PROBABILITY OF SUCCESS IN PROGRAM MANAGEMENT

by

TEJAS PAWAR

Presented to the Faculty of the Graduate School of

The University of Texas at Arlington in Partial Fulfillment

of the Requirements

for the Degree of

DOCTOR OF PHILOSOPHY

THE UNIVERSITY OF TEXAS AT ARLINGTON

DECEMBER 2017

Acknowledgement

As I complete a significant milestone in my life, I would like to acknowledge the people without whom this Doctoral Degree wouldn't have been possible.

To begin with, Dr. James Royce Lummus, my advisor and mentor, thank you for your patience and confidence and my heartfelt gratitude for giving me your time and wisdom in this incredible journey and your unwavering persistence to make sure I fulfill this milestone. I am grateful for all the life lessons that your guidance and critical feedback have taught me. Thank you.

I would like to thank Dr. Donald Liles for his guidance, advice and support throughout my graduate career of Masters in Engineering Management and PhD in Industrial Engineering.

I would also like to express my heartfelt appreciation to Dr. Paul Componation for being thoughtful and supportive throughout the initiatives for American Society of Engineering Management and the doctoral program. I would like to thank Dr. Brian Huff for his support. I am honored that you are my dissertation committee member.

I would also like to thank Mr. Mark Woolley for his valuable insights to my research and guidance regarding application of this research to the real world.

I would also like to thank Dr. Chen, Dr. Leboulluec and Ms. Julie Estill for their help during my graduate education.

Thanks to my dearest parents, Mr. Subhash Pawar and Mrs. Anjana Pawar for caring, nurturing and motivating me throughout my life. I would like to share this achievement also, with my better half, Sneha who has believed in me throughout and motivated me endlessly to achieve this milestone.

November 14, 2017

Abstract

PROBABILITY OF SUCCESS IN PROGRAM MANAGEMENT

Tejas Pawar, PhD

The University of Texas at Arlington, 2017

Supervising Professor: Donald Liles

Co- Supervising Professor: James Royce Lummus

The field of Program Management is subject to high program failures. The Project Management Institute (PMI) states that 74% of programs are executed unsuccessfully (Mulcahy, Rita). The high rate of program failures is primarily due to inadequate planning before a program begins and inadequate management of a program when it is being executed. To avoid these high failure rates, a Program Manager needs a tool to help him assess the Probability of Success (POS) of fully accomplishing the objectives of his program from the initial planning phase and throughout all phases of program execution.

Purpose: The purpose of this research is to define and demonstrate a methodology for assessing the Probability of Success of achieving the program cost and schedule objectives of the program during all phases of the program.

Methodology: Monte Carlo Methods, Oracle Crystal Ball, and Risk Management methods were used to develop this methodology.

Findings: The findings indicate that the application of Risk Management combined with Monte Carlo Methods and Simulations into a Probability of Success Evaluator (POSE) tool can significantly improve the Probability of Success of a program achieving the desired program cost and schedule objectives. POSE can also be used to test various risk mitigation plans for a program to drive to a program plan the meets the program objectives. This dissertation further demonstrates how POSE can be used to effectively perform trades between various variables like risk mitigation and management reserves to derive the best value program solution for the required organizational program Probability of Success.

Practical Implication: This dissertation is aimed at delivering solutions to the problems in the field of Program Management. A formal user-friendly risk management process has been defined to help program managers accommodate risk and prepare for uncertainty. This dissertation has defined the POSE tool that utilizes a clear process for applying statistics and simulation to validate program plans before beginning and while managing program execution to determine the likelihood that the program will succeed in achieving the organization’s requirements. The POSE tool and process helps the Program Manger significantly better understand and manage the critical success and failure factors of the program and serves as a constant means to study and mange how to bring a program to completion successfully throughout the program.

Table of Contents

List of Illustrations

List of Tables

Chapter 1

INTRODUCTION

Overview: The introduction of this dissertation provides (1.1) an introduction to the field of Program Management including an explanation of the differences between Project, Program and Portfolio management, along with an explanation of why the focus of the dissertation is on Program Management in this dissertation; (1.2) why programs fail? ; (1.3) a discussion of how these program failures lead to the need for research into developing a tool called the Probability of Success Evaluator tool (POSE) to help remedy the problems of program failure; and (1.4) the organization of the dissertation.

1.1 Project, Program and Portfolio Management

The field of “Endeavor Management” may be classified into 3 categories: Project-, Program- and Portfolio Management. The definitions of each level are described in the paragraphs below. There are important similarities, differences, and overlaps in these categories, but many of the reasons for failure in each can be improved or eliminated by using the Probability of Success Evaluator (POSE) approach.

Project Management: The Project Management Institute (henceforth referred to as PMI) defines a Project as a temporary endeavor undertaken to create a unique product, service or result. There are four characteristics of a project: in that it has (1) an established objective, (2) a defined life span with a beginning and end, (3) typically does something that has never been done before, and (4) has specific time, cost and performance requirements (Project Management Book of Knowledge, fifth edition).

Program Management: The terms Project and Program usually cause confusion. PMI defines a Program as a group of related Projects designed to accomplish a goal over an extended period of time. The major difference in Projects and Programs lies in scale of effort and time span. There is no clear definition of the scale of effort or time span for each classification. It’s usually stated that a Project has a duration of 6 months and a Program has a duration of five years. In some industries, Program Management and Project Management are treated as synonyms; in others, Project Management is a subset of Program Management. (Project Management Book of Knowledge, fifth edition).

Portfolio Management: Portfolio Management often refers to selection and support of multiple project and program investments. These investments in projects and programs are guided by an organization's strategic objectives and the availability of resources. The content of this dissertation can be applied to portfolio managements, but it requires integration of individual program plans into a portfolio. (Project Management Book of Knowledge, fifth edition).

For this dissertation, the focus will be on applying the POSE approach to improve Program Management practices because programs represent the level of effort that is managed by those charged with the execution of complex endeavors made up of multiple projects (i.e., a Program), but not so large a responsibility as the management of whole Portfolios of Programs, as done say, for a whole company. So, focusing on Program Management applications of POSE provides the best illustration of the POSE value. It should be understood however, that POSE can also be applied to the other levels of effort as well, for Projects or even Portfolios if the Portfolio is treated as an aggregate of Programs to a single "Portfolio Program".

1.2 Problem Statement: Why Programs Fail?

Programs are measured across three attributes: Cost, Schedule and Performance of the program. Programs are subject to uncertainty thus leading to failure. Statistics show that only 26% of all programs attempted succeed (Mulcahy, Rita, 1999); this means 74% of all programs attempted fail. By "succeed", we mean the program was completed achieving all three of the promised Cost, Schedule and Performance requirements for the program. Furthermore, PMI interviewed 2900 Program Management practitioners across various industries in 2016 and concluded that 53% programs fail on Cost, 49% programs fail on Schedule and 62% programs fail on performance (Pulse of Profession, PMI, 2016). Despite the maturity of Program Management techniques, we still face a high rate of program failures.

Every aspect of Program Management has two dimensions—a technical dimension and a human dimension. The technical dimension encompasses those groups of practices or processes that are integral to Program Management, while the human dimension includes not only the people who are operating these processes but their specific expertise as well (Cooke-Davies, T. & Arzymanov, A., 2003). In this dissertation, we acknowledge only the technical dimension of Program Management, thus excluding all of the human dimension reasons for program failures; e.g., communication, leadership, etc.

The reasons for program failures have been extensively researched allowing us to conclude that the primary reasons for program failure are **Poor Planning**, **Scope Creep, Poor Execution**, and **Poor Risk Management** as explained below (Black, Ken, 1996, Larson and Larson, 2009, Matta, Ashkenas, 2003, PMI, Pulse of the Profession, 2016)

i) **Poor Planning:** Research conducted across 70 Program Managers found that 60% of the program failures were related to program planning (Black, Ken, 1996). After formulating the initial program plan, the plan needs to be validated to determine if it will execute the program in the estimated time and cost, and deliver the required performance (i.e., the required simultaneous program cost, schedule, and performance requirements known as the triple constraints). Due to lack of methodologies to predict the program execution on all three fronts (i.e. Cost, Schedule and Performance), program plans usually end up with unrealistic schedules and cost estimates. Getting this planning and forecasting correct is of paramount importance or else the program is doomed from the outset.

ii) **Scope Creep:** PMI defines Scope as the extent of what a project will produce (product scope) and the work needed to produce it (Project Scope). (Larson, Larson, 2009). Scope Creep is defined as adding features and functionality (project scope) without addressing the effects on time, cost and resources, or without customer approval. In the survey of PMI (2900 practitioners), it was concluded that 42% programs fail due to scope creep (PMI, Pulse of the Profession, 2016). This does not imply that addition of features is to be avoided, but this inevitable change needs to be incorporated in program plan knowing the effect on the whole program plan and whether this incorporation is viable as per the initial estimates.

iii) **Poor Execution**: Poor Execution is primarily due to uncertainty and risk faced by the program and the decision-making process that follows it. During execution, we need to monitor the program performance on a continuous basis and compare it to the baseline program plan. But if the program plan is poorly designed, then comparing the execution to a poorly planned program still leads to potential failure of the program. (Matta, Ashkenas, 2003).

iv) **Poor Risk Management:** Lack of-, or poor risk management practices is one of the prime reasons for program failure. The PMI survey shows that 31% of programs that failed lacked risk management practices (PMI, Pulse of the Profession, 2016). Furthermore, research was conducted for correlation between Program Success and Risk Management for 127 programs. Although, no correlation was found between the risk management practices and programs meeting their performance requirements, a statistically significant correlation was found between risk management practices and the program meetings its cost and schedule requirements (Tzvi Raz, Aaron Shenhar and Dov Dvir, 2002).

This dissertation aims at building a Probability of Success Evaluator (POSE) tool to address all of the above 4 reasons for program failure and uses risk management as one of the drivers to increase the Probability of Success of programs.

1.3 Research Objective: Probability of Success Evaluator (POSE) Tool

So, programs are seen to fail for the four major reasons discussed above. This dissertation provides the POSE tool to help reduce program failures by reducing or eliminating these four primary reasons for program failure.

Poor planning often underestimates the scope of effort required and does not account for the risks and uncertainty allowances and mitigations that must be included for a successful program. Programs also fail in execution because the plans were too poorly constructed to allow successful execution, or the control methods and visibility into the execution and the ability to adequately analyze and solve the changes/problems that occur are not available, or used effectively. We notice that all the four major reasons cited for program failure are inter-related and any one of these reasons can produce ripple effects causing the program plan to be vulnerable to all the four of them.

Current Program Management methods in sophisticated organizations have reduced program failure rates by focusing on planning and executing to simultaneously achieve planned cost, schedule, and performance goals using more sophisticated methods that include risk and opportunity assessment and mitigation efforts in their plans and execution plus the use of more sophisticated performance management systems (Earned Value Management System) to get a true picture of the value of the effort accomplished for the time and budget expended. However, even with these more sophisticated planning and execution tools, it is often difficult to roll all of these metrics up into a single, meaningful, easily understood, parameter that tells the Program Manager, the senior management and customers the status of achieving program success (i.e. performing the program for the required cost while achieving the required performance for the required schedule) at any time from the outset of program planning phase all the way through the full execution phase of the program.

This desired single meaningful roll up metric that conveys easily understood meaning for all involved is the Probability of Success (POS) parameter which can be calculated using an application of Monte Carlo Methods. In fact, some of the most sophisticated organizations now require the use of this POS parameter as a proprietary process in their program planning and pursuit approval process and during management of their programs. But there is no readily available POS methodology available for Program Managers outside of these organizations. So, it is the purpose of this dissertation to create a POS tool that is called Probability of Success Evaluator (POSE) that can be made available to the Program Management and business community that is an Oracle Crystal Ball- based commercial software application that can be easily implemented using the instructions and methodology contained in this dissertation. Based on the experience gained using this POSE tool and the very favorable response from experts in the Program Management field surveyed about the value of this POSE tool, it is believed that POSE may be very much appreciated and utilized when made available through a commercial offering (Subject Matter Expert: Dr. James Royce Lummus).

1.4 Organization of the Dissertation

Chapter 1 is the introduction. Chapter 2 is the literature review. Chapter 3 is the research methodology used for the dissertation. A survey was conducted as a part of this research, the survey results are discussed in Chapter 4. We use Monte Carlo Methods (Chapter 5) and Oracle Crystal Ball (Chapter 6) as tools for this dissertation. In Chapter 7 we discuss the pre-requisites needed to apply the POSE tool and introduce the POSE tool. In Chapter 8 we discuss application of POSE during program planning and in Chapter 9 we discuss the application of POSE during execution of a program. In Chapter 10 we demonstrate the application of POSE to a real world complex program plan. Chapter 11 concludes by summarizing the research and further research options.

CHAPTER 2

LITERATURE REVIEW

Overview: The purpose and organization of this literature review is to answer what the literature review, expert opinions and survey results say about (2.1) how we currently manage programs?; (2.2) what the shortfalls are with the current program management approaches ?; (2.3) what improvements in program management could be achieved with a POS metric and tool?; (2.4) is anybody out there today using a proprietary POS metric and tool successfully to improve their program management practices?; and (2.5) would it be a valuable addition to the practice of Program Management for everyone to have a POS tool?; thereby (2.6) justifying this dissertation which will make a viable commercial POS tool available to everyone.

2.1 How do we Currently Manage Programs?

Every program is managed based on 4 attributes: Cost, Schedule, Performance and Risk. In the field of Program Management there are two primary aspects: Planning the program and executing (or managing) the program. We will discuss the current process for planning and managing programs.

2.1.1 Current Program Planning Process:

This program planning process is a part of "Lockheed Martin Program Management Training Program" and derived from Program Management 101 and Program Management 201 coursework of Lockheed Martin.

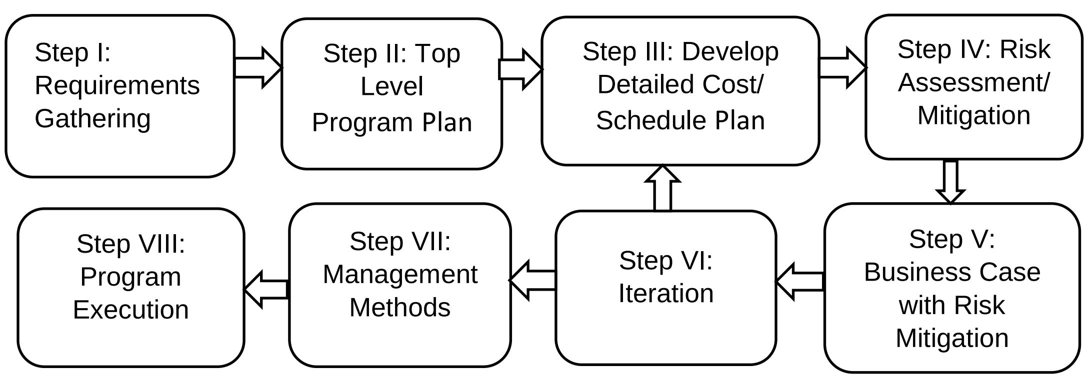

Figure 2.1: Current Program Planning Process

In reference to Figure 2.1, the sequential steps for program planning are as follows:

- **Step I: Requirements Gathering:** These requirements include the technical specifications, terms and conditions, goals and priorities and if any technical prior work is needed for the program. One of the most important outputs of requirements gathering is Statement of Work (SOW). PMI defines Statement of Work as “a narrative description of products or services to be supplied under contract”. (Project Management Book of Knowledge, fifth edition)

- **Step II: Top Level Program Plan:** This step has a “top to bottom” meaning, the requirements and statement of work which define the top-level deliverables are broken down into small work packages and allotted to teams in the organization. The primary outputs of this step are: Work Breakdown Structure (WBS), Organization breakdown Structure (OBS), Integrated Master Plan (IMP) and an estimated budget for each of the activities. See Appendix A for details.

- **Step III: Develop Detailed Cost/Schedule Plan**: We detail the WBS and OBS to allocate resources and budget for each activity. The primary output of this step is to formulate a cash flow for the whole program. This program plan is termed as the “Pre-Mitigated Baseline plan” and the resulting cash flow is the “Pre-Mitigated Baseline Cash Flow”.

- **Step IV: Risk Assessment and Mitigation Plans**: We run risk analysis on the baseline plan and formulate a mitigation plan for the possible risks the program can face. See Appendix A for details.

- **Step V: Business Case Analysis with Risk Mitigation plans**: In this step, we incorporate the risk mitigations plan in the baseline plan and the resulting program plan is termed as the “Risk Mitigated Plan” and the resulting cash flow is termed as the “Risk Mitigated Cash flow”.

- **Step VI: Iteration:** After the formulation of the risk mitigated plan, we compare the result with the program requirements and conclude if we have an acceptable plan to achieve the technical and business solution. If not, we keep running the iteration and adjusting detailed plan until we achieve one.

- **Step VII: Management Methods**: In this step, we define all the management methods and metrics to be used to track the progress and performance of the program.

- **Step VIII: Program Execution:** Once all the steps of the program planning are satisfied, we start executing the plan.

Detailed Explanations of each of the steps in Figure 2.1 is covered in Appendix A.

2.1.2 Current Methodology for Managing Programs:

Every program has four primary planning and control attributes (See Figure 2.2): Cost, Schedule, Performance and Risk. Nowadays organizations use the approach of **Integrated Management** which simultaneously assesses the metrics associated with all four of these attributes into the status of the program. (Piney,C 2007, Bodych, M.A, 2012)

Each of the attributes of a program have their own metrics and they are tracked simultaneously as the program is being executed for example: Cost Management uses the Earned Value Management System (EVMS), Schedule Management uses tools like Gantt Charts, Critical Path Method (CPM) and Program Evaluation and Review Technique (PERT), Performance Management uses Technical Performance Measurement (TPM) and Risk Management uses Probability and Impact Matrix. (Details of all the abbreviated methods are covered in Appendix B).

These techniques have proven very effective and are used across the industry. The issue faced by organizations is that a gamut of techniques results a large number of metrics. These metrics, although useful individually, do not directly or easily access the overall performance of the program; rather they assess performance of the 4 attributes of the program individually.

However, even with this Integrated Management Approach of looking at the metrics associated with cost, schedule, performance and risk, the Program Manager still has a difficult time providing himself and others of interest in the Program's success, an overall roll-up, easily understood, assessment of how the program is going and it will likely turn out (i.e., Probability of Success).

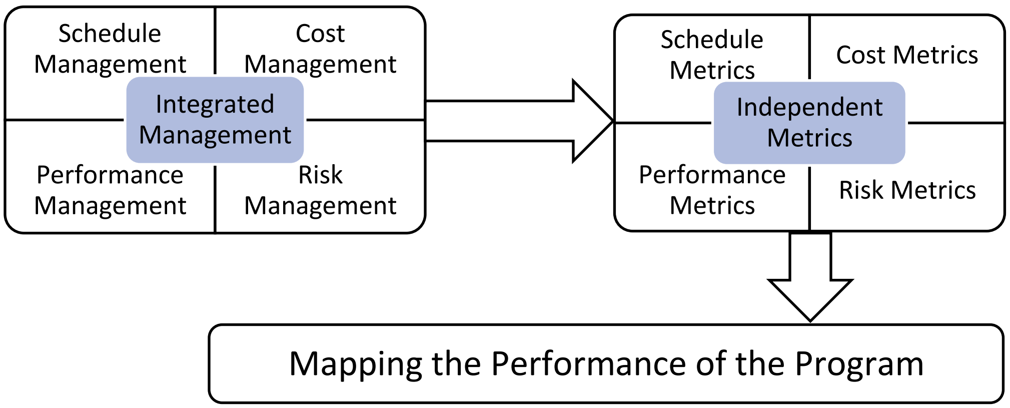

Figure 2.2: Current Program Managing Process

2.2 What are the Shortfalls with the Current Program Management Approaches?

As mentioned in Section 1.2 above, there are several accepted shortfalls in current Program Management approaches that lead to program failure: poor program planning, scope creep, poor execution, and the lack of risk management. This dissertation will show that there is another key shortfall in the current program management approaches that can be alleviated with the inclusion of the POSE tool developed in this dissertation which is the failure to provide an overall assessment of the program's Probability of Success.

The issue faced by organizations (see Figure 2.1 and Figure 2.2) is that a gamut of techniques results in many metrics. These metrics, although useful individually, do not easily allow determination of the overall performance of the program; rather they assess performance of the 4 attributes of the program individually which must somehow be mentally/ manually "integrated" to gain an overall assessment of program performance. However, even with this Integrated Management Approach of looking at the metrics associated with cost, schedule, performance and risk, the Program manger still has a difficult time providing himself and others of interest an assessment of the program's

Probability of Success (see Figure 2.3), which is an overall roll-up, easily understood, assessment of how the program is going and will likely turn out (Probability of Success).

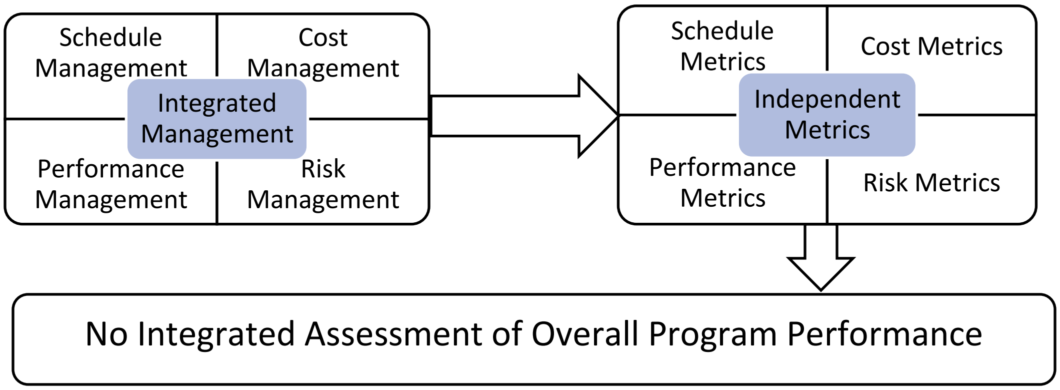

Figure 2.3: Shortfalls of Program Management

Organizations executing program use various methodologies and techniques for planning and managing programs. (See Appendix A). Over decades the techniques in the field of Program Management have evolved but there still exist drawbacks regarding these techniques.

Drawbacks of current Program Planning Techniques: The procedure we discussed in Section 2.1 and Figure 2.1 is a very detail oriented and meticulous process of drafting a program plan. Once the plan is formulated, the question remains whether this plan will really work to execute the program successfully or not? If it will work, what is the probability that it will achieve all the objectives of the program? POSE aims at validating whether a program as planned, has an expected and quantified Probability of Successfully achieving its cost, schedule and performance objectives by using Monte Carlo Simulation.

After the application of the POSE tool to a baseline program plan, the output of the POSE tool will answer the following questions:

- What is the probability that the program will succeed? By succeed, we mean achieve the required performance in the estimated cost and schedule.
- What is the probability of achieving a certain cost for the program considering that schedule and performance are constant?

- What is the probability of achieving a certain schedule for the program considering cost and performance are constant?
- Are the reserves, as defined for the program for both Management and Risk mitigation; enough to cover all the uncertainties that the program can potentially face?

POSE has the capability to answer these questions before we start executing the program; this capability is lacked by the current tools used in the industry.

The drawbacks of current managing techniques and using various metrics to measure program progress while executing programs is the difficulty to roll all of these metrics up into a single, meaningful, easily understood, parameter that tells the Program Manager, the senior management and customers the status of achieving program success (i.e. performing the program for the required cost while achieving the required performance for the required schedule) at any time through the full execution phase of the program.

Another drawback that is noticed is the lack of metrics to forecast the performance of the program. Metrics in EVMS, for example CPI, SPI and estimate at completion, although helpful for forecasting the cost and schedule to complete the remaining program, lack the ability to directly assist us in calculating the probability of achieving that estimate of cost at completion.

Similarly, to applying POSE during program planning, POSE also aims at answering the following questions:

- What is the probability of the remaining program successfully achieving the cost, schedule, or performance requirements of the program at any point during the execution of the program?

POSE aims at addressing the above question which is not being addressed by the current program management approaches. (In this version of POSE, we address only the cost and the schedule of the program. The next version of POSE will address the performance attribute of a program)

2.3) What Improvements in Program Management could be achieved with a POS Metric and Tool?

2.3.1 Impact of POSE on Program Planning:

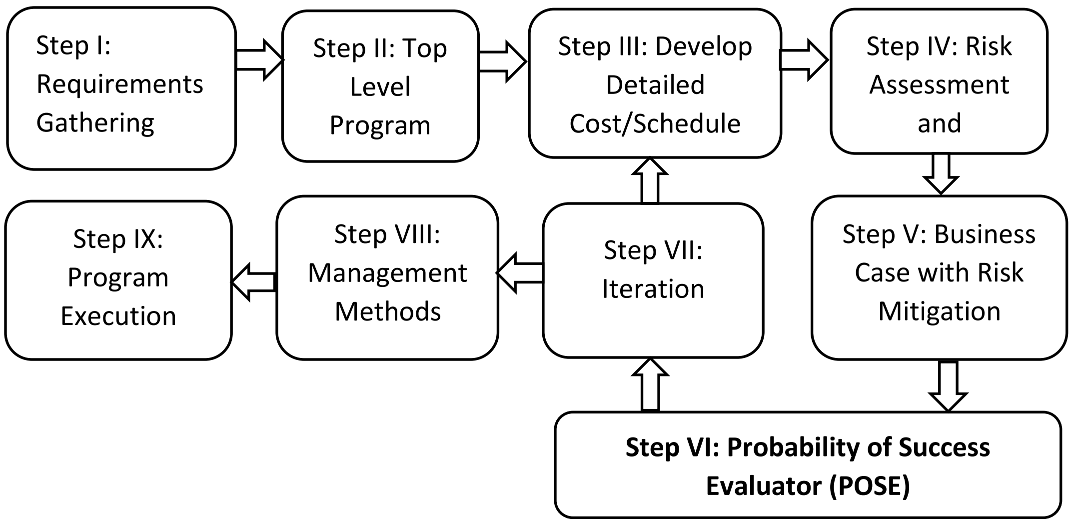

Figure 2.4: Impact of POSE on Program Planning

In comparison to the current program planning process (Figure 2.1), the modified program planning process (Figure 2.4 above) will have an added step (Step VI) employing the POSE tool to assess the overall Probability of Success of the program to achieve the desired cost, schedule, or performance (holding the other two metrics requirements constant) or for trading any three of the metrics to achieve a POS for a desired balanced of these three metrics; this of course is done considering a comprehensive risk assessment and risk mitigation planning included in the business and technical planning process.

The aim of this additional POS capability is to validate that we have achieved the program plan that will provide an acceptable business solution, that is, with an acceptable Probability of Success assessment even at the program outset. In the current program planning process, the iterations are continued until an acceptable program plan is derived. But even if an acceptable program plan is formulated, the probability of the plan executing the desired cost, schedule and performance per requirements might be low and is unknown unless a POSE analysis is performed which is not currently done by most organizations. POSE validates the business plan to achieve a certain Probability of Success of a program.

Example: Once a risk mitigated plan is formulated, after applying POSE to the plan, we might conclude that the probability of this plan succeeding is only 50%. Thus, by traditional method we might conclude that we have reached an acceptable solution, but a 50% Probability of Success dictates that the plan still needs to be substantially improved. In order to consider moving forward, the plan should have an acceptable POS which usually should be nearer to 80 or 90%.

2.3.2 Impact of POSE on Managing a Program:

POSE application to managing programs results in a shift from only using a gamut of metrics for cost, schedule, performance and risk to adding the powerful one integrated metric of Probability of Success to forecast the overall performance of the program.

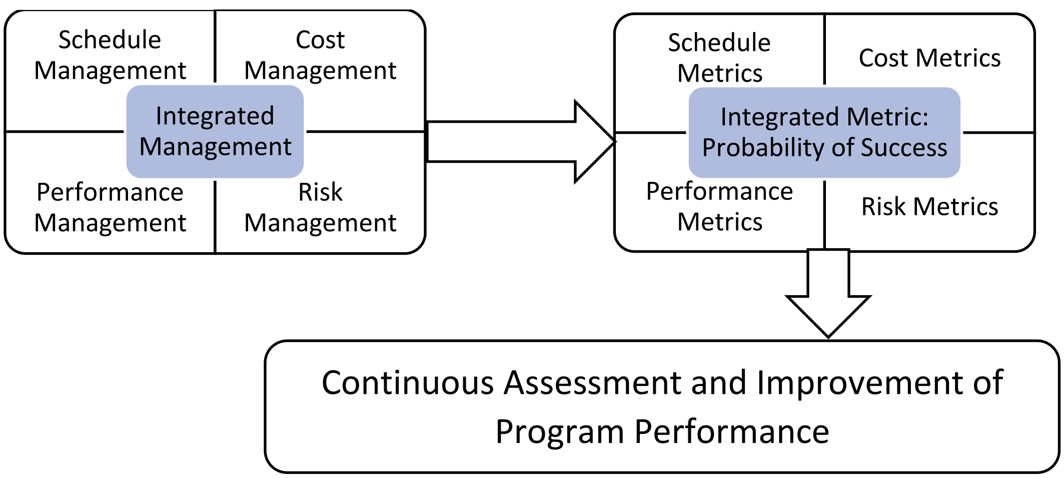

Figure 2.5: Impact of POSE on Program Managing

In the current method of managing, we use metrics to track the progress of the program and to help us estimate the future progress with respect to the cost, schedule, and performance program attribute parameters, but these methods often do not directly account for possible future risks and opportunities in the program. The application of POSE to managing programs helps us predict the Probability of Success of the remaining program by accounting directly for the future risks that a program will likely face or occur as they develop.

2.4 Is Anybody out there today using a Proprietary POS Metric and Tool successfully to Improve their Program Management Practices?

As we discussed in introduction Section 1.2, the 3 out the 4 attributes of a program (i.e. Cost, Schedule, and Performance) can be directly correlated to the risk in the program. The performance attribute can be correlated to risk in delivering the features of the program (Subject Matter Expert: Dr. James Royce Lummus). POSE uses an approach of linking the 3 attributes to risk, deriving a risk mitigated baseline and simulating it using Monte Carlo Simulations to derive the Probability of Success. There have been tools over the years that have managed to integrate two or more of these attributes to help plan and manage programs. Out of the recent developments in this field, integrated cost/schedule risk analysis using risk drivers (Hulett, 2010) and the event chain methodology (Lev Virine, 2011) have proven to be widely accepted by the Program Management community. These methods have been explained in detail in Appendix C.

There are two important differentiations between current methods and adding POSE: one is generation of a single metric called Probability of Success and the feedback loop to the program plan to provide continuous improvement. Methods similar to POSE are being used in defense organizations like Lockheed Martin and General Dynamics (SME Dr. James Royce Lummus and Mr. Mark Woolley). These organizations now use these metrics as a propriety process in their program planning and pursuit approval process and during management of their programs. Due to the lack of knowledge and high copyright of these techniques in the defense fields, these methodologies are not available for program managers across various sectors of the industry.

Furthermore, there are a lot of existing commercially available software for performing Monte Carlo Simulations and risk management example @Risk, Crystal Ball, etc. but studies have shown that application of Monte Carlo Methods to this field is still lacking (Kwak and Ingall, 2007). One of the aims of this research is to provide a step by step methodology of applying Monte Carlo Simulation to program planning and managing in the form of the POSE tool application.

This tool adds a lot of value to a program and answers some challenging questions about program planning and managing (SME: Dr. James Royce Lummus and Mr. Mark Woolley). There is no commercially available tool for program managers to use this methodology in their programs. Thus, the aim of this research is to formulate a tool called Probability of Success Evaluator (POSE), which defines the addition of the application of the POS parameter to program management and make it commercially available instead of just for a handful of organizations using these tools today.

2.5 Would it be a Valuable Addition to the Practice of Program Management for everyone to have a POS Tool?

The value proposition of POSE is the roll up metric of "Probability of Success (POS)". This metric can be used for the following:

- Correlating cost, schedule and performance of a program to the risk of the program.
- Validating a program plan and calculating the probability that the plan will execute the program successfully.
- Forecasting the program performance while being executed and addressing risk and opportunity in the remaining program.
- Deriving the probability of achieving a particular cost, while schedule and performance are constant.
- Deriving the probability of achieving a particular schedule, while cost and performance are constant.
- Deriving the probability of achieving particular performance level for a specified requirement set, while cost and schedule are constant. (Although this capability will not be included in this dissertation version of the POSE tool).
- Corroborating the management and risk mitigation reserves to help overcome uncertainties in a program.

This dissertation uses two ways to demonstrate the value of the POSE tool. One is by directly conducting interviews with Subject Matter Experts to determine their opinion about the value of the research and the value of having a POSE tool available to them. Second is to conduct a survey conducted across the potential users of the tool. This survey will be discussed in Chapter 4.0.

2.5.1 Interviews with Subject Matter Experts:

To justify the need for the research, interviews were conducted with subject matter experts regarding their opinions about the POSE tool:

Subject Matter Expert: Name: Dr. James Royce Lummus

Background: Dr. James Royce Lummus has practiced Program Management throughout his professional Life. He has been the Director of Program Management at Lockheed Martin Aerospace and spent 31 years at Lockheed Martin. He has been a Management consultant/Business Owner for more than 15 years consulting a wide range of companies from Fortune 500 to Mom and Pop Stores. He holds a Doctorate in Aerospace Engineering alongside 5 other degrees under his name. He is currently a faculty member at University of Texas at Arlington for over 10 years teaching Engineering Management and Program Management courses.

Interview: The below interview is a verbatim response of the interviewee:

Q1. Do you feel the application of Monte Carlo Simulation to the field of Program Management is adequately carried out across various sectors of the industry?

My experience from working in Aerospace and many other industries and businesses (Management Consulting for over 150 companies) is that only the most sophisticated companies do risk and risk mitigation analysis and even fewer do Probability of Success Evaluations. The concept is almost unknown by practicing Program Managers and business owners. When introduced to the concepts many are willing to embrace the concepts, but few have the discipline or experience to really adopt it and effectively utilize it even if they see the value. That's why an easy to use tool and process like the POSE tool would likely do a great deal to enable more companies to improve their Program Performance Success Rate.

Q2. The overview of the dissertations explains the basic aims of my research. Do you feel this research is needed? If yes, how do you think will it add value to the current practitioners in the field?

The POSE tool will enable the Program Mangers and Senior Management in their organizations to have the ability to constantly assess where they are on Program performance and take action to improve their success. The ability to have a straight forward simple tool and self- leading process, standardized process will take a lot of the fear and uncertainty out of performing a new management practice that they are not familiar with. My experience in companies that do use this process is that it becomes a very relied on process for program success and everybody from the CEO to the working Program Manger relies on it to understand and improve performance. It is the “go-to” gold standard for program assessment and performance improvement.

Q3. Do you think a single roll metric to assess the program performance is needed? Why?

The POS roll up metric is needed because, although we innately understand from our EVMS assessments where we are on cost (overrun or underrun) and schedule performance (behind or ahead) relative to the value of what we have accomplished for the time and money spent, and performance assessments (Technical or other critical Performance Measurements), we do not have the ability to roll of this information up to an integrated understanding what all of this really means about completing the Program as planned. We have individual pieces of the story but not an integrated assessment that helps us get a full picture of where we are. POS allows us to do that. It’s an indicator we can understand and use that puts all of the pieces together at all levels in the management chain from CEO to the worker level. The fact that we can determine three kinds of POS (POS of finishing for the cost, the schedule, or the performance, with the other two parameters help constant) is a great benefit in guiding how to do trades to achieve what becomes the real measure of success for the program as it progresses.

Q4. What do you think is the potential of the POSE tool if it is made commercially available to the industry including a training program for the same?

I would expect the POSE tool and training to be a commercial success and very valuable to many companies if it is well promoted. Making it a sponsored application of the Crystal Ball and Excel Software by the owners of these companies may be a way to achieve this sponsored promotion. I think getting the tool out to MBA Programs around the country and to the PMI are other ways to get the tool promoted. Obviously getting POSE out there and using it through consulting assignments and through introduction by trained MBA and Engineering Management students taking the tool into industry are other ways to get it widely used and valued.

