangers told that they take expert opinions (managers who have done similar projects) but not always.

Figure 4.2 shows the usage of tool/techniques being used for risk identification. Numerical values shows frequency of usage. 1 shows never, 2 shows rarely, 3 shows sometimes, 4 shows very often and 5 shows always. The same scale is used for rest of graphs of other processes. It is clear from the Figure 4.2 that brainstorming is used from very often to always, as a tool for risk identification. Documentation of these risks is usually done very often. Interviewing, SWOT analysis, expert judgment, standard templates, risk categorization, checklist analysis, documentation reviews and root cause analysis are done rarely to sometimes. Delphi techniques and diagramming techniques are also used from never to rarely.

4.2 The Risk Analysis Process

This is the area where approximately all of managers are doing the same. The values of probability and consequences are assigned in an old traditional way. One of two scales either 1-5 or 1-3 are selected. Based on individual perception, values for probability and consequence of each risk are given by all project team members. After that there is a voting process which is used to reach on a consensus about these values.

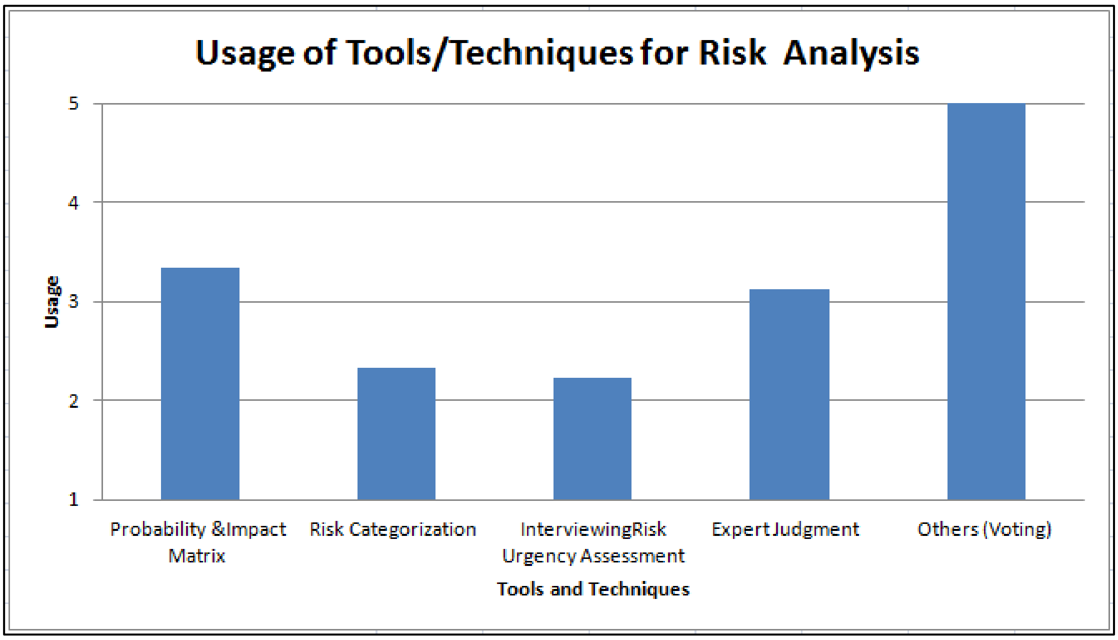


Figure 4.3: Present usage of tool/techniques for Risk Analysis.

Summary of the responses from all of 9 interviewees regarding risk analysis is shown in Figure 4.3. It tells that risk analysis is done always through voting. Use of expert judgment and probability and impact matrix is made sometimes. Risk urgency assessment, probability and impact matrix and risk categorization are used rarely to sometimes during risk analysis.

There are serious issues associated by analyzing this way. There is no unique scale being followed. So it is very hard to visualize risks at portfolio level.

4.3 The Risk Evaluation Process

Like risk analysis, there is deep correlation between Elekta project managers for evaluation of risks. Based on weighted values of probability and consequences, risk factor is calculated by simple multiplication of these two numbers. Furthermore, the list of risks is sorted based on risk factor values. Higher the risk factor, higher the risk is considered.

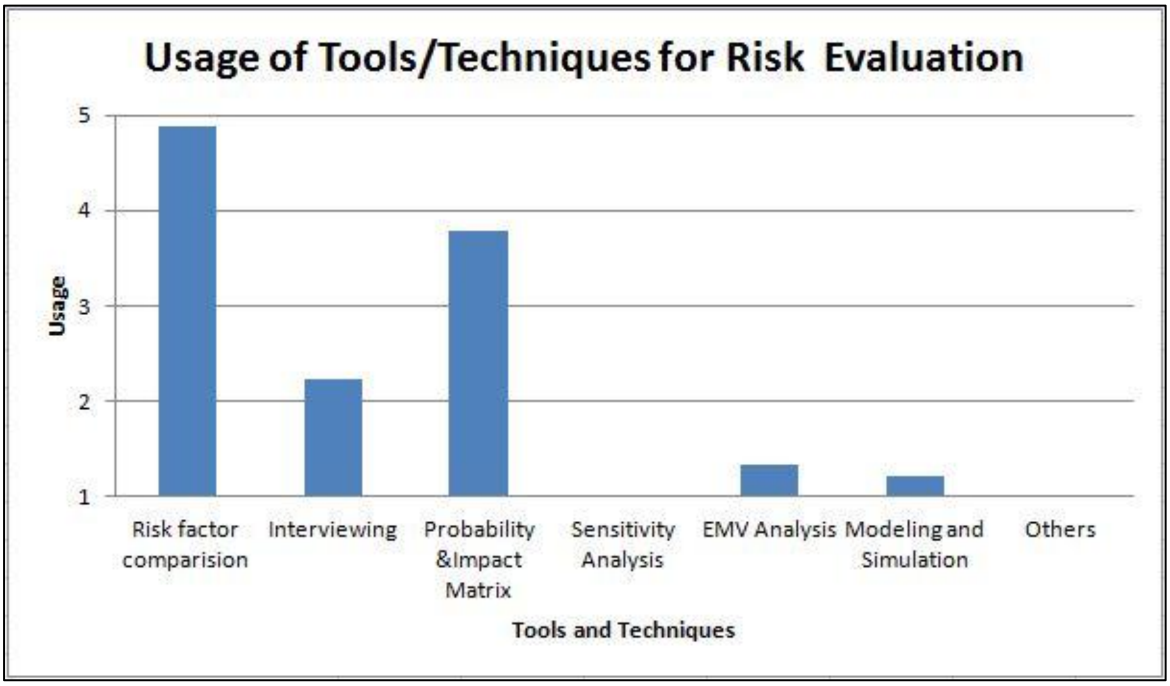


Figure 4.4: Present usage of tool/techniques for Risk Evaluation.

Summary of the responses from all of 9 interviewees regarding risk evaluation is shown in Figure 4.4 which shows that risk factor comparison is done almost always. Probability and impact matrix is used from sometimes to very often while interviewing is done from rarely to sometimes. Use of EMV analysis and modeling and simulations is made almost never.

4.4 The Risk Response Process

There is no specific strategy defined by project managers to respond to project risks. However, some actions based on experience of project managers are defined to mitigate project risks. Very little information is mentioned in risk register regarding risk response. Reason for selecting particular response is also not part of risk response plan.

4.5 Communication and Consultation

Although risks are reported periodically to the steering group, the communication of risk is basically limited to project teams. Consequently, other stakeholders are left out and the implication of this is that customers and owners are not given the opportunity to understand and appreciate the risks and trade-offs in projects. Figure 4.5 below summarizes the techniques and tools used in the communication process. Regular project meetings is the commonly use technique, followed by reporting using specific templates.

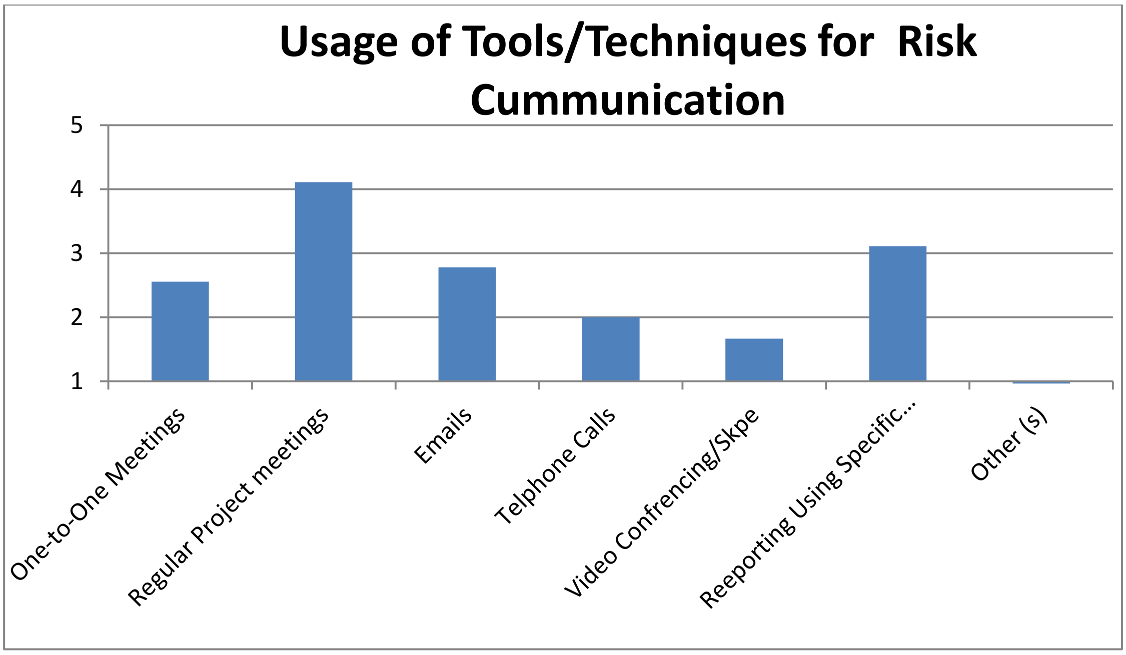


Figure 4.5: Usage of tools/techniques for Communication and Consultation.

In summary, the investigation of the project risk management process revealed that the process is done to some extent with varying techniques and tools, however, it has not so systematic since project managers use different approaches and techniques to a large extend.

4.6 The Monitoring and Control Process

Most of the managers admitted that there is poor follow-up for project risks. There is no defined system which test health of current uncertainty management process. However, serious project risks are followed up during regular project meetings.

Summary of the responses from all of 9 interviewees regarding monitoring and control is shown in Figure 4.5. It shows that project risk reviews are done from sometimes to very often whereas project risk response audits, technical performance measurements and additional risk response planning are done rarely.

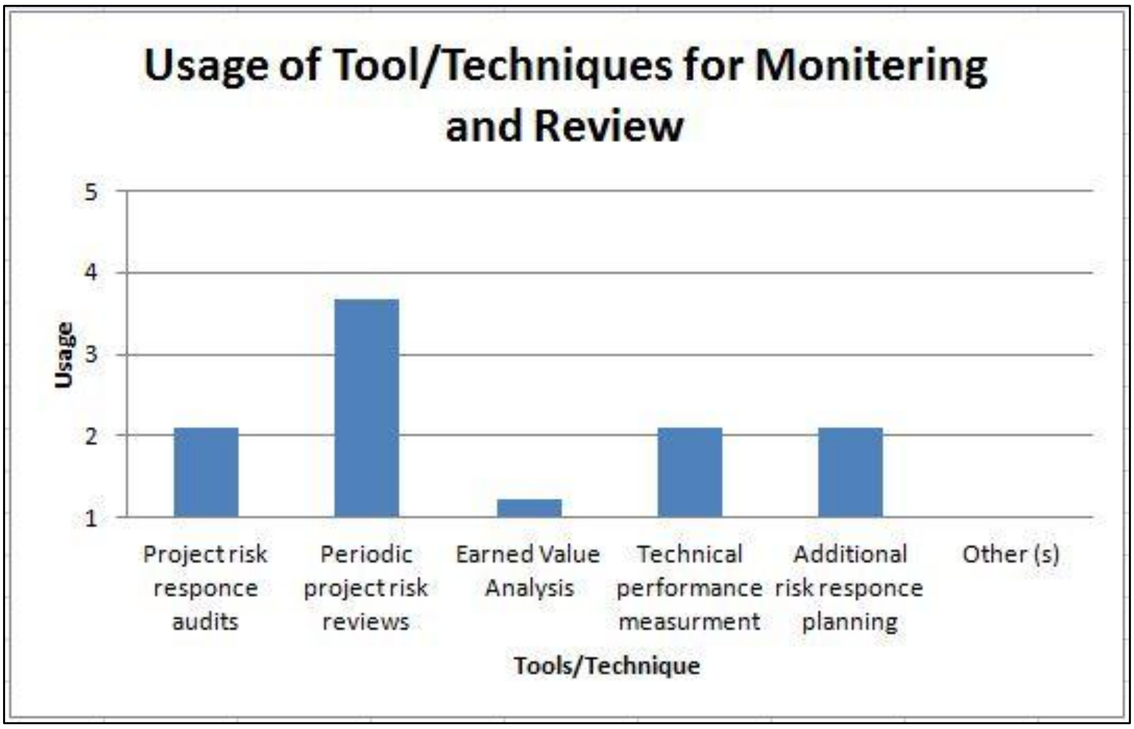


Figure 4.6: Present usage of tool/techniques for monitoring and review.

This is the area which needs the most concentration. Project managers make a good start when identifying project risks but most of the time there is lack of good follow-up. Our analysis suggests that there is an urgent need of defining a process which not only ensures sound follow-up of identified project risks, but also examine the health of whole system dealing with project uncertainties.

The investigation revealed that project risk management is done to some extent; however, it is not well organized and systematic. Most of things are done based on past experience and no particular model/standard is being followed.

CHAPTER 5

RESULTS AND DISCUSSION

5.1 Conceptual framework of the Model

The main outcome of this study is the proposed Integrated Risk and Uncertainty Management Model. This chapter presents and discusses its components, its functionality as well as the results from piloting the model on an ongoing project. Figure 5.1 below illustrates the components and conceptual framework of the model and described in more detail in the following sections.

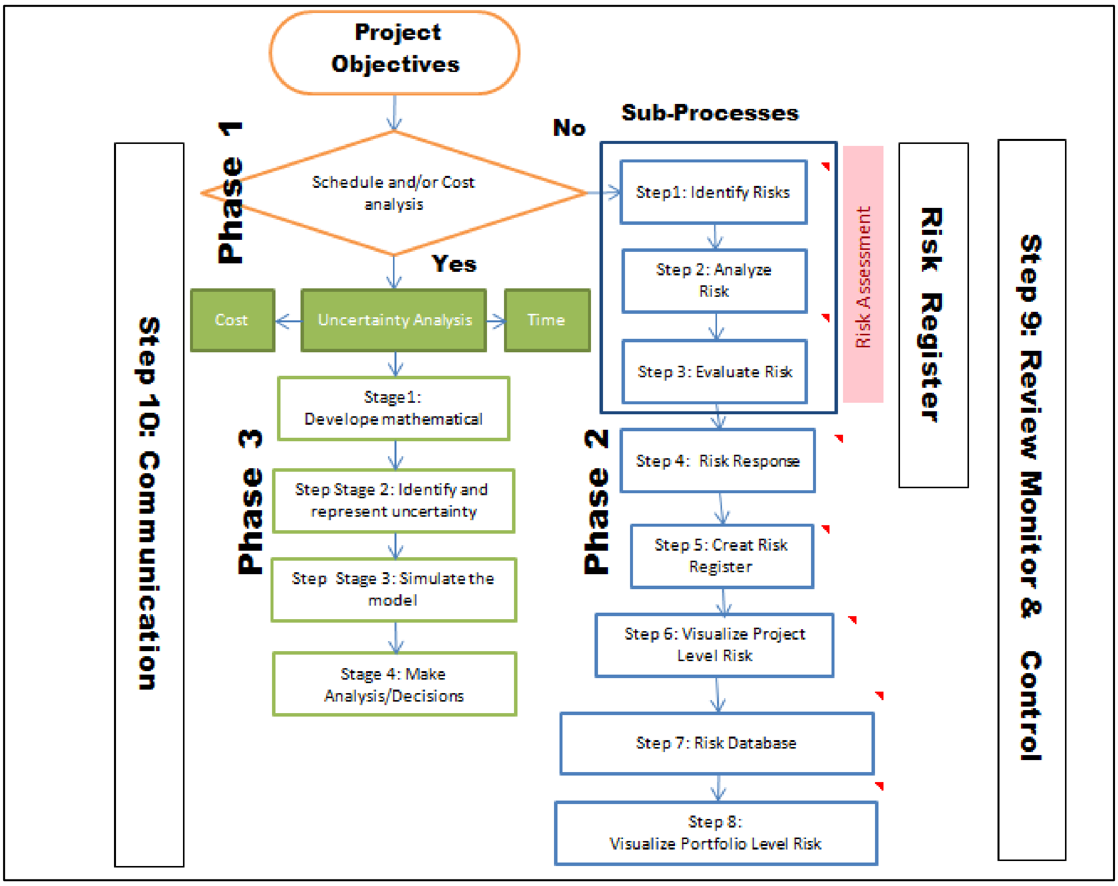


Figure 5.1: The Integrated Risk and Uncertainty Management Model.