Subject Matter Expert: Name: Mr. Mark Woolley

Background: After obtaining his MBA, Mr. Woolley was involved in strategic planning, internal and external consulting and special project analysis for over twenty-five years. He worked for or with CEO's at four public corporations and served as the Director of Strategic Planning for Lockheed Martin Aeronautics and as Corporate Vice-President of Strategic Planning for General Dynamics.

Interview: The below interview is a verbatim response of the interviewee:

Q1. Do you feel the application of Monte Carlo Simulation to the field of Program Management is adequately carried out across various sectors of the industry?

Based on the five corporations I worked for (primarily aerospace and defense and conglomerates), various consulting roles, and a review of a variety of academic publications, I found that Monte Carlo analysis is rarely used as an integral part of Program Management. It is also important to note that when Monte Carlo analysis has been employed, it is often either a: performed before a program commitment is made to assist with appropriate bidding or pricing given the risk factors and range of potential outcomes identified, or b: during a major program crisis in order to better understand the range of possible financial outcomes. I have not encountered any situation where Monte Carlo analysis is used on a continual basis throughout the life of a program to provide a better understanding of the ongoing probability of program success or to clearly segregate and better understand the distribution of potential outcomes and critical drivers of cost, schedule, risk and technical performance. In one particular instance, I was involved in twenty-five years ago (a major program crisis; the only time that Monte Carlo analysis was ever used during my tenure at that firm), the lack of senior management knowledge regarding Monte Carlo analysis was initially a major stumbling block. Only after running a number of preliminary simulations and providing a significant number of briefings, was the power of the analysis better understood. The program in question, which was large enough to constitute a separate division within the corporation, was significantly restructured and ultimately sold based on the Monte Carlo analysis performed because we could demonstrate that the underlying probability distribution was bi-modal – your either had tremendous success or very substantial failure.

Q2. The overview of the dissertations explains the basic aims of my research. Do you feel this research is needed? If yes, how do you think will it add value to the current practitioners in the field?

Q3. Do you think a single roll metric to assess the program performance is needed? Why?

Given the close interrelationship between questions 2 and 3, I have chosen to provide a combined response. The research is directly aimed at a very real issue that Program Managers and Senior Management all face. While they have a wide range of data, tools and techniques at their disposal, in order to assess overall program status at any point in time they must individually synthesize some or all of the available data and only then arrive at a truly unique viewpoint on how things stand. More importantly, they have no common means or frame of reference to rigorously evaluate the probability of program success, the range of probable outcomes for cost, schedule, risk or technical performance, or a clear method to determine how sensitive the probable outcomes are to specific facts or assumptions. Bottom line, each individual arrives at a viewpoint based on their own experience. Though I highly value hard-earned experience, there is no easy means for it to be consistently or widely shared or that the analogies a manager draws are correct for every new set of circumstances. The Probability of Success Evaluator that is being developed can provide a common frame of reference and rigorous analysis that is as good as the input provided. In many respects, the POSE tool will serve as a means of continuous program learning that can be applied to and single programs or programs with similar characteristics throughout an organization. Moreover, it sets a standard for common language concerning how a program is performing. I have personally encountered too many situations where the most vocal advocate of a viewpoint on a program or simply the most senior person in the room passes judgment. With appropriate training and usage, POSE will fill a critical gap and provide significant, concise and actionable information that can put all important parties on the same page.

Q4. What do you think is the potential of the POSE tool if it is made commercially available to the industry including a training program for the same?

I believe that POSE has strong potential for commercial success, but I believe it will start in a manner that is limited and carefully controlled – particularly in public corporations. In an environment where any program that is material to a public company is reviewed quarterly, discussed with external auditors in terms of profit rates and adequacy of reserves, and Sarbanes-Oxley is in the minds of responsible parties in finance, I would limit the output of POSE to selected individuals and treat it as company proprietary sensitive information. Since the output could certainly be misinterpreted unless the recipients are knowledgeable regarding Monte Carlo analysis (training is critical), care will need to be given – particularly with programs that are early in their life-cycle and employ either new product or process technology. Since the number of public companies has fallen by almost 50% in the past 20 years, this issue isn't a show- stopper, many major new organizations have chosen not to become public. I would initially focus marketing to non-public companies, consulting firms and selected, sophisticated public companies that manage large, high-dollar programs that often have independent cost estimating groups or other internal groups with similar roles (aerospace, defense, pharmaceuticals, petroleum, etc.). As Dr. Lummus suggested, making this a sponsored application of Crystal Ball or @Risk would be very valuable. Basing it on Excel is essentially a given. Exposure through the PMI or other similar organizations would certainly help. POSE is truly a unique tool that will appeal to the program management community and senior management.

2.5.2 Industry Opinion

A survey is conducted as a part of the literature review to gauge the industry response regarding the need of the tool. The survey response has been discussed in Chapter 4.0.

2.6 Justification of the Dissertation

The current method of planning and managing programs uses various numbers of techniques resulting in a gamut of metrics. These metrics though useful, usually make decision making difficult for program managers and management. There is need for a single roll up metric (POS) and tool (POSE) needed to improve the program planning and management practice. This kind of metric and tool is being used by highly sophisticated organizations as a proprietary method and is a preferred method for decision making.

The need for the tool is explained by the subject matter experts and verified by the survey analysis (will be discussed in Chapter 4).

Further, the tool provides with a methodology to validate program plans, monitor the performance and provides a feedback loop to help continuously improve the program plan further. It also helps us verify if the management and risk reserves will be sufficient with respect to the program execution.

We conclude from the above literature review that there is a strong need for the POSE tool in the field of program management and this dissertation aims at satisfying the need in the field.

Chapter 3

RESEARCH METHODOLOGY

Overview: This Chapter describes the objectives of the dissertation research and the deliverables that will result.

3.1 Objective of the Research

The objective of this research is to create a tool termed as “Probability of Success Evaluator (POSE)” based on Monte Carlo Methods to be applied to Project and Program Management planning and execution. This POSE tool defines a methodology to be applied to both Program Planning and Execution by providing the ability to calculate the Probability of Successfully achieving the desired cost and schedule of the program. (Calculating the Probability of Successfully achieving the desired Performance of the program is not included in this version of the POSE tool.)

3.2 Research Methodology

The literature review was conducted to assess the current practices in the field of Program Management, specifically with respect to the application of Monte Carlo Methods in Program Management practices. To further clarify the practicality of the research, a survey was conducted among the practitioners in the industry.

The survey is being discussed in Chapter 4.0. In this survey, 91 responses were collected from two pools of data. One pool of data is through a personal network, which resulted in 37 responses. The second pool of data is through the American Society of Engineering Management (ASEM), which resulted in 54 responses. Further conclusions in addition to the literature review about the current practices have been mentioned in this Chapter. There are two analyses done of the survey data: First is the comparative analysis between the two pools and second are the overall survey analysis results.

This research is focused on developing the POSE tool, which is an application of Monte Carlo Methods to the field of Program Management. In Chapter 5, we discuss the Monte Carlo Methods and principles in some detail, so the reader is referred there for more of these details. Our research started with becoming familiar with the history of Monte Carlo and the basic principle upon which Monte Carlo Methods are based, Bernoulli’s Law of Large Numbers. We discuss the basic working of the Monte Carlo Methods and Monte

Carlo Integration. Further, it is to be noted that the Monte Carlo Method is based on random sampling. Historically, many sampling methods have been presented by developers for different applications. We discuss Inverse Transform sampling which was the first method used by Ulam and John von Neumann when Monte Carlo Methods were invented. We discuss the Latin Hypercube sampling method to conclude the Chapter because it is the sampling method used by many Monte Carlo Simulation software across the industry in the field of Program Management.

In the next Chapter of our dissertation, i.e. Chapter 6, we have presented a user's manual for employing the Oracle Crystal Ball software which is the commercial software tool used in this dissertation for conducting the Monte Carlo Simulations required for POSE and is therefore the "engine- enabler" for the POSE tool. Oracle Crystal Ball is a Microsoft Excel- based software tool used for Monte Carlo Simulations, predictions and optimizations. In our user manual, we limit our discussion only to Monte Carlo Simulations, and demonstrate the use of the tool with an example. This user's manual is a concise version of the manual published by Oracle and is based on the book, "Financial Modelling with Oracle Crystal Ball and Excel" by John Charnes.

All the above Chapters in this dissertation are a pre-requisite to understand and implement the POSE methodology. The POSE methodology is discussed in the next 4 Chapters i.e. 7,8,9 and 10. The POSE tool will allow the user to determine the Probability of Successfully accomplishing the program for the desired cost or desired schedule at any point in the program life cycle, from inception to completion, by modeling risk/opportunities and associated cost and schedule distributions for the program. In Chapter 7, we introduce the POSE methodology and outline the pre-requisites required for application of POSE. The POSE methodology has 11 steps: the first 7 steps are applied during program planning (Chapter 8) and the last 4 steps are applied during program execution (Chapter 9). These steps are described in detail for achieving the cost and schedule attributes of programs. The POSE tool includes a step by step instruction guide for creating inputs to the POSE tool, for running the tool, and for determining and explaining the outputs; all the steps are explained by using a rather simple example program case. This simple example consists of generic terminology which is easily understood and can be replaced by the user to execute the program plan by just replacing the terms with specific information for his program. In addition to this simple example, in Chapter 10 we also demonstrate the application of the POSE tool to a much more complex program to demonstrate the detailed approach for planning a real-world program. The Chapter 11, summarizes the POSE conclusions that can be drawn from using POSE for decision making by management.

Further in Chapter 11, we also discuss further research possibilities for the POSEs area of research. The future research ideas have been drawn from two sources. One is the survey analysis conducted among the industry practitioners and the second is the potential problems and opportunities for further development which surfaced while conducting this research.

3.3 Conclusion

This Chapter outlines the objective and methodology that has been used to conduct this research. To summarize, there are 7 Chapters that cover the dissertation. Chapter 4 is the survey analysis, Chapter 5 and 6 are pre-requisite Chapters for understanding and applying the POSE methodology. Chapter 5 describes Monte Carlo Methods and Chapter 6 is the user`s manual for Oracle Crystal Ball. The POSE methodology is divided into 3 Chapters: Introduction to POSE (Chapter 7), application of POSE (7 Steps) during planning phase (Chapter 8), application of POSE (4 Steps) during execution phase (Chapter 9). These 3 Chapters have been explained with a simple example. Chapter 10 demonstrates the application of the POSE methodology to a real-world program. Chapter 11 summarizes the POSE methodology and the possible conclusions that can be drawn using the POSE methodology and the future research possibilities. Over the course of the dissertation, we will refer to excel spreadsheets to explain POSE steps; all of these excel files can be downloaded from the following link:

https://www.dropbox.com/sh/fx3ilox3u6hqhdl/AAAYI3CpF3Yvffh4O7JVomREa?dl=0

Chapter 4

SURVEY ANALYSIS

Overview: This Chapter discusses the survey that was conducted as a part of this research. In Section (4.1), we explain the questionnaire used in the survey. In Section (4.2), we discuss the approach and methodology to collect the responses. In Section (4.3) we do the analysis of the responses that have been collected from each of two pools, compare the results of the two pools, and then provide an overall discussion of these results. In Section (4.4), we summarize all of the results and focus on future research areas.

4.1 Survey Questionnaire

This survey questionnaire was devised for two purposes: (1) to understand the current program management practices that are used in the industry, and (2) to understand the need for and value of this research to develop a commercially available POSE tool that determines probability of program success to as a means to achieve improved program success.

Listed below is the questionnaire that was circulated to collect responses of the people working in industry with projects, programs and portfolio management.

1. Which of the following management methods do you use **to pursue or choose** business /program/projects? (mark all applicable answers)

   ☐ Quantitative Risk and Opportunity Analysis

   ☐ Monte Carlo Analysis

   ☐ Automated Decision Support tools

   ☐ Management Dashboards

   ☐ All the above

   ☐ None of the above

2. Which of the following management methods do you use **to manage** business/program/projects? (mark all applicable answers)

   ☐ Quantitative Risk and Opportunity Analysis

   ☐ Earned Value Management System

   ☐ Automated Decision Support tools

   ☐ Management Dashboards

   ☐ Monte Carlo Analysis

   ☐ All the above

   ☐ None of the above

3. When do you perform Monte Carlo Analysis to determine Probability of Success of programs? (mark all applicable answers)

   ☐ During Planning phase

   ☐ During Execution phase

   ☐ Both

   ☐ Do Not perform Monte Carlo Analysis

4. Which of the following tools do you use for project/program status and performance measurement? (mark all applicable answers)

   ☐ Earned Value Management system

   ☐ Technical Performance Metrics

   ☐ Monte Carlo Analysis

   ☐ None of the above

5. Do you think that there is a need for a tool to determine the Probability of Success of a program i.e. the likelihood of complete the program in the estimated Cost and Schedule and deliver the required performance? (mark only one answer)

   ☐ Strongly Disagree

   ☐ Disagree

   ☐ Neither Agree or Disagree

   ☐ Agree

   ☐ Strongly Agree

6. It is necessary to outline a step by step methodology regarding application of statistical method (Monte Carlo Analysis) to quantitative risk management. (mark only one answer)

   ☐ Strongly Disagree

   ☐ Disagree

   ☐ Neither Agree or Disagree

   ☐ Agree

   ☐ Strongly Agree

7. It is necessary to outline a step by step methodology regarding application of statistically monitor of program performance. (mark only one answer)

   ☐ Strongly Disagree

   ☐ Disagree

   ☐ Neither Agree or Disagree

   ☐ Agree

   ☐ Strongly Agree

8. It is necessary to design an automated decision support tool for managing programs to provide the best value suggestion. (mark only one answer)

   ☐ Strongly Disagree

   ☐ Disagree

   ☐ Neither Agree or Disagree

   ☐ Agree

   ☐ Strongly Agree

9. It is necessary to design program management dashboards to capture decisions in a user-friendly format. (mark only one answer)

   ☐ Strongly Disagree

   ☐ Disagree

   ☐ Neither Agree or Disagree

   ☐ Agree

   ☐ Strongly Agree

10. Which of the below features would you like in a tool to manage and execute projects/programs? (mark all applicable answers)

   ☐ It calculates the probability of achieving a particular cost at any point of time in the project/program lifecycle

   ☐ It calculates the probability of achieving a particular schedule at any point of time in the project/program lifecycle

   ☐ It calculates the probability of achieving a particular performance at any point of time in the project/program lifecycle

   ☐ None of the above are important features

4.2 Approach and Methodology for Data Collection

4.2.1 Finalizing the Questionnaire

The questionnaire that was circulated for the survey was the third draft of the survey. The first two sets of questionnaires that were formulated were tested in a focus group of 5 UTA students. All these 5 students had no industry experience, and everyone had taken the course OPMA 5364 i.e. Project Management at UTA. The idea behind this focus group was to test the language of the survey. The idea was that if an inexperienced student, with only basic project management knowledge can understand each question and option in the survey, then the survey should not raise any doubts when circulated to people in industry. This was done because the survey must be self-explanatory to the respondent since we cannot afford to lose a response because the respondent needs clarification.

After the trial of the questionnaire using two focus groups, the questionnaire was finalized for circulation. Please Note: Question no. 8 and 9 are questions for follow up research to this dissertation.

4.2.2 Data Collection

The POSE Survey was conducted using Survey Monkey, the online portal to conduct surveys. Along with the questionnaire, a basic description of the intended output of the research was shared with the respondents. This basic description is mentioned in as survey brief. Responses were collected from two sources: One is through the personal network of Dr. James Royce Lummus and Tejas Pawar, Second was through the American Society of Engineering Management (ASEM).

Survey Brief:

Overview of the dissertation: My dissertation is titled “Probability of Success in Program Management”, it aims at creating a tool termed as “Probability of Success Evaluator (POSE)” which can be used to derive an integrated metric to monitor and assess a program plan during planning and execution phase.

Why Probability of Success Evaluator (POSE)?

The issue faced by organizations is that a gamut of techniques results in many metrics. These metrics, although useful individually, do not easily allow determination of the overall performance of the program; rather they assess performance of the 4 attributes (cost, schedule, performance and risk) of the program individually which must somehow be mentally/ manually "integrated" to gain an overall assessment of program performance. However, even with the Integrated Management Approach of looking at the metrics associated with cost, schedule, performance and risk, the Program manger still has a difficult time providing himself and others of interest an assessment of the Program's Probability of Success, which is an overall roll-up, easily understood, assessment of how the program is going and will likely turn out (Probability of Success). This tool that will calculate the Probability of Success of a program is termed as Probability of Success Evaluator (POSE).

Application of the tool: The tool aims at answering the following four questions:

- What is the probability that the program will succeed? By succeed, it means achieve the required performance in the estimated cost and schedule.
- What is the probability of achieving a certain cost of the program considering that schedule and performance are constant?
- What is the probability of achieving a certain schedule of the program considering cost and performance are constant.
- Are the reserves defined: Management and Risk mitigation; enough to cover all the uncertainties that the program can potentially face?

Survey Analysis: The respondents of the survey are the target audience intended to use this tool. The respondent pool has been selected various sectors of the industry like IT, Pharmaceuticals, consulting, defense, aerospace, etc. The survey is aimed at drawing conclusions on the following:

- Understanding and application of Monte Carlo Simulation in real world, addressing the hindrances of the application on a wider scale.
- Focus on amplifying intended features of the resulting tool. Example: Which of the 4 attributes of a program are most critical to a program manager?

- Streamlining the performance of the tool to focus decision making to minimum possible criteria's encompassing all the applicable attributes of a program to measure the program plan efficiency and program performance while execution.

Summary: The literature review conducted for the dissertation shows the lack of applicability of Monte Carlo Simulation in the field of Project and Program Management. The intended metric of Probability of Success will add value to the field taking into consideration the current tools and lack of an integrated metric to assess program performance. Your responses will help me draw conclusions from the real world about developing the features in the intended tool.

Survey Reponses:

The survey responses were collected in two pools of data: First was through personal network and second was through the American Society of Engineering Management(ASEM).

In the first pool, we collected 37 responses. The respondent was emailed the link to the survey along with the basic description of the research (Survey Brief). A typical profile of a respondent in this category consisted work experience in handling projects, program or portfolios for an organization. Typical designations of the respondents were "Project Manager" or "Program Manager".

In the second pool, we collected 54 responses. In this approach, the survey was circulated among the closed group for the members of ASEM. The members of this organization are from the industry or academia. It is difficult to describe the profile of a typical respondent in this pool because it was accessed by people with a wide range of background. The survey brief was shared with the members, if they were interested by the research, they could read the whole description and fill out the survey.

4.3 Survey Analysis

4.3.1 Survey Analysis: Pool I

The first 4 questions of the survey focus on current practices in the industry. The response to the first two questions shows that approximately 70% of the industry people use quantitative risk and opportunity analysis and 60% use management dashboards to pursue and manage business. But even though 70% of respondents use quantitative risk and opportunity analysis, we can see that 62% do not even perform Monte Carlo analysis. So, this implies that majority of the respondents who use quantitative risk and opportunity analysis, do it by other methods except Monte Carlo Analysis. It is very difficult to understand which method is used by these respondents due to the abundance of options available like heuristics, expected value methods, etc. (Meyer, W.G. 2015). This dissertation focuses on application of Monte Carlo Simulations, so will not discuss about other possible methods. Further, 85% of the respondents express the need for defining a step by step methodology regarding application of Monte Carlo Simulation in quantitative risk and opportunity analysis

Further analysis of the survey also shows that the most common technique used for program status and performance measurement is Technical Performance Metrics (TPM), used by 86% of the respondents while the second most common technique is Earned Value Management System(EVMS), used by 68% of the respondents. This dissertation aims at defining a procedure to use Monte Carlo Simulations for program statusing and performance measurement and 98% of the respondents require such a process to be defined.

The intended research output is to develop a tool termed as Probability of Success Evaluator (POSE), to determine Probability of Success of a program that is to calculate the likelihood of completing a program in the estimated cost and schedule and deliver the required performance. 46% of the respondents strongly agreed, while 49% agreed (total: 95%) that there is need of a tool like POSE. POSE has three types of applicability as mentioned in question 10 of the survey:

- It calculates the probability of achieving a particular cost at any point of time in the project/program lifecycle.
- It calculates the probability of achieving a particular schedule at any point of time in the project/program lifecycle.
- It calculates the probability of achieving a particular performance at any point of time in the project/program lifecycle.

The below Table summarizes the interest of respondents in the feature. The ✓ in the box symbolizes the interest of respondents in the respective probability of the attribute.

Table 4.1: Question 10, Pool I Response

Probability of achieving a particular cost	Probability of achieving a particular schedule	Probability of achieving a particular performance	No. of Respondents
✓			2
	✓		7
		✓	3
✓	✓		5
	✓	✓	6
✓		✓	1
✓	✓	✓	13

From this pool, we can conclude that cost is of least concern for the respondents while heavy interest emphasis is laid on achieving schedule of a program. Further analysis of the above Table shows that out of 37 responses, 31 respondents want to calculate probability of achieving schedule, 23 respondents want to calculate the probability of achieving performance and 21 want to calculate the probability of achieving cost.

4.3.2 Survey Analysis: Pool II

The analysis and conclusions of the second pool are very similar to the first pool of response. It is seen that approximately 50% of the industry people use quantitative risk and opportunity analysis and automated decision support tool to pursue business and approximately 50% use quantitative risk and opportunity analysis and Earned Value Management System (EVMS) to manage business. But even though 50% of respondents use quantitative risk and opportunity analysis, we can see that 67% do not even perform Monte Carlo Analysis. So, this implies that majority of the respondents who use quantitative risk and opportunity analysis, do it by other methods except Monte Carlo Analysis. In this dissertation, we will be focusing only on the use of Monte Carlo. Further, 54% of the respondents expressed the need for defining a step by step methodology regarding application of Monte Carlo Simulation in quantitative risk and opportunity analysis.

The survey shows that the most common technique used for program status and performance measurement is Technical Performance Metrics (TPM), used by 78% of the respondents while the second most common technique is Earned Value Management System(EVMS), used by 61% of the respondents. This dissertation aims at defining a procedure to use Monte Carlo Simulations for program statusing and performance measurement, 50% of the respondents are in favor of defining such a process.

The intended research output is to develop a tool termed as Probability of Success Evaluator (POSE), to determine Probability of Success of a program that is to calculate the likelihood of completing a program in the estimated cost and schedule and deliver the required performance. 43% of the respondents strongly agreed, while 24% agreed (total: 67%) that there is need of a tool like POSE. POSE has three types of applicability as mentioned in question 10 of the survey:

- It calculates the probability of achieving a particular cost at any point of time in the project/program lifecycle.
- It calculates the probability of achieving a particular schedule at any point of time in the project/program lifecycle.
- It calculates the probability of achieving a particular performance at any point of time in the project/program lifecycle.

Table 4.2: Question 10, Pool II Response

Probability of achieving a particular cost	Probability of achieving a particular schedule	Probability of achieving a particular performance	No. of Respondents
✓			2
	✓		3
		✓	10
✓	✓		3
	✓	✓	2
✓		✓	2
✓	✓	✓	25
None	None	None	7

From this pool, we can conclude that cost is the least concern for the respondents while heavy interest is laid on achieving performance of a program. Further analysis of individual responses shows that out of 54 responses, 32 respondents want to calculate probability of achieving cost, 33 respondents want to calculate the probability of achieving schedule and 39 want to calculate the probability of achieving performance. There are 7 respondents with the opinion that none of the above 3 probabilities are important for program management.

4.3.3 Comparative Study of the Two pools

The pools represent a different set of population. Thus, we cannot statistically put the responses together and draw conclusions using the responses as one sample. Since, it is mathematically incorrect to do any analysis on the whole sample, we will just draw general conclusions regarding the overall direction pointed by the responses. Also, we will plot the response together to gauge the opinion regarding the research and development of POSE.

The responses of the two pools shows slight differences in percentage responses regarding the current practices and the opinions about the research, but overall, we can draw similar inferences from both the pools.

The most prominent difference in the two pools is seen in the responses for question 10. In pool 1, the most important attribute of a program from Cost, Schedule and Performance is Schedule, but in pool 2, the most important attribute of a program is Performance. At the inception of this research, the assumption was that cost is the most important attribute in program management, but as it is seen in the survey, in both the pools, cost is the least important attribute. In the next Section, we will graphical plot the responses of all the respondents to understand opinions of the respondents.

4.3.4 Overall Survey Analysis:

In this Section, we discuss the overall survey analysis. There is a total of 91 responses. Listed below is the graphical representation of the responses except for Q8 and Q9. After the graphical representation, we will discuss the survey results.

Below is the graphical representation of 91 responses.

1. Q1. Which of the following management methods do you use **to pursue or choose** business /program/projects? (mark all applicable answers)

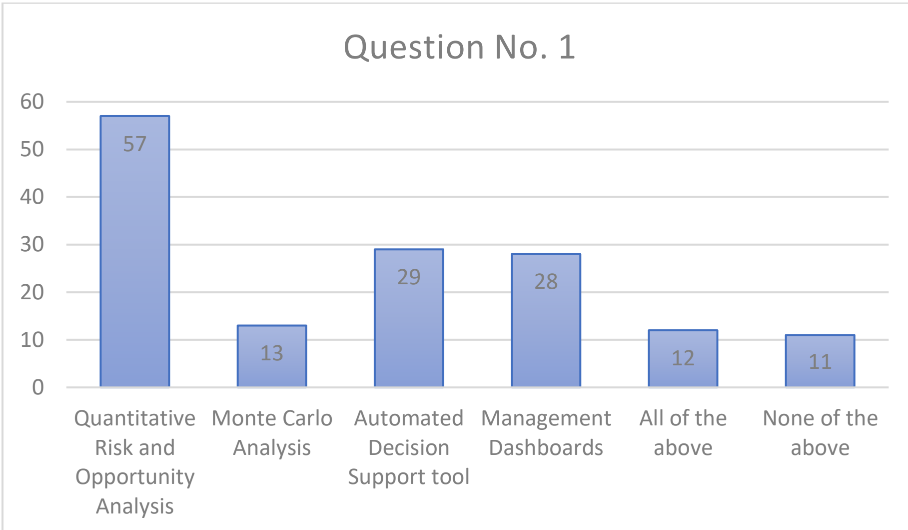

Figure 4.1: Response of Q1

2. Which of the following management methods do you use **to manage** business/program/projects? (mark all applicable answers)

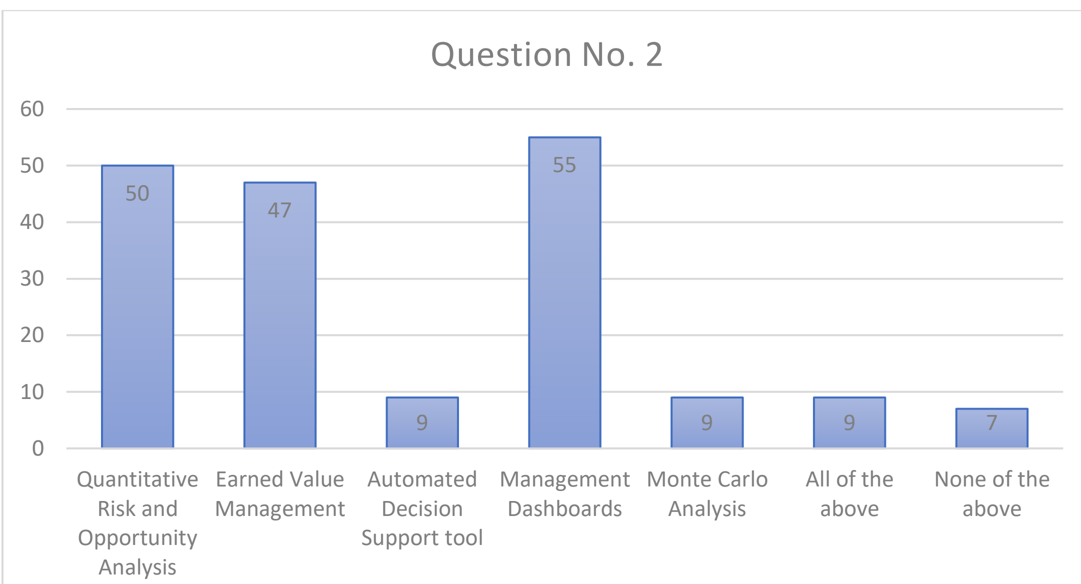

Figure 4.2: Response of Q2

3. When do you perform Monte Carlo Analysis to determine Probability of Success of programs? (mark all applicable answers)

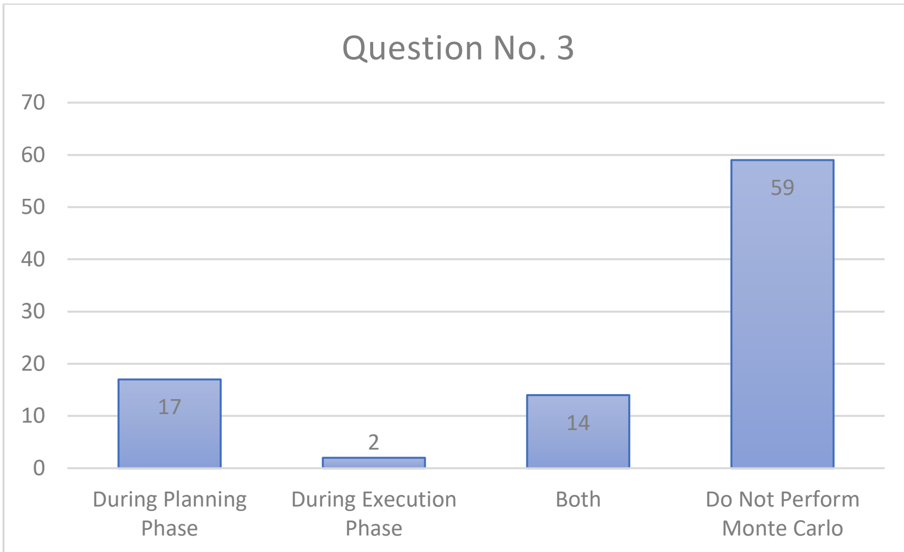

Figure 4.3: Response of Q3

4. Which of the following tools do you use for project/program status and performance measurement? (mark all applicable answers)

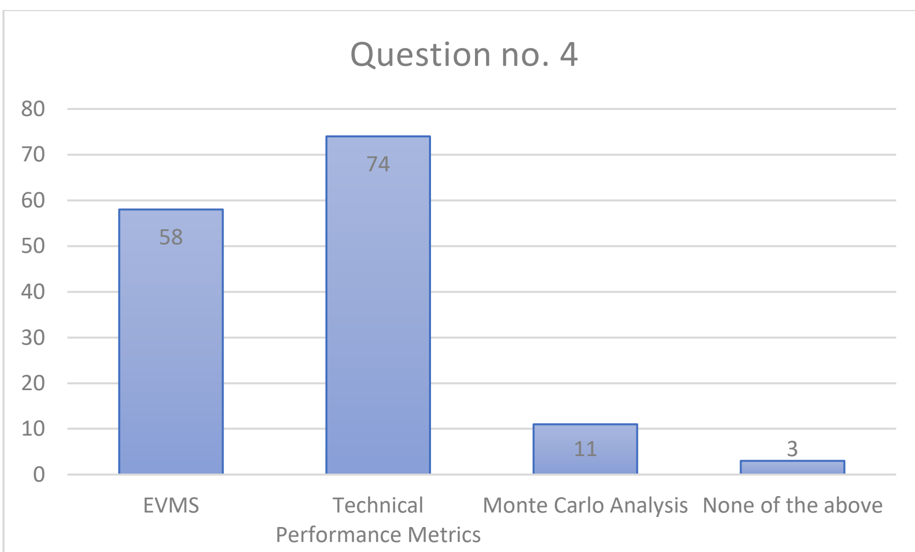

Figure 4.4: Response of Q4

5. Do you think that there is a need for a tool to determine the Probability of Success of your program that means the likelihood that you complete the program in the estimated Cost and Schedule and deliver the required performance? (mark only one answer)

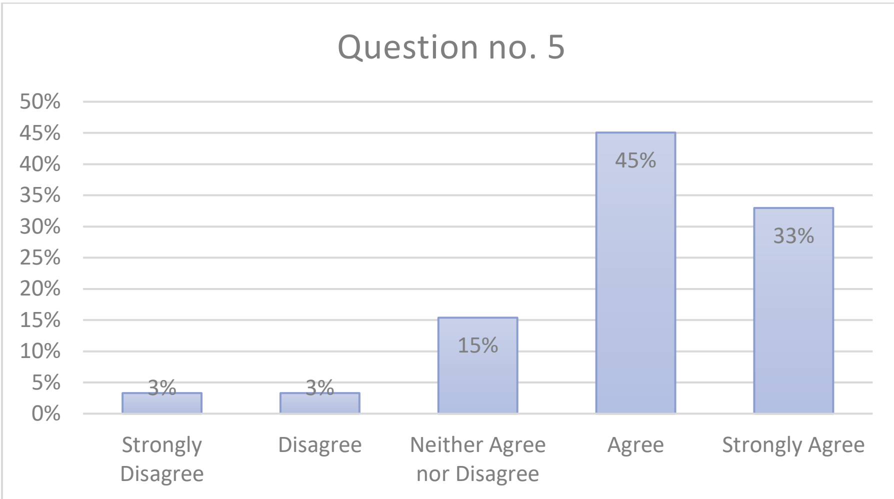

Figure 4.5: Response of Q5

6. It is necessary to outline a step by step methodology regarding application of statistical method (Monte Carlo Analysis) to quantitative risk management. (mark only one answer)

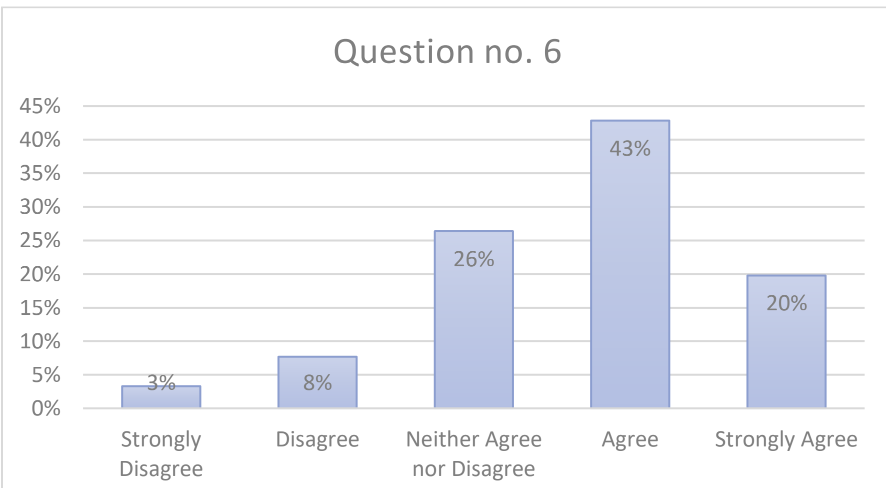

Figure 4.6: Response of Q6

7. It is necessary to outline a step by step methodology regarding application of statistically monitor of program performance. (mark only one answer)

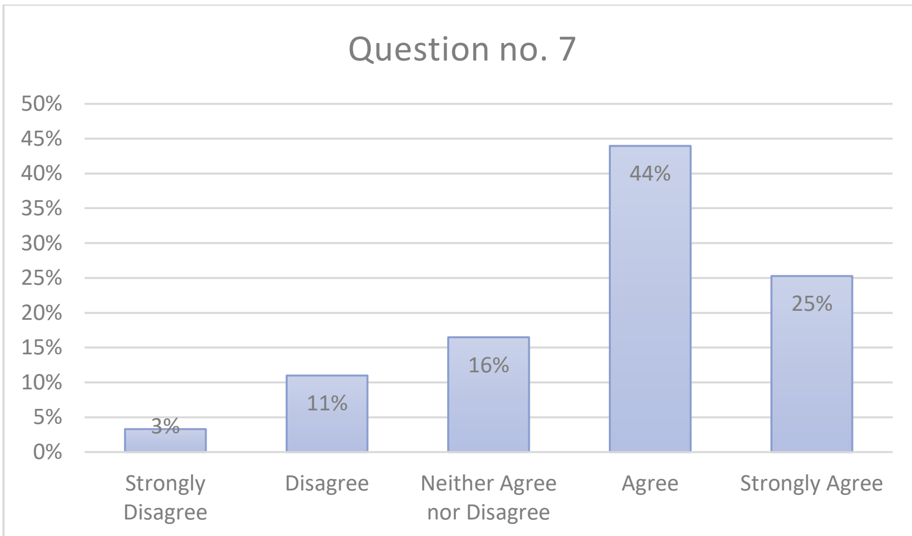

Figure 4.7: Response of Q7

No. 8 and No. 9 will be discussed in Chapter 11. (Future Research)

10. Which of the below features would you like in a tool to manage and execute projects/programs? (mark all applicable answers)

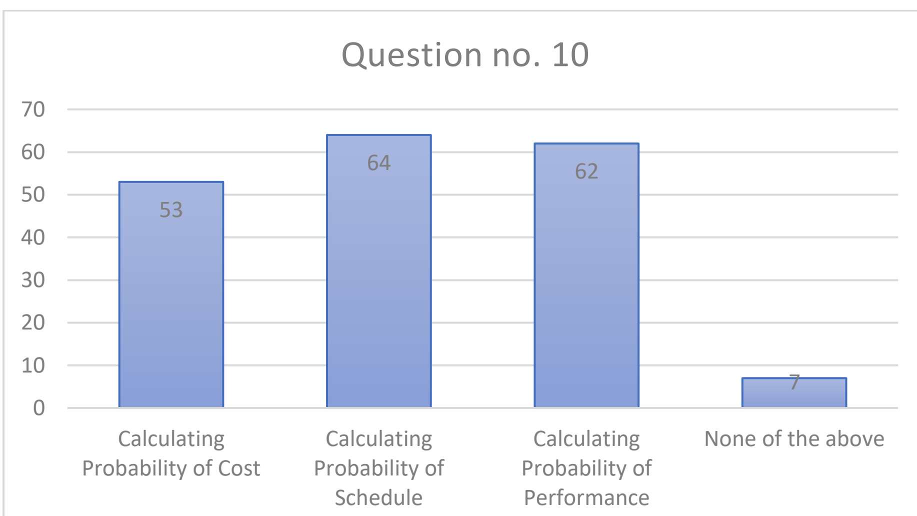

Figure 4.8: Response of Q10

The overall survey analysis is of the whole pool of data i.e. 91 responses. As we discussed, since the samples represent two different pools, so we cannot technically do any statistical analysis, we can only make general conclusions with respect to the all the responses.