The model is made of three major phases which are then further broken down into sub-processes.

Phase 1 - Establish the context: That is what we intend to achieve? It involves reviewing the project objectives and specifying the objectives of the risk management. The outcome of this process is to decide on whether quantitative (uncertainty analysis) or qualitative process should be followed.

Phase 2 - Qualitative analysis: This process is made up of the following sub-processes. The role and responsibilities during the execution of each sub-process are specified in the model.

(Note: The risks register needs to be updated after every step)

Asses risks in the project:

This sub-process is made of three steps as shown in figure 5.1 above: Identify, Analyze and Evaluate the Risks.

Step 1: Identify and categorize and record all possible risks in a given project.

The most important management question in this step is what might happen that can affect the project objectives. The purpose is to determine the risks that are likely to affect the project objectives and to document their characteristics. The outcome of the risk identification step is a comprehensive list of all known risks and this will form the basis for the risk register. The need to identify and manage new risks that may come up as the project is being run.

To identify the risks in a project, the following techniques can be applied:

1. Review Risk Database and Lessons Learnt: Use past experience and knowledge effectively. Review historical record about risks available in the risk database and lessons learnt documentations from previous similar projects to an idea about possible project risks and note them down.
2. Brainstorm: this involves identifying and listing all candidate project risks in a group workshop lead by a facilitator without assessing the importance of these risks in the initial stages of the brainstorming session.
3. Would bring better visualization of challenges that might come during the project.
4. Use interviews: involves asking people with similar project experience, stakeholders, experts, and anybody within your reach who has an idea about

risk in the specific project field by using face-to-face, phone, e-mail, or instant messaging interactions.

5. Give risk ID numbers, categorize, and record all the identified risks into the risk register. Suggested risk ID numbers could be R1, R2, R3,… etc. We suggest that the risks are categorized or classified both by their nature and by their value. Clustering risk by nature such as technical, software, hardware, human resource, financial, schedule, safety, environmental, performance, legal, business, etc can be helpful in identifying risk owners, whether as individuals or as units due their skills and competences and to then to facilitate the location of additional contingency resources. The risks also need to be clustered on the basis of their value their impacts on project objectives (Low, Medium, High or similar valuations), the risk analysis and evaluation steps below provide the means to do clustering of risks by value. The object of clustering risks by their value is to help prioritize risks in order to make decisions about them.

Step 2: Perform qualitative and Semi - qualitative Risks Analysis.

The task here is to determine the likelihoods and consequences of all the risks identified in a specific project by using historical data, expert judgments etc. to carefully analyze how many times a specific risk has occurred and what are its impacts. Estimate their risk factors (values) and then use these risk values to evaluate each risk. Hence, the qualitative risk analysis and risk evaluation steps are done together as one step. Two approaches are provided for executing this combines step depending on the level of detail required. In both approaches, the likelihood, the impact and the risk factor scales ranges from 1 to 5 as opposed to 1 to 3 or 1 to 10 scales. This is because the 1 to 3 is too aggregate and does not give sufficient detail for the ratings and the 1 to 10 scale is also too detail for our purpose. However, to avoid confusion, we give the following interpretations for the scales:

Likelihood or probability rating:

5 = Almost certain (i.e. Very High, May occur once per project)

4 = Highly likely (i.e. High, Likely to arise at least in every 5 projects)

3 = Likely (i.e. Moderate, May arise at least in every 10 projects)

2 = Unlikely (i.e. Low, May arise at least in every 15 projects)

1 = Rare (i.e. Very Low, May arise at least in every 20 projects)

Impact or consequence rating:

5= Extreme (i.e. Project cost estimates increased by more than 15%, Project Times increase by more than 30 days (1 month),

4 = Serious

3= Moderate

2= Minor

1= Negligible

Risk Factor rating

5=Very High

4=High

3=Medium

2=Low

1=Very Low

The first approach is the most popular approach for doing qualitative analysis. Thus, a probability impact matrix is built for assessing the likelihood, consequence and risk factor/score value a given risk can have on a project objectives (see figure 2.2).

As opposed to the macro level analysis and evaluation of risks in the first approach, the second approach assumes that the likelihood that a particular risk may occur is constant on all the project objectives but the impact of the risk if it should is not equally distributed across all the project objectives. Thus, the impact may vary over the objectives; some objects may have worst affect while other may not be affected at all. To incorporate this assumption into the model, the risk formula is modified by introducing a third variable, which is the importance of a given project objective as perceived by the project stakeholders.

Hence, the relationship: Risk (probability, Impact) = probability * Impact becomes

Risk (Probability, Impact Project, Objective) = $P * I_i * W_i$ …………………….. (5.1)

Where W_i = the weight of the i^{th} objective, I_i = the impact of the risk on the i^{th} objective, and P = the probability of the risk occurring (which is the same for a specific risk for all the objectives). Since it will be more demanding to perform the micro level analysis for all identified risks, the top ten risks can be selected for the micro level analysis and the others can be analyzed at the macro level.

The outcome of each of the two qualitative risk analysis and evaluation is the risk value (risk factor) for each identified risk, thus, risk value rates on the scale of 1-5 are obtained and this allow us to prioritize risk by comparing their value on the very low, low, medium, high and very high scale base on their likelihoods and impacts on the project. These results are recorded into the risk register.

Step 4: Respond to risk.

Risk response is planned in order to change either the probability of a given risk occurring or to change its impact if should occur to accept the risk and create a contingency resources for it. Inputs to this process include the prioritized list of risks based on their value, current project plans, budgets and the respond strategy (The set of risk response strategies are described in section 2.2.4). Perform a cost-benefit analysis to select the most suitable strategy from the list of available options to respond to each listed or prioritized risk. The output is a document giving clear road map and responsibilities so as to protect project objectives from identified risks. The response process could be started by discovering if the problem is new or not? This would help to avoid reinventing the wheel. Make detailed risk response plan for risks with higher risk factors i.e. risks with higher probabilities and higher impacts. Risks having higher likelihoods but moderate impacts should be handled with improved management procedures to reduce likelihood. Risk having low likelihood but potentially higher impacts should be either dealt with making effective contingency plan or transferring the risk to other party. Risks having less likelihood and small impacts could be handled by improving routine procedures at ad-hoc basis. Before implementing selected risk response strategies, peer review by experts is required. This review would ensure that response to each risk is adequate. Allocate the necessary contingency resources and assign responsibilities, making sure that every risk has a risk owner. Allocate all necessary resources assigned in risk response plan.

Step 5: Create a risk register.

The risk register is a detailed set of all the project risks and their characteristics such as name, ID, likelihood, impact, risk value or factor, risk category, status, dates, cost of risk, response strategy, and other properties. The risk register is created at the beginning of the risk management process and updated consistently throughout the process. The risk register in the model is implement in spread sheet, thus, making it easy to update, view risks and their attributes, sort or rank risks on the basis of their score (risk value), view issues or lessons learnt, sort risks by their ID, or similar criteria.

Step 6: Risk database

This aims at saving risk history for future use and to bring together risks for projects of the same portfolio so as to ease portfolio risk/uncertainty analysis. The risk register suggested in the model is supposed to contain comprehensive information about all the risks and how they were managed during the project and therefore has to be entered into risk database with project name and under appropriate portfolio. Comments on issues and lessons learnt from a specific project need to also be added in the risk register.

Step 6: Visualizing risk at Project Level

The risk values (factors) for each risk can be extracted from the risk register and put together to estimate the risk value of the entire project. This process is automated in spreadsheet and described below.

To assign risk value to a project as a whole, one may be tempted to compute the average of all the risk factors for all the identified risks in the project (in some cases the lower risks may be omitted) and then assign this average value to the project as a whole. However, the degree of influence each risk factor has on the project will not captured by this simple approach. Thus, high risk items have more weight on the on the overall project risk and therefore should be given more weight in the estimation. The overall risk formula suggested by Royer (2000) has the ability to account for this imbalance and was therefore adopted in our model to estimate the risk for the whole project.

$$Overall\ project\ Risk = \sqrt{\frac{\sum_{1}^{n}(RF)_i^2}{n}} \qquad (5.2)$$

Where RF_i = the i^{th} risk factor for risk i and n = the number of the risk factors.

Also, another measure of aggregate project risk can be obtained by determining the number of risk factors for each risk factor level as a percentage of the total number of risk factors in the project. For instance, consider a 5 point risk factor rating scale (where 1 = very low, 2 = Low, 3= Medium, 4= High and 5= very High). In a situation where 5 risks are identified in a project and 3 of these risks have risk factors of high, 1 of the risks has a risk factor rating of Medium and the other has a risk factor rating of very High Then we can say that 60% of the risks in the project high in both their likelihood and impact, 20% of the risks are medium in both their impact and likelihood and another 20% are very high in their impact and probability. This potentially indicates a very risky project.

As the project proceeds, the risk factors (RF_s) may change over time and therefore monitoring the changes in the individual risk factors and recalculating the overall project risk factor with the above formula, we can see if the project is going into danger and demand some immediate attention to avoid failure. Thus, increasing aggregate project risk factor would be an indication that the project is in the yellow light and could get into red light if measures are not taken. However, a decreasing aggregate project risk factor is an indication of green light.

Step 7: Visualizing risk at Portfolio Level

With the same aggregate risk formula or percentage measure approach described in step 6, we can aggregate project risk factors to obtain the aggregate portfolio risk factor in order to visualize risk at the portfolio level. The procedure and logic is the same as in step 6.

Step 8: Communicate and Consult

This process is to ensure that all involved parties are informed to avoid horrible surprises which can have far reaching consequences on future business deals. Thus, customers and owners can understand and appreciate the risks and trade-offs in projects. Regular reporting is an important form of communication where the risk register and the risk response plans form the basis. Risk reports summarize the projects risks and their response statuses.

Step: 9 Monitor and Review

The interviews indicated that this is one of the most poorly performed processes in Elekta and therefore deserves some attention. It has components

- The day-to-day management of the risks, that knowing when in the project calendar a specific risk (s) is likely to occur, carrying out the response plan, as well as knowing and tracking the risk status. The register suggested in the model made provisions for the day-to-day monitoring and control of the risks.

- The other part is monitoring and reviewing the effectiveness of the entire risk management process. Check list is suggested in the model for this process.

Phase 3 – Uncertainty or Quantitative analysis

The third and last phase of the model is uncertainty analysis and focuses on schedule risk and cost risk analysis which are described in the following sections. The detail principles and justification for this kind of uncertainty analysis are provided in the literature review in chapter (2). Thus, in the third phase, the model suggested Monte Carlo simulation for addressing uncertainties in project schedule and cost estimates. It is four step model which provides a level of certainty that helps decision makers to visualize impact of certain change on over-all project duration or cost. Palisade @risk is good software that implements Monte Carlo simulation using Microsoft excel as a modeling environment. We have chosen some activities from one of Elekta's project and gave dummy values. These activities are simulated for cost and schedule estimates.

Considering Elekta's requirements, this stochastic simulation can be applied for:

1. Estimations of project cost and schedule during project planning
2. Monitoring and controlling project schedule and budget
3. Performing scenario analysis – I.e. scenario analysis can be done to determine the different combinations of inputs which results in certain output values. For instance, how will low and high combinations of the input variables: operating cost, sales prices, and sales volume affect the output variable: profit. The combination, low operating cost, high sales prices and high sales volumes will results in high profit.
4. Performing sensitivity analysis – in @ Risk, the input distributions are ranked on the basis of their impact on the output variable, this enables us to perform sensitivity analysis that shows the sensitivity of each output variable to its input variable.

5.2 Piloting the Model

To demonstrate the usefulness of the model, it has been applied in two different cases. For sake of confidentiality, original name of activities have been replaced by activity 1, activity 2…etc. Case 1 illustrates how the model can be applied for schedule uncertainty analysis and Case 2 showed how the model can be used to perform cost uncertainty analysis.

Case 1: Schedule Analysis

- For each activity in a phase, @risk Pert function is inserted and maximum, minimum and most likely values for corresponding activity are assigned.
- At the end of each phase, the result is made by using SUM function to add duration of each activity.
- From menu option, add output is selected for result cell.
- From menu option, simulation setting is selected and number of iterations was set to 5000 (increasing this number increase scenarios to be considered).
- From menu option, run the simulation.
- Result would be a histogram distribution which would help determining certainty level for a phase to be completed in X number of days and vice versa.
- To estimate whole duration of the project, find out critical path activities and simulate them in separate section in same way.

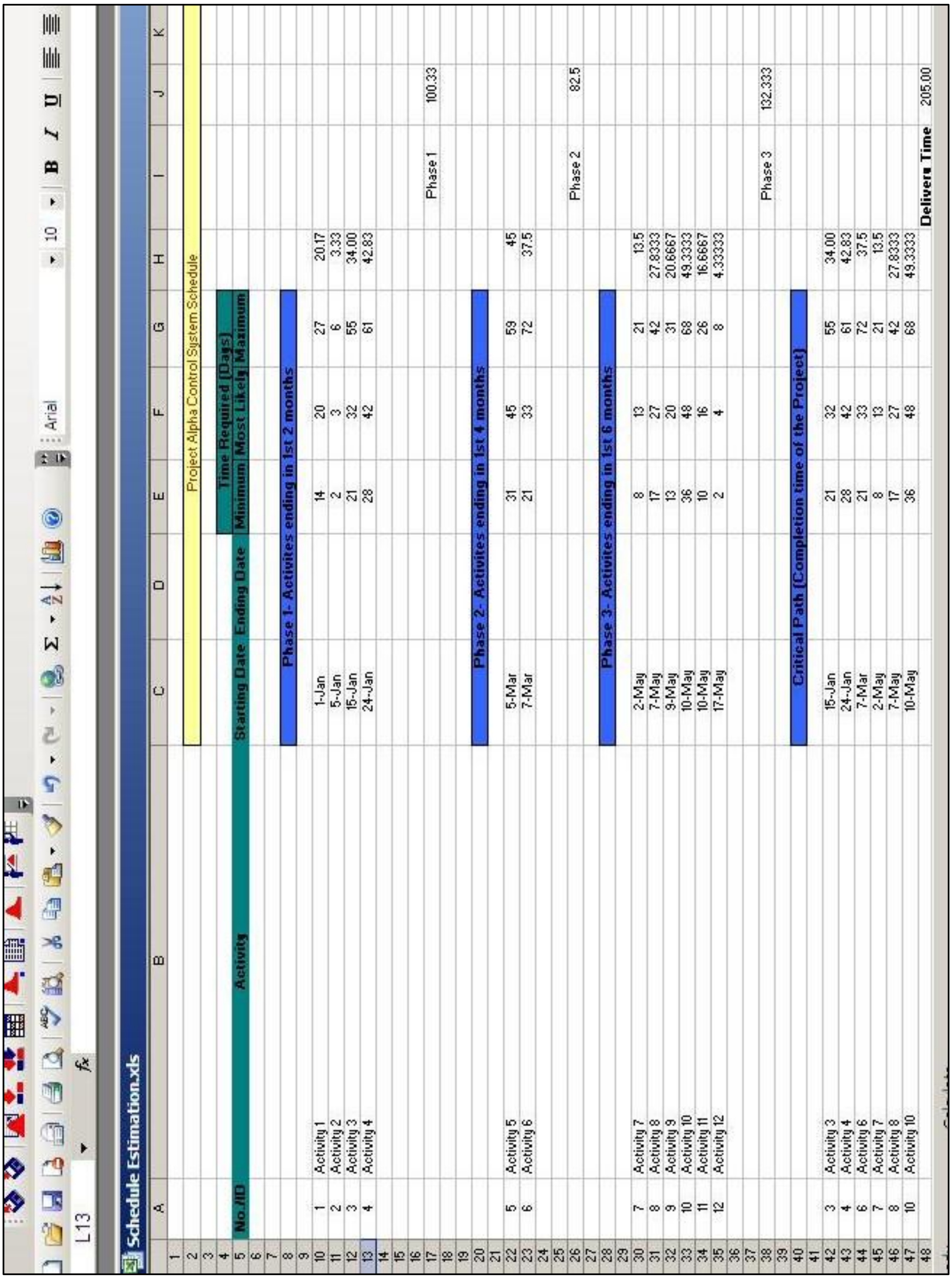


Figure 5.2: Snapshot of simulation model in @risk for schedule analysis.