General Conclusions: It is seen that 63% of the industry people use quantitative risk and opportunity analysis to pursue business opportunities. While 55% use quantitative risk and opportunity analysis, 52% use Earned Value Management System (EVMS) and 60% use Management dashboards to manage business. But even though approximately 55% of respondents use quantitative risk and opportunity analysis, we can see that 65% do not even perform Monte Carlo analysis. Further 63% respondents are in favor of defining a step by step process for quantitative risk and opportunity analysis using Monte Carlo Simulations.

The survey shows that the most common technique used for program status and performance measurement is Technical Performance Metrics (TPM), used by 81% of the respondents while the second most common technique is Earned Value Management System(EVMS), used by 64% of the respondents. This dissertation aims at defining a procedure to use Monte Carlo Simulations for program statusing and performance measurement. 69% of the respondents are in favor of defining a process of monitoring a program using Monte Carlo Simulation.

The intended research output is to develop a tool termed as Probability of Success Evaluator (POSE), to determine Probability of Success of a program that is to calculate the likelihood of completing a program in the estimated cost and schedule and deliver the required performance. 45% of the respondents strongly agreed, while 33% agreed (total: 88%) that there is need of a tool like POSE.

POSE has three types of applicability as mentioned in question 10 of the survey:

- It calculates the probability of achieving a particular cost at any point of time in the project/program lifecycle.
- It calculates the probability of achieving a particular schedule at any point of time in the project/program lifecycle.
- It calculates the probability of achieving a particular performance at any point of time in the project/program lifecycle.

The below Table summarizes the interest of respondents in the feature. The ✓ in the box symbolizes the interest of respondents in the respective probability of the attribute.

Table 4.3: Question 10, Overall Response

Probability of achieving a particular cost	Probability of achieving a particular schedule	Probability of achieving a particular performance	No. of Respondents
✓			4
	✓		10
		✓	13
✓	✓		8
	✓	✓	8
✓		✓	3
✓	✓	✓	38
None	None	None	7

From this pool, we can conclude that cost is of least concern for the respondents while heavy interest is laid on achieving schedule and performance of a program. Out of 91 responses, 64 respondents want to calculate probability of achieving schedule, 62 respondents want to calculate the probability of achieving performance and 53 want to calculate the probability of achieving cost. There are 7 respondents with the opinion that none of the above 3 probabilities are important for program management.

4.4 Conclusion

The survey analysis has provided valuable insight into the current practices in the industry and their opinion is about this research. Form this survey we can conclude that the intended output of the research will add value to current practices in the field of Program Management.

We can conclude from the survey, although quantitative risk and opportunity analysis is used by over 50% of the industry, application of Monte Carlo Simulation for this analysis is still not a common practice. Further, it is seen that Technical Performance Metrics

(TPM) and Earned Value Management System (EVMS) are two most commonly used methods for monitoring program status and performance of the program. Application is Monte Carlo Simulations for program statusing and performance management is not done by approximately 70% of the industry.

This dissertation aims at creating a tool called Probability of Success Evaluator (POSE), 88% of the respondents are in favor of this tool being created in order to add value to the field of Project/Program Management. Further, at the inception of the research idea, we were under the assumption that cost is the most important attribute among the 3 attributes of a program (Cost, Schedule and Performance). But after the analysis, it is seen that cost is the least important attribute while schedule and performance of a program are approximately of equal importance for the industry.

This dissertation defines the methodologies for calculating Probability of Success to achieve a particular cost and Probability of Success to achieve a particular schedule of a program; calculating the Probability of Success of performance of a program is a future research topic. The value of this research is clearly seen from responses that have been collected in this survey.

Chapter 5

MONTE CARLO METHODS

Overview: We start this Chapter with a discussion about (Section 5.1) the history of the Monte Carlo principle and the evolution of the method called Monte Carlo that arise from this principle. In Section (5.2), we discuss the basic principle of Monte Carlo Methods, mathematical workings of Monte Carlo Methods, and the sampling method used in this dissertation to execute Monte Carlo Simulations. In Section (5.3) we specifically discuss the application of Monte Carlo Methods in the field of program management. In Section (5.4) we discuss the conclusions we have reached about Monte Carlo Methods and Monte Carlo Simulations.

5.1 History of Monte Carlo Methods

An early variant of Monte Carlo Methods can be seen in Buffon's needle experiment, in which "pi" can be estimated by dropping needles on a floor made of equidistant and parallel strips. In 1930's Enrico Fermi first experimented with the Monte Carlo method he but did not publish anything about these experiments. (Metropolis, 1987)

The modern version of Monte Carlo Method was invented by Stanislaw Ulam, while working on the Manhattan project at the Los Alamos National Laboratory. Immediately after Ulam's breakthrough, Jon Von Neumann understood its importance and programmed ENAIC (the first computer) to carry out Monte Carlo calculations.

Ulam is quoted about his rationale behind inventing Monte Carlo Methods, "The first thoughts and attempts I made to practice [the Monte Carlo Method] were suggested by a question which occurred to me in 1946 as I was convalescing from an illness and playing solitaires. The question was what are the chances that a Canfield solitaire laid out with 52 cards will come out successfully? After spending a lot of time trying to estimate them by pure combinatorial calculations, I wondered whether a more practical method than "abstract thinking" might not be to lay it out say one hundred times and simply observe and count the number of successful plays. This was already possible to envisage with the beginning of the new era of fast computers, and I immediately thought of problems of neutron diffusion and other questions of mathematical physics, and more generally how to change processes described by certain differential equations into an equivalent form interpretable as a succession of random operations. Later [in 1946], I described the idea to John von Neumann, and we began to plan actual calculations." (Eckhardt, 1987)

The name, Monte Carlo, was suggested by Nicholas Metropolis, which refers to the Monte Carlo Casino in Monaco where Ulam's uncle would borrow money from relatives to gamble. (Metropolis and Ulam, 1949). The work of Ulam, Jon Von Neuman and Metropolis transformed this method of statistical sampling "from a mathematical curiosity to a formal methodology applicable to a wide range of problems" (Monte Carlo Method, 2005). Monte Carlo Methods first found its application in designing of nuclear weapons in the Manhattan Project. Although it developed in 1940's the Monte Carlo methods did not gain popularity until the 1990's. Over this period, many papers were published too refine the methodology and its applications. In this dissertation, we will only focus on application of Monte Carlo Method to the field of program management.

5.2 Monte Carlo Methods

The Monte Carlo method is basically the application of random sampling to problems in applied mathematics. While subtle doubts may appear, most problems can be treated without use of statistical theory. But to understand Monte Carlo methods, we assume that the reader has intuitive notion of the idea of probability. This means that the reader knows what is meant by the statement "The probability that a fair coin lands heads when tossed is ½.". Further the reader also needs to understand the definition of mutually exclusive and independent events in terms of probability. (Herman, 1956)

5.2.1. Basic principle of Monte Carlo Methods:

The basic principle over which Monte Carlo methods have been invented is "Bernoulli's Law of Large Numbers". This law states that independent repetitions of an experiment average over long time horizons in an arithmetic mean which is obviously not generated randomly but is a well-specified deterministic value. This exactly reflects the intuition that a random experiment averages if it is repeated sufficiently often. What does this mean? If we have a fair coin and we toss it, there are only two possible outcomes, either heads or tails. The probability of the individual outcome is 1/2. Now, if we toss the coin 10 times, we cannot guarantee that it will land 5 times on heads and 5 times on tails. But if we do it infinite number of times, it is expected that 50% of the outcomes will be heads and 50% will be tails. Further, this law was applied to how unknown probabilities can be approximated by samples. This means that if the outcome probability of an experiment is to be approximated, it can be done by repeating the experiment infinite number of times with samples from the input of the experiment (Bernoulli, J. 1899)

5.2.2 Working of Monte Carlo Method

A formal definition of Monte Carlo Methods was given by Halton (1970). He defined Monte Carlo as a method of “representing the solution of a parameter of a hypothetical Population, and using a random sequence of numbers to construct a sample of the population, from which statistical estimates can be obtained.”

Let us discuss the working of Monte Carlo Methods at a rudimentary level. Suppose, there are only two routes from your house, one goes to the university and the second goes to the stadium. Assuming the probability of going to class in the university is 0.2 and the probability of going to watch a sporting match is 0.8. Since there are only two possibilities, their individual probabilities have to sum up to 1. Now on a given day, where would you be if you left the house?

This is where Monte Carlo method is applied. Using the Monte Carlo method, at any given day we choose a random number between 0 and 1. If the number is between 0-0.8, then you go to the stadium for the sporting match or else you go to the university. The process of choosing a random number between 0 – 1 is termed as “sampling”. Sampling is the most important characteristic of Monte Carlo Methods. Now the law of large numbers states that, if you do this sampling for an infinite number of days, 80% of the days you will watch a match at the stadium and 20% of the days you will be in the university. This is a basic explanation for Monte Carlo analysis. But as we go into detail there are a lot more complications that arise regarding sampling and random number generation.

Now, that a basic description of Monte Carlo is done, let us discuss the Monte Carlo Method in mathematical terms for a general function we will call f(x). In this example we discuss Monte Carlo Integration and how Monte Carlo helps in “converging” the results to a specific arithmetic mean of the output.

Let us define an integral function as: $\alpha = \int_0^1 f(x)dx$

We need to determine α. We will use the Monte Carlo Method approach to solve this integral. Monte Carlo method is a model sampling method. A random number generator will generate a variable between 0 and 1. This random variable "u", used in function f(x) will result in one possible value of α say ά. So similarly, u_1 will result in $ά_1$, u_2 will result in $ά_2$ and so on u_i will result in $ά_i$. Now as per the principle of Monte Carlo analysis:

$$ά = (ά_1 + ά_2 + ά_3 + \ldots + ά_i)/ i.$$

Therefore, the Monte Carlo estimate of this integral will be:

$$ά = \frac{1}{n}\sum_{i=1}^{n} f(u_i)$$

where $u_1, \ldots, u_n$ are independently drawn from the uniform distribution on (0,1).Strong Law of Large numbers states that more test cases in an analysis involving randomness will increase our confidence in the results. Therefore:

$$ά \longrightarrow α \text{ if } n \longrightarrow +\infty$$

The above is the basic principle behind working of Monte Carlo Methods. The earliest sampling method that was used in Monte Carlo Methods was developed by Ulam and Von Neuman in 1947 (Eckhardt, 1987) termed as the "inversion method". In this method, it generates a random variable, from a distribution with a cumulative density function, F(x). (A cumulative distributive function or CDF of a function f(x), is the probability that the variable takes a value less than or equal to x). This method takes a random number, u, from the interval (0,1) and transforms it into a random variable, x, using the inverse of the X's distribution function, $F^{-1}(x)$. (Inverse Cumulative Distribution Function (ICDF): For a number p in the closed interval [0,1], the inverse cumulative distribution function of a random variable x determines, a value of x such that the probability of X<=x is greater than or equal to p. ICDF is the value that is associated with an area under the probability density function)

Following this sampling method, a series of algorithms were developed to increase the efficiency of sampling and Monte Carlo methods on a whole. The variation of Monte Carlo methods used today is termed a Markov Chain Monte Carlo (MCMC). The first paper published towards the development of the current version of Monte Carlo can be dated to Metropolis in 1953. (C Robert and G Casella). Due to lack of computing capabilities during that era, the next breakthrough in the development of Monte Carlo methods was in 1970 by Hastings, when he generalized the Metropolis algorithm. Some of credited algorithms in Monte Carlo were Geman and Geman (1984) which defines Gibbs Sampling for Monte Carlo methods. It was further developed by Tanner and Wang in 1987. It was only in 1990 that the use of MCMC came to mainstream statistics when defined by Gelfand and Smith. There are a lot of sampling methods defined for Monte Carlo methods, each with its own advantage and application. In this dissertation, we use Oracle Crystal Ball to perform Monte Carlo Method. Oracle Crystal Ball uses a sampling method termed as Latin Hypercube Sampling. In the next Section, we will discuss this sampling, to understand the simulation procedure in detail.

To summarize the application of Monte Carlo methods, we can say that Monte Carlo methods can be used to predict the behavior of a resulting population of a function, if can we draw infinite test samples from the input to the function. In addition, the variation in the expected result will decrease with increase in sample size of the inputs.

5.2.3 Latin Hypercube Sampling

What is Latin Hypercube?

A Latin hypercube approach was developed by Mckay et al (1979). Latin Hypercube Sampling (LHS) was demonstrated by Mckay (1979,1992) to, on average, be better than Monte Carlo Sampling for the selection of input variables and to be unbiased estimator. A Latin Square has a property that each of the three symbols A, B and C, appear only once in each row and column of a two-dimensional matrix as shown below:

$$\begin{pmatrix} A & B & C \\ B & C & A \\ C & A & B \end{pmatrix}$$

A Latin cube has the property that each symbol appears only once in each row or column of a three-dimensional matrix, as shown below in three layers of Latin squares.

$$\begin{pmatrix} A & B & C \\ B & C & A \\ C & A & B \end{pmatrix} \begin{pmatrix} C & A & B \\ A & B & C \\ B & C & A \end{pmatrix} \begin{pmatrix} B & C & A \\ C & A & B \\ A & B & C \end{pmatrix}$$

A Latin Hypercube has the property that each symbol appears only once in each row or column of a higher than three-dimensional matrix.

Latin Hypercube Sampling: A Latin Hypercube Sampling (LHS) is a form of stratified sampling that helps ensure that all the portions of the distribution are used to generate random variables. This sampling method is used in most of the Monte Carlo Simulation software like Crystal Ball and @Risk.

Let us discuss employing LHS for a general function f(x). The Figure 5.1 shows the cumulative distribution function f(x) being stratified into 5 equal parts:

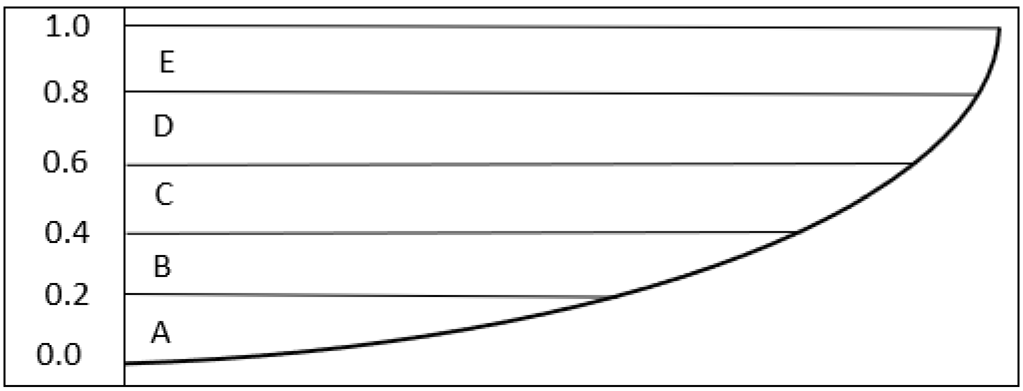

Figure 5.1: Cumulative Distribution Function F(X)

- Stratum A: Includes values of f(x) between 0.0 – 0.2
- Stratum B: Includes values of f(x) between 0.2 – 0.4
- Stratum C: Includes values of f(x) between 0.4 – 0.6
- Stratum D: Includes values of f(x) between 0.6 – 0.8
- Stratum E: Includes values of f(x) between 0.8 – 1.0

In LHS, you select one of the strata, then generate a random variable u, within that strata and compute the corresponding random variable, x. On the next trial, you will select another stratum, which has not selected and then generate a random variable, u, and then compute the corresponding random variable, x. You will continue this process until all of the process has been repeated for all 5 of the strata. This process will continue until we reach the defined number of trials. This is the sampling method that is used to generate random numbers in Crystal Ball as explained in the next Chapter.

5.3 Monte Carlo Method in the field of Project/Program Management

Monte Carlo Methods have a wide range application. They can be applied to Industrial Engineering, operations research, processes, economics, finance, etc. In dissertation, we focus on the application of Monte Carlo methods to program management. Henceforth, we will use the term Monte Carlo Simulations instead of Monte Carlo methods because in practical applications, it is a tedious process to choose random variables and run the experiment infinite number of times manually. So, with the computational abilities available, we use simulation to choose random variables and run the experiment. Hence the term Monte Carlo Simulation.

Project Management Institute (PMI) defines Monte Carlo Simulation as “a technique that computes and iterates the project cost or schedule many times using input values selected from probability distributions of possible costs or durations, to calculate a distribution of possible total project cost or completion dates”. Monte Carlo Simulation is not widely used in the field of project/program management, its primary uses in the field to quantify risk level of the program (Project Management Book of Knowledge, fifth edition).

Programs are uncertain by nature. One of the best ways to model uncertainty in programs is Monte Carlo Simulation. Programs in their early stages must balance the demands of accuracy with a scarcity of details. Ultimately, upper management wants to know how much the project will cost and how much funding will be requested. The cost of funding a project is an important aspect that should not be ignored. The capital the organization uses to fund projects, and specifically to support contingency or management reserve, is a tied-up commitment once the approval for project funding is received. The cost of capital used to support contingency and management reserve is a burden the organization bears until the project is complete and the remaining funds are returned. Longer projects should consider a strategically time-based allocation of contingency funds to reduce the cost of capital. (Barreras, Anthony J.,2011).

Although Monte Carlo simulation is an extremely powerful tool, but it is only as good as the model it is simulating and the information that is fed into it. If the project model or network is lacking information, the simulation will not reflect real-world activities accurately. If project task duration distributions used for a project duration simulation are incorrect or inadequate, the simulation will be off as well. Estimating the durations of project activities normally requires expert knowledge, and even when a three-point estimate is given to incorporate uncertainty into the model, there is still some latent uncertainty in the three-point estimate. Prior experience and detailed data from previous projects of the same type are both useful in mitigating this estimate uncertainty, although these data are often not available. Therefore, project manager must be very careful in both reviewing estimates and choosing probability distributions with which to model these estimates to avoid "Garbage In, Gospel Out" syndrome. (Kwak and Ingall, 2007).

The biggest drawback of using Monte Carlo Simulations in project management to simulate risk, cost and schedule is that simulations simply carry through each iteration. They consider all the samples as possible outcomes for the program. They assume no management action. (Williams, T. 2003). A few authors do include management decisions in their models, like Golenko-Ginzburg (1998) or Statoil's TOPPS system and TerreMar's DynRisk Package (Skogen & Huseby, 1992). This work has indeed recognized the need to incorporate management controls and actions, but the practical results of such actions is not obvious. To, address this issue, this dissertation demonstrates a method of simulating programs while being executed. After a management control or decision has been incorporated in the program plan, we can simulate the remainder of the plan to predict its execution Probability of Success.

Monte Carlo Simulations has not yet found a strong footing in the actual practice of program management in the “real world” probably because of lack of understanding (1) how to apply it, (2) its power to improve program performance, and (3) the lack of a practical available tool like POSE to make its use possible. The results of the survey in the previous Chapter also describe the lack of understanding and application of this statistical method.

5.4 Conclusion:

In this Chapter, we discussed Monte Carlo Methods and Monte Carlo Simulations. Although the method was invented in 1940's, the lack of computing abilities and technology were a hindrance for Monte Carlo Methods to be practical applicability. Monte Carlo was founded based on the Bernoulli's law of large numbers and has been continuously evolving since its inception. Monte Carlo Methods is a methodology of random sampling to predict the outcome. We described the workings of Monte Carlo Methods at a rudimentary level and followed that up with an example of how it can be used in integral functions. There are a lot of sampling algorithms developed over time, e.g. Gibbs Sampling, Metropolis-Hastings algorithm, etc., but it is not possible to go through all the sampling methods. We discussed the one sampling method called the "Latin Hypercube Sampling", which is used in the majority of software used for Monte Carlo Simulations and which is particularly used in the Oracle Crystal Ball software we are employing in POSE. We further discussed the application of Monte Carlo Methods using simulations in the field of Program Management. In this dissertation we use Oracle Crystal Ball to perform Monte Carlo Simulations. The next Chapter is a user manual to perform Monte Carlo Simulations for the POSE methodology.

Chapter 6

ORACLE CRYSTAL BALL

Overview: This Chapter outlines the user manual for Oracle Crystal Ball. Oracle Crystal Ball is a spreadsheet based (Excel add- in) application used for predictive modelling, forecasting, simulation and optimization. But, we restrict this manual only to Monte Carlo Simulation and the functions are to be used for POSE. In Section 6.1, we outline an introduction to the tool and the example to be used to describe the tool. In Section 6.2, we discuss Monte Carlo Simulation process using Crystal Ball. In Section 6.3, we discuss the use of decision variables in Crystal Ball and POSE. In Section 6.4, we discuss how the initial assumptions must be changed after analyzing the results using Monte Carlo Simulations. To download, install and license Oracle Crystal Ball, the reader is referred to Appendix D.

In this chapter, we will refer to excel spreadsheets for simulation purposes. These spreadsheets are available for download from the link:

https://www.dropbox.com/sh/fx3ilox3u6hqhdl/AAAYI3CpF3Yvffh4O7JVomREa?dl=0

in the folder named Chapter 6. For the reference of the reader, a snapshot of all the referred excel spreadsheets in mentioned in Appendix G. The snapshot in the appendix has the same name as the referred excel spreadsheet.

6.1 Introduction to Oracle Crystal Ball

This Chapter acts as a manual for the user to understand and employ Oracle Crystal Ball. This Chapter is based on two sources: The Oracle Crystal Ball manual published by Oracle on its website. The second source is the book, “Financial Modelling with Oracle Crystal Ball and Excel” by John Charnes. This Chapter is a concise version of these two sources to discuss the functions used in the POSE methodology. Oracle Crystal Ball is an Microsoft Excel Add-in. This means that when we work with Crystal Ball, it is the same as working in Microsoft excel. We can incorporate all the functions that are provided by Microsoft excel and then just use Crystal Ball to run the Monte Carlo Simulation. Crystal Ball is additional tab which appears next to the view tab in Microsoft excel. Throughout the dissertation, there are reference spreadsheets provided to practically execute the programs in the dissertation. All these spreadsheets are Microsoft excel files. When running all the spreadsheets mentioned in the dissertation, the user needs to have Microsoft excel and Oracle Crystal Ball installed. (For installation of Oracle Crystal Ball, refer appendix D). Further, please note all the popular spreadsheet programs are capable of reading the spreadsheets provided in the dissertation, but Oracle Crystal Ball works only with Microsoft Excel. When we open Crystal Ball, it opens a Microsoft excel spreadsheet and Crystal Ball is an additional tab. The enhanced image of the crystal ball tab is as shown in Figure 6.1.

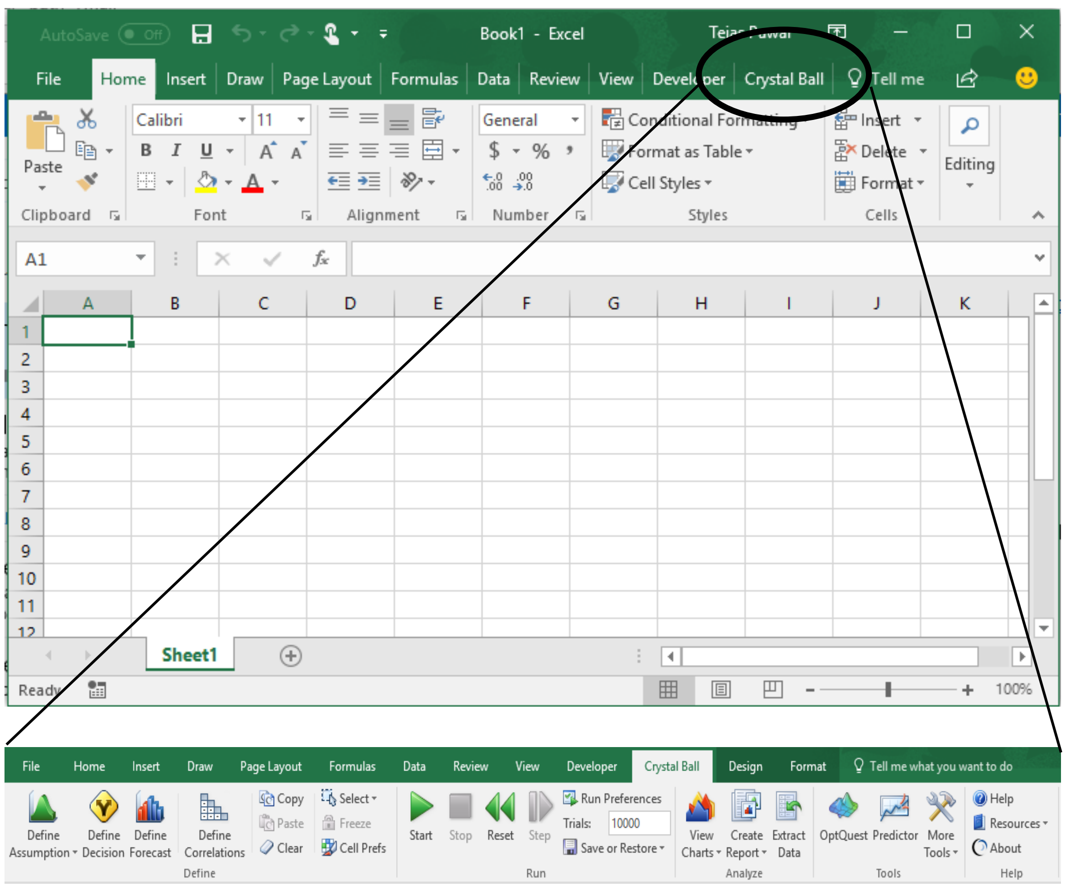

Figure 6.1: Oracle Crystal Ball

In this Chapter, we use a very basic example of 3 resources needed to build a product. Remember, a large aspect of a simulation procedure is decision making. Over the course of this Chapter, we will make decisions like to outsource and buy in bulk. Do not focus on these decisions. These decisions are put in place to best explain all of the intended features of Oracle Crystal Ball.

Consider the following Example: We need to manufacture a product; it requires resources: raw material, labor and machinery. The estimated cost of raw materials is $40, labor expense is $30 and price of machinery is $30 respectively. In a stable environment with no variations/uncertainties, our total product cost is 40+30+30 = $100. This will be the final expected total product cost and there is no other possibility. In the real world, variations and uncertainties lead to changes in the process/output. To account for the real world potential variations, we define the costs of the resources as a distribution of costs. Let us consider that the cost of each of these resources is defined by a triangular distribution as shown in Table 6.1.

Table 6.1: Estimated Total Cost of the Product

	Minimum Cost	Estimated Cost	Maximum Cost
Raw Materials	35	40	45
Labor	27	30	33
Machinery	24	30	36
Total Estimated Cost		$100	

Total Estimated Cost = Estimated Cost of Raw Materials + Estimated Cost of Labor + Estimated Cost of Machinery

6.2 Monte Carlo Simulation

Assuming that we have properly purchased, licensed and installed Crystal Ball on the PC, when we open Crystal Ball it will open a blank Microsoft Excel spreadsheet page. When we open this spreadsheet, in the menu bar we see options of File, Home, Insert, Draw, Page Layout, etc. In this menu bar the last tab will be Crystal Ball. When we click on the Crystal Ball Tab, you will see the Crystal Ball as shown in Figure 6.1. Now, we use Oracle Crystal Ball to run the Monte Carlo Simulation on the total product cost. Crystal Ball will help to determine the likely total product cost considering the variation in the individual costs of the resources.

The input model for the Monte Carlo Simulation is as defined in Table 6.1. The Monte Carlo Simulation has 4 steps: Defining Inputs, Running the simulation, Analyzing the output and Feedback to the model. This process is shown in Figure 6.2 below:

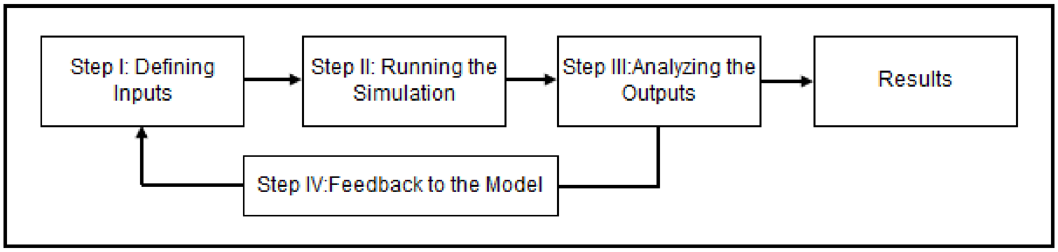

Figure 6.2: Monte Carlo Simulation Process

6.2.1 Step I: Defining Inputs

In this Step, we define the model that is to be simulated. We use the “Define” tab of the Crystal Ball shown in Figure 6.3.

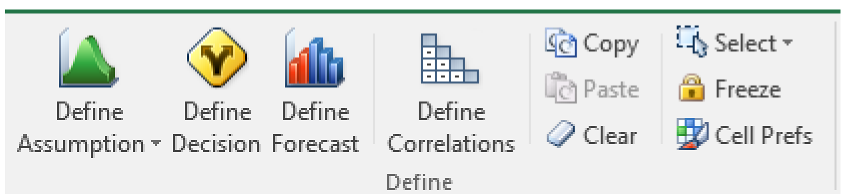

Figure 6.3: Define Tab of Crystal Ball

Refer Spreadsheet: Chapter 6_Initial Estimates (Snapshot in Appendix G)

We develop a model that “behaves like” the real problem, with a special consideration of the assumptions. In this Section, we define assumptions, forecast and define correlations. Defining a decision variable requires a slightly different approach, this will be demonstrated in Section 6.3.

The Functions of Copy, Paste, Clear, Select, Freeze and Cell preferences are typical functions used for basic formatting purposes of the spreadsheet.

- Copy: This will copy Crystal Ball data from one cell to another
- Paste: This will paste the copied Crystal Ball data
- Clear: This is clear the Crystal Ball data from a cell.

- Select: This will select all the cells with their respective Crystal Ball data. If we select the cells how we normally do in excel, it will not select the Crystal Ball data, it will select only the contents of the cell.
- Freeze: This freezes the Crystal Ball data in a particular cell.
- Cell Preferences: This helps you choose the color for various Crystal Ball inputs.

6.2.1.1 Define Assumptions

In any model, there are factors or variables that are uncertain. These factors are termed as assumptions and are defined as a distribution, based on historical data or expert opinion. In Crystal Ball, we can select the distribution or Crystal Ball can find the best “fit” for the data. To define an assumption, select the cell or range of cells. The cells can be blank or have numeric values, but cannot have a formula or text. In the Define tab click Define Assumption. For each of the selected cells a gallery box as shown in Figure 6.4 will be seen. In this distribution gallery, select the distribution to be defined, fill the required parameters for the distribution and press ok, or we can select Fit button in the bottom to fit a distribution to historical data. In order to fit a distribution to a historic data, Crystal Ball needs a minimum sample of 15 to fit a distribution. In our case, we will be working with triangular distribution. Let’s define the assumptions as shown in Table 6.1 using triangular distribution.

Each of the assumptions as mentioned in Table 6.1 are defined as triangular distributions as shown in Figures 6.5, 6.6 and 6.7. We define the minimum, maximum and the likeliest value for each of the assumption (resources) required to build the product. Once we define the assumptions, the cell turns green as shown in Table 6.2.