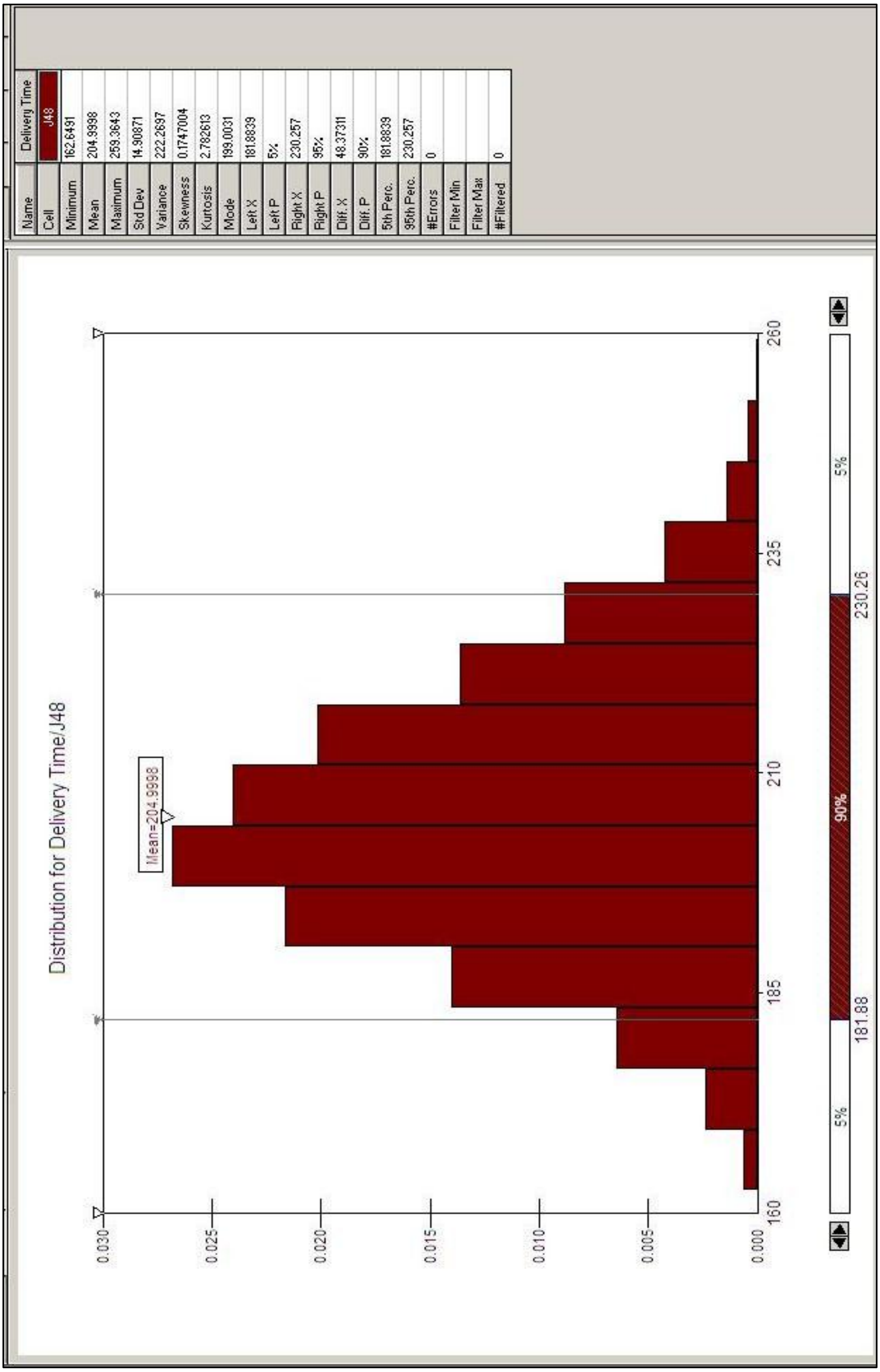


Figure 5.3: Simulation result for schedule analysis.

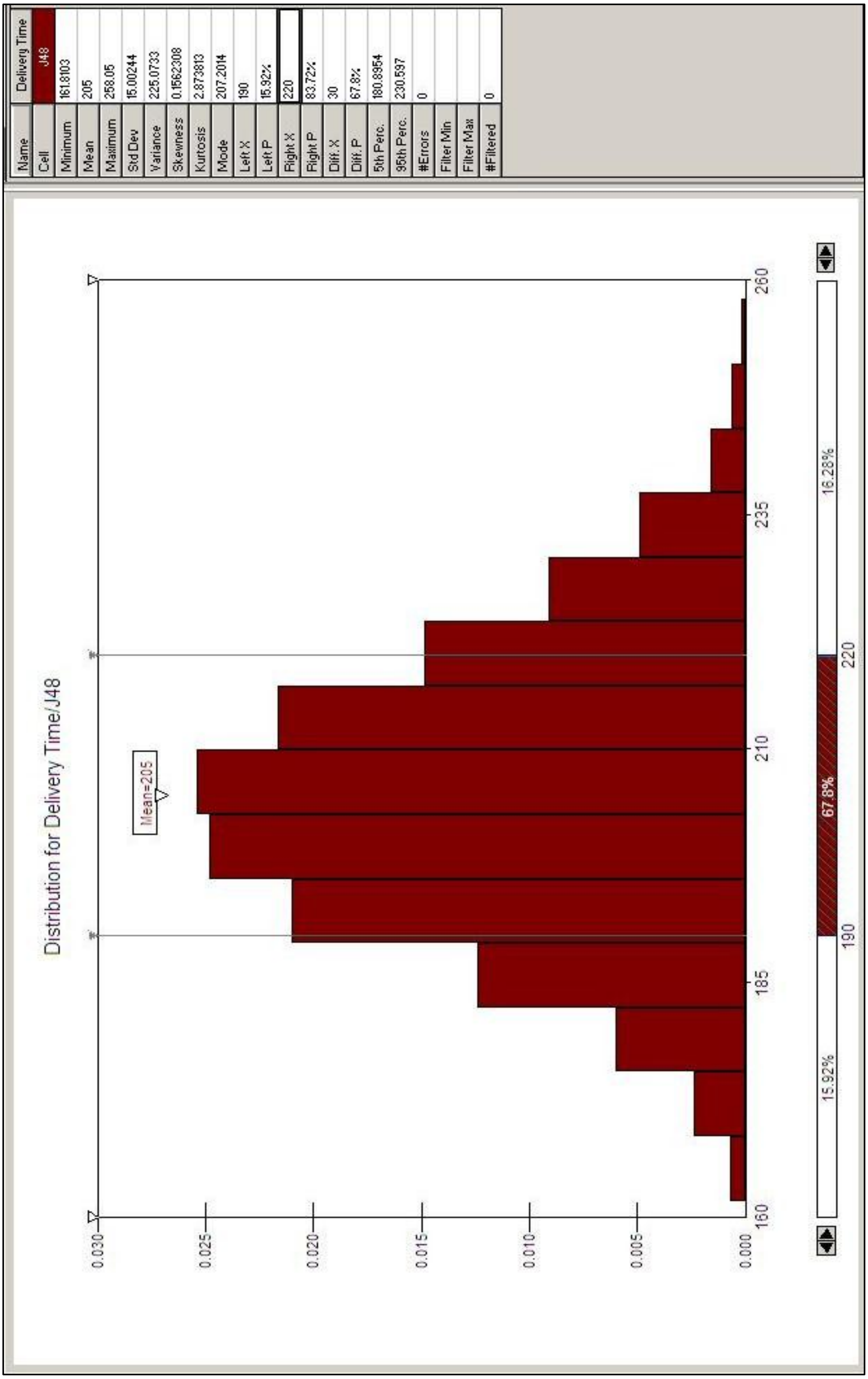


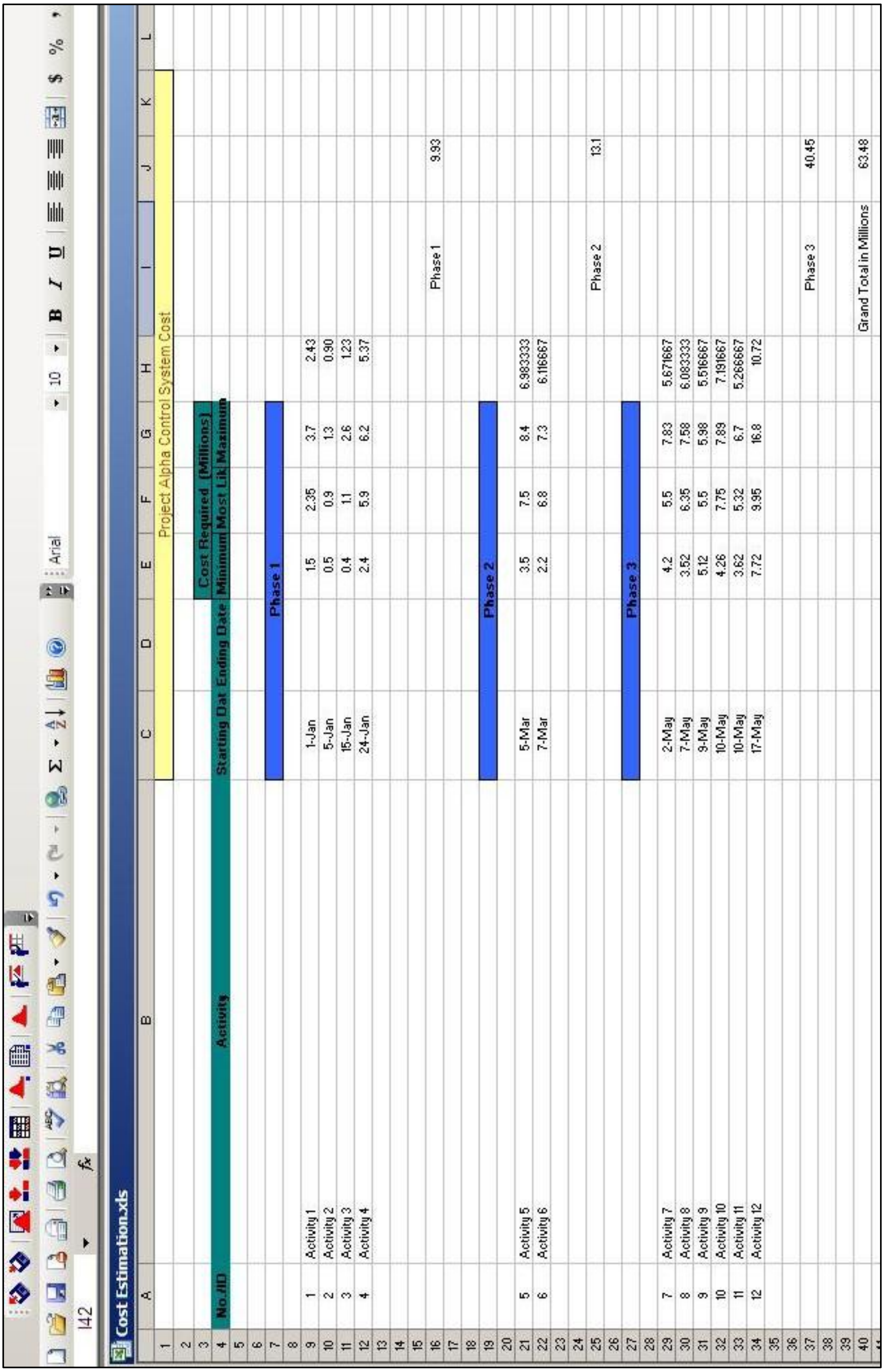
Figure 5.4: Simulation result for schedule analysis.

Figure 5.3 shows that it is 90% certain that project would be completed between 181 to 231 days. Another way to visualize this graph is getting certainty level for desired duration. For example Figure 5.4 shows that it is 67.8% certain that project would complete between 190 to 220 days.

Case 3: Cost Analysis

The cost analysis were performed with same procedure like schedule analysis.

- For each activity in a phase, @risk Pert function is inserted and maximum, minimum and most likely cost values for corresponding activity are assigned.
- At the end of each phase, the result is made by using SUM function to add duration of each activity.
- From menu option, add output is selected for result cell.
- From menu option, simulation setting is selected and number of iterations was set to 5000 (increasing this number increase scenarios to be considered).
- From menu option, run the simulation.
- Result would be a histogram distribution which would help determining certainty level for a phase to be completed in X million SEK.



No./ID	Activity	Starting Dat	Ending Date	Minimum	Most Lik	Maximum			
				Project Alpha Control System Cost					
				Cost Required (Millions)					
		Phase 1							
1	Activity 1	1-Jan		1.5	2.35	3.7	2.43		
2	Activity 2	5-Jan		0.5	0.9	1.3	0.90		
3	Activity 3	15-Jan		0.4	1.1	2.6	1.23		
4	Activity 4	24-Jan		2.4	5.9	6.2	5.37		
								Phase 1	9.93
		Phase 2							
5	Activity 5	5-Mar		3.5	7.5	8.4	6.983333		
6	Activity 6	7-Mar		2.2	6.8	7.3	6.116667		
								Phase 2	13.1
		Phase 3							
7	Activity 7	2-May		4.2	5.5	7.83	5.671667		
8	Activity 8	7-May		3.52	6.35	7.58	6.083333		
9	Activity 9	9-May		5.12	5.5	5.98	5.516667		
10	Activity 10	10-May		4.26	7.75	7.89	7.191667		
11	Activity 11	10-May		3.62	5.32	6.7	5.266667		
12	Activity 12	17-May		7.72	9.95	16.8	10.72		
								Phase 3	40.45
								Grand Total in Millions	63.48

Figure 5.5: Snapshot of simulation in @risk for cost analysis.