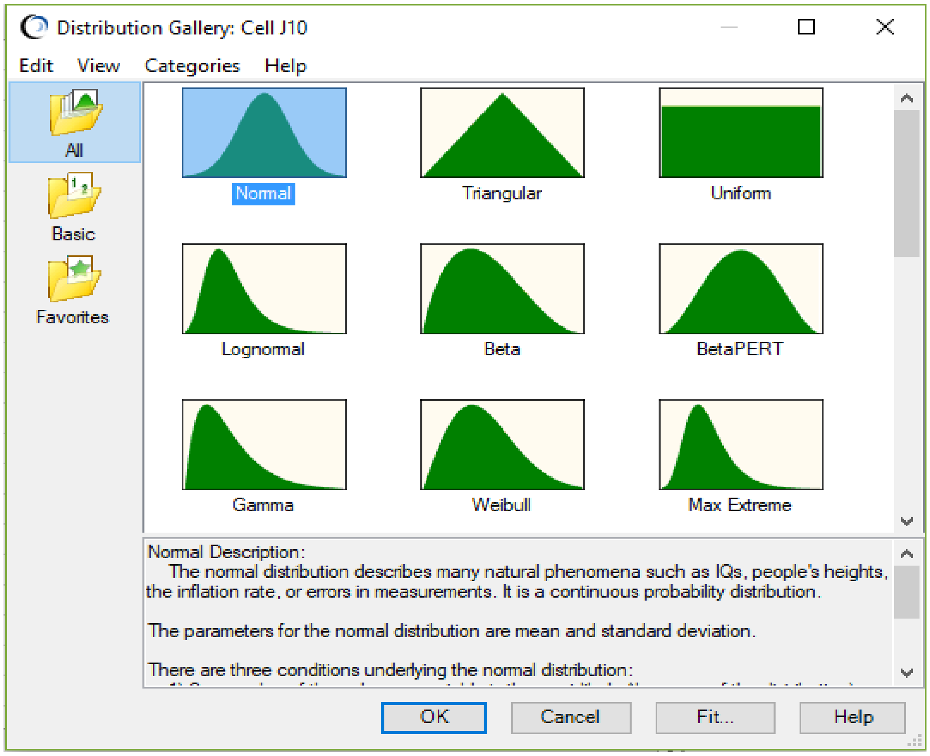

Figure 6.4: Distribution Gallery of Crystal Ball

- Assumption 1: Estimated Cost of Raw Materials

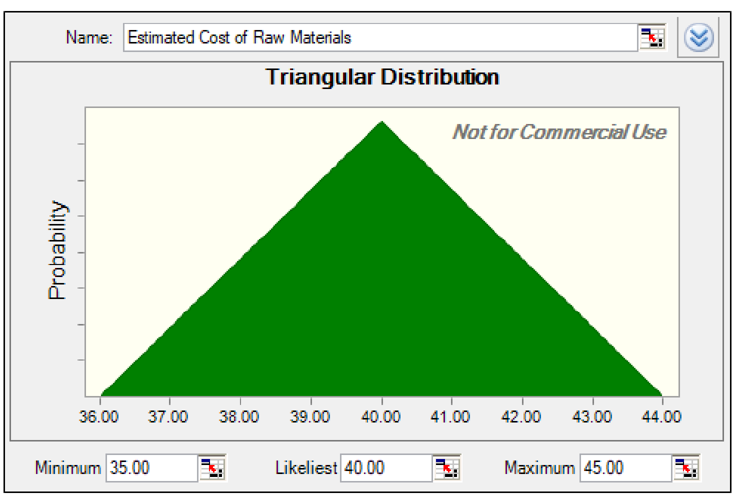

Figure 6.5: Defining Assumption “Estimated Cost of Raw Materials”

- Assumption 2: Estimated Cost of Labor

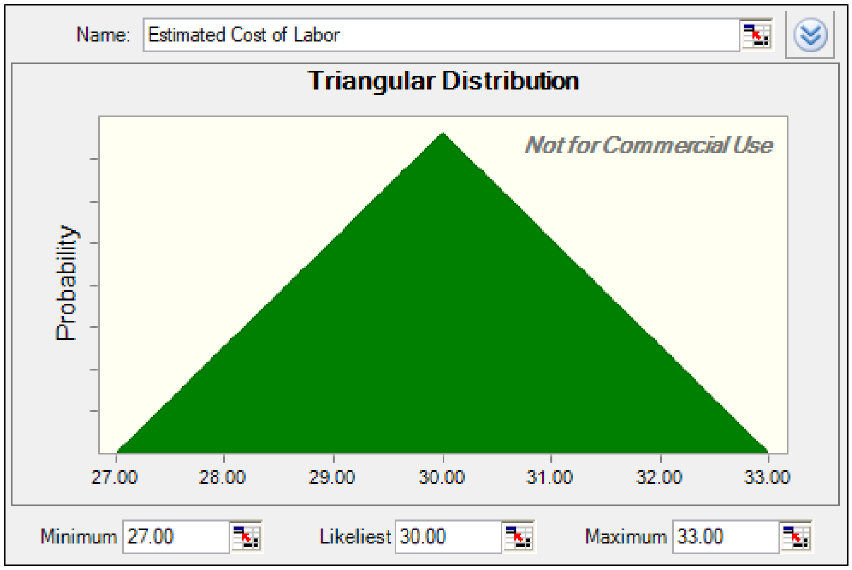

Figure 6.6: Defining Assumption “Estimated Cost of Labor”

- Assumption 3: Estimated Cost of Machinery

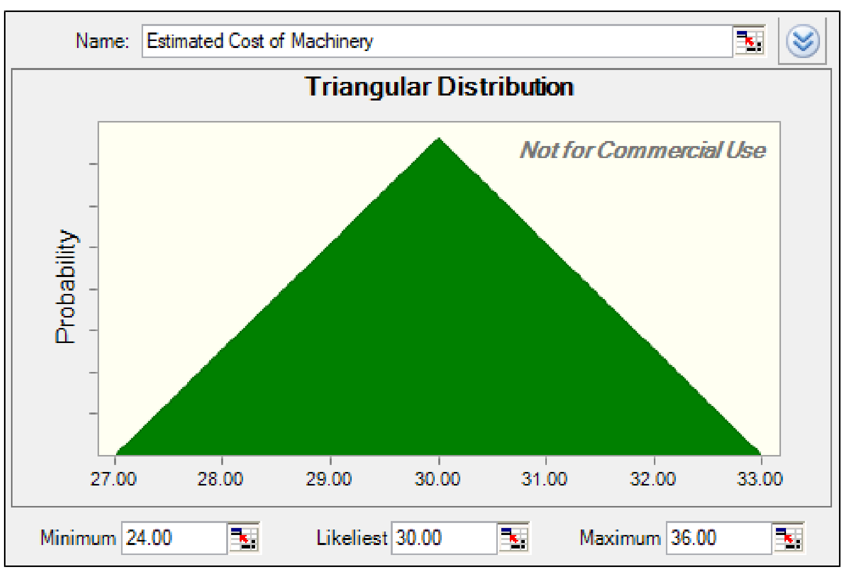

Figure 6.7: Defining Assumption “Estimated Cost of Machinery”

6.2.1.2 Define Forecast:

A forecast variable is defined as a function of the assumptions and decision variables. The forecast variable must be defined as a formula, this example the forecast variable is the “total estimated cost” of the product, which is defined as the summation of estimated cost of raw materials, labor and machinery. Crystal Ball will not allow a cell with a numerical value to be defined as a forecast variable.

Total Estimated Cost = Estimated Cost of Raw Materials + Estimated Cost of Labor + Estimated Cost of Machinery

To define a forecast cell, select the formula cell or cells, in the define tab, click define forecast. A dialogue box will appear as shown in Figure 6.8. In this dialogue box, enter the name of the forecast variable and the units of the forecast. In our example, the name of the forecast is “total estimated cost” and units is “$”. All other are defaults settings, any changes to be made can be done by expanding the forecast dialog box. Then Click OK.

Note: We can describe a forecast variable of a function of decision variables also. Defining a decision variable has a different approach as compared to assumptions, it will be discussed in Section 6.3.

Once a forecast variable is defined, the cell turns blue. The excel spreadsheet will look like the Table 6.2, where green cells denote assumption variables and blue cells denote forecast variables.

Table 6.2: Spreadsheet after defining assumption and forecast variables

	Minimum Cost	Estimated Cost	Maximum Cost
Raw Materials	35	40	45
Labor	27	30	33
Machinery	24	30	36
Total Estimated Cost		100	

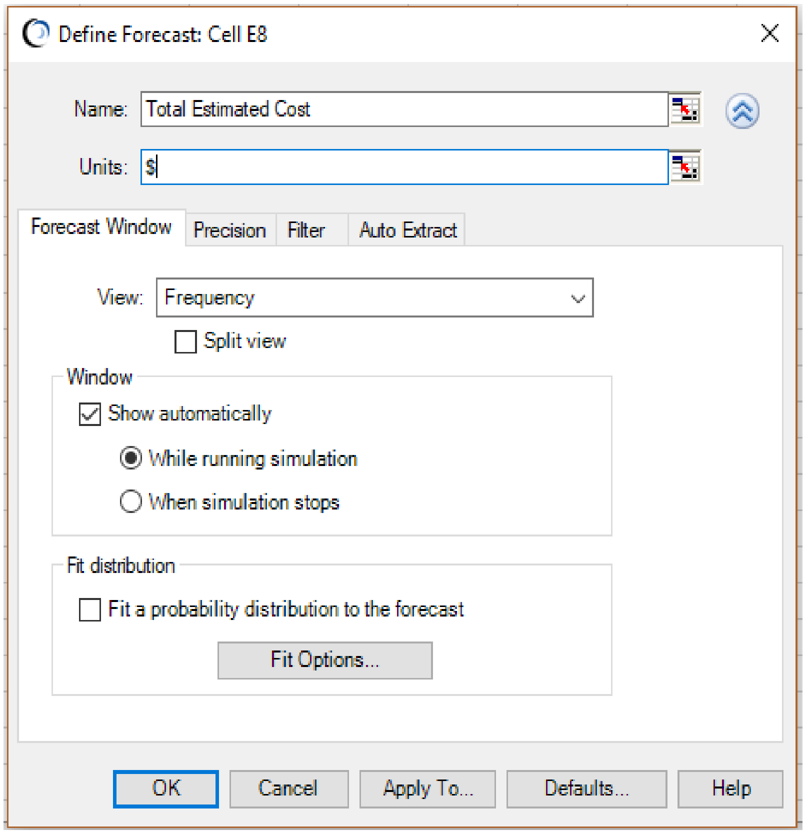

Figure 6.8: Defining the Forecast Variable

6.2.1.3 Define Decision:

Defining decision variables is a different and slightly complicated method as compared to assumptions and forecast variables. This is a very crucial feature provided by Crystal Ball. This will be discussed in Section 6.3.

6.2.1.4 Define Correlations:

This function helps us to correlate two assumptions. For defining correlation, select the assumption that we want to define the correlation and click on "Define Correlations" in the define tab. Once we click define correlations, the dialogue box in Figure 6.9 is seen. In the tab we can see that we have selected "Estimated Cost of Raw Materials" as the first assumption for which we want to define the correlation.

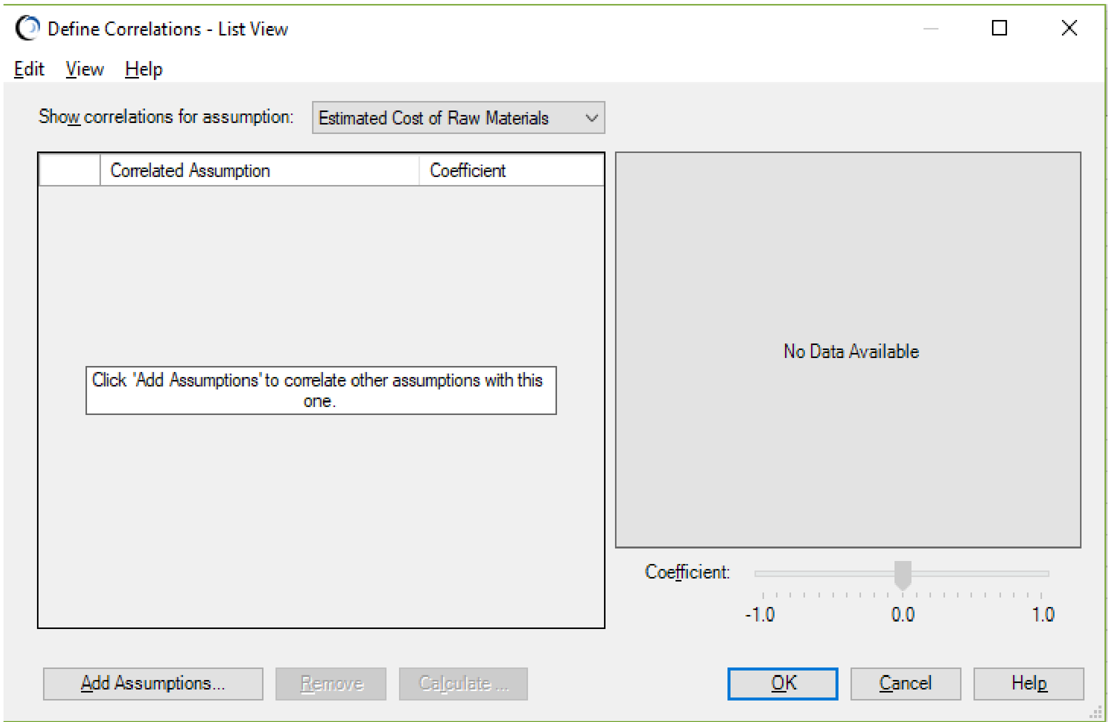

Figure 6.9: Define Correlations

Once this tab is open, in the bottom left we see add assumptions, after clicking on add assumptions, a new window listing all the assumptions in the model is seen (Figure 6.10). We select the corresponding assumption that is to be correlated to the initial assumption i.e Estimated cost of Raw Materials. Once that is done, we need to define the correlation coefficient (r). We can either manually enter the coefficient (on the left side) or as seen in Figure 6.9, we can use the scale (on the right side) that ranges from -1.0 to 1.0. We can just move to scale in the required direction to define the correlation coefficient between the two variables. Please note, defining correlations, requires a basic understanding of correlation analysis and correlation coefficient ‘r’. Crystal Ball does not help to calculate the value of the coefficient, the user is expected to define the value.

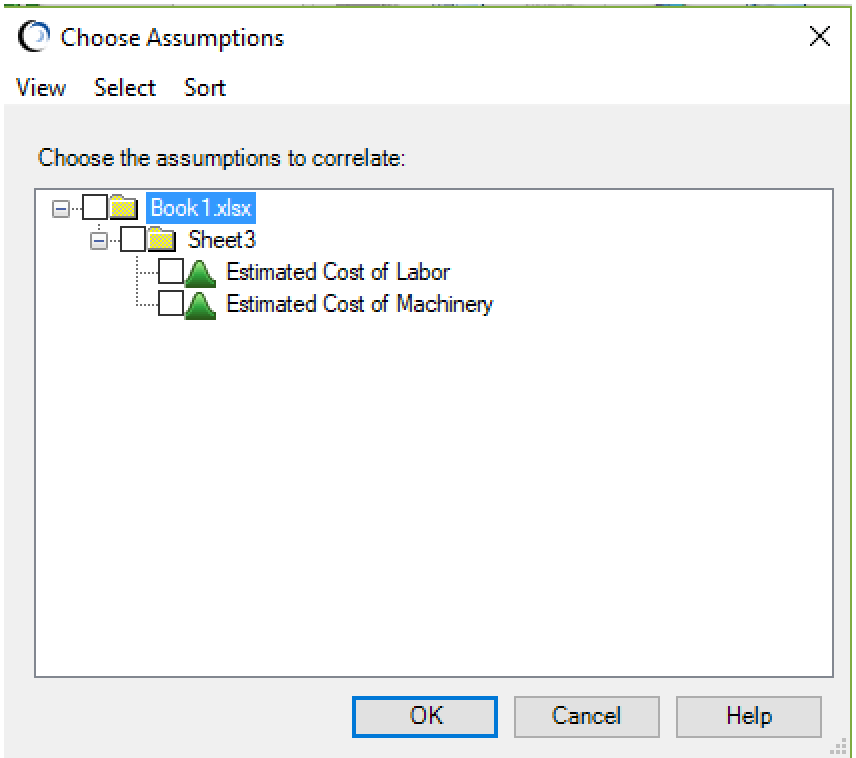

Figure 6.10: List of assumptions for correlation

Suppose we choose that “Estimated Cost of Raw Materials” is correlated to “Estimated Cost of Labor” by a correlation coefficient, r = 0.6. The Figure 6.9 changes to as seen in 6.11.

In this example, we will not be using correlations. But in the real world, correlations are very useful because risks/events in a program might be correlated, this means if a particular risk/event occurs, then it will lead to an increase in probability of another risk/event occurring. In these cases, we can use correlations to accommodate for this information in the model. Such correlations can be defined while analyzing cost, schedule or performance of the program to demonstrate the interdependence on each other.

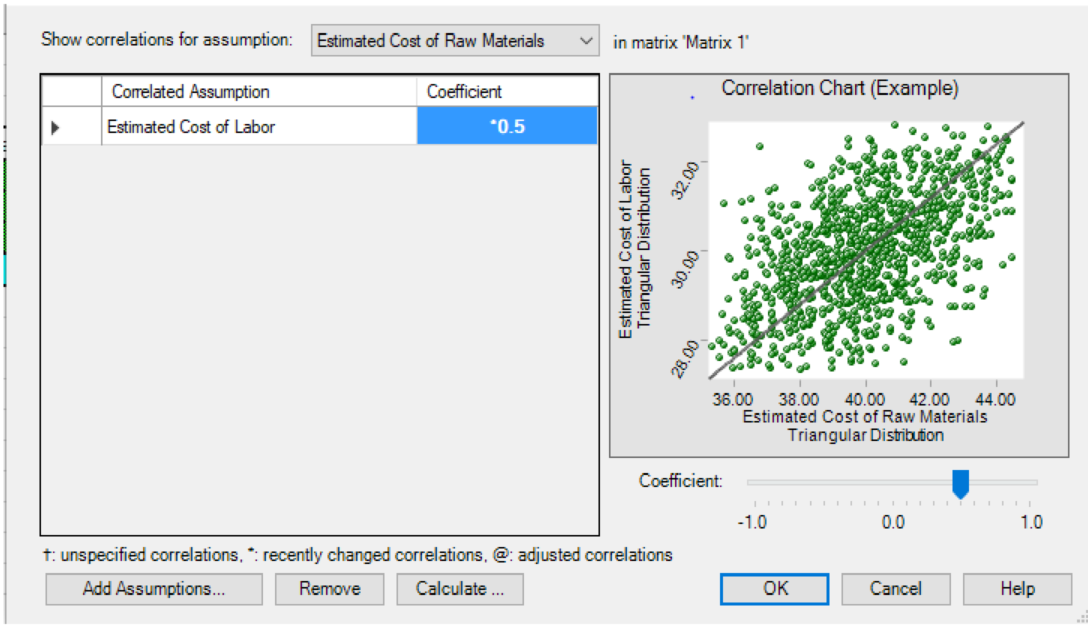

Figure 6.11: Correlation of two assumptions

Now, we have discussed the define tab (except define decisions) of the Crystal Ball. Once the inputs are defined, we go to Step 2 i.e. running the simulation. Please Note: It is very crucial to define the inputs to model as close as possible to the real-world scenario. If the assumptions are not defined correctly, the simulation output will not show replicate the possible output of the model.

6.2.2 Step II: Running the Simulation

In Section 6.1, we explained, the 5 parts of Crystal Ball. In this step of the process, we use the second tab termed as "RUN" as shown in Figure 6.12.

Figure 6.12: Run Tab of the Crystal Ball

There are four buttons in the Run Tab, let us discuss those first:

- Start: Once all the assumptions, decision variables and forecasts have been defined. This button starts the Monte Carlo Simulation Process.
- Stop: The simulation will stop automatically after the defined number of trials are conducted. But if the simulation is to be stopped before that, we can use this button.
- Reset Button: While a simulation is being conducted, the assumption cells assume a range of different values are per the distribution for simulation purposes. Before running another simulation, all these values have to be reset to the original values as defined by the user. We use the reset button for this purpose.
- Step: If we use the step button instead of the run button, every time you click step, Crystal Ball runs one trial. This is done in order to see how the assumption values are being changed to run the simulation. If we are running 10,000 trials, we need to press the step button 10,000 times in order for the simulation to be complete.
- Save and Restore: This button helps to save the results of the current file in "Crystal Ball Results file (.cbr)" format. The Restore function helps us to access to previously saved files. This button only accesses .cbr files from the computer.

In this tab, the most important function is "Run Preferences". This function defines how the user wants the simulation to run. When you click on Run Preferences, a dialog box with 5 tabs will appear: Trials, Sampling, Speed, Options and Statistics as seen in Figure 6.13. We will discuss each of the tabs individually.

6.2.2.1 Setting Trials Preferences

As per Bernoulli's law of large numbers, the more the trials the better the estimate. Ideally, we would want to perform infinite trials, but since that is not possible, we usually perform simulation with 10000 trials. The trials are to be defined as per the user, but to conduct high number of trials we need better technology and longer simulation time. A significant change in the distribution of the output is seen as the number of trials are increased.

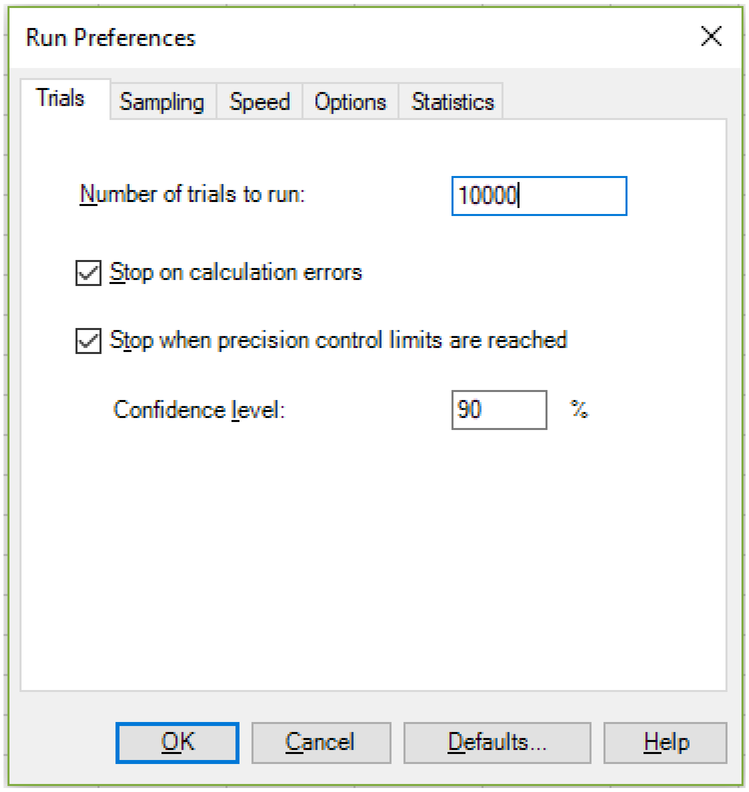

Figure 6.13: 5 Tabs of Run Preferences: Trial Window

- Number of Trials: Defines the maximum number of trials to be run in the simulation.
- Stop on Calculation Errors: When selected, Crystal Ball stops the simulation when a mathematical error occurs (such as division by zero) in any forecast cell.
- Stop when precision control limits are reached: When selected stops the simulation when certain statistics reach a specified level of precision.
- Confidence Level: Sets the precision level (confidence level) that indicates when to stop the simulation

In conclusion, this tab helps us define how many trials are to be run, to what precision do we want to simulate the model, and should we stop the simulation if the model faces a mathematical error or should it ignore the error and continue the simulation.

6.2.2.2 Setting Sampling Preferences:

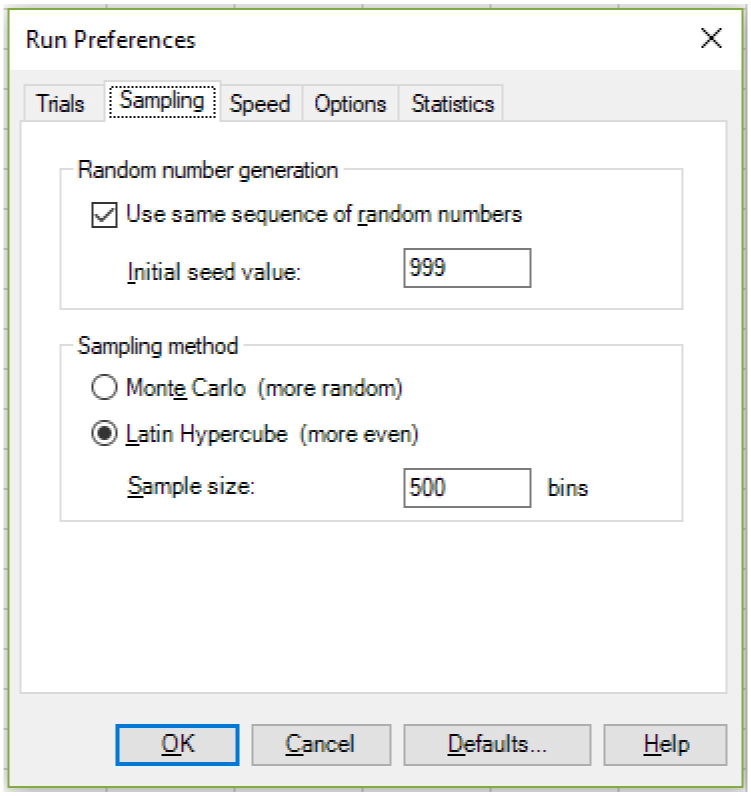

Figure 6.14: Sampling window of Run Preferences

- Use same sequence of random numbers: Sets the random number generator to generate the same set of random numbers for assumptions, so it can repeat simulation results. If this is not selected, every simulation with the same model, will result in a different output.
- Initial seed value: Determines the first number in sequence of random number generated for the assumption cells(integer)
- Sampling Method: Latin hypercube sampling generates the values more evenly and consistently across the distribution, but requires more memory. (refer Section 5.2.3)
- Sample size: In Latin Hypercube sampling, divides each distribution into specified number of intervals(bins). A higher number increases the evenness of the sampling method, while reducing randomness.

Seed Value is an important parameter to be defined in a simulation. This is because for every simulation we run, the random numbers used should be the same and the variation caused in the output should be due to the input model and not due to random numbers. Thus, it is important to know how Crystal Ball generates the random numbers. Crystal Ball uses the method of multiplicative congruential generator to generate random numbers for the Monte Carlo simulation.

The method uses the formula: $X_{n+1} = (62089911\ X_n) \bmod (2^{31} - 1)$, where X_n is the already generated random number and X_{n+1} is the next random number to be generated. Here, X_0 is the seed value. If the seed value is not defined, Crystal Ball uses the number of milliseconds between when the computer has started to when we hit the run button to start the simulation. So, if not defined, for every simulation of the same model, Crystal Ball generates a different series of random numbers, thus causing variation in the output. By default, the seed value is defined as 999. For further details on random number generation and multiplicative congruential generator please refer “Financial Modelling with Oracle Crystal Ball and Excel” by John Charnes.

6.2.2.3 Setting Speed Preferences:

- Run Mode: Determines the overall simulation speed.
- Options: Set update rules for active worksheet in normal and demo speeds.
- Chart Windows: Set redraw rate for any charts open during the simulation. Suppress chart windows: closes all charts during simulation and therefore executes the simulation faster.

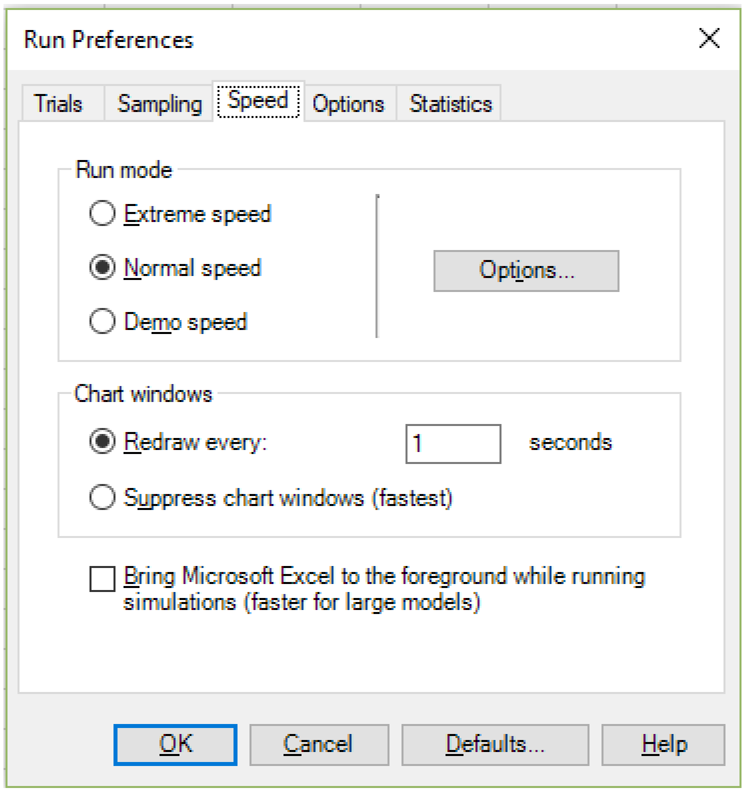

Figure 6.15: Speed window of Run Preferences

6.2.2.4 Setting Options Preferences:

- Store Assumptions values for sensitivity analysis: We use sensitivity charts for the giving feedback to the model, thus it important to select this option.
- Enable Correlations: Activates any defined correlations between assumptions.
- Run User defined macros: Runs macros as a part of the simulation.
- Leave control panel open on reset: When selected continues to display the control panel (Figure 6.17) after simulation is reset.

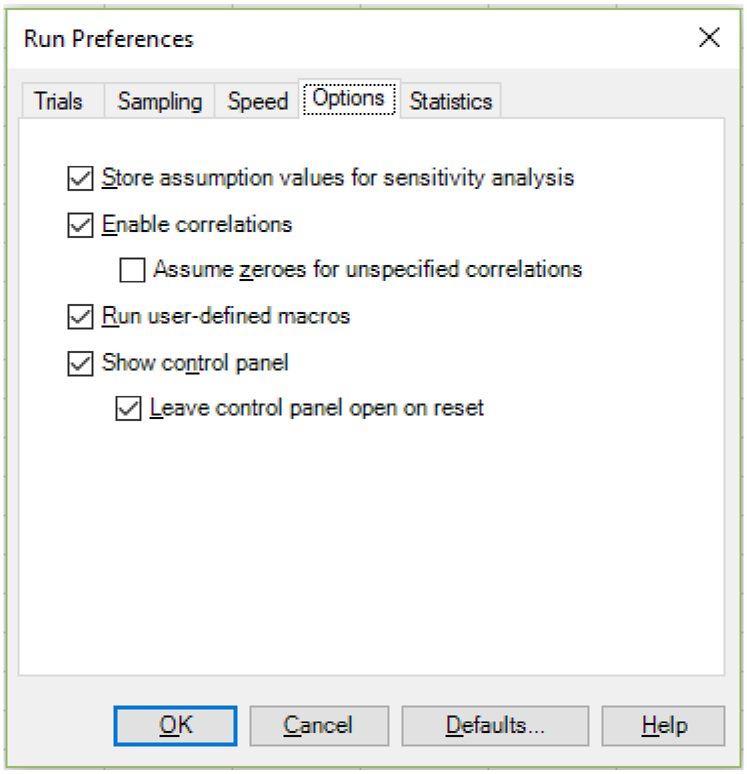

Figure 6.16: Options Window of Run Preferences

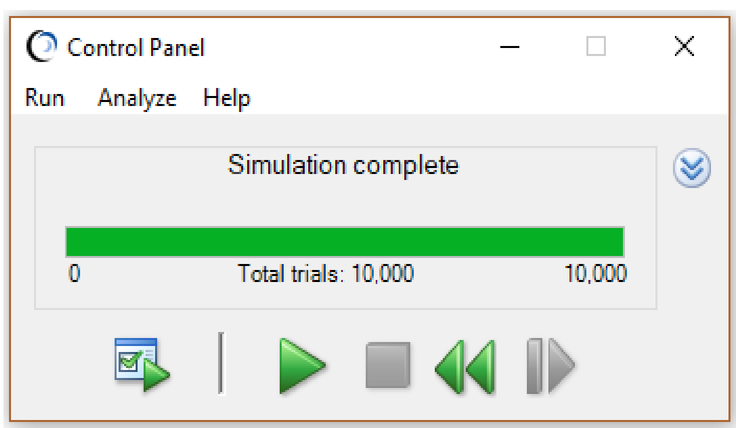

Figure 6.17: Control Panel of the Crystal Ball simulation

6.2.2.5 Setting Statistics Preferences

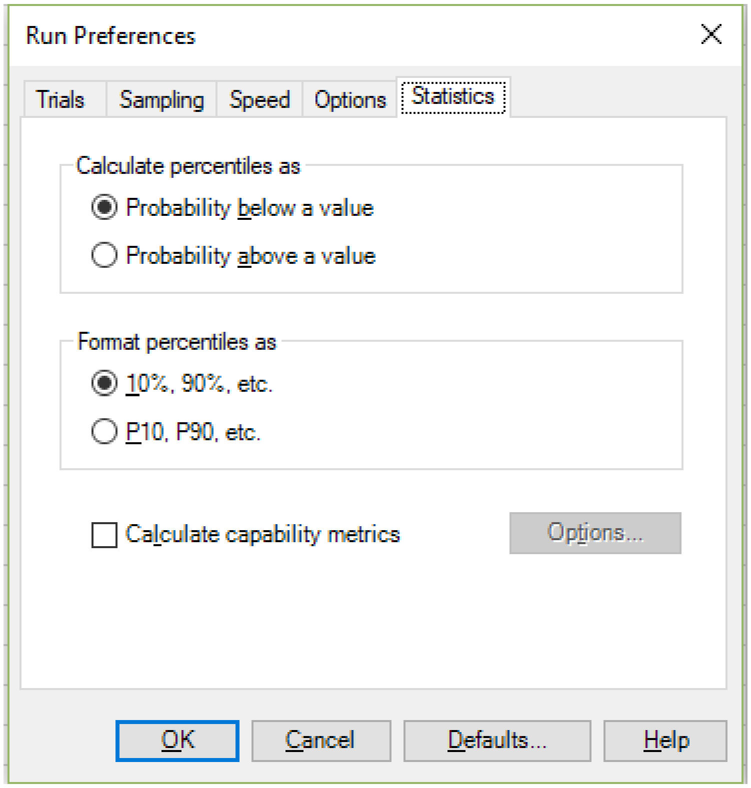

Figure 6.18: Statistics Window of Run Preferences

- Calculate Percentiles as probability above or below a particular value.
- Format Percentiles: determines how Crystal Ball displays the percentile values in charts
- Calculate Capability metrics: activates process capability features in Crystal Ball to be used for indicating process quality.

After defining the preferences to run the simulation, assuming that we have defined all the assumption and forecast cells and optionally decision cells. we hit the start button in the Run Tab. During the simulation, we can stop, reset or continue the simulation at any time and interpret the forecast charts independently. By default, forecast charts are displayed after the simulation. These charts can be analyzed, and other charts can be formulated using the analyze tab of control panel (Figure 6.17). For this example, we will run the simulation with all the default values of Crystal Ball. Once we run the simulation, there are two outputs seen by default: Control Panel as seen in Figure 6.17 and a forecast chart of the output variable, in the case, “Total Estimated Cost” as seen in Figure 6.21.

Now once we have the output, we move on to analyzing the output and drawing conclusions from the simulation we performed.

6.2.3 Step III: Analyzing the Output

Before we start analyzing the output, it is important to know how the output has been generated and how we deduce the Probability of Success from the output.

6.2.3.1 Deriving the Probability of Success from the Output

In the example, we are simulating calculating a Probability of Success of achieving an estimated total cost of $100. For each trial of a simulation, Crystal Ball repeats the following steps as shown in Figure 6.19. We will explain the process with the same example of “Estimated total cost”.

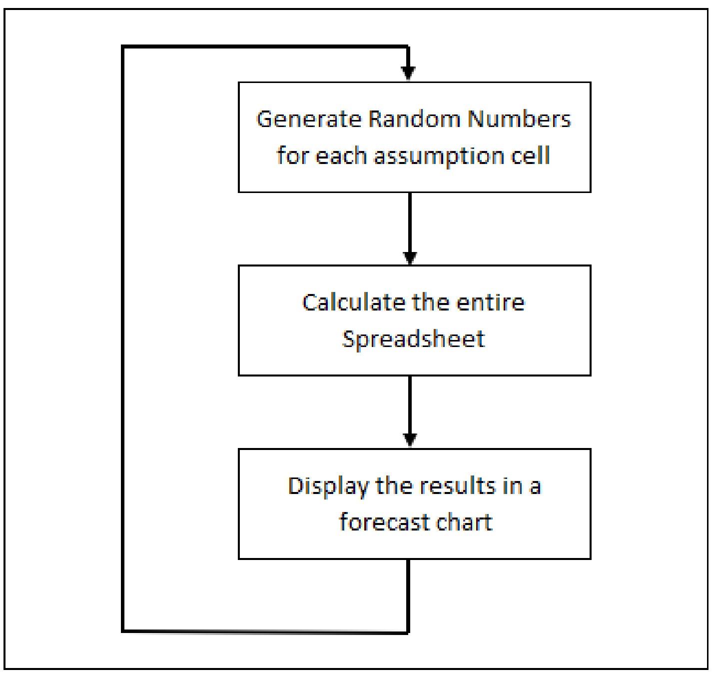

Figure 6.19: Process of each trial of Simulation

Step I: Generate Random Numbers for Each assumption cell

We have three assumption cells: raw materials, labor and machinery. The forecast variable is the total estimate cost of $100. Refer Table 6.1.

The random number generator generates a random number and sets the corresponding value of each of the assumptions as one of possibilities as per the distribution. Refer Section 5.2.3 regarding Latin Hypercube sampling, how a random number is generated and how it calculates the possible values of each assumptions. Let us assume, the random numbers generate the following possibilities for each of the inputs: raw material: 41, labor: 28 and machinery: 31.