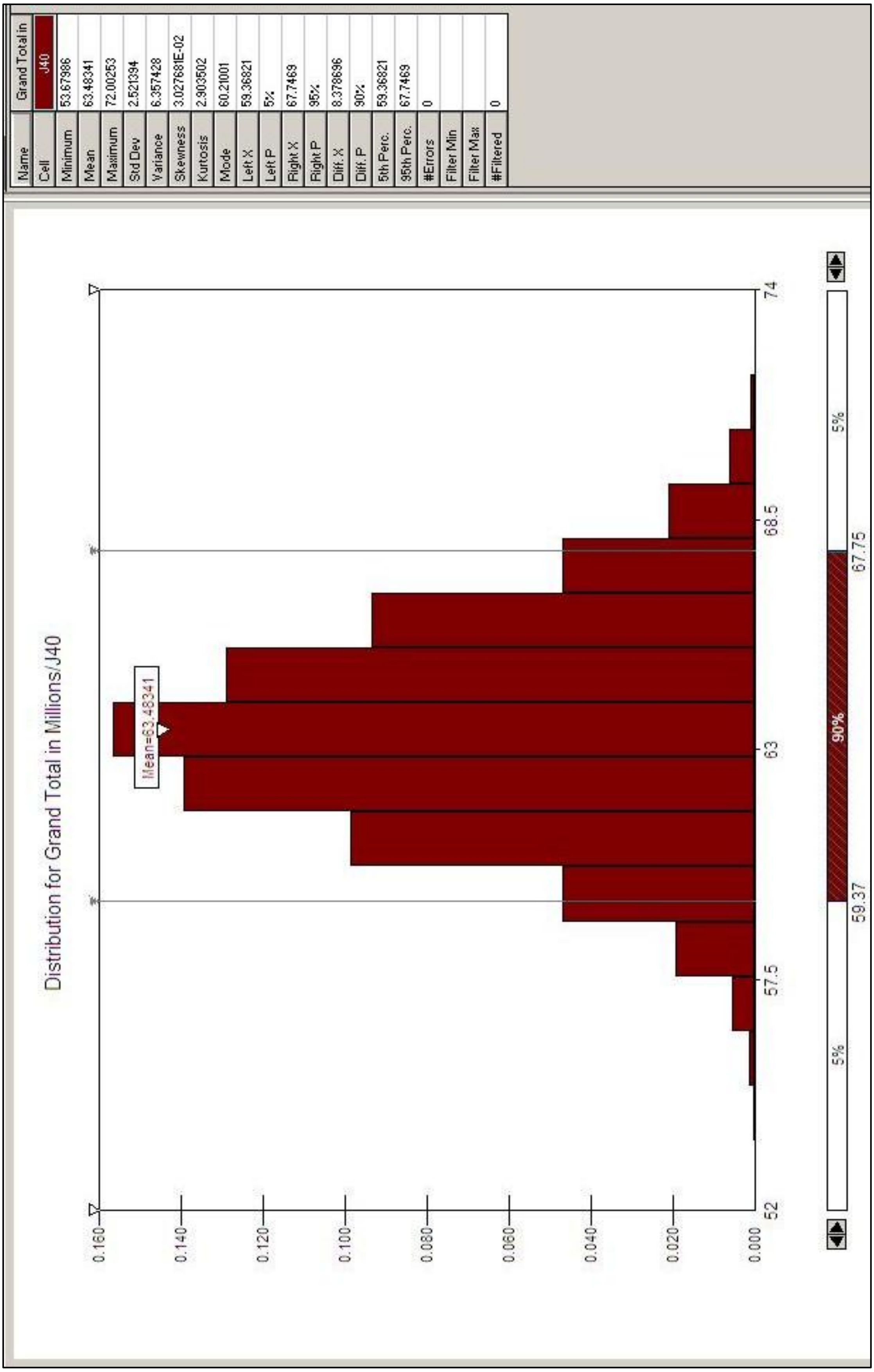


Figure 5.6: Simulation result for cost analysis.

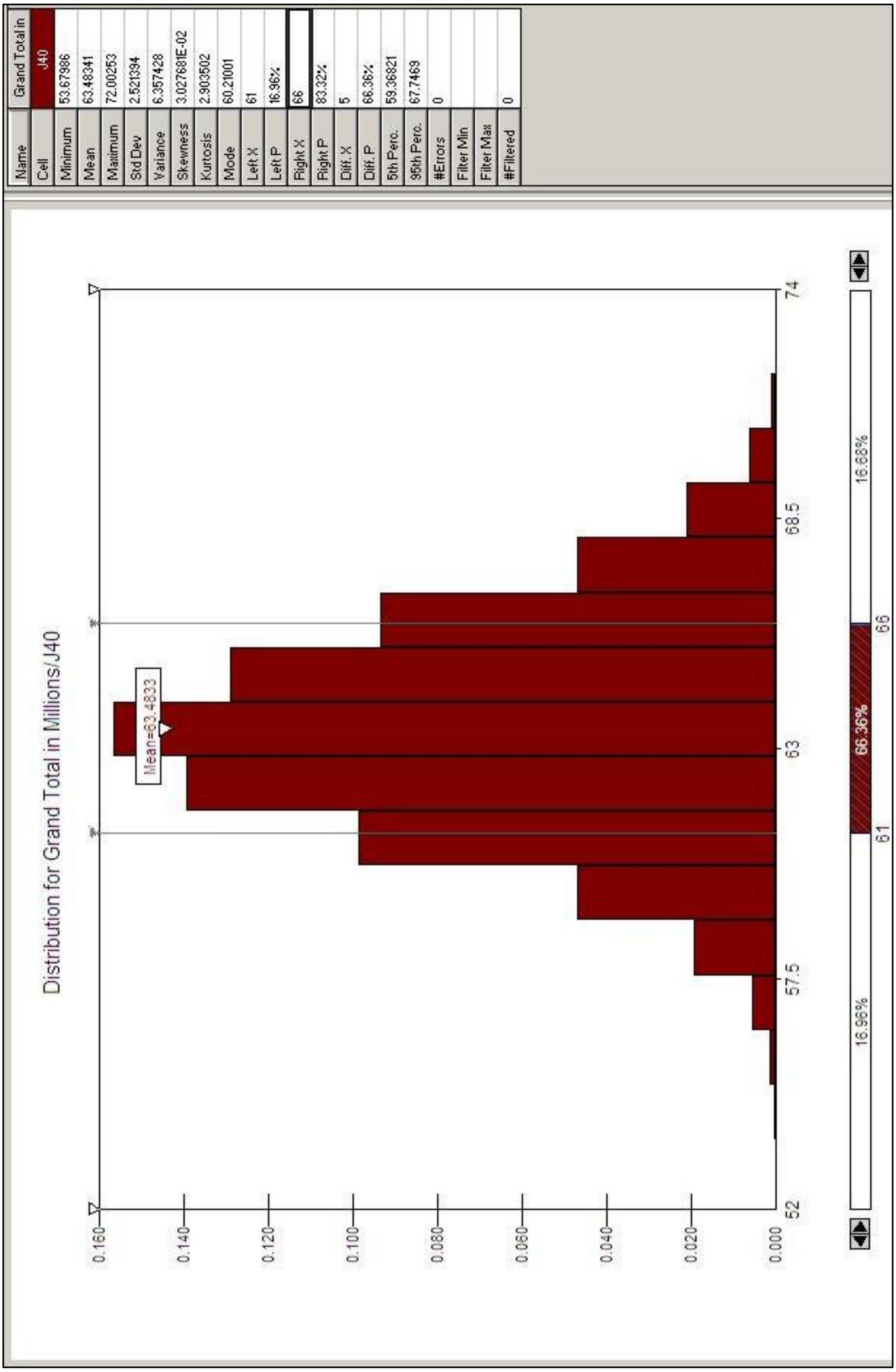


Figure 5.7: Simulation result for cost analysis.

Figure 5.6 shows that, it is 90% certain that project would be completed between 59.36 to 67.74 million SEK. Another way to visualize this graph is getting certainty level for desired amount. For example Figure 5.7 shows that it is 66.36% certain that project would be completed between 61.00 to 66.00 million SEK.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

The purpose of this study was to develop a prototype of a project uncertainty and risk management model to help improve project risk management in Elekta-Stockholm, yet it can be adopted by similar organizations. To realize this goal, the ISO 31000 standard was employed to evaluate and understand the project risk and uncertainty management process in Elekta by conducting interviews and analyzing these interviews. This initial investigation was then used as input for specifying the model and for establishing its functional logic. Also, to ensure the quality of the model, the criterion suggested by Cooper et al (2005) for assessing the quality of risk management models was considered and this criterion can therefore be used to measure the goodness of the model. The conclusions and recommendations from the study are summarized in the following sections.

6.1 Conclusions

The following conclusions are derived from the research:

- The review of literature revealed that uncertainty and risk are related but different concepts, and that probability distributions are much more realistic way of describing uncertainty. The review also showed that there exist a variety of risk management frameworks and models globally and their basic structures are similar. ISO31000 (2009), PMBOK (2008) and AS/NZS 4360 (2004) were considered in the study. Also, risk exists in all aspects of projects and the key word in project risk management is ***systematic***, the more disciplined or structured a risk management approach, the more is its ability to control and manage risks.

- ❖ The evaluation of the project risk management process in Elekta confirmed that project risk management is done to a certain degree but not in a well structured manner. The evaluation also pointed out that the risk analysis process in Elekta is skewed towards qualitative/semi-qualitative which is not always suitable. Thus, making it difficult for project teams to handle uncertainty. Also, quantitative (uncertainty) analysis techniques such stochastic simulation and decision trees and so on are not used at all for project risk/uncertainty management.
- ❖ Testing the model on an ongoing project suggested that the proposed model can help improve the project schedule uncertainty analysis and project cost uncertainty analysis. The results also demonstrate that the model provides a means for analyzing risks at a good level of detail. That is, on the basis of the level of impact each risk may have on each specified project objectives, as well as for performing higher level and less rigorous analysis of minor project risks. The model has also proved to be suitable for aggregating individual project risks to visualize risk at project and portfolio levels.
- ❖ Being systematic is central to effective and efficient risk/uncertainty management and by following a structure model like this, Elekta can enhance its project risk management process to a good extend.

6.2 Recommendations

- Excel is recommended for implementing the prototype model since it easy and efficient to use.
- Since it will be more demanding in term of time and effort to perform the micro level analysis for all identified risks, we recommend that the top ten or most important risks should be selected for the micro level analysis and the rest of the risks should be analyzed at the macro level. Note that the risks status may change as the project runs therefore the top ten risks may change and new risks may join the list and existing ones dropped.
- To improve project managers ability of project teams to better handle uncertainties in project cost and time, we recommend project managers and other relevant project team member be should be given training on uncertainty/quantitative risk analysis using stochastic (Monte Carlo)

simulation technique with the @risk/@risk for project package. This package has managed to hide most of the difficult aspects of stochastic simulation and that makes easy to learn and user-friendly.