Step II: Calculate the entire spreadsheet: In this example, the forecast value is total estimated cost, which is the sum of the three input variables. Thus, for the above random numbers generated, total estimated cost = 41 + 28 +31 = 100.

Step III: Display the results in a forecast chart: The value 100 is plotted in the forecast chart. Similarly, the process is repeated for the number of iterations as defined by the user to receive a range of possible values for the forecast variable.

The first default output chart displayed after the simulation is the histogram of the forecast variable as shown in Figure 6.21.

Before we start analyzing the histogram for the “Total Estimated Cost”, let us consider a basic frequency view histogram to understand how to read the result of Crystal Ball simulation.

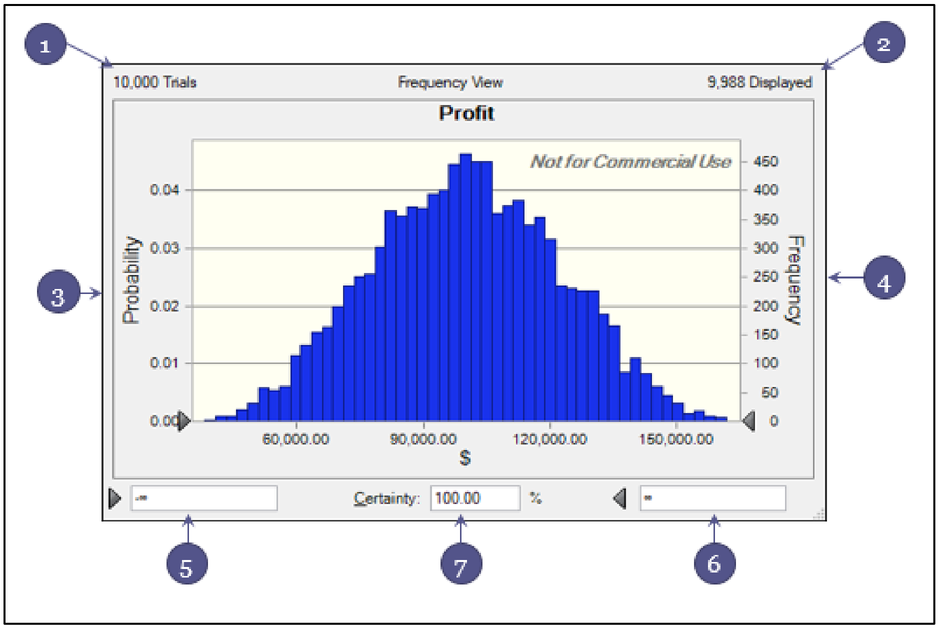

Figure 6.20: Output chart of the Simulation

1 – Number of trials run

2 – Number of trials displayed

3 – Probability of mode in a column

4 – Frequency of the forecast for the column

5 - Lower limit at a particular certainty level

6 – Upper limit at a particular certainty level

7 – Probability of Success (Certainty) of the forecast Variable.

Once 10,000 trials of the simulation have been run following the process as described in Figure 6.19, the final histogram with all the possible values is plotted by Crystal Ball. Now, we discuss how the histogram of forecast variable has been plotted.

In the above example, 100 is one of the possible answers. But we can receive a total estimated cost of 100 by various combinations of assumptions. For example,

- Raw materials: 38, Labor: 32 & machinery: 30 will also result in a total estimate of 100.
- Raw materials: 40, Labor: 31 & Machinery: 29 will also result in a total estimate of 100.

And so on. The below graph shows the output of the entire simulation, the above 3 step process after running it 10,000 times for the example as defined in Table 6.1.

Please Note: By default, Crystal Ball provides us a two-sided confidence interval. We will be using one sided confidence interval. Appendix E discusses the two confidence intervals and the necessary settings for a one-sided confidence interval. Please refer Appendix E before proceeding.

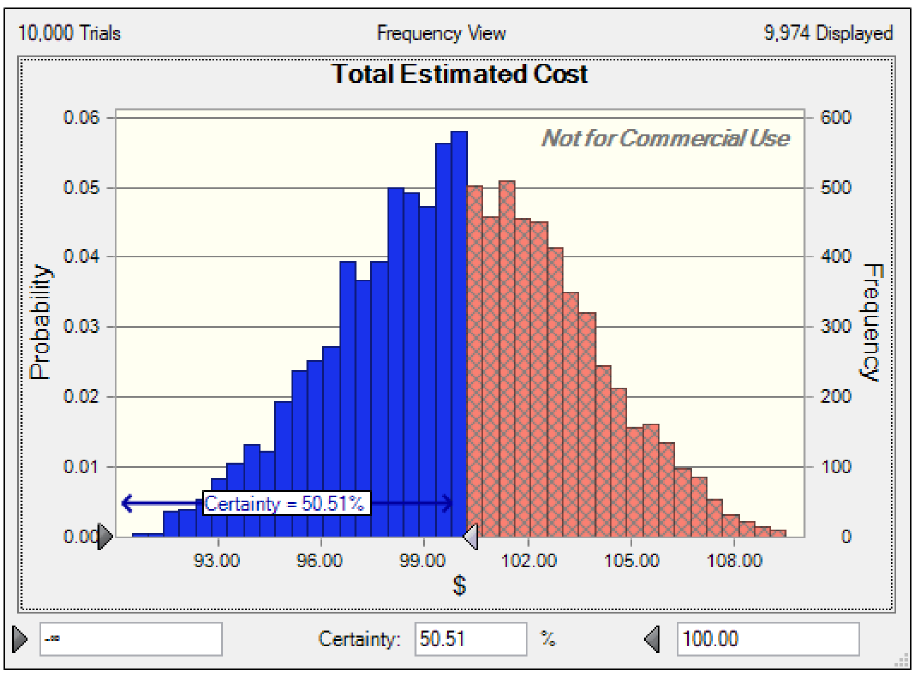

Figure 6.21: Frequency histogram of Estimated Total cost

We see that the Total estimated cost value is $100. The last column on the right in the blue area represents the values between 99.7 and 100. As discussed above, there are number of possible combinations of assumptions that will result in the same value of the forecast variable, in this case a value between 99.7 and 100. The number of possible combinations of assumptions resulting in the same forecast value is termed as frequency. This frequency is plotted on the right axis.

In this chart we see that the number of possible combinations resulting in a total estimated cost between 99.7 and 100 is slightly less than 500.

The Left axis of the chart is termed as “Probability”. Probability is the likelihood of an event occurring. In our simulation, we ran 10,000 trials. Out of these 10,000 trials, approximately 600 trials result in a total estimate cost between 99.7 and 100. Thus, the probability of receiving a total estimated cost between 99.7and 100 as the forecast value is 500/10000 = 0.06. If you look in the above Figure 6.2.1, you see that the particular column bar corresponds to a probability value of 0.06.

In a similar manner trials are simulated 10,000 times. Each of the forecast values is plotted in the histogram to define the distribution of the output. Now, the next question is “how do we derive the Probability of Success of cost from these individual probabilities?”.

6.2.3.2 Probability of Success:

We discussed above how the forecast values between 99.7 and 100 have a frequency of 500 and a probability of 0.05. Similarly, the simulation plots all the possible forecast values in the output. In the blue area, we see there are many columns representing different sets of forecast values. Each column has a probability and a frequency.

Now, in this example, we want to know the Probability of Success of the estimated total cost being $100 or less. The certainty box in the bottom center of the output displays the probability. This certainty is basically a summation of frequency of all the blue bars below the $100 divided by the number of iterations conducted in the simulation.

The Probability of Success (certainty) can also be explained in terms of probability (left axis) of individual bars. All the forecasted values are mutually independent events. That means under no circumstances will the estimated total cost have more than one value from the possible forecasts. Thus, by the addition rule of probability states that

P (A or B) = P(A) + P(B), where A and B are mutually exclusive events and cannot occur simultaneously.

If there are n column bars defined below the forecast value of 100, each with a probability of P_i, then we can conclude that the Probability of Success of achieving an estimated total cost below 100 is $\sum_0^n \mathrm{Pi}$. In this case, $\sum_0^n \mathrm{Pi}$ = 0.5051 or 50.51%. This value of probability is defined as the Probability of Success of achieving the estimated total cost ($100).

6.2.3.3 Analyzing the result

We have run the simulation for the model defined in Table 6.1 with all the default values in run preferences. The simulation result can be used to derive following conclusions:

- Assessing Probability of Success of a particular cost: The output in Figure 6.21 represents the distribution of the total estimated cost. Our base cost is $100, but it is seen that there is only a 50.51% probability that the total estimated cost of the product can be maintained at $100 over 10000 trials. This is interpreted that the Probability of Success of the estimated total cost being $100 is only 50.51%. To access the probability of a specific cost, we enter that cost in the right bottom corner of the output. As you can see in Figure 6.21, we have entered $100 in the bottom right box and hit enter.

- Assessing cost to achieve a particular Probability of Success: Suppose, organization wants all their plans to have a minimum Probability of Success of 80%. In that case, we can input the required probability and derive the corresponding cost to that probability. In this case, for a Probability of Success to be 80%, the organization has to assume that the estimated total cost of the product will be $102.89, as shown in Figure 6.22. To access the cost for a particular probability, we enter the required probability in the bottom center box labelled “certainty” and hit enter.

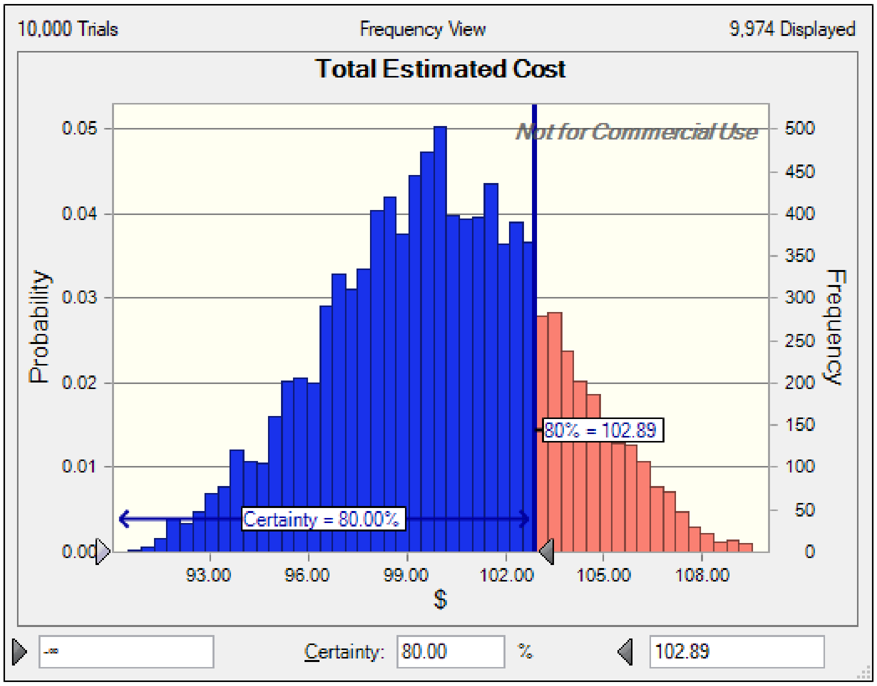

Figure 6.22: 80% Probability of Success of Estimated Total Cost

Crystal Ball also calculates detailed statistics of the output. These statistics are seen in the "view" tab of the output. If we go to the view tab and click on "output statistics", we will the statistics as shown in Table 4.3. From this Table we can conclude that at 90% confidence level, estimated total cost of the product will be between $89.35 and $111.33.

Table 6.3: Output Statistics

Forecast: Total Estimated Cost			
Statistic	**Forecast values**	**Statistic**	**Forecast values**
Trials	10,000	Skewness	-0.0057
Base Case	100	Kurtosis	2.74
Mean	100	Coeff. of Variation	0.034
Median	99.96	Minimum	89.35
Mode	'---	Maximum	111.33
Standard Deviation	3.4	Mean Std. Error	0.03
Variance	11.53		

Now, we have analyzed the output and it does not meet the requirement of 80% Probability of Success of achieving an estimated total cost of $100. This means that, this probability is not possible with the current assumptions that we have for the system. Thus, we need to change our assumptions regarding the costs of Raw Materials, Labor and Machinery to achieve 80% probability. Thus, we need to provide feedback to the system based on the output to change the assumptions of the inputs.

6.2.4 Step IV: Feedback to the Model

In order to provide feedback to the model to achieve the 80% POS, we use the feature of sensitivity charts in the Crystal Ball. When the frequency histogram is generated, there are 5 tabs on the forecast chart: Edit, View, Preferences, Forecast and Help. To access sensitivity charts, we go to the “Forecast” tab and click “Open Sensitivity Analysis”.

Sensitivity Chart: It shows the influence of each assumption on the forecast. The overall sensitivity of a forecast to an assumption is a combination of two factors: Model sensitivity of forecast to assumption and assumption’s uncertainty. This means how sensitive is the output to each of its input and how uncertain is the input (as the uncertainty of an input increases, the width of the distribution of the assumption increases). The sensitivity chart to provide the feedback to the model to increase the Probability of Success of manufacturing the cost for $100 is as seen in Figure 6.23.

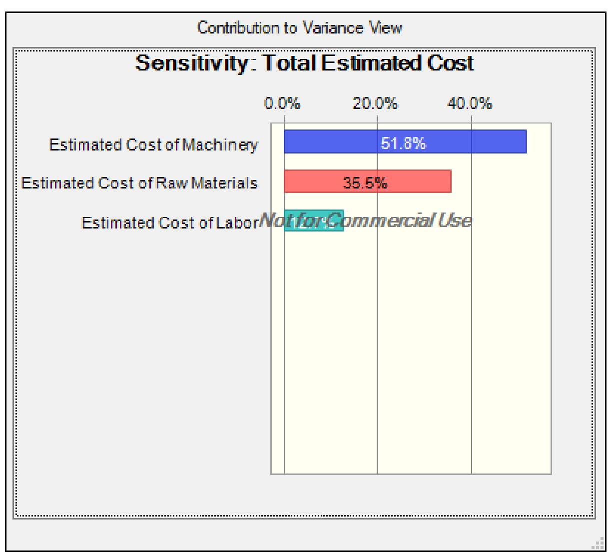

Figure 6.23: Sensitivity Chart of Estimated Total Cost

From the sensitivity analysis, we see the variation caused in the output. There are 3 factors that are affecting the product cost. The sensitivity analysis describes the contribution of each factor towards the output. The variation of product cost is 51.8% due to variation in cost of machinery, 35.5% due to raw materials and 12.7% due to labor. The variation of all factors will always sum up to 100%. This implies that we need to reduce the variation in cost of machinery and raw materials to reduce the variation in the estimated total cost. This reduction in variance will increase the probability of achieving $100 as an estimated total cost of the product.

In this phase, we involve the decision makers of the organization. The data will show the cause of the variation and how much effect does each cause have on the forecast. But the decision to decrease the variation of an assumption is to be made by program managers or the management of the organization. Since, this is an example to demonstrate the usage of the tool, suppose the decision made is that the organization decides that it will buy all the machinery required in bulk at one point of time at a fixed price of $29. (Do not focus on the decision, please follow through on how the feedback is given to the model and its effect on the forecast.)

Now, the machinery cost is the deterministic value of $29 (no distribution), labor and raw materials still follow the same distribution as before. We make the changes to the spreadsheet and we simulate the model again. Now, the simulation of this revised cost is as shown in Figure 6.24:

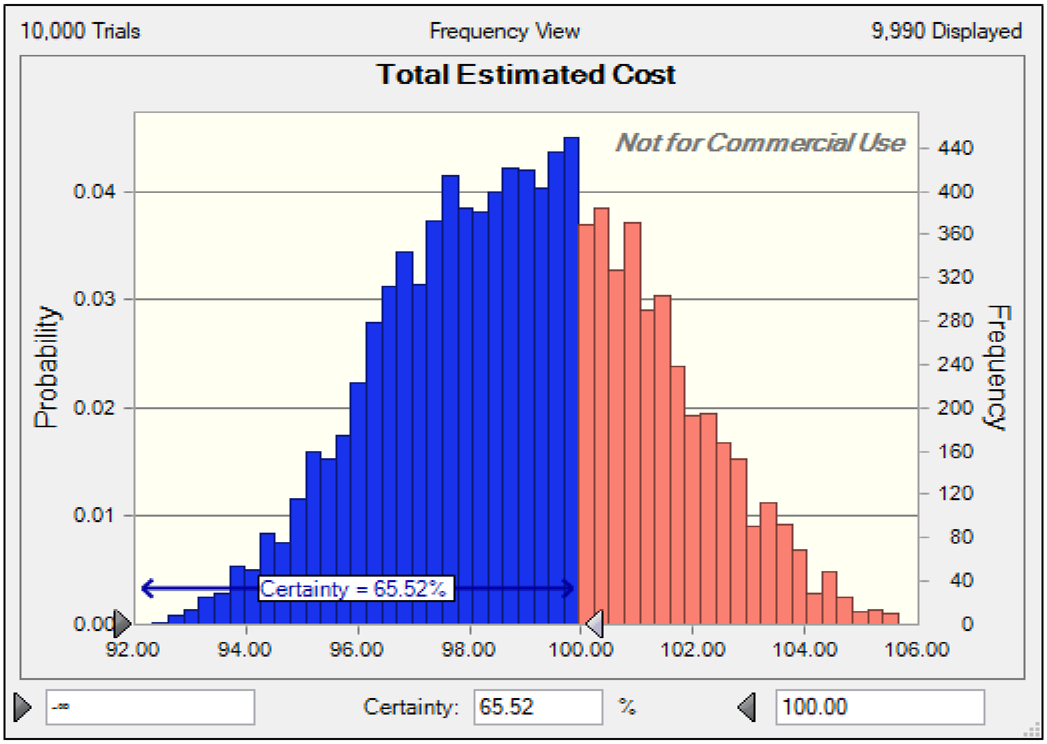

Figure 6.24: Revised Probability of Estimated Total Cost

Refer Spreadsheet: Chapter 6_Revised Estimates_Machinery Cost (Snapshot in Appendix G)

Now, the revised probability of achieving $100 cost of the product has increased to 65.52%. Under out initial assumptions the probability was 50.51%. But the organization is still not satisfied with the probability and needs to achieve a probability of at least 80%. Now they look at the sensitivity analysis as soon in Figure 6.25. It is seen that the cost of machinery is no more a factor for variability because it has been defined as a deterministic value. Please note: by definition, a deterministic input will never be responsible for causing any variation in the model. Only inputs that do not have a deterministic value and need to be defined as an assumption following a distribution will be responsible for the variation in the model output.

Consider that further analysis revealed that the cost of raw materials cannot be changed, and the company must take into consideration the variability as defined initially in Table 6.1. Thus, the only factor that remains is the estimated cost of labor. Now, the organization decides that they will outsource the labor at a fixed cost and use contractual labor to satisfy their demand. The company has a budget of $30, but the minimum acceptable wage is $25. The decision to be made is what is the maximum wage that can be paid and still have the organization maintain a probability of 80% of achieving $100 as the product cost. At this stage, we consider “Decision Variables”.

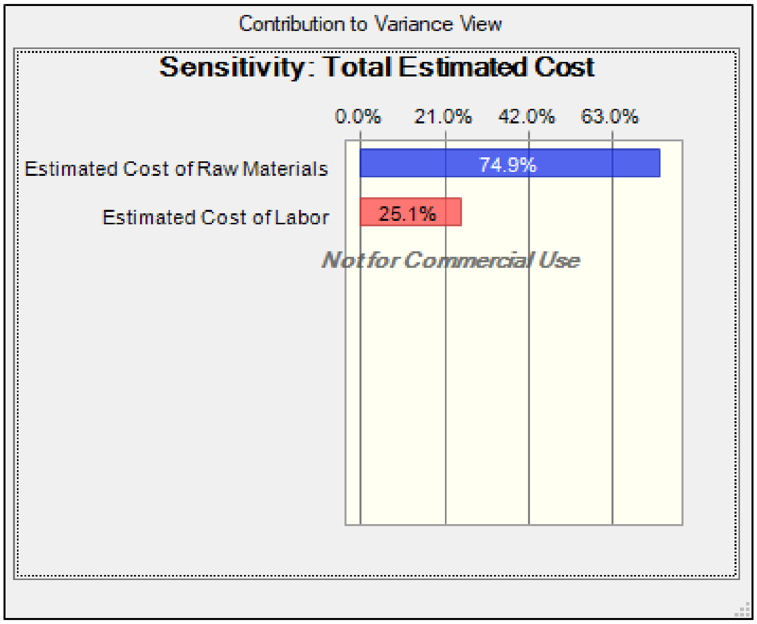

Figure 6.25: Sensitivity chart of the Revised Model

6.3 Decision Variables

6.3.1 Defining a Decision Variable

Decision variables are inputs to the system similar to assumptions and forecast variable. These are the variables that can be controlled, such as rent or per hour wage. Decision variables are not required by the simulation model, but they can be useful when comparing alternate scenarios. Decision variables unlike assumptions are not defined as distributions. The value of the decision labor is decided by the user and the simulation is carried out considering these values. In this example, we want to define the estimated cost of labor as the decision variable. We select the cell that has the mean estimate of labor and click on decision variables in the define tab, the window will look like Figure 6.25.

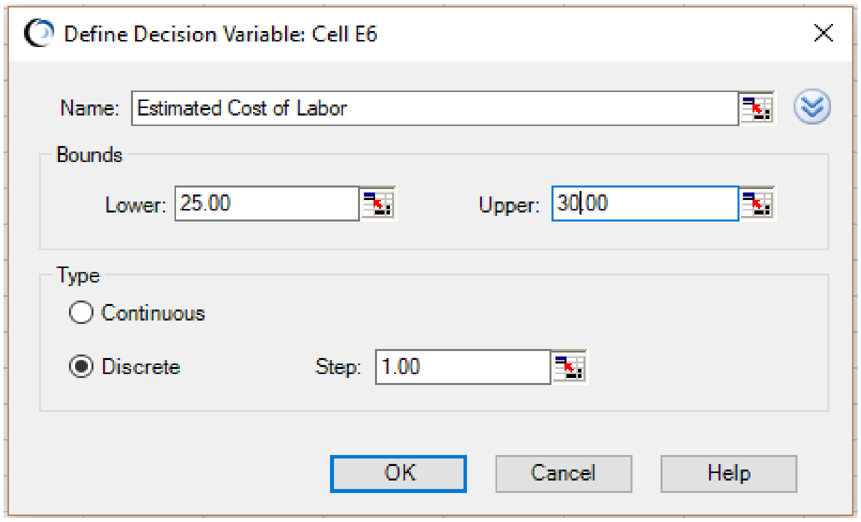

Figure 6.26: Decision Variable: Estimated cost of Labor

Refer Spreadsheet: Chapter 6_Revised Estimates_Labor Cost (Snapshot in Appendix G)

This input means that estimated cost of labor has been defined as a decision variable. The acceptable range of the estimated labor cost is $25 - $30. The simulation will be run at discrete intervals of 1.00 (as seen in Figure 6.26) of the estimated labor cost. The above decision variable means that the software will run 6 separate simulations of 10,000 trials each will be run, under 6 values of estimated cost of labor i.e. $25, $26, $27, $28, $29 and $30. Typically, a decision variable cell is yellow in color. Remember, a decision variable is a deterministic value when you consider an individual simulation. This means, the first simulation of 10,000 trials will consider $25 as a fixed cost for labor; then the second 10,000 trials will consider $26 as a fixed cost for labor and so on.

We now run the simulation with the following assumptions as inputs:

- Estimated cost of Raw Materials is a triangular distribution with a mean of 40, minimum value of 35 and a maximum value of 45 (same as initial, Table 6.1).
- Estimated cost of Machinery: fixed at $29.
- Estimated cost of Labor: 6 possible values ($25, $26, $27, $28, $29 and $30). These six possible values are defined with the help of “Decision Variables” in Crystal Ball.

6.3.2 Running a Decision Variable simulation:

When a decision variable is one of the outputs, the simulation procedure is slightly different. We use the “Tools” tab in the Crystal Ball ribbon to do so. The tools tab looks like Figure 6.27.

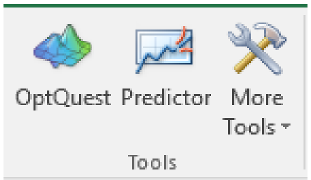

Figure 6.27: Tools Tab of Crystal Ball

The two functions in the tab i.e. “OptQuest” and “Predictor” are used for other applications of Crystal Ball. We will not be discussing them in this Chapter. In Section III of the Crystal Ball ribbon, go to “More Tools”, then go to decision Table. After clicking on decision Table, the window as shown in Figure 6.28 will be seen. In the Figure 6.28, we select the target forecast for the simulation. Remember, we can define more than one forecast variable for one model. In this case, we have defined only one i.e. estimated total cost. Thus, we select “Estimated Total Cost” and click on next. Once you click next, the next window as shown in Figure 6.29 will be seen. Again, we can have more than one decision variables in a model. If we select on decision variable out of list of variables, the other will be treated as deterministic values for the purpose of the simulation. We select the decision variable from the list of available decision variables in this case it is “estimated cost of labor” and then click on “>>”, the chosen variable will be transferred to the box on the right titled “chosen decision variable”. After this we click on next, the final “options” window as shown in Figure 6.30 will be seen. In our example, we have defined 6 cases for the decision variable (labor cost of: $25, $26, $27, $28, $29 and $30), we want to run each simulation for 10,000 trials. Since we have only one forecast, options in Figure 6:30 are not applicable. But if we had multiple forecast variables, we can select the options to see all forecasts or only the one that we have selected in Figure 6.27. After this we hit “Run”. Once the simulation is done, an excel sheet opens with an output as soon in Figure 6.31.

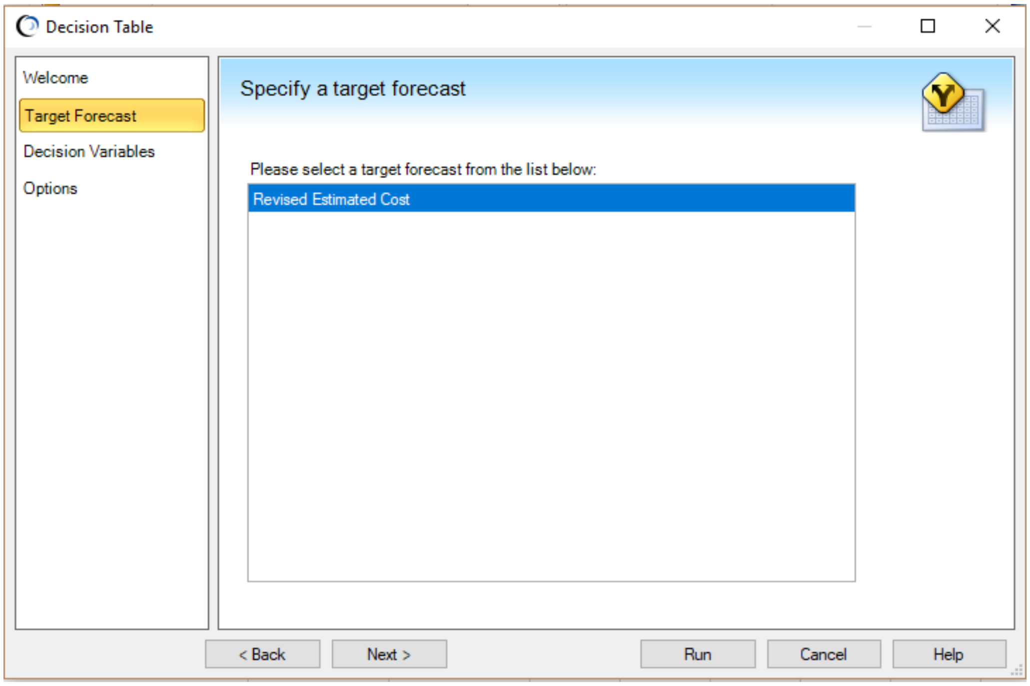

Figure 6.28: Decision Variable: Target Forecast

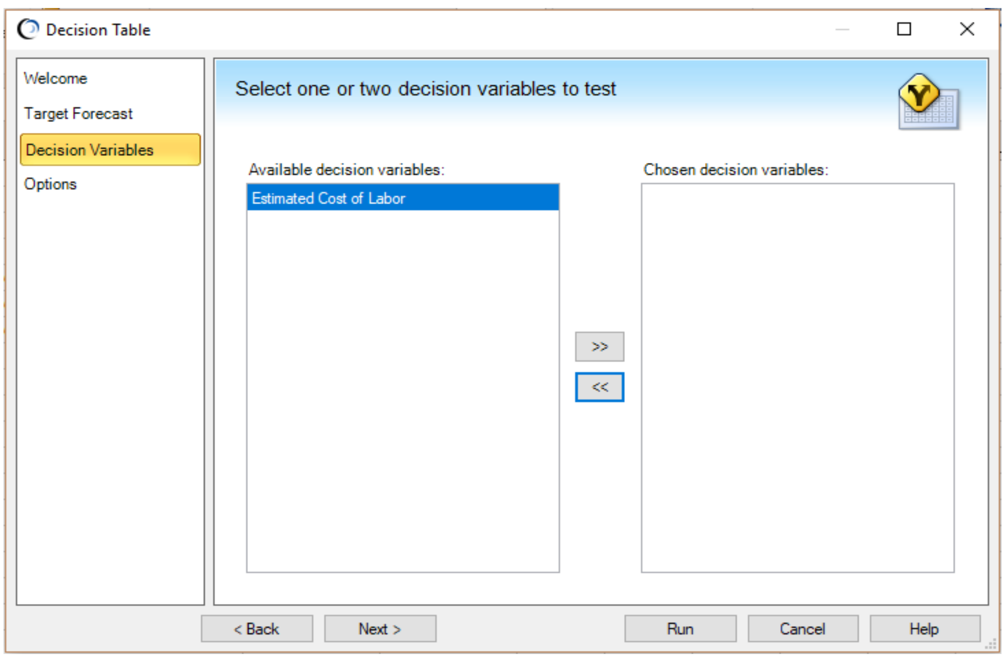

Figure 6.29: Choosing the Decision Variable for the Simulation

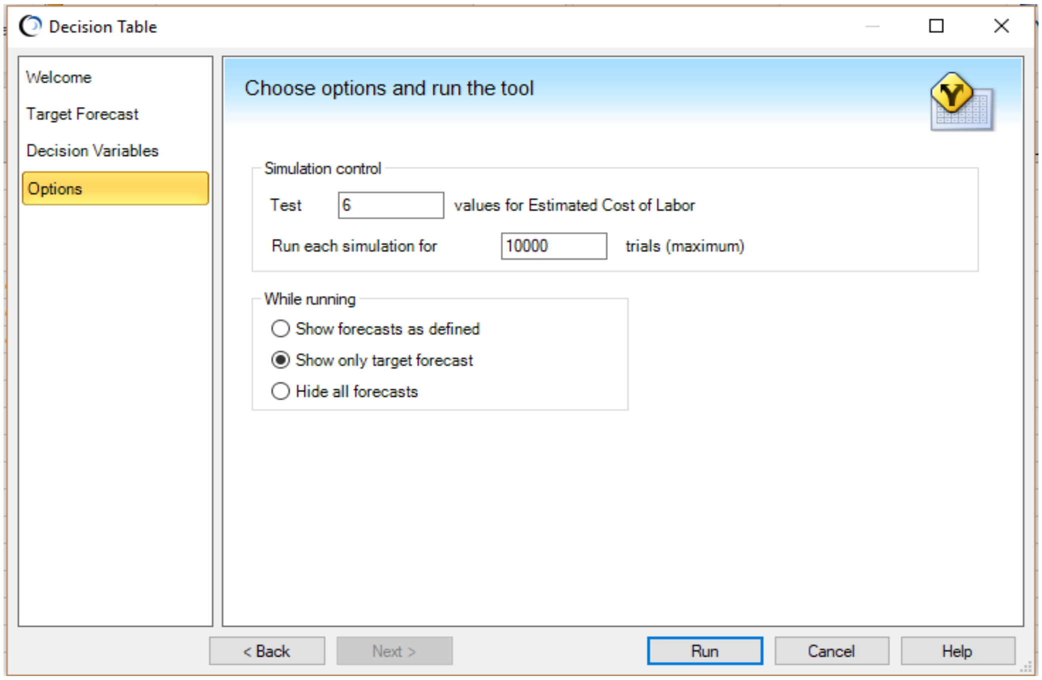

Figure 6.30: Options Window for Decision Variables.

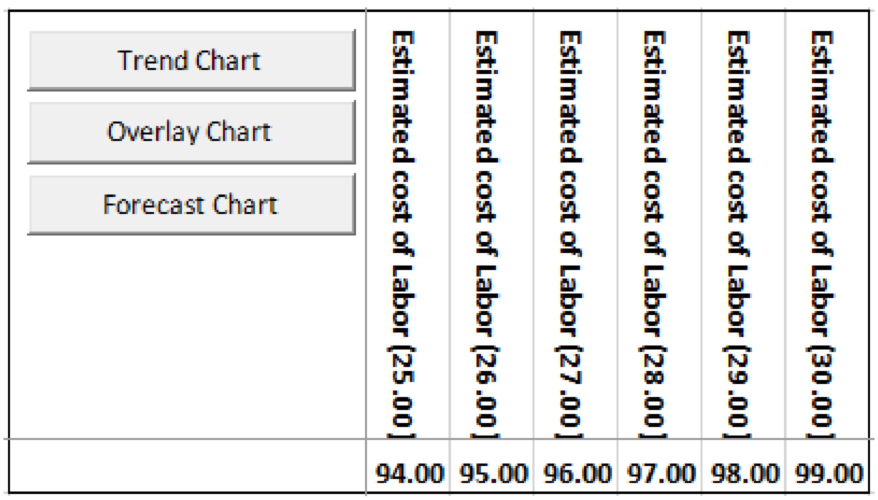

Figure 6.31: Output of the Simulation with Decision Variables.

A simulation with decision variables produces larger output thus it is important to understand how to read the output. In this example, 6 simulations have been run; with 6 possible values of estimated cost of labor; each simulation has been run for 10,000 trials. Thus, in total we have run a total of 60,000 trials for this model using decision variables.

In the output (Figure 6.31), we have the forecast variable “estimated total cost” in the row (94.00,95.00,96.00,97.00,98.00 and 99.00) and the corresponding value of the decision variable is seen in the column (Estimated cost of labor (25.00), etc.).

6.3.3 Analyzing the output of simulation using Decision Variables

Individual outputs of the simulation can be viewed by selecting the “estimated total cost” and clicking the button “Forecast Chart” on the left. We will individually go through all the 6 possible forecast charts and determine what the possible estimated cost of labor must be for the organization to reach a Probability of Success of 80% for the estimated total product cost of $100.

- Case I: In this case, the estimated cost of labor is considered as a deterministic value of $25. To access the forecast chart, we select the cell with the corresponding estimated total cost i.e. 94, and then click on forecast chart button on the left. We access the forecast charts all the subsequent decision variables in a similar fashion. We are looking for the Probability of Success for the estimate cost to be $100. Whenever we open a forecast chart, we enter the value $100 in the bottom right box to access the probability. As soon as you enter $100 and hit enter, the certainty box in the center of the chart, will show the probability of achieving an estimated total cost of $100. Remember, we need to the maximum labor cost at which the organization can achieve an 80% Probability of Success of the estimated total cost being $100.

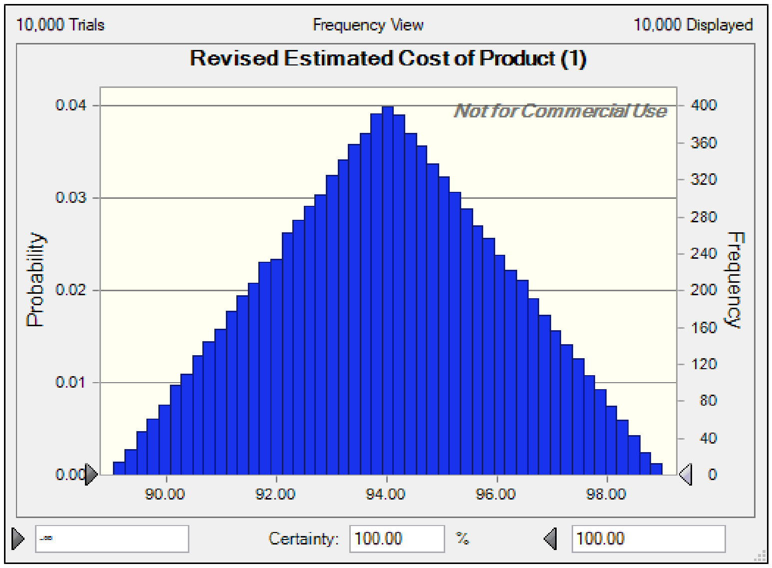

Figure 6.32: Forecast Chart at Estimated Labor cost of $25

In this chart, we see that, if we pay $25 to the labor, we have a 100% probability of achieving an estimated total cost of $100. So, perform the similar process for all of the results in Figure 6.30.

- Case II: Estimated Labor cost is $26

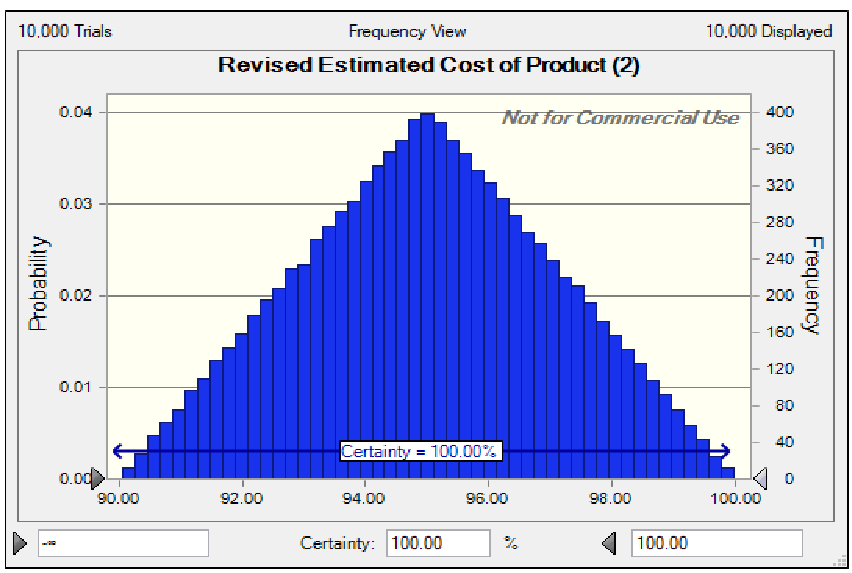

Figure 6.33: Forecast Chart at Estimated Labor cost of $26

- Case III: Estimated Labor Cost is $27

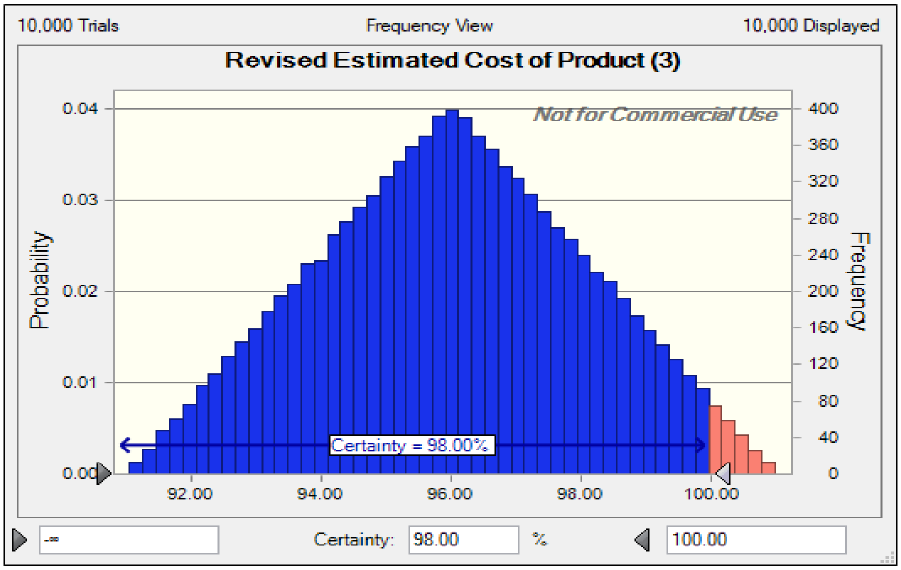

Figure 6.34: Forecast Chart at Estimated Labor cost of $27

- Case IV: Estimated labor Cost is $28

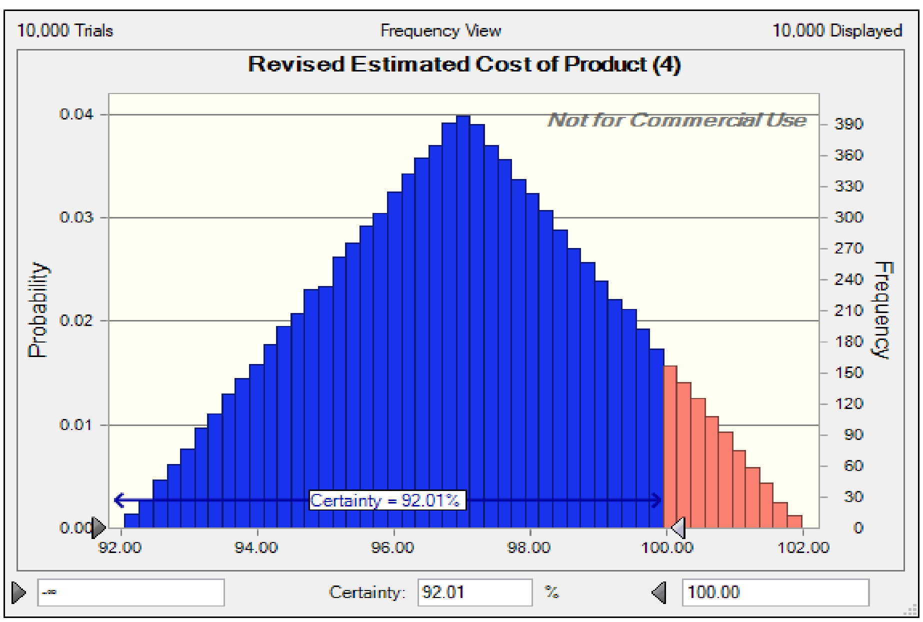

Figure 6.35: Forecast Chart at Estimated Labor cost of $28

- Case V: Estimated labor Cost is $29

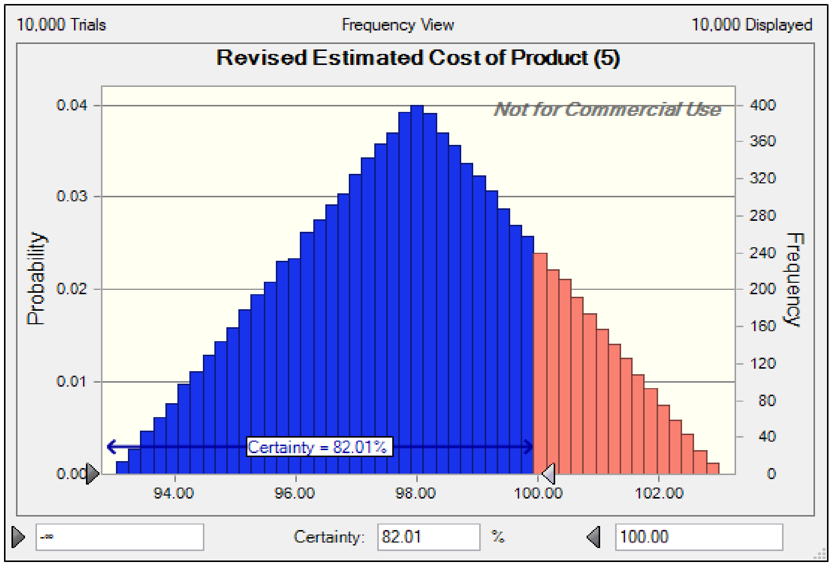

Figure 6.36: Forecast Chart at Estimated Labor cost of $29

- Case VI: Estimated labor Cost is $30

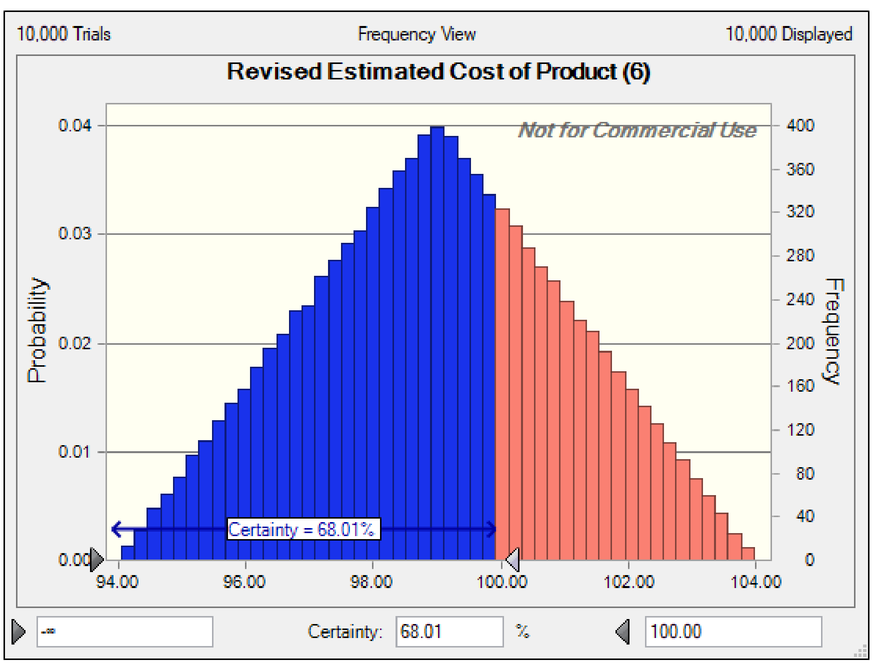

Figure 6.37: Forecast Chart at Estimated Labor cost of $30

Each of the six cases above show us the Probability of Success of achieving $100 estimated total cost. Table 6.3 summarizes the probabilities of each of the forecast under different estimated labor cost:

Table 6.4: Probability of Success under different Estimated Labor Costs

Estimated Cost of Labor	Probability of Achieving $100 Product Cost
$25	100%
$26	100%
$27	98.00%
$28	92.01%
$29	82.01%
$30	68.09%

From the above Table, we can see that when the estimated labor cost is $29, and the Probability of Success of estimated total cost being $100 is 82.01%. Therefore, the maximum labor cost under which 80% probability of cost of $100 can be achieved is $29.

6.4 Conclusion

We started our discussion with an overview of the Crystal Ball in excel and defined an example in Section 6.1 which is to be used to explain the features and functions of Crystal Ball to be used in POSE. In Section 6.2, we discussed the simulation procedure followed by Crystal Ball. In Section 6.3 we discussed a very important feature of decision variables in Crystal Ball. In this Section, we defined the conclusions we draw from the simulation in comparison to the initial assumptions as defined in Table 4.1.

From the above simulation, to achieve 80% Probability of Success for an estimated total cost of $100 for the product, our assumptions need to be as follows:

- Estimated Cost of Raw Materials: It is same as when we started the analysis, minimum cost of $35, most likely cost of $40 and maximum cost of $45.
- Estimated Cost of Labor: The initial assumption for labor was an estimated cost of $30, with a minimum of $27 and a maximum of $33. But at the end of the

simulation, the decision is to outsource Labor with a contract of at a fixed cost of $29.

- Estimated Cost of Machinery: The initial assumption was to an estimated cost of $29, with a minimum of $24 and a maximum of $36 to be spend on the machinery for building the product. But the simulation results show that, this is not a viable approach and the machinery cost must be maintained at a fixed cost of $29.

All the above changes to the initial set of assumptions to build the product, generates an 82.10% probability of maintaining the estimated product cost at $100 subject to the predicted uncertainties that can be faced.

Please Note: The purpose of this Chapter is not to focus on the decision-making procedure to vary the cost. The purpose of the example is to demonstrate the usage of the functions of Crystal Ball for the POSE methodology.

Chapter 7

PROBABILITY OF SUCCESS EVALUATOR (POSE)

Overview: In this Chapter we introduce the basic POSE methodology. It is to be noted that POSE can be applied only after the formulation of the baseline program plan. In this Chapter, in Section 7.1 we discuss what constitutes a baseline program plan for cost and schedule. In Section 7.2, we discuss the concept of contingency reserves in a program. In Section 7.3, we outline the POSE methodology. The POSE methodology has 11 steps: The first 7-steps are used during Planning the Program and the next 4-steps are used in Managing a Program.

7.1 Baseline Program Plan

The program manager needs to formulate a baseline program plan before we apply POSE. The application of POSE is demonstrated with the help of an example in the following Chapters. We require certain inputs for the POSE tool and this Section explains the details required from a program manager or management team before we start to apply POSE.

The example we will be using to demonstrate POSE is as follows:

"A company has just decided to execute a new program. The company is going to get paid $200,000 for delivering this program. This program is to be delivered in 100 days. (In this version of POSE we are not discussing performance of a program, so we are not worried about what kind of program it is.) The company has a requirement of making 25% profit on its programs; therefore, the budget allocated for the program is $150,000 (before tax). Now, the management needs a program plan that has an 80% Probability of Success of achieving the cost of $150,000 and the program being completed within a schedule of100 days." (please note: We are not taking into consideration the tax payable regarding the program. We are assuming that the 25% profit is the profit before tax)

Program Baseline Plan: Before applying the POSE methodology the program manager should have defined the program plan as shown below in Table 7.1.

This means that the program plan should have completed the Work Breakdown Structure (WBS) using the Organization Breakdown Structure (OBS) according to the Integrated

Master Plan (IMP). In simple words, the program plan should be broken down into tasks and all tasks should be allocated along with estimated costs and schedule for each task.

Table 7.1: Baseline Program Plan Example

Phase	Task	Estimated Cost of the Phase ($)	Number of Days Required to Complete the Phase
Phase 1	Task 1	5000	4
Phase 2	Task 2	7500	5
Phase 3	Task 3	10000	6
Phase 4	Task 4	12500	5
Phase 5	Task 5	15000	7
Phase 6	Task 6	17500	9
Phase 7	Task 7	17500	11
Phase 8	Task 8	20000	10
Phase 9	Task 9	15000	15
Phase 10	Task 10	5000	8
Total		**$125,000**	**80**

Please Note: In this example, for simplicity purposes, we consider that all the tasks are sequential, i.e. a new task cannot start until the previous task is done. The example in Chapter 11 will demonstrate a complex program plan and show how we construct the baseline plan for a more complex program so that we may apply POSE.

7.1.1 Requirements for Cost

The costs listed in the Table 7.1 are the most likely estimated costs of each phase of the program. There has been extensive research done on how to develop cost estimates for a program. For calculating phase wise cost estimates, the reader is referred to the Project Management Book of Knowledge (PMBOK) published by the Project Management Institute. The PMBOK defines a basic approach for estimating phase wise cost estimates. Another of the more intensive approaches to cost estimating and budgeting is provided by Kerzner Harold.1989. (Project Management: A systems approach to planning, scheduling and controlling. New York: Van Nostrand Reinhold). For further reading on deriving cost distributions of a program, also refer to Scotto, Marie

(1994). (Scotto, M. (1994). Project budgeting: the key to bringing business projects in on-time and on-budget. Project Management Journal*, 25*(1), 35–42.).

Using the references above, we can derive a distribution of estimated costs for the program. In this example, to explain POSE we will use triangular distributions for each of the phase wise costs as shown below in Table 7.2.

Table 7.2: Phase Wise Cost Details of the Program

Phase	Task	Minimum Cost ($)	Most Likely Cost of each Phase ($)	Maximum Cost ($)
Phase 1	Task 1	4500	5000	5200
Phase 2	Task 2	7000	7500	8250
Phase 3	Task 3	9000	10000	12000
Phase 4	Task 4	10000	12500	15000
Phase 5	Task 5	14500	15000	15500
Phase 6	Task 6	17000	17500	19000
Phase 7	Task 7	16000	17500	19000
Phase 8	Task 8	18000	20000	22000
Phase 9	Task 9	14500	15000	16500
Phase 10	Task 10	4500	5000	7500
Total (Program Costs)		$115,000	$125,000	$139,950

7.1.2 Requirements for Schedule:

Table 7.1 shows the most likely estimated schedule for each phase. But, to apply POSE to the schedule of the program, we need to determine the critical path of the program.

Critical Path: A continuous string(s) of critical activities in the schedule between the start and the finish of the program. The sum of the activity durations in the critical path is equal to the program duration. Therefore, a delay to any critical path activity will result in a delay in the project completion date. (Kramer, S. W. & Jenkins, J. L., 2006).

In this example, the critical path is the same as the program baseline program plan since all the activities are sequential and no activity happens parallel to any other activity. In general, all of the project planning software currently in use (e.g. Microsoft Project, et. al.) calculate the critical path for the user by default. For details about calculating the critical path please refer to Project Management Book of Knowledge (PMBOK) or Kramer, S. W. & Jenkins, J. L. (2006).

Table 7.3: Critical Path of the Program

Phase	Task	Minimum Number of Days	Estimated Cost Number of Days	Maximum Number of Days
Phase 1	Task 1	3	4	6
Phase 2	Task 2	3	5	6
Phase 3	Task 3	4	6	7
Phase 4	Task 4	4	5	8
Phase 5	Task 5	5.5	7	8
Phase 6	Task 6	6	9	10
Phase 7	Task 7	10	11	14
Phase 8	Task 8	9	10	13
Phase 9	Task 9	12	15	18
Phase 10	Task 10	7	8	9
Total (Program Schedule)		64	80	99

7.2 Contingency Reserves:

The contingency reserves are reserves for the “Unknown Unknowns”. These are the events that are not anticipated to occur in the risk management plan (discussed in Chapter 8). An important difference to remember is that, if we can quantify the probability of an event occurring, it should be addressed in the risk management plans; if not, then it is addressed by contingency reserves.

The most common type of contingency reserve for cost is the “Management Reserve” and for schedule is “Schedule Reserve”. There is no generally accepted rule as to what these contingency reserves should be. It is usually decided based on past experiences of similar kind of programs that have been executed for a specific organization and industry. The thumb rule for these reserves is 10% of the program cost or schedule. This is a decision that has to be made by the management or the program manager. This is not a value that is deducted using mathematical methods. Thus, it becomes important to analyze the repercussions of the decision made on the monetary value of the management reserve or the schedule reserve.

Thus, for our example program, the maximum cost is $150,000 and is to be completed in 100 days. Thus, let us consider that for this program that the management reserve is $15,000 and the schedule reserve is 10 days. These reserves are added to the initial phase wise estimates of cost and schedule.

7.3 Probability of Success Evaluator (POSE):

The Probability of Success Evaluator has three types of applications: Deriving Risk Mitigations leading to Probability of Success Estimates for Cost and Schedule, validating that a Program Plan has an adequate POS for achieving program cost and schedule, and continually assessing the POS for completing the program during the process of Managing the Program execution.

Figures 7.1 & 7.2 below show the 11-step POSE methodology split into 7 -steps during the Program Planning and 4- steps during the Program Execution to calculate the Probability of Success of achieving the required cost and schedule of a program.

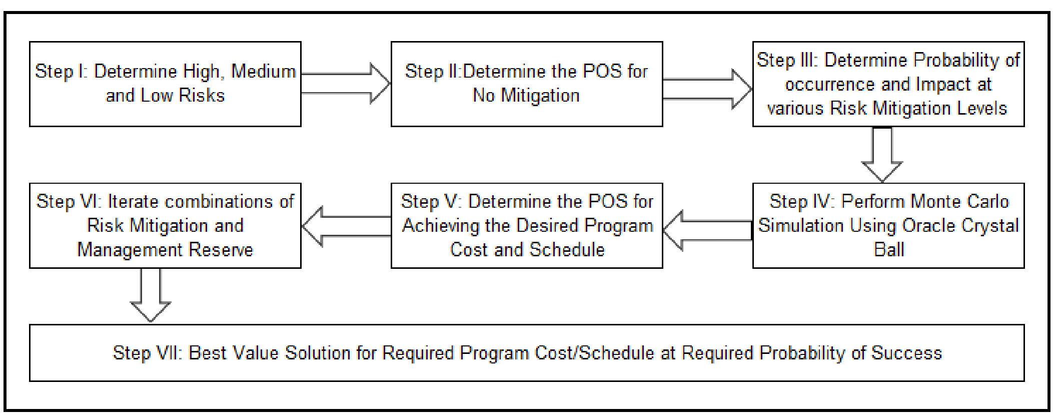

Figure 7.1: The 7-Step POSE Process for Program Planning

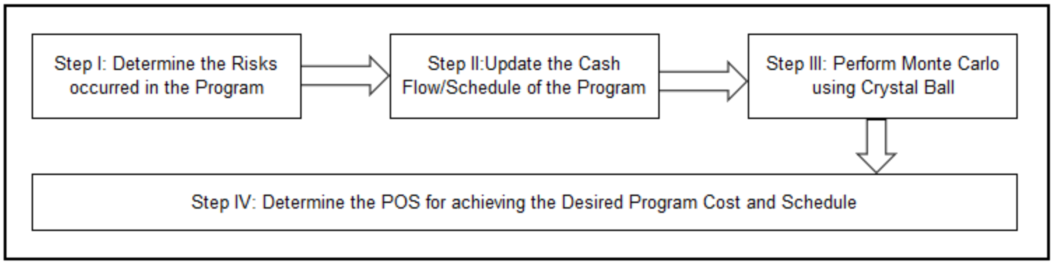

Figure 7.2: The 4-Step POSE Process for Program Execution

The POSE methodology is explained in detail in the next two Chapters.

7.4 Conclusion

This Chapter outlines the pre-requisites to apply the POSE process. It introduces the POSE methodology. The Probability of Success Evaluator has three types of applications: Deriving Risk Mitigations leading to Probability of Success Estimates for Cost and Schedule, validating that a Program Plan has an adequate POS for achieving program cost and schedule, and continually assessing the POS for completing the program during the process of Managing the Program execution. In Chapters 8 and 9, the POSE methodology is explained in detail by utilizing the example defined in Section 7.1. In Chapter 10, we demonstrate POSE for a more complex real-world program plan.

Chapter 8

POSE FOR PROGRAM PLANNING

Overview: In this Chapter, we discuss the 7-Step POSE methodology to derive the Probability of Success of achieving the desired cost and schedule of a program plan as a key part of the program planning process and continually during the execution of the program as a management tool to insure program success. In Section 8.1 we provide a comprehensive description of the same 7-Step process that is followed to derive the Probability of Success for achieving both program cost or program schedule. In Section 8.2 we demonstrate this 7-step POSE process to calculate the Probability of Success of achieving the desired program cost for an example simple program. In Section 8.3 we demonstrate the 7-Step POSE process to calculate the Probability of Success of achieving the desired program schedule for the same simple example program. In Section 8.4 we discuss the conclusions that we have reached about the POSE process methodology that has been presented.

In this chapter, we will refer to excel spreadsheets for simulation purposes. These spreadsheets are available for download from the link:

https://www.dropbox.com/sh/fx3ilox3u6hqhdl/AAAYI3CpF3Yvffh4O7JVomREa?dl=0

in the folder named Chapter 8. For the reference of the reader, a snapshot of all the referred excel spreadsheets in mentioned in Appendix H. The snapshot in the appendix has the same name as the referred excel spreadsheet.

8.1 7- Step POSE Process Description

The 7-Step POSE process methodology is illustrated in Figure 8.1 (a repeat of Figure 7.1 presented again for clarity and ease for the reader) and described step by step in the following paragraphs of this Section. As noted previously, the 11-Step process is used for program planning phase and during the program execution phases for determining the probability of achieving both program cost and program schedule. In this Chapter and Section, we will focus on its use during the planning phase i.e the 7-Step Process for determining POS for both cost and schedule. In the next Chapter we will focus on using the 4-Step process for determining the probability of achieving cost and schedule during the execution phases.

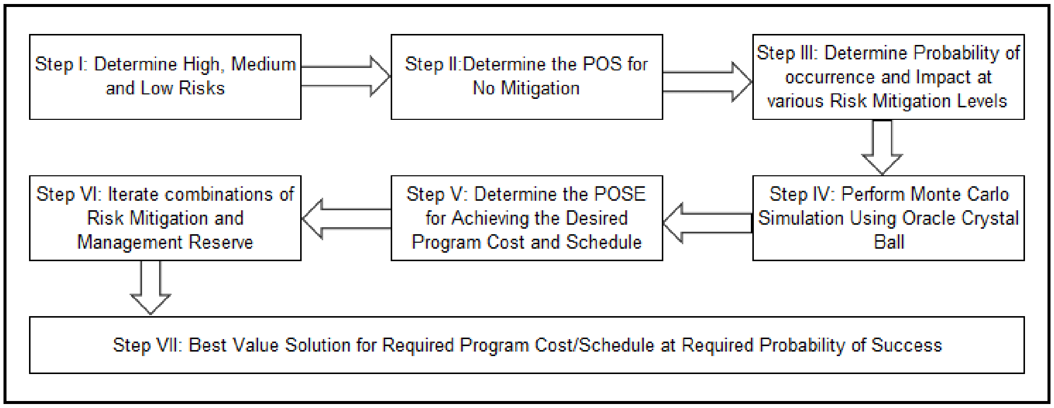

Figure 8.1: The 7-Step POSE Process for Program Planning

The POSE process assumes that the Contingency Reserves for Cost (Management Reserve) and Schedule (Schedule Reserve) are fixed for conducting the POSE analysis. If the POSE analysis cannot determine a risk mitigation plan that achieves the desired POS for program cost or schedule, then the reserves may be traded against risk mitigation plans as another effort to try to achieve an acceptable POS program plan. But this is only done after all other avenues of risk mitigation are exhausted. One final iteration beyond reducing Management Reserves could also be reducing the required profitability or decreasing or trading performance requirements to achieve an acceptable program solution. These cases are beyond the scope of this dissertation.

Step I: Determine High, Medium and Low Risks

In Step I we identify, quantify, and prioritize the risks in the program. The action required for each of these efforts is described as follows:

Risk Identification: In this step, we must identify all the possible risks the program can face during execution. This is done by program managers, systems engineers, subject matter experts, and by using historical data of similar programs. Please note, we only list the risks which can be assigned a probability of occurrence and the possible impact if the risk occurs. The risks which cannot be assigned a probability are termed as “Unknown Unknowns”, if they occur, they are managed by other contingency reserves. (e.g., Management Reserve and Schedule Reserve).

Risk Quantification: The reader is referred to Appendix A for a more detailed discussion of the theory of risk management as it is applied to the POSE process. In this Section we streamline the risk management process for the POSE methodology. We assign the **probability of occurrence of the risk** and the **impact** on the program if the risk occurs. **Risks impacts** can be in terms of Cost ($), Schedule (Days, months), or Performance (TPM).

(In this dissertation we discuss only achieving the POS of the desired program cost and schedule with the performance goals held constant. The POS of achieving the performance of the program with either the cost or schedule held constant is the subject of future research.)

With the probability of occurrence and the impacts for each risk item assigned, we can then calculate the resulting **risk value**, which is the product of the probability of occurrence and Impact. The impact of the risk which is defined in this step is the **most likely impact with no risk mitigation applied**. Thus, we calculate the **most likely risk value = probability of occurrence * most likely impact with no risk mitigation applied.**

Risk Prioritization: The risk value is calculated to prioritize the risks into high, medium and low risks to understand the priorities of the risks and to start helping to determine which ones should and can be mitigated. This segregation varies from organization to organization. A threshold is set for the risk values and the associated risks are categorized accordingly. Then we start developing the risk mitigation plans for the high and medium risks only.

Risk Mitigation (RM): Risk mitigation is the process of determining the plans, schedules, costs and resources and implementing them to reduce and/or eliminate the risks associated with the program. Risk mitigation costs or budgets are the funds that will be planned for and expended to mitigate or reduce either the probability of occurrence of the risk item, or the impact of the risk item, or both to reduce the risk value associated with a particular risk. We start the POSE analysis process by determining the POS with no risk mitigation employed and accepting the full impacts of the unmitigated risk on POS. We then add varying levels of Risk mitigation and determine the resulting improvement in POS to ultimately determine the risk mitigation required to achieve the desired POS.

Step II: Determine the POS for No Risk mitigation

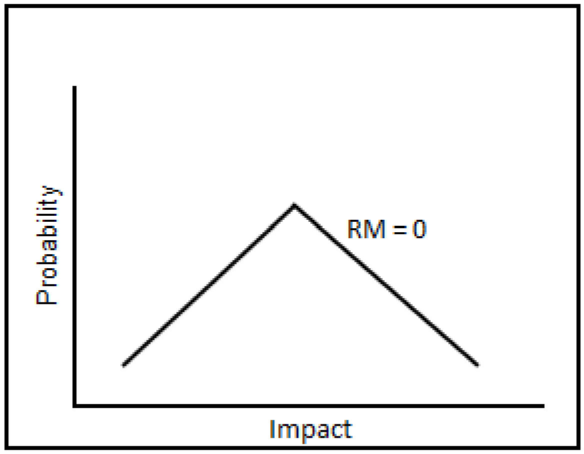

Figure 8.2: Distribution of Risk Impact

As noted above, we start the POSE process by determining the POS for achieving the desired program cost or schedule with full risk values and no risk mitigation as shown in Figure 8.2. This is the base case of the risk management process. The risks have been identified, quantified and prioritized. When there is no risk mitigation plan and no allocated risk mitigation budget (RM), the impact of each of the risks can be defined by a three-point estimate. If we have historical data regarding the impacts of these risks, we can fit a distribution to the data points. This three-point estimate, as seen in the Figure 8.2, defines the minimum impact, maximum impact and the most likely impact data points. The most likely impact has the highest probability of occurrence and the minimum and maximum represent the extremes of the distribution.

We follow this same approach whether analyzing for POS of program cost or schedule; the impacts simply vary from $ to time. Instead of using the term risk mitigation (RM) for cost, we refer to the risk mitigation for schedule impacts as schedule delay risk mitigation (SD).

Step III: Determine Probability of occurrence and Impact at various risk mitigation Levels (see Figure 8.3)

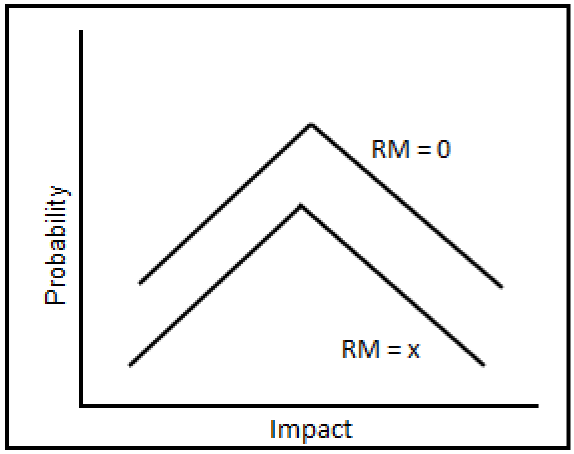

Figure 8.3: Risk Impact at various Risk Mitigation levels

After evaluating the base case with no risk mitigation, we then start evaluating the impacts of each of the risks at various risk mitigation levels. The impacts of the risk should go on decreasing as we increase the risk mitigation budget. As seen in Figure 8.3, at various levels of risk mitigation, the distribution of the impact of the risk changes. It is to be noted, that we are still using three-point estimates, where the most likely impact has the highest probability and the maximum and minimum impact represent the ends of the distribution.

We do a similar process for various schedule delay risk mitigations (SD).

Step IV: Perform Monte Carlo Simulation Using Oracle Crystal Ball

This evaluation of risk mitigation defines the budget under the assumptions that all the identified risks will all occur in the program as planned. But this does not happen in the real world. Hence, we use Monte Carlo to simulate the possible scenarios of the program for varying levels of Risk Mitigation. The risk mitigation budget / schedule delay risk mitigation which provides an 80% Probability of Program Success (POS) of achieving the required cost and schedule is considered as the risk mitigation budget for the program plan.

Step V: Determine the Probability of Success for Achieving the Desired Program Cost and Schedule.

Once we have derived the risk mitigation budgets with the fixed Management Reserves (MR for cost reserves, SR for Schedule reserves), we introduce these risk mitigation budgets and resulting risk probability distributions into Oracle Crystal Ball which determines the Probability of Success (POS) for the program versus Program Cost or Program Schedule as shown in Figure 8.4.

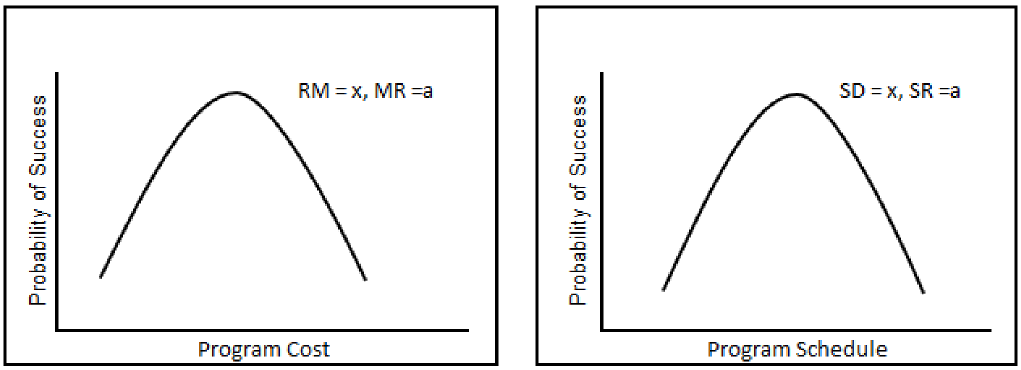

Figure 8.4: Distribution of Program Cost and Schedule vs Probability of Success

Please Note: We are talking about two different probabilities in this process. In Figure 8.2 and 8.3, the probability axis refers to the probability of the risk regarding the minimum, most likely and maximum impact of the corresponding risk. This probability is the input to the simulation. In Figure 8.4 and 8.5, probability axis refers to the Probability of Success of cost/schedule of the program. This is the output of the simulation.

Step VI: Iterate combinations of Risk Mitigation and Management Reserve

At the end of Step V, we calculate the Probability of Success of achieving the desired program cost and schedule. This is the first iteration of the Probability of Success of cost at a certain risk mitigation budget and certain management reserve. Similarly, we have the first iteration for Probability of Success of schedule at a certain schedule delay risk mitigation and schedule reserve. If we do not achieve the desired POS with risk mitigation, we may need to iterate with other variables like Management Reserve as suggested in the 7-Step Process Paragraph at the beginning of this Section.

In Step VI we iterate steps I – V, we can calculate the Probability of Success of achieving program cost or schedule at different levels of risk mitigation and management reserve combinations as shown in Figure 8.5.

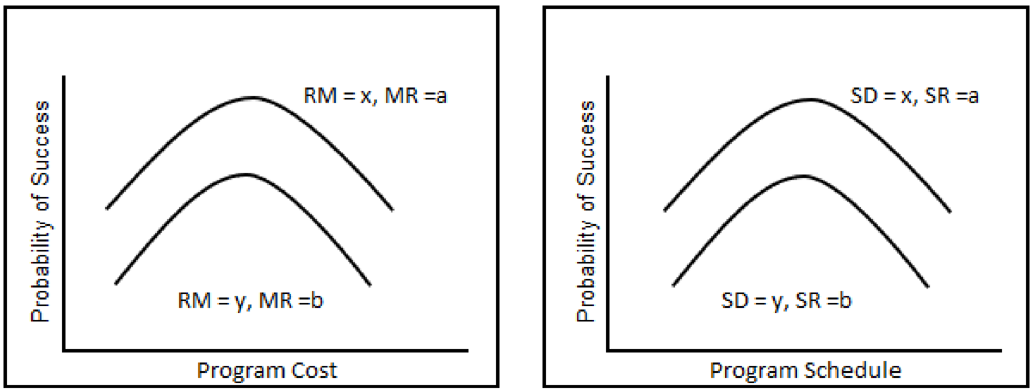

Figure 8.5: Distribution of Program Cost and Schedule vs Probability of Success at various levels

Step VII: Best Value Solution for Required cost/schedule and Required Probability of Success

After Step VI, the combination of risk mitigation budget and management reserve which gives the required cost at the required probability is the best value solution. Similarly, the combination of schedule delay risk mitigation and schedule reserve which gives the required schedule at the required probability is the best value solution.