- The risk/uncertainty management process suggested in the model focused more on managing risk as a threat, even though it can also be apply for opportunity management, it requires some minor adjustments to be more effective for that purpose and therefore further research can be done to explore this.
- To ensure reliability, trust, continuity, effectiveness and efficiency, we recommend that the model should be tried, evaluated and for improvement.

`

REFERENCES

- Adams, J., Khan, H.T.A., Raeside, R. And White D. (2007). Research Methods for Graduate Business and Social Science Students. Response.
- ALHawari, S., Thabtah, F., Karadsheh, L., and Hadi, W.M. (2011). A Risk Management Model for Project Execution. Information Management in Modern Organizations: Trends & Challenges. http://www.ltu.edu/cm/attach/A1A5680A-B853-4B21-879A-2FE643B16BAD/paper%20111.pdf. Accessed on 03-12-2011.
- AS/NZS 4360, 2004. The Australian and New Zealand Standard on Risk Management.
- Aven, T. (2008): "Assessing Uncertainties beyond Expected Values and Probabilities" John Wiley & Sons, Ltd
- Biggam, J. (2008). Succeeding with your master's dissertation – A step-by-step hand book. 1st Ed. ISBN-10: 0 335 22719 8. McGraw Hill.
- Chapman, C., Ward, S. (2003). Project Risk management- processes, techniques and insights. 2nd Ed. ISBN 0-470-85355-7. John Wiley & Sons Ltd.
- Cooper, D. F., Grey S., Raymond G. and Walker P., 2005. Project Risk Management Guidelines: Managing Risk in Large Projects and Complex Procurements. John Wiley & Sons Ltd.
- Duncan, William R. A. (1996). "Guide to the Project Management Body of Knowledge" PMI standards Committee, Pennsylvania, USA. . (1996),
- Elekta Anual Report (2010/2011). Elekta AB (publ).
- ISO 3100 (2009). Risk management — Principles and guidelines. 1st Ed. ISO, Switzerland.
- Fisher, C. (2007). Researching and Writing a Dissertation: A Guide Book for Business Students. 2nd Ed. ISBN: 978-0-273-71007-3. Prentice Hall (FT)

- Kerzner, H. 2001. Project Management: A Systems Approach to Planning, Scheduling, and Controlling. Seventh Ed. John Wiley & Sons, Inc.
- Langhe´, R. (2010). Lecture notes on Advance Risk Management, KTH, Södertälje.
- Martland, C. D. (2004). Notes on Project Evaluation. Department of Civil & Environmental Engineering, Massachusetts Institute of Technology.
- Maylor, H. (2003). "Project Management"3rd e. Prentice Hall Retrieved September 29, 2010
- McDermott, E.R., Mikulak, R., and Beauregard, M. (1996). The Basics of FMEA. Portland, Oregon. Productivity, INC.
- Project Management Institute, 2008. A Guide to the Project Management Body of Knowledge, third ed. Project Management Institute, Pennsylvania.
- Royer, P.S. (2000). Risk Management: The Undiscovered Dimension of Project Management. Vl.31, No. 16-13. Project Management Journal, PMI.
- Schuyler, John R. (1950). "Risk and Decision analysis in projects" 2nd Ed. PMI, Pennsylvania, USA.

APPENDIXES

8.1 Appendix A:

PROJECT RISK AND UNCERTAINTY MANAGEMENT INTERVIEW, ELEKTA

Masters' Thesis Project, KTH, Stockholm

There is always the chance of something happening that can affect specified project objectives in a good or bad way. This may include a possibility of loss or gain or deviation from desired or planned results. This interview is therefore intended to investigate how project risks and uncertainties are currently handled in Elekta for the purpose of understanding and to identify options for improving the situation. Your Opinions are very helpful and the interview is anonymous. If you feel something is not relevant or does not apply please enter NA (Not Applicable). If you cannot answer any of the questions, feel free and leave it. You will need just about 30 - 40 minutes or less to complete this interview.

Thank you for your effort at this busy time.

Part 1 - The Risk and Uncertainty Management Process

1. Is it a common practice for you to ask yourself about risk (what can go wrong or what can improve the objectives of a given project) at the start of every project that you are part of? Yes ☐ No ☐ . If yes, continue to question 2, if no, go to question 4.
2. What action (s) do you normally take at this early stage of thinking about risks in your projects?
3. Which of the following techniques or tools do you use in an attempt to figure out risks in your projects? Please rate how much you use them by ticking the appropriate cell in the table below.

Technique or Tool	Never	Rarely	Sometimes	Very Often	Always
Brainstorming					
Delphi Technique					

Interviewing					
SWOT analysis					
Expert Judgment					
Risk register					
Standard Templates					
Risk Categorization					
Checklist Analysis					
Documentation reviews					
Root cause Analysis					
Diagramming techniques					
Others					

4. Do you usually estimate the likelihood and impacts of risks in your project? Yes☐ No ☐ If yes, continue to question 5, and if no, go to question 7.
5. How do you estimate the likelihood and impacts of risks in projects?
6. Which of the following techniques or tools do you use in estimating the likelihood and impacts of risks in your projects? Please rate them by ticking the appropriate cell in the table below.

Technique or Tool	**Never**	**Rarely**	**Sometimes**	**Very Often**	**Always**
Probability &Impact Assesment					
Probability &Impact Matrix					

Risk Categorization					
Risk Urgency Assessment					
Expert Judgment					
Others					

7. Is it a common practice for you to prioritize the project risks that you discover in your projects?

Yes [ ] No [ ]. If yes, continue to question 8, and if no, go to question 10.

8. How do you usually prioritize the risks?
9. Which of the following techniques or tools do you use in ranking the risks in projects? Please rate them by ticking the appropriate cell in the table below.

Technique or Tool	Never	Rarely	Sometimes	Very Often	Always
Risk factor comparision					
Interviewing					
Probability &Impact Matrix					
Sensitivity Analysis					
EMV Analysis					
Modeling and Simulation					
Others					

10. Is it a common practice for you to respond to projects risks?

Yes ☐ No ☐ . If yes, continue to question 10, and if no, go to question 11.

11. How do you normally respond to discovered project risks?
12. Is it a common practice for you to monitor the risk management process?

Yes ☐ No ☐. If yes, continue to question 15, and if no, go to question 17.

13. How do you monitor that process of dealing with risks?
14. Which of the following techniques or tools do you use in monitoring the performance of the risk management process? Please rate them by ticking the appropriate cell in the table below.

Technique or Tool	Never	Rarely	Sometimes	Very Often	Always
Project risk responce audits					
Periodic project risk reviews					
Earned Value Analysis					
Technical performance measurment					
Additional risk responce planning					
Other (s)					

15. Is it a common practice for you to make an effective communication about project risks among all concern stakeholders?

Yes ☐ No ☐. If yes, continue to question 18, and if no, go to question 20.

16. How do you make communication during the process of dealing with project risks?

17. Which of the following techniques or tools do you use for communication among concerning stakeholders about status of project risks and system dealing with these risks? Please rate them by ticking the appropriate cell in the table below.

Technique or Tool	Never	Rarely	Sometimes	Very Often	Always
One to One meeting					
emails					
Telephone call					
Video conferencing/Skype					
Reporting using specific templates					
Other (s)					

18. Is it a common practice for you to make a register for identified project risks?

Yes ☐ No ☐. If yes, continue to question 19, and if no, go to question 21.

19. What are contents of the risk register?

20. How frequently you update this database?

Technique or Tool	Never	Rarely	Sometimes	Very Often	Always
Update Risk database					

21. Do you normally assign risk owners for each identified project risk?

Yes ☐ No☐ . If yes, how do you make sure every owner knows the risks he/she is responsible for?

22. Do you feel that you have enough authority and accountability to manage the risks that you are assign to? Yes ☐ No ☐

23. Write down here if you have any specific suggestion (s) for improving risk /uncertainty management in Elekta.

24. How important are the following factors on the basis of your experience in Elekta's projects? Please tick in the table below.

Factor	Very Unimportant	Unimportant	Neutral	Important	Very Important
Time					
Cost					
Scope					
Quality					
Others (list below and rate)					

Part 2 – Demographics

25. Sex ☐ Male ☐ Female

26. How long have you worked in Elekta's projects?

Less than 3 years ☐ Between 3 and 5 Years ☐ More Than 5 years ☐

27. Job tile ………………………………………..

Thank you Very Much!!