This concludes the Section 8.1 7- Step POSE Process description.

The next Section demonstrates the application of these 7 steps to calculate the Probability of Success of achieving the desired program cost using a simple example program case.

8.2 Probability of Success of Achieving Desired Program Cost for a Simple Example Problem Case

The example program used to describe this POSE process in this Section has been explained in detail in Section 7.1. The program example used has a total phase wise cost estimate of $125,000 as shown in Table 7.1 and a management reserve of $15,000 as discussed in Section 7.3. Thus, the total estimated cost of the program so far is $140,000 and, we need to achieve a Probability of Success of 80% for $150,000.

Step I: Determine High, Medium and Low risks

We have described the simple program plan example in Chapter 7. Now, as we discussed in Section 8.1, we identify, quantify and prioritize the risks in this step.

- Risk Identification: Risk 1 – 10 are the corresponding risks associated with each task in the program. This list of risks is the result of the risk identification.
- Risk Quantification: Probability of Occurrence: This is the probability of occurrence assigned to the risk either from historical data, risk register or a subject matter expert. Impact: In this case, we just consider the impact on the cost and define the three-point estimate for cost associated with each risk i.e. minimum, most likely and maximum.
- Risk Prioritization: Risk Value: The risk value is the product of the most likely impact and the probability of occurrence. Risk prioritization is done as per organization needs. For example, we can say any risk value above 2000 is high priority, 1000 – 2000 is medium priority and less than 1000 is low priority. Then the organization makes a call whether they want to make mitigation plans only for high priority risks, or high and medium, etc. In this dissertation, we assume we will assume we are developing the risk mitigation for all the risks that have been identified in the risk management plan.

For the simple example program case below with 10 Tasks, the result of Step I is as defined in Table 8.1. This is the base case of risk management, with no risk mitigation for the program plan.

If all the risks occur and the program manager does nothing, the cost impact on the program will be $37500. Therefore, to avoid or reduce this risk cost, we must formulate a risk mitigation plan and risk mitigation budget.

Table 8.1: Risk Prioritization (No risk mitigation)

Task	Risk	Probability of Occurrence	Impact of the Risk Minimum ($)	Most Likely ($)	Maximum ($)	Risk value ($)
Task 1	Risk 1	0.9	2250	2500	2750	2250
Task 2	Risk 2	0.7	2520	2800	3080	1960
Task 3	Risk 3	0.1	2880	3200	3520	320
Task 4	Risk 4	0.2	2160	2400	2640	480
Task 5	Risk 5	0.5	2160	2400	2640	1200
Task 6	Risk 6	0.8	3420	3800	4180	3040
Task 7	Risk 7	0.3	4500	5000	5500	2700
Task 8	Risk 8	0.15	4860	5400	5940	810
Task 9	Risk 9	0.24	4050	4500	4950	1080
Task 10	Risk 10	0.25	4950	5500	6050	1375
Total Impact (Most Likely)				**$37500**		

Step II: Determine the POS for No Mitigation

In this step we use Oracle Crystal Ball to determine the Probability of Success of achieving the desired program cost under no Risk Mitigation plan.

Refer Spreadsheet: POS_No Risk Mitigation_Cost. (Snapshot in Appendix H)

We see the results of this simulation in Figure 8.6. The Probability of Success of the program cost with no risk mitigation is 15.36%. The required Probability of Success is 80% for the $150,000 program cost. Thus, this program plan is not acceptable.

So now we must develop a risk mitigation plan for the program to increase the Probability of Success.

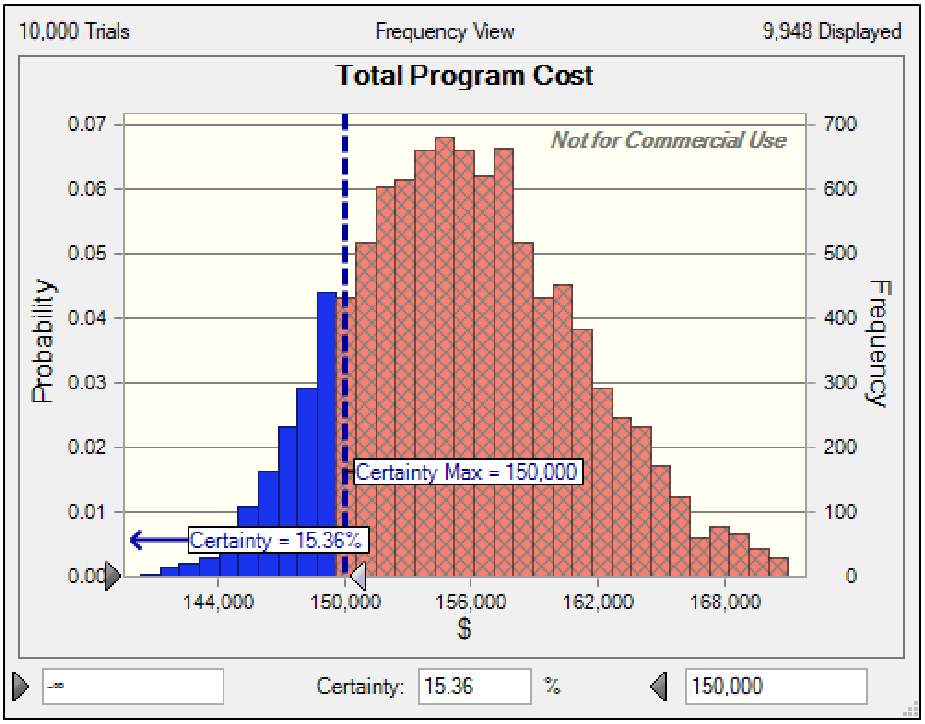

Figure 8.6: POS at No Risk Mitigation

Step III: Determine Risk Probability of occurrence and Impact at various risk mitigation levels

The program plan has been budgeted for $150,000 at a required 80% Probability of Success. Out of this $150,000, $140,000 has already been allocated (Phase wise: $125,000 and Management Reserve: $15,000). We are left with only $10,000 to come up with a mitigation plan. The first attempt at the risk mitigation plan is as shown in Table 8.2. When a mitigation plan is formulated for the program, the probability and impact of each of the identified risk changes. After the formulation of the risk mitigation plan, we have a Risk Mitigation budget of $10,150. Now we have to run the simulation with (1) this risk mitigation, (2) a phase wise expense of $125,000, and (3) a management reserve of $15,000 to determine if we can achieve an 80% Probability of Success of achieving required program cost of $150,000.

This is one attempt at the mitigation, as we discussed in Section 8.1, Step III and Figure 8.3, We can formulate many risk mitigation plans. With each mitigation plan we will have a different distribution of probability of occurrence and impact of the risk.

For this example, let us now determine whether the program plan based on this one risk mitigation plan meets the required POS of achieving the desired program cost.

Table 8.2: Risk Mitigation budget

Risk	Mitigation Plan	Probability of Occurrence	Impact with risk mitigation budget ($)			Mitigation Cost ($)
			Minimum	Most Likely	Maximum	
Risk 1	Plan 1	0.5	1080	1200	1320	1200
Risk 2	Plan 2	0.7	1080	1200	1320	950
Risk 3	Plan 3	0.1	3240	3600	3960	1400
Risk 4	Plan 4	0.15	1125	1250	1375	950
Risk 5	Plan 5	0.4	1125	1250	1375	1000
Risk 6	Plan 6	0.6	2520	2800	3080	1250
Risk 7	Plan 7	0.25	3420	3800	4180	1175
Risk 8	Plan 8	0.1	22500	3000	2750	1050
Risk 9	Plan 9	0.24	135	150	165	75
Risk 10	Plan 10	0.25	1575	1750	1925	1100
Total				**$20000**		**$10150**

Step IV: Perform Monte Carlo Simulation Using Oracle Crystal Ball

We have already simulated the Probability of Success if no risk mitigation is considered in Step II. We saw that with no risk mitigation plan, the Probability of Success of achieving the program cost of $150,000 is 15.36%. Now, we run the Monte Carlo Simulation for various levels of risk mitigation (in this example we have only one risk mitigation level).

Refer Spreadsheet: POS_Risk Mitigation_Cost (Snapshot in Appendix H)

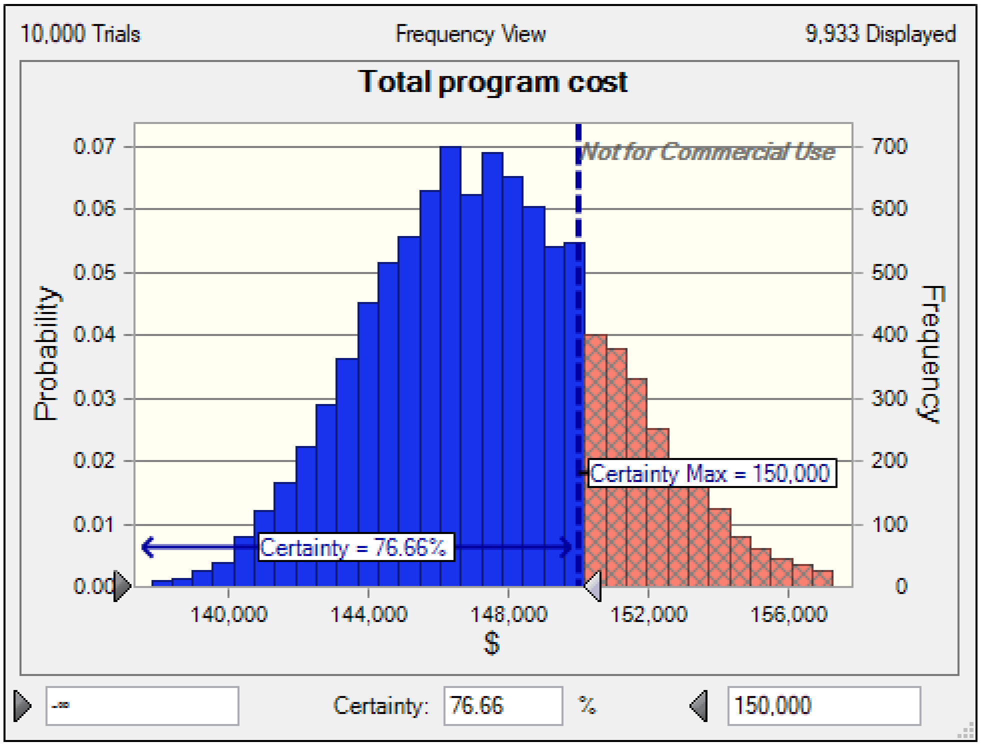

Figure 8.7: POS at a Risk Mitigation of $10,150

Step V: Determine the Probability of Success for Achieving the Desired Program Cost and Schedule

In Figure 8.7, the Probability of Success of achieving the program cost of $150,000 is 76.66% considering the risk mitigation plan that has been formulated. But, we require a Probability of Success of 80%. In the real world, we will iterate the risk mitigation plan and the budget to make it better and better and to achieve the required Probability of Success i.e. repeat Steps I – IV. But, for this example, we consider that this risk mitigation plan is the best plan the program team could formulate, and they cannot reduce the risk any further. So, considering the current budgets, what do we do to achieve the required cost and required Probability of Success?

Step VI: Iterate combinations of Risk Mitigation and Management Reserve

In the previous step, we have concluded that $10150 is the best risk mitigation budget that can be formulated, and it cannot be reduced any further. This risk mitigation budget has provided us a 76,19% Probability of Success for the required cost of $150,000. Since, we cannot the change the risk mitigation budget, we must next consider changing the management reserve. To iterate the various combinations of risk mitigation and management reserve, we define management reserve as a decision variable in Crystal Ball. (refer to Section 6.3 about decision variables). Consider that minimum the acceptable value of management reserve is $12,000. After the simulation, the results of the Probability of Success of achieving the required cost under different combinations of management reserve and a fixed risk mitigation budget of $10150 is as seen below:

Refer Spreadsheet: RM_MR_Iteration_Cost (Snapshot in Appendix H)

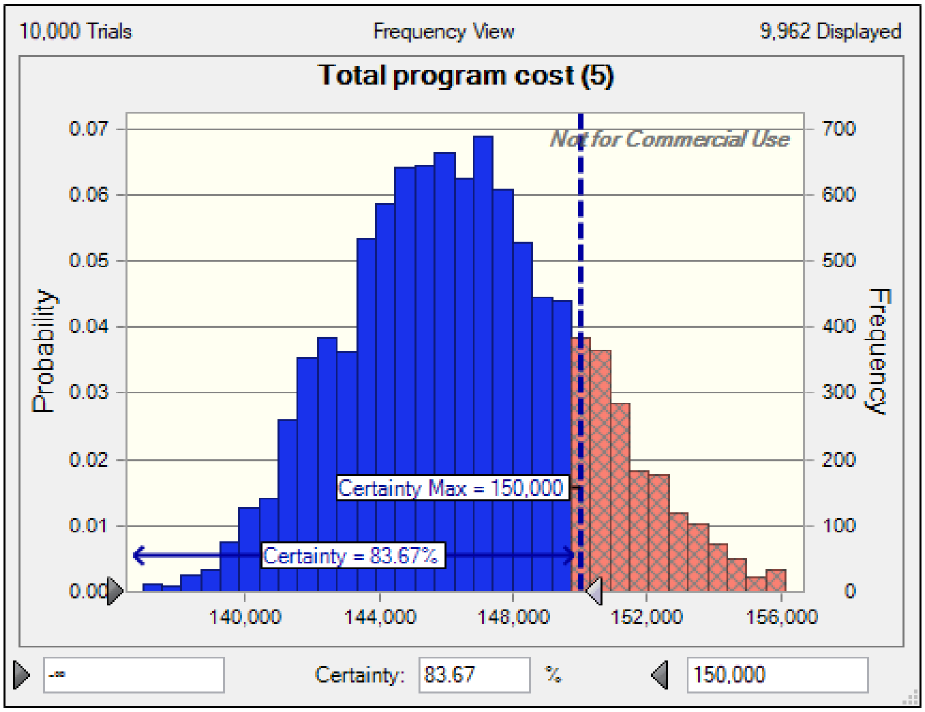

Figure 8.8: Probability at MR = $14,000 and RM = $10150

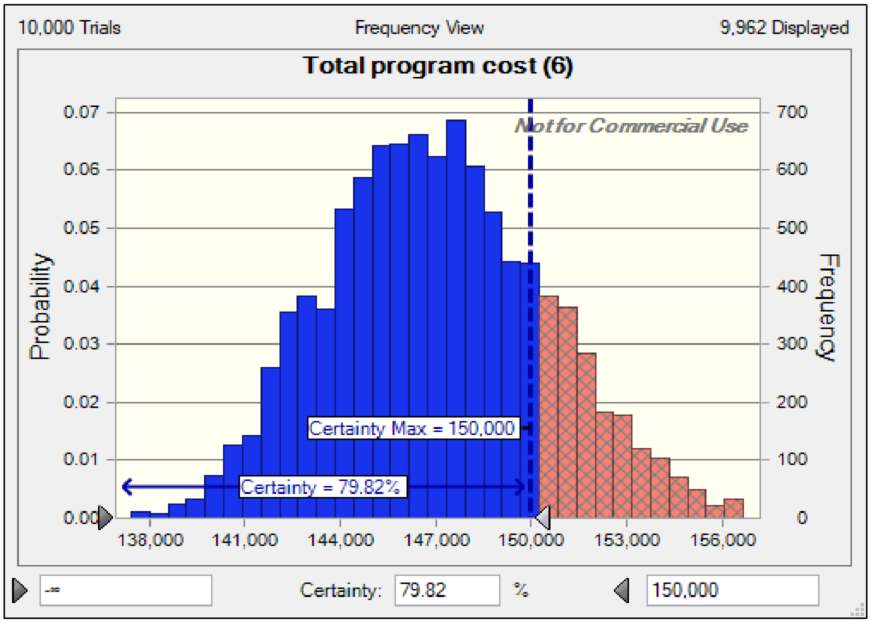

Figure 8.9: Probability at MR = $14,500 and RM = $10150

Now, we can see the management reserve has to be slightly less than $14,500 for the program to have a Probability of Success of 80%.

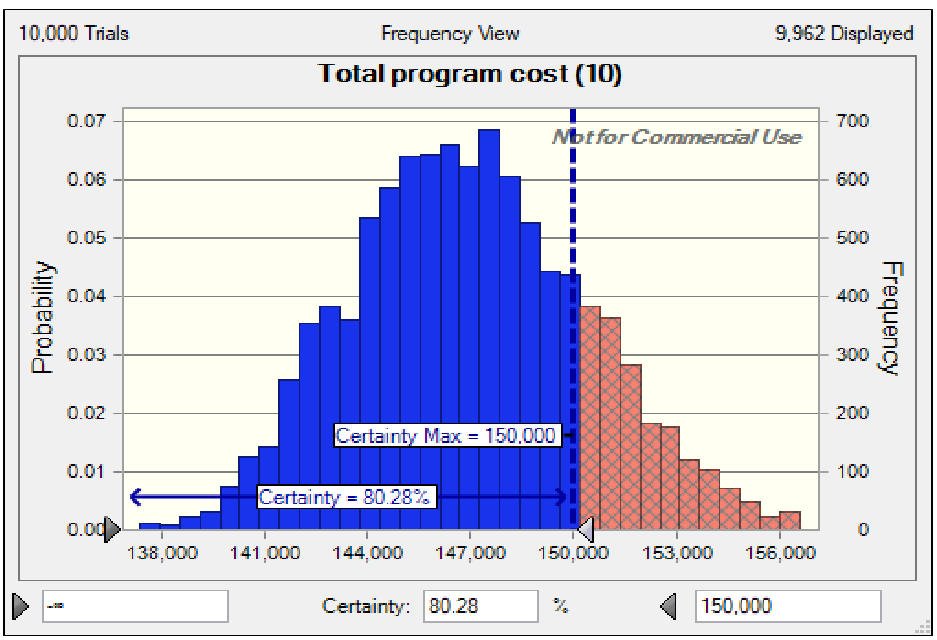

Figure 8.10: Probability of Success with Management Reserve = 14450

Now, we can go back to Oracle Crystal Ball, re- define the decision variable with limits between $14000 and $14500, and re- run the simulation. Further analysis, shows that the output of the simulation is as shown in Figure 8.10:

Step VII: Best Value Solution for Required cost/schedule and Required Probability of Success

To summarize the various levels we have simulated, refer to Table 8.3.

Table 8.3: Probabilities at various levels of Risk Mitigation budget and Management Reserve

Risk Mitigation Budget	Management Reserve	Probability of Success of Cost	Figure No
$0.00	$15,000	15.36%	8.6
$10,150	$15,000	76.66%	8.7
$10,150	$14,000	82.89%	8.8
$10,150	$14,500	79.81%	8.9
$10,150	$14,450	80.28%	8.10

Step VII: Best Value Solution for required cost and required probability

In this iteration, we can say that one acceptable program plan is with a risk mitigation budget of $10150 and a management reserve of $14450. This combination gives the Probability of Success of 80% (79.81%) for the program cost. We have applied POSE to achieve the best value solution for required cost and required Probability of Success (POS); now we move on to apply POSE to calculate the best value solution for the required schedule and the required Probability of Success (POS).

8.3 Probability of Success of Achieving Desired Program Schedule for a Simple Example Problem Case

The example program used to describe this POSE process in this Section has been explained in detail in Section 7.1. The program example used has a total phase wise schedule estimate of 80 days as shown in Table 7.1 and a schedule reserve of 10 days as discussed in Section 7.3. Thus, the total estimated schedule of the program so far is 90 days, we need to achieve a Probability of Success of 80% for 100 days.

As we discussed in Section 7.1, for the application of POSE to program schedule, we need the critical path of the program. In this example, since all the tasks are sequential, the critical path covers all the tasks in the program. Further, we consider only the risks related to the task on the critical path. But in this example, since all the tasks are on the critical path, therefore we consider all the risks as identified in Section 8.2.

Step I: Determine High, Medium and Low risks

We have described the simple program plan example in Chapter 7. Now, as we discussed in Section 8.1, we identify, quantify, and prioritize the risks in this step.

- Risk Identification: Risk 1 – 10 are the corresponding risks associated with each task in the program. This list of risks is the result of the risk identification.
- Risk Quantification: Probability of Occurrence: This is the probability of occurrence assigned to the risk either from historical data, risk register or a subject matter expert. Impact: In this case, we just consider the impact on the schedule and define the three-point estimate for schedule associated with each risk i.e. minimum, most likely and maximum.
- Risk Prioritization: Risk Value: This is the product of the most likely impact and the probability of occurrence. Risk prioritization is done as per organization needs. For example, we can say any risk value above 1 is high priority, 0.5 – 1.0 is medium priority and less than 0.5 is low priority. Then the organization makes a call whether they want to make mitigation plans only for high priority risks, or high and medium, etc. In this dissertation, we assume we will assume we are developing the risk mitigation for all the risks that have been identified in the risk management plan.

For the simple example program case below with 10 Tasks, the results of Step I are shown in Table 8.4. This is the base case of risk management, with no risk mitigation for the program plan.

If all the risks occur and the program manager does nothing, the program schedule will be increased by 16 days. Therefore, to avoid this schedule slip, we must formulate a risk mitigation plan and schedule delay risk mitigation.

Table 8.4: Risk Prioritization (No Schedule Delay risk mitigation)

Task	Risk	Probability of Occurrence	Impact of the Risk (days)			Risk value (days)
			Minimum	Most Likely	Maximum	
Task 1	Risk 1	0.9	0.9	1	1.1	0.9
Task 2	Risk 2	0.7	1.8	2	2.2	1.4
Task 3	Risk 3	0.1	1.8	2	2.2	0.2
Task 4	Risk 4	0.2	1.8	2	2.2	0.4
Task 5	Risk 5	0.5	1.8	2	2.2	1
Task 6	Risk 6	0.8	1.8	2	2.2	1.6
Task 7	Risk 7	0.3	0.9	1	1.1	0.3
Task 8	Risk 8	0.15	0.9	1	1.1	0.15
Task 9	Risk 9	0.24	1.8	2	2.2	0.48
Task 10	Risk 10	0.25	0.9	1	1.1	0.5
Total Impact (Most Likely)				**16 days**		

Step II: Determine the POS for No Mitigation

In this step we use Oracle Crystal Ball to determine the Probability of Success of achieving the desired program schedule with no schedule delay risk mitigation applied.

Refer Spreadsheet: POS_No Risk Mitigation_Schedule (Snapshot in Appendix H)

The results of the simulation are as seen in Figure 8.6. The Probability of Success of achieving the required program schedule with no schedule delay risk mitigation is 1.90%. The required Probability of Success is 80% for the 100 days. Therefore, this approach to the program plan is not acceptable. Now, we must develop a risk mitigation plan for the program to increase the Probability of Success for meeting the required schedule.

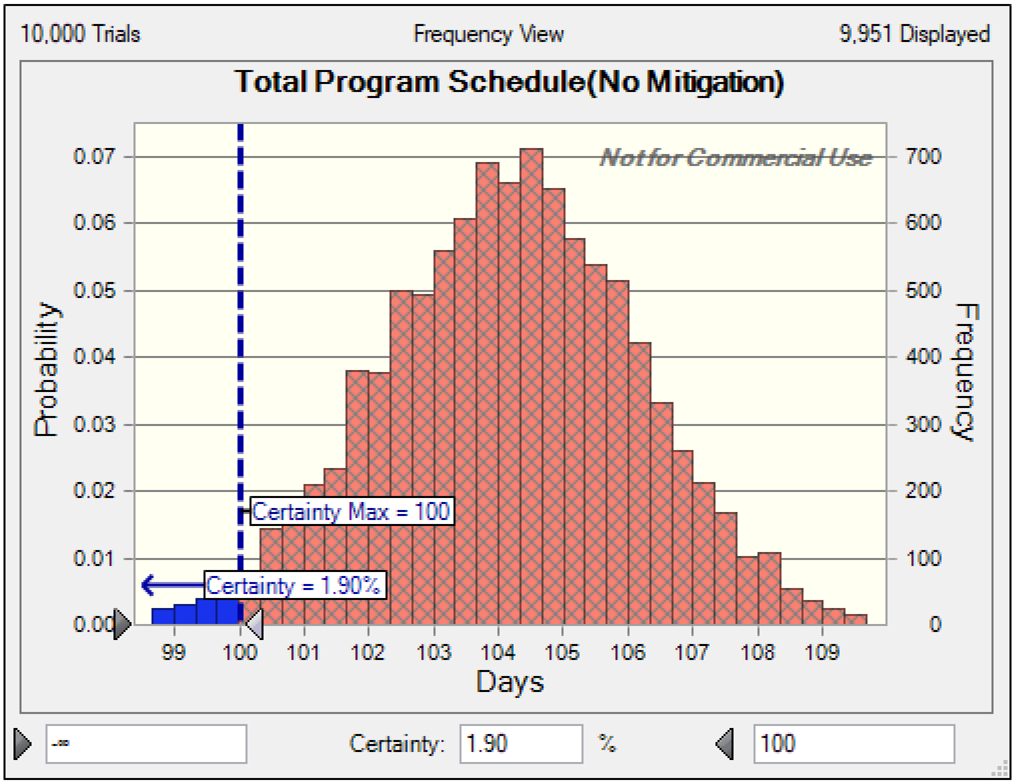

Figure 8.11: POS at No Risk Mitigation for Schedule Delay

Step III: Determine Probability of occurrence and Impact at various risk mitigation levels

The program plan is required to be accomplished in 100 days with an 80% Probability of Success for achieving that 100 days schedule. Out of these 100 days, 90 days have already been allocated (Phase wise: 80 days and Schedule reserve: 10 days). We are left with only 10 days to use for a mitigation plan. The first attempt at the risk mitigation plan is as shown in Table 8.2. When a mitigation plan is formulated for the program, the probability and impact of each of the identified risks changes. After the formulation of the risk mitigation plan, we have a Schedule delay risk mitigation of 10 days. Now, the we have to simulate the possibility that with (1) this this risk mitigation plan, (2) a phase wise estimate of 80 days, and (3) a schedule reserve of 10 days, whether we can achieve an 80% Probability of Success of schedule of performing the program in 100 days.

This is one attempt at the mitigation, as we discussed in Section 8.1., Step III, and Figure 8.3.

We can formulate many risk mitigation plans. Each Mitigation plan will have a different distribution of probability of occurrence and impact for each of the risks. For this example, let us now determine whether we have, with only this one risk mitigation based plan, a program plan that will achieve the required Probability of Success of 80% for 100 days program schedule.

Refer Spreadsheet:POS_Risk Mitigation_Schedule (Snapshot in Appendix H)

Table 8.5: Schedule Delay Risk Mitigation

The Risk	Mitigation Plan	Probability of Occurrence	Impact with a Schedule Delay Risk Mitigation (days)			Mitigation Schedule (days)
			Minimum	Most Likely	Maximum	
Risk 1	Plan 1	0.5	0.9	1	1.1	1
Risk 2	Plan 2	0.7	1.8	2	2.2	0.5
Risk 3	Plan 3	0.1	1.8	2	2.2	1
Risk 4	Plan 4	0.15	1.8	2	2.2	1
Risk 5	Plan 5	0.4	0.9	1	1.1	0.5
Risk 6	Plan 6	0.6	1.8	2	2.2	1
Risk 7	Plan 7	0.25	1.8	2	2.2	1
Risk 8	Plan 8	0.1	1.8	2	2.2	1
Risk 9	Plan 9	0.24	1.8	2	2.2	1
Risk 10	Plan 10	0.25	0.9	1	1.1	2
Total				**17**		**10**

Please Note: If we compare Table 8.5 to Table 8.4, we see that the sum of most the likely impact has increased. It is important to note that a risk mitigation affects the both the probability of occurrence and impact. So, if we can reduce the probability of occurrence of the risk substantially, even if it increases the impact, the mitigation plan might produce a better program solution.

Step IV: Perform Monte Carlo Simulation Using Oracle Crystal Ball

We have already simulated the Probability of Success if no risk mitigation is considered in Step II. We saw that with no risk mitigation plan, the Probability of Success of achieving the required program schedule is 1.90% for 100 days. Now, we run the Monte Carlo Simulation for various levels of risk mitigation (in this example we have only one risk mitigation level).

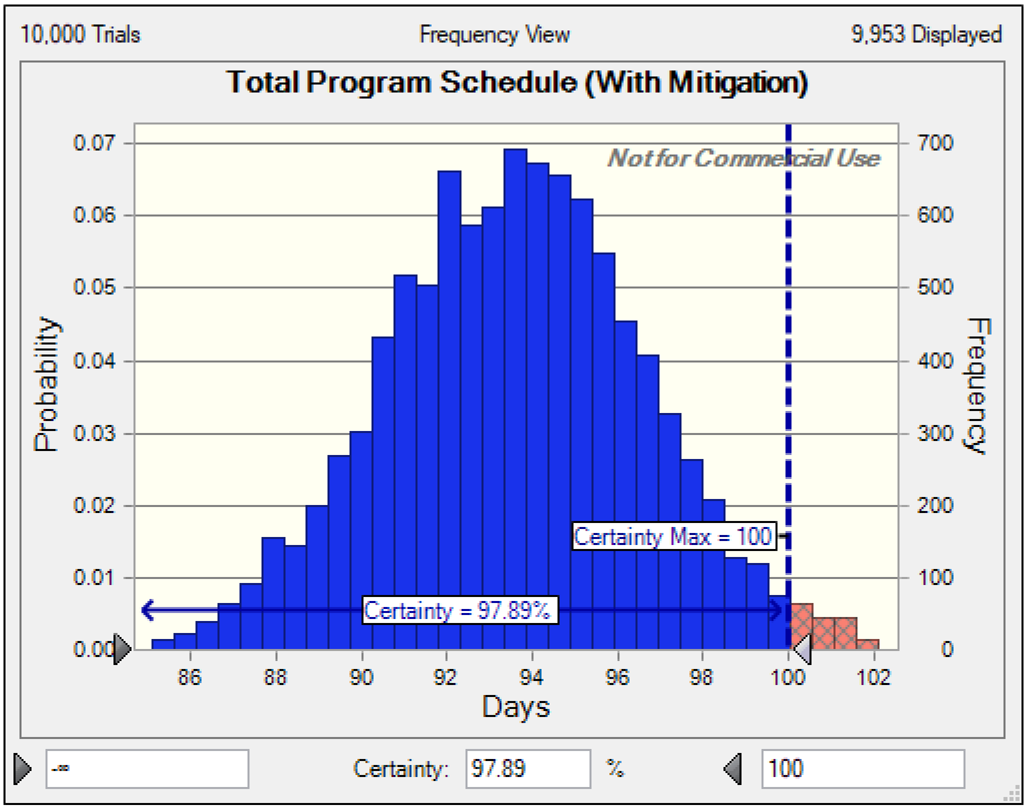

Figure 8.12: POS at a Schedule Delay Risk Mitigation of 10 days

Step V: Determine the Probability of Success for Achieving the Desired Program Schedule.

In Figure 8.7, the Probability of Success of achieving the required schedule is 97.89% considering the risk mitigation plan that has been formulated. But, we require a Probability of Success of 80%. This means that we have mitigating the risks to a greater level than required. If we have a probability of 97.89%, it means that we do not need a

Schedule delay risk mitigation of 10 days. We can decrease the mitigation to a level where we need to 80% Probability of Success. For this dissertation, let us consider that we do not want to reduce the schedule delay risk mitigation and we begin the program execution with a schedule delay risk mitigation of 10 days and a schedule reserve of 10 days.

For this example, the POSE process ends here because we have fulfilled the requirements of Probability of Success of achieving the desired schedule. But, to give an overview about the next POSE steps, in case we do not fulfill the requirements for Probability of Success of achieving desired schedule, we will discuss Step VI and Step VII.

Step VI: Iterate combinations of Schedule Delay Risk Mitigation and Schedule Reserve

In the previous step, we have concluded that 10 days is the best schedule delay risk mitigation that can be formulated, and it cannot be reduced any further. This schedule delay risk mitigation has provided us a 97.89 % Probability of Success for the required schedule of 100 days. This is higher than the required probability of 80%. For this example, we accept this solution and start the execution of the program.

But, if we were not able to achieve the desired probability, we could have reached it by it by iterating between schedule delay risk mitigation and schedule reserve. This is carried out in a similar fashion as we did for cost. In this case, we define the schedule reserve as a decision variable in Crystal Ball. Since, we have achieved the required probability in step V only, this iteration step is not needed for this example.

Step VII: Best Value Solution for Required Schedule and Required Probability of Success

Table 8.6: Probabilities at various levels of Schedule Delay Risk Mitigation and Schedule Reserve

Schedule delay risk mitigation	Schedule reserve	Probability of Success of Schedule	Figure No
0	10	1.90%	8.11
10	10	97.89%	8.12

In this iteration, we can say that the acceptable program plan is with a schedule delay risk mitigation of 10 days and a schedule reserve of 10 days. This combination gives the Probability of Success of 97.89% for achieving the desired program schedule of 100 days.

We have applied POSE to achieve best value solution for required schedule and required Probability of Success (POS).

8.4 Conclusion

In this Chapter, we have demonstrated the application of the POSE process to calculate the Probability of Success of achieving desired cost and schedule. An important point to note is that the application of POSE for required cost and required schedule should be done simultaneously. This is because any change in schedule will have a direct impact on cost of the program and vice versa. Therefore, the decisions/changes taken keeping into consideration only the cost of the program may or may not affect the schedule probability. So again, this becomes an iterative process, even if we have achieved the required POS for achieving the required cost, it may or may not be the best value solution for the schedule of the program.

So, it is paramount to remember that we need a required POS for both cost and schedule. The POSE method can be used to perform the tradeoffs in cost and schedule individually so that we understand what is required to achieve the best balanced possible combination of POS for both cost and schedule.

Chapter 9

POSE FOR MANAGING A PROGRAM

Overview: In this Chapter, we discuss how to use the 4-Step POSE process while a program is being executed as shown in Figure 9.1. In Section 9.1, we discuss the 4- step POSE process in detail. In Section 9.2, we demonstrate the application of this process to manage the cost of the program for the simple example discussed in Chapter 7. In Section 9.3, we discuss the application of the process to managing the schedule of the same Chapter 7 example program. In Section 9.4, we discuss the conclusions regarding the application of POSE to manage programs.

In this chapter, we will refer to excel spreadsheets for simulation purposes. These spreadsheets are available for download from the link:

https://www.dropbox.com/sh/fx3ilox3u6hqhdl/AAAYI3CpF3Yvffh4O7JVomREa?dl=0

in the folder named Chapter 9. For the reference of the reader, a snapshot of all the referred excel spreadsheets in mentioned in Appendix I. The snapshot in the appendix has the same name as the referred excel spreadsheet.

9.1 The 4 -Step POSE Process Description

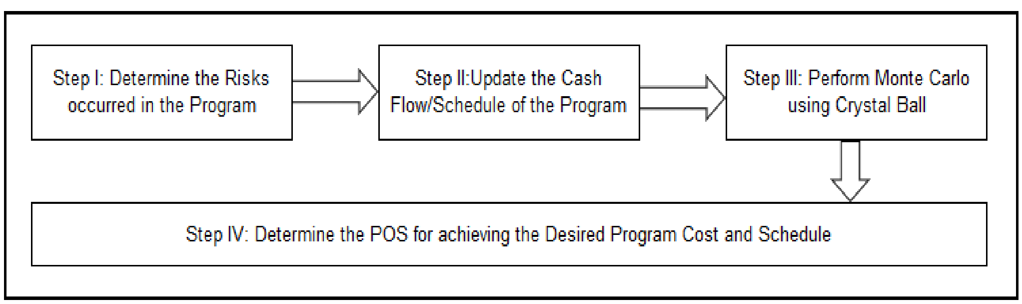

Figure 9.1: The 4- Step POSE Process for Managing a Program

Before we began execution of the Example Program from Chapter 7, we derived the plans for the best value solution for the program using the 7-step POSE process shown in Figure 7.1. We introduced the process in Chapter 7 and demonstrated its use for program planning for an example program in Chapter 8. The cost of the example program was planned for $125,000 with a management reserve of $14,450 and a risk mitigation budget of $10,150. The schedule of the program was planned for 80 days with a schedule reserve of 10 days and a schedule delay mitigation budget of 10 days.

We will now describe the 4- Step POSE Process shown in Figure 9.1 that is used for Managing the Program during the Execution Phases and demonstrates its application using the example program from Chapter 7.

Step I: Determine the Risks occurred in the Program

In this step, we determine the risks which have occurred in the program to the point in time that we are at during the program's execution. During the planning of the program, we had assigned a probability of occurrence to each risk identified in the program. During execution, we change the probability of any risk that occurred to 1. When we determine the occurred risk in the program, it also means that this risk must have used some of the risk mitigation budget of the program. The next step is to determine the expenditure from the risk mitigation budget.

Please Note: Contingency Reserves (i.e. management and schedule reserves) are the last reserves that a company spends on the program. Generally, only after all the resources have been exhausted, we turn to these reserves to solve problems that were totally unexpected and unidentified in our risk planning.

Step II: Update the Cash Flow Model and the Schedule of the program.

As we discussed in Chapter 7, Table 7.2 and 7.3, we have cost and schedule probability distributions associated with each phase of the program. Since we have now already executed a certain part of the program, we know exactly how much cost and schedule we have incurred to date including the status of all risk mitigation actions and spending and their impacts, and the remaining program budget and schedule available to complete the program.

Now, we can consider the fully updated cash flow model of the program with the exact expenses incurred so far, and the remaining tasks on the critical path of the program schedule to obtain a true picture of the remaining program to be executed.

Step III: Perform Monte Carlo using Crystal Ball

Now that we are out of the planning phase and into the program execution phases, we have an opportunity and an obligation to consider everything we have learned about the program so far, and reflect any changes that come out of this learning, or other unexpected developments and include these, into updated plans for the remaining program efforts by relooking at our remaining risks and risk mitigation plans as well as any changes to the planned tasks or schedules in the remaining program. So we next define the changes to the risks and their mitigations for the remaining program and update the inputs to the Monte Carlo Simulation from Step I and II. In this step, we remove the distributions used to describe the cost and schedule estimates of the phases that have been executed. As part of this process, for the inputs to the Monte Carlo Simulation for the risks items in the past, we change the probability of occurrence of the risks that have occurred to 1, and the probability of occurrence of risks that did not occur to 0 for considering the POS for the remaining program.

Step IV: Determine the POS for achieving the Desired Program Cost/ Schedule

Once we have derived the remaining risk mitigation budget, reserves and the remaining estimated expenses for the program, Oracle Crystal Ball determines the Probability of Success (POS) for the remaining program cost and schedule with results depicted similar to that in Figure 8.4.

The next Section demonstrates the application of these 4-steps to calculate the Probability of Success of achieving the desired program cost during execution of the example program from Chapter 7.

9.2 Probability of Success of Achieving Desired Program Cost during Execution of a Program.

Let us consider that we have executed the first three phases of the Chapter 7 example program, and are now at the end of phase 3. We will now use POSE to determine the Probability of Success for achieving the required program cost, considering the phase wise expended and future estimated costs highlighted in Table 9.1.

Refer Spreadsheet: POS_Managing_Cost (Snapshot in Appendix I)

Step I: Determine the Risks occurred in the Program

We have executed 3 phases and assumed that the risks in phase 1 and phase 2 occurred. The risk in phase 3 did not occur. Since Risk 1 and 2 occurred, this means that they incurred a risk mitigation cost. The Table 9.1 shows the risks we had identified for the risk mitigation budget of $10,150. We change the probability of the risks which occurred to 1 and the risk which did not occur to 0. Thus, we change the probability of occurrence of risk 1 and 2 to 1 and risk 3 to 0. Further, this means that we incurred the cost listed in the Mitigation Cost column in the Table 9.1. i.e. $1,200 and $950. Thus, out of the risk mitigation budget of $10150, we have spent $2150.

So now, we have a remaining risk mitigation budget of $8000 for the rest of the program plan.

Table 9.1: Updated Risk Mitigation Plan

The Risk	Mitigation Plan	Probability of Occurrence	Impact when risk mitigation budget is considered			Mitigation Cost
			Minimum	Most Likely	Maximum	
Risk 1	Plan 1	1	1080	1200	1320	1200
Risk 2	Plan 2	1	1080	1200	1320	950
Risk 3	Plan 3	0	3240	3600	3960	1400
Risk 4	Plan 4	0.15	1125	1250	1375	950
Risk 5	Plan 5	0.4	1125	1250	1375	1000
Risk 6	Plan 6	0.6	2520	2800	3080	1250
Risk 7	Plan 7	0.25	3420	3800	4180	1175
Risk 8	Plan 8	0.1	2700	3000	3300	1050
Risk 9	Plan 9	0.24	135	150	165	75
Risk 10	Plan 10	0.25	1575	1750	1925	1100

Step II: Update the Cash flow of the program

We discussed in Section 7.1, Table 7.2, that the phase wise risk mitigation estimates were described by a triangular distribution. Now that the first 3 phases have been executed, we know the costs incurred in each phase of the program. We update the cash flow of the program to reflect the costs of the program phases that we have already executed. The Table 9.2 shows the final costs for the first 3 phases which have been completed, while the estimated cost of the rest of the program phases remains the same as previously planned.

Step III: Perform Monte Carlo using Crystal Ball.

Now, we remove the distributions which defined the probability of occurrence of risk 1 and 2. We change the probability of occurrence to 1. In the cash flow; we remove the distributions used to describe the estimated costs of phase 1,2 and 3; we update the cost incurred during these phases to the cash flow; and we then run Crystal Ball to obtain the results shown if Figure 9.2.

Table 9.2: Updated Cash Flow of the Program

Phase	Task	Minimum Cost	Most Likely Cost of each Phase	Maximum Cost
Phase 1	Task 1	-	5000	-
Phase 2	Task 2	-	7700	-
Phase 3	Task 3	-	11000	-
Phase 4	Task 4	10000	12500	15000
Phase 5	Task 5	14500	15000	15500
Phase 6	Task 6	17000	17500	19000
Phase 7	Task 7	16000	17500	19000
Phase 8	Task 8	18000	20000	22000
Phase 9	Task 9	14500	15000	16500
Phase 10	Task 10	4500	5000	7500

Please note: We do not have to make any other changes to the spreadsheet during simulation. As we have changed the probability of risk to one, this means that the risk has occurred, and the mitigation costs has been incurred by the program.

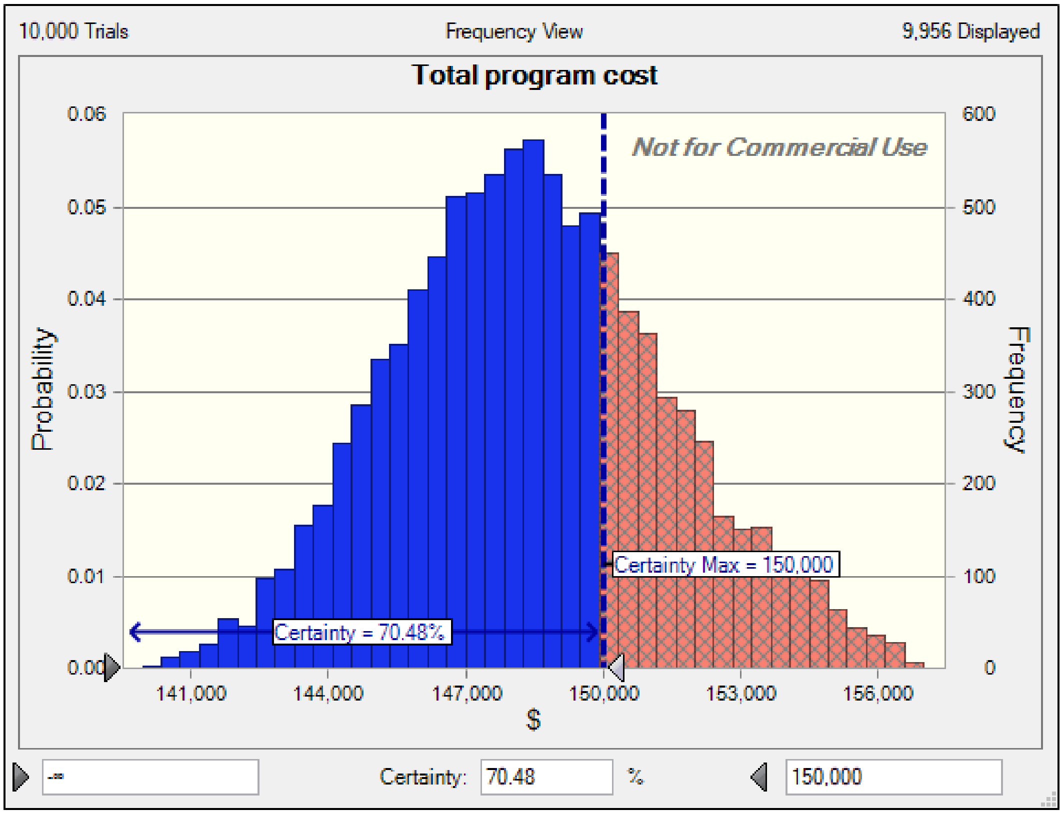

Figure 9.2: Probability of Success of the Desired Cost

Step IV: Determine the POS for the Desired Program Cost

We have considered we have executed the first 3 phases of the program and we are assessing the probability at the end of phase 3.

The most likely phase wise estimate of cost for the first three phases was $22500 (5000 + 7500 + 10000, as shown in Table 7.2), but we have spent $23,700 on the program. In addition to this expense, we incurred a risk mitigation expense of $2150.

The initial Probability of Success of the desired cost of the program was 80.28%. The execution of the first 3 phases has dropped this Probability of Success to 70.48%.

The execution so far, has led the Probability of Success of cost to drop from 80.28% to 70.48%. Now, let us apply POSE to the schedule of the program.

9.3 Probability of Success of Achieving Desired Program Schedule during Execution of a Program.

Refer Spreadsheet: POS_Managing_Schedule (Snapshot in Appendix I)

Step I: Determine the Risks occurred in the Program

We consider that, out of the risks listed for the first 3 program phases, the risks in phase 1 and 2 occurred and the risk in phase 3 did not occur. The Table 9.1 shows the risks we had identified for the Schedule Delay risk mitigation budget of 10 days. We change the probability of the risks that occurred to 1 and the risk that did not occur to 0.

Further, this means that we have a schedule delay of 1.5 days as seen in the Table 9.3. i.e. 1 day (for risk 1) and 0.5 day (for risk2). Thus, out of the schedule delay risk mitigation of 10 days, we are already delayed by 1.5 days. So now, we have a pending schedule delay risk mitigation of 8 days for the rest of the remaining program plan.

Step II: Update the Schedule of the program

As we discussed in Section 7.1, Table 7.3, the phase wise estimates of schedule were described by a triangular distribution of the number of days it will take to complete the phase. Now that the first 3 phases have been executed, we know the number of days it took to execute each phase of the program. We update the schedule of the program through the phases that we have executed to this point in time. Table 9.4 shows the final schedule it took to execute the first 3 phases, while the estimated schedule of the rest of the program phases remains the same.

Please Note: When we are assessing the Probability of Success of achieving the schedule, we use the critical path of the program. So basically, we need to update the number of days it took to execute the tasks on the critical path of the program.

Step III: Perform Monte Carlo using Crystal Ball.

Now, we remove the distributions which defined the probability of occurrence of risk 1 and 2. We change the probability of occurrence to 1 (since we know that risk 1 and risk 2 occurred), while the probability of occurrence of the risk 3 is changed to 0 (since we know that risk 3 did not occur), as shown in Table 9.3

Table 9.3: Updated Schedule Delay Risk Mitigation Plan

The Risk	Mitigation Plan	Probability of Occurrence	Impact with schedule delay risk mitigation (days)			Mitigation Schedule (days)
			Minimum	Most Likely	Maximum	
Risk 1	Plan 1	1	0.9	1	1.1	1
Risk 2	Plan 2	1	1.8	2	2.2	0.5
Risk 3	Plan 3	0	1.8	2	2.2	1
Risk 4	Plan 4	0.15	1.8	2	2.2	1
Risk 5	Plan 5	0.4	0.9	1	1.1	0.5
Risk 6	Plan 6	0.6	1.8	2	2.2	1
Risk 7	Plan 7	0.25	1.8	2	2.2	1
Risk 8	Plan 8	0.1	1.8	2	2.2	1
Risk 9	Plan 9	0.24	1.8	2	2.2	1
Risk 10	Plan 10	0.25	0.9	1	1.1	2
Total				**17**		**10**

Table 9.4: Updated Schedule (Critical Path) of the Program

Phase	Task	Minimum No. of Days	Most Likely No. of Days	Maximum Number of Days
Phase 1	Task 1	-	5	-
Phase 2	Task 2	-	5	-
Phase 3	Task 3	-	6	-
Phase 4	Task 4	4	5	8
Phase 5	Task 5	5.5	7	8
Phase 6	Task 6	6	9	10
Phase 7	Task 7	10	11	14
Phase 8	Task 8	9	10	13
Phase 9	Task 9	12	15	18
Phase 10	Task 10	7	8	9
Total (Program Schedule)		64	80	99

In the schedule of the program, we remove the distributions used to describe the schedule of phase 1, 2, and 3 and we update the schedule with the actual days it took to execute the phases as seen in Table 9.4. The inputs to the simulation have been redefined considering that we have executed the first 3 phases of the program. After updating the inputs, we run the Monte Carlo Simulation using Crystal Ball for the remaining program. The output of this simulation is shown in Figure 9.3.

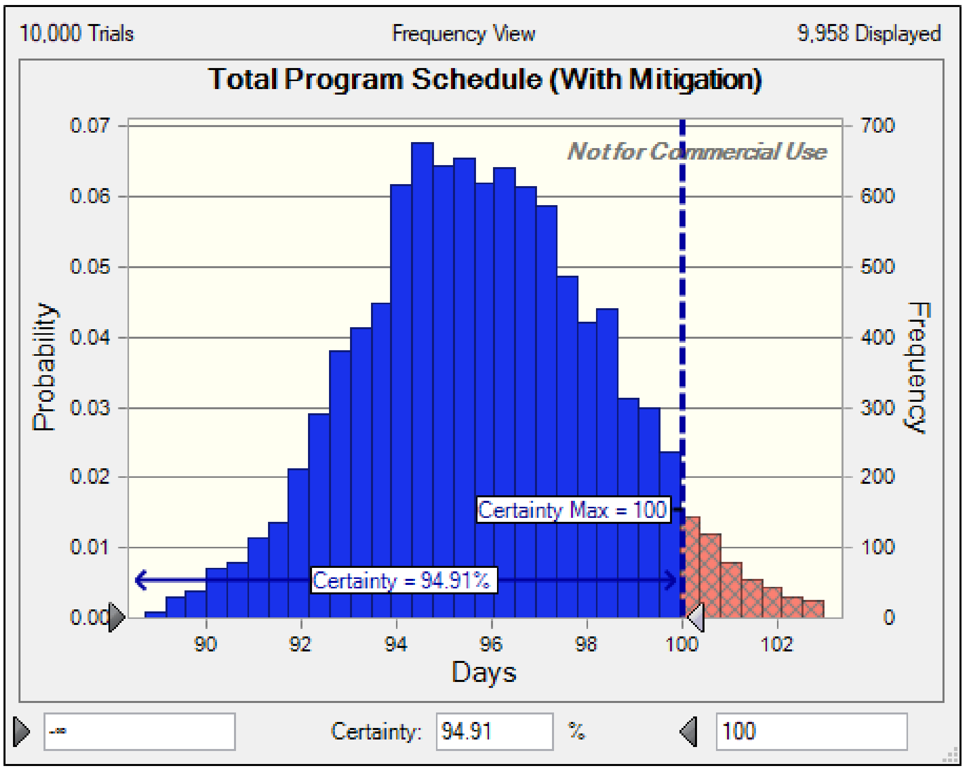

Figure 9.3: Probability of Success of the Desired schedule

Step IV: Determine the POS for the Desired Program Schedule

We have considered that we have executed the first 3 phases of the program and we are assessing the Probability of Success after the completion of phase 3. The most likely phase wise estimate for schedule of the first three phases was 15 days (4 + 5 + 6, as shown in Table 7.3), but it took 16 days to execute the 3 phases. In addition to the delay of 1 day in the phase wise estimated schedule, we have an additional delay of 1.5 days due to the risk that occurred.

The initial Probability of Success of the desired cost of the program was 97.29%. The execution of the first 3 phases has dropped this Probability of Success to 94.91% as seen in Figure 9.4. Thus, we can conclude that the program has a high probability of achieving the desired schedule.

9.4 Conclusion:

This Chapter has demonstrated the application of the 4-step POSE process to help manage a program during actual execution. This POSE Process can and should be done often to maintain visibility of what's going on the program and to aid in decision making about what fixes or modifications are required to continue to achieve an acceptable level of POS for the remaining program, whether that's even possible, or whether the program might even be terminated.

From this application, we can see that when we started the execution of the program plan, cost and schedule were planned to achieve a minimum acceptable Probability of Success of 80% each. During execution, we accounted for the risks that occurred and the expenses and delays caused by these risk events. So, by constantly considering the continual estimate of POS using POSE, the program manager can make better decisions regarding the program execution.

The POSE gives an integrated metric for managing programs. In the POSE analysis for achieving the required POS for cost, we saw the probability has dropped to 74.23% by the time we have completed Phase 3 of the program. Just as we decided on a minimum threshold of acceptable POS for cost and schedule to be 80% before beginning the program, we can also use POSE to decide when the program baseline needs to change. For example: if the POS drops below 40%, this means that there is a 60% chance of the program not achieving its desired cost/schedule. If the program is beyond recovery, we may have to totally re-plan the rest of the program to achieve the desired probability. Once the program is re-planned, we can again use POSE to calculate the probability of the revised program plan succeeding as we continue execution.

In this Chapter, we applied POSE to a simple program plan, to understand the POSE process during program execution. In the next Chapter, we apply POSE to a complex real-world program plan to get a better understanding of its value and insights for the program manager.

Chapter 10

APPLICATION OF POSE TO A COMPLEX PROGRAM

Overview: In this Chapter, we demonstrate the application of POSE to a complex real-world program. In Section 10.1, we describe the program, its objectives and the baseline program plan. In Section 10.2, we discuss validating the program plan by performing a POSE analysis to confirm or determine whether we have a plan that has an acceptable POS to the company before beginning execution. In Section 10.3 we discuss managing the program plan during execution using POSE. In Section 10.4 we discuss the conclusions regarding the program and the application of POSE methodology to achieve the desired results from the program.

In this chapter, we will refer to excel spreadsheets for simulation purposes. These spreadsheets are available for download from the link:

https://www.dropbox.com/sh/fx3ilox3u6hqhdl/AAAYI3CpF3Yvffh4O7JVomREa?dl=0

in the folder named Chapter 10. For the reference of the reader, a snapshot of all the referred excel spreadsheets in mentioned in Appendix J. The snapshot in the appendix has the same name as the referred excel spreadsheet.

10.1 Baseline Program Plan

Program Objective: The program objective is to build and sell a Mid-tier cell phone. The program plan is to be designed to manufacture 6 million phones and sell them for $150 each in 48 months. Thus, the total expected revenue is $900 Million. The sponsoring organization wants to make a profit of $270 million after tax. (This version of POSE deals only with cost and schedule of the program, therefore we will be focusing on only these two attributes of the program)

Program Details: The total revenue expected is $900 million and the expected profit is $270 million after tax. Assuming a 28% tax rate, the profit before tax should be $375 million. Thus, the total cost of the program must be $900 - $375 = $525 million. The organization must plan a program that provides 80% Probability of Success of achieving a cost of $525 million and an 80% Probability of Success of achieving the planned program schedule of 48 months. We have 262 working days in each year, so 262 * 4 = 1048 days. This 1048 days will vary depending on which years we plan the project. So, for the purposes of simplification, we round to 1050 working days for this program. We will use days as the unit for schedule and the desired schedule is 1050 days for the program. Further, for this program, the program manager has decided that the management reserve will be $40 million, and the schedule reserve will be 50 days.

Once these program objectives are clear, the organization starts building the baseline plan. This baseline program plan has been designed using MS Project. (Refer file: Baseline Program Plan, user needs to have MS project to access this file. Another copy of this file with the name “Baseline Program Plan_Excel”, has been provided for users that do not have MS project. This file can be accesses using MS Excel). This baseline program plan shows that the program has 7 phases and defines the phase- wise cost and schedule estimates needed to deliver the program.

Table 10.1: Phase Wise Estimate of Cost and Schedule of the program

Task Name	Duration	Start	Finish	Cost
Program Summary	1018 days	Mon 10/9/17	Wed 9/1/21	$461,878,000.00
Phase I: Market Planning	91 days	Mon 10/9/17	Mon 2/12/18	$6,880,000.00
Phase II: Placement and Acceptance	95 days	Tue 2/13/18	Mon 6/25/18	$7,057,000.00
Phase III: Project Definition	84 days	Tue 6/26/18	Fri 10/19/18	$3,046,000.00
Phase IV: Implementation	202 days	Mon 10/22/18	Tue 7/30/19	$95,625,000.00
Phase V: Launch and Close Out	71 days	Wed 7/31/19	Wed 11/6/19	$79,670,000.00
Phase VI: Production	270 days	Thu 11/7/19	Wed 11/18/20	$173,550,000.00
Phase VII: Customer Support	475 days	Thu 11/7/19	Wed 9/1/21	$96,050,000.00

Once the baseline program plan is designed, we can start the application of POSE to the baseline program plan to determine the POS of achieving the desired program costs and profits to the desired schedule.

10.2 Probability of Success of 80% for Desired Program Cost

In this Section, since we are still in the program planning phase, we follow the 7- step POSE process to derive the Probability of Success of achieving the desired 80% for a desired cost of $525 million. The phase- wise cost estimates are described in Table 10.1.

Step I: Determine High, Medium and Low risks

Refer to spreadsheet: Step I_POSE_Cost (Snapshot in Appendix J)

In the referenced spreadsheet, we have identified all the risks in each phase of the program. We assign a probability of occurrence for each of the risks and the corresponding impacts (minimum, most likely and maximum) of each the risks. Further, we calculate the risk value of each risk which is the product of probability of occurrence and the most likely impact of the risk.

We then prioritize the risks based on risk value. In this example, we have considered that risks with a risk value greater than $1,000,000 are high risks, greater than $500,000 are medium risks and all others are low risks. Usually, organizations focus on high and medium risks for mitigation planning. But for this dissertation we will plan on mitigating all of the risks, irrespective of their category.

Step II: Determine POS for No Risk Mitigation

Refer spreadsheet: Step II_POSE_Cost (Snapshot in Appendix J)

In this step we calculate the Probability of Success of achieving the desired cost of $525 million with no risk mitigation applied. The inputs to this simulation are:

Assumptions:

- Probability of occurrence: Defined as a Yes-No Distribution
- Impact of the risk: Defined as a triangular distribution
- Phase- Wise estimate of Cost: Define as a normal cost distribution as shown in Table10.1

Forecast: Total Program Cost

After defining the inputs, we perform the Monte Carlo Simulation using Oracle Crystal Ball. We see the output of the simulation is as shown in Figure 10.1.

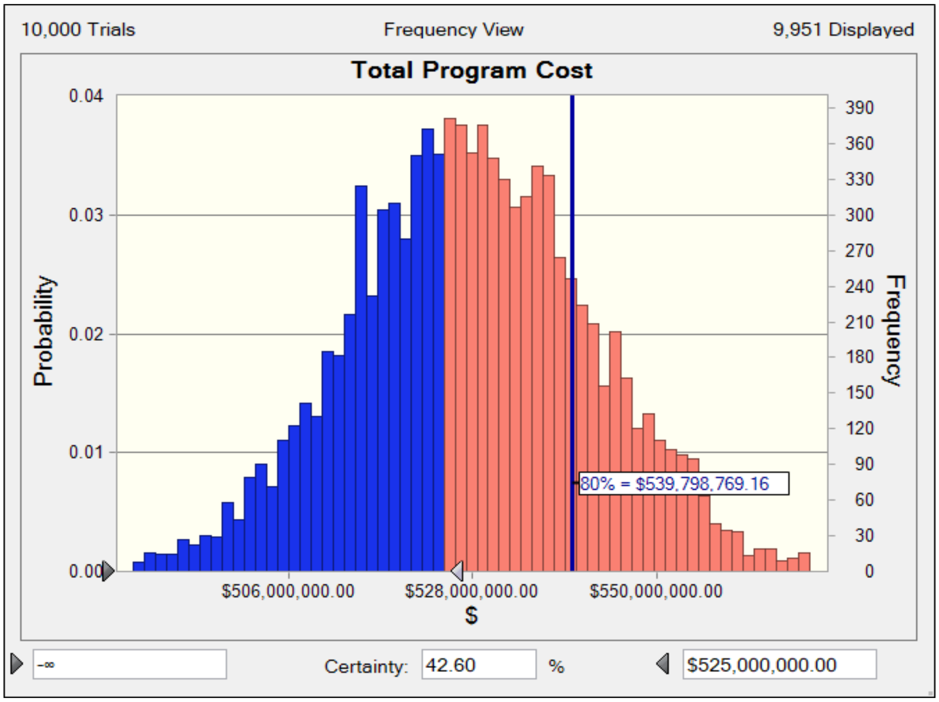

Figure 10.1: Probability of Success of Cost with No Risk Mitigation

After performing the simulation, we can see that the Probability of Success of the achieving the desired cost of $525 Million is only 42.60% with no risk mitigation. Thus, we need to have risk mitigation plans that increase our POS for the program to have it be acceptable. So, in the next step we start to formulate the risk mitigation plans to create an acceptable POS program.

Step III: Determine Probability of occurrence and Impact at various risk mitigation Levels

Refer Spreadsheet: Step III_POSE_Cost (Snapshot in Appendix J)

In this step, we allocate a risk mitigation budget to all the identified risks. We define the probability of occurrence of these risks and the impact of the risks under the allocated mitigation budget. After this allocation, the total risk mitigation budget for the program sums up to be $18,728,415. In this example, we formulated only one risk mitigation plan and assumed that this is the best possible risk mitigation. But we can formulate risk mitigation plans for various levels of risk mitigation budget and then use them to simulate each of the plans to achieve the desired probability for the desired cost thereby allowing us to trade various risk mitigation plans to achieve the required POS. So, risk mitigation becomes a powerful tool for reaching an acceptable program plan, provided you have a POSE tool available to study the trades.

Step IV: Perform Monte Carlo Simulation Using Oracle Crystal Ball

Refer Spreadsheet: Step IV_POSE_Cost (Snapshot in Appendix J)

The Monte Carlo Simulation results for determining the probability of achieving the project cost with the planned risk mitigation budget are shown in Figure 10.2.

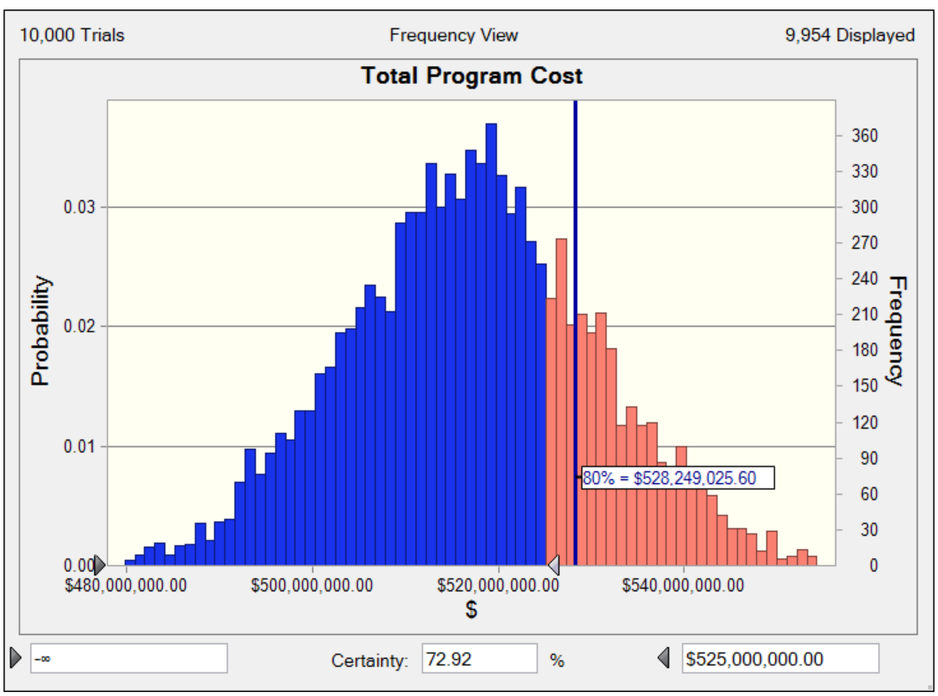

Figure 10.2: Probability of Success of Achieving the Desired Program Cost with Risk Mitigation Budget

Step V: Determine the Probability of Success for Achieving the Desired Program Cost with Risk Mitigation Budget

After running the simulation in Step IV, the output of the simulation is as shown in Figure 10.2. In this Figure we can see that the Probability of Success of achieving the desired cost has increased from 42.60% to 72.92%. This Probability of Success is still less than desired. It is also seen that at 80% Probability of Success, the program cost will be $528,249,025. Thus, more changes are needed to the program plan to achieve the desired probability for the desired cost i.e. 80% Probability of Success for a cost of $525 million.

Step VI: Iterate combinations of Risk Mitigation and Management Reserve

Since we assume that we have virtually finalized the risk mitigation plan and the risk mitigation budget cannot be changed much further, we must now iterate between the risk mitigation (possible small changes only) and the management reserve to achieve the desired probability for the cost of $525 million. In this step, we decide the minimum acceptable management reserve. We assume that the minimum acceptable management reserve is $34 million based on our experience from previous similar programs. To perform this iteration, we define the management reserve as a decision variable with a range of $34 million to $40 million. (refer Section 6.3 for decision variables).

Refer Spreadsheet: Step VI_POSE_Cost (Snapshot in Appendix J)

After performing the simulation, we see that the probability of 80% of achieving the desired cost of $525 million is when the management reserve is $35.5 million with the risk mitigation plan we are using.

Step VII: Best Value Solution for Desired cost and Desired Probability of Success

Before POSE, we had assumed a management reserve of $40 million. But after application of POSE, we have formulated a risk mitigation budget of $18,728,415. Further in step IV, we derived a probability of 72.92% with the risk mitigation budget and a management reserve of $40 million.

But after the iteration in Step VI, we have seen that to achieve the desired probability at the desired cost, we can have a risk mitigation of $18,728,415 and a management reserve of $35.5 million only as shown in Figure 10.3.

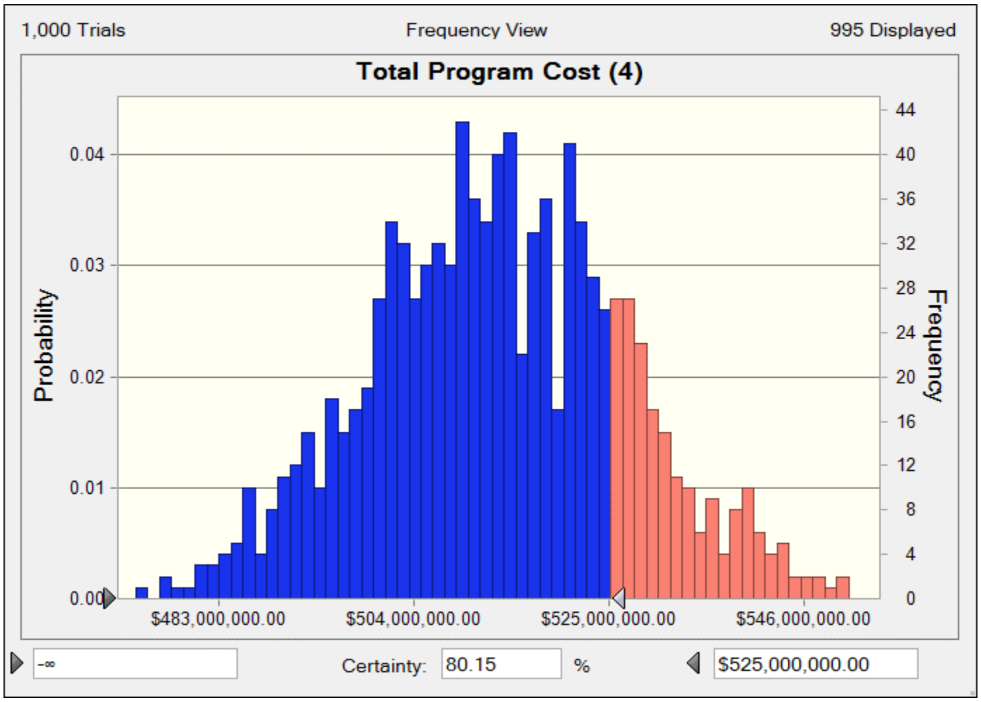

Figure 10.3: Iteration of Risk Mitigation and Management Reserve

We have applied POSE to the program cost to derive the best value solution.

10.3 Probability of Success of 80% for Desired Program Schedule

As we discussed in Section 10.1, the total schedule available for the program is 1050 days. We need design a program to receive an 80% Probability of Success for the desired schedule of 1050 days. For the schedule, we assume that the schedule reserve is 50 days for the program.

Remember, during assessing the Probability of Success for achieving desired schedule, we only take into consideration the activities on the critical path. The sum of the activity durations in the Critical Path is equal to the program's duration; therefore, a delay to any critical activity will result in a delay to the program completion date. We can derive the critical path of the program by using the MS project file: Baseline_Program_Plan, which can be downloaded via the link mentioned in the overview Section. In this file, we see that the total duration of the critical path is 1018 days. The critical path of the program has been clearly shown in the spreadsheet: Critical_Path. The tasks listed in the spreadsheet are critical tasks.

Step I: Determine High, Medium and Low risks

Refer Spreadsheet: Step I_POSE_Schedule (Snapshot in Appendix J)

We use the same risks as identified in Step I of POSE for cost (Section 10.2). We modify the list of risks only to the risks that are related to tasks on the critical path of the program. In the referenced spreadsheet, we have updated the list of identified risks. The probability of occurrence of the risk remains the same as assigned in step I of POSE for cost (Section 10.2). Now, we assign the impact of the risks in terms delay in number of days, if the risk occurs.

Step II: Determine POS for No Risk Mitigation

Refer Spreadsheet: Step II_POSE_Schedule (Snapshot in Appendix J)

In this step we calculate the Probability of Success of achieving the desired schedule of 1050 days with no risk mitigation for schedule delay. The inputs to this simulation are:

Assumptions:

- Probability of occurrence: Defined as a Yes-No Distribution
- Impact of the risk: Defined as a triangular distribution
- Estimates of schedule for the critical tasks: Defined as a triangular distribution

Forecast: Total Program Schedule

After defining the inputs, we perform the Monte Carlo Simulation using Oracle Crystal Ball. We see the output of the simulation is as shown in Figure 10.4.

After performing the simulation, we can see that the Probability of Success of the achieving the desired schedule of 1050 days is only 1.27% without a schedule delay risk mitigation. Thus, we need to have risk mitigation plans that increase our POS for the program to have it be acceptable. So, in the next step we start to formulate the risk mitigation plans to create an acceptable POS program.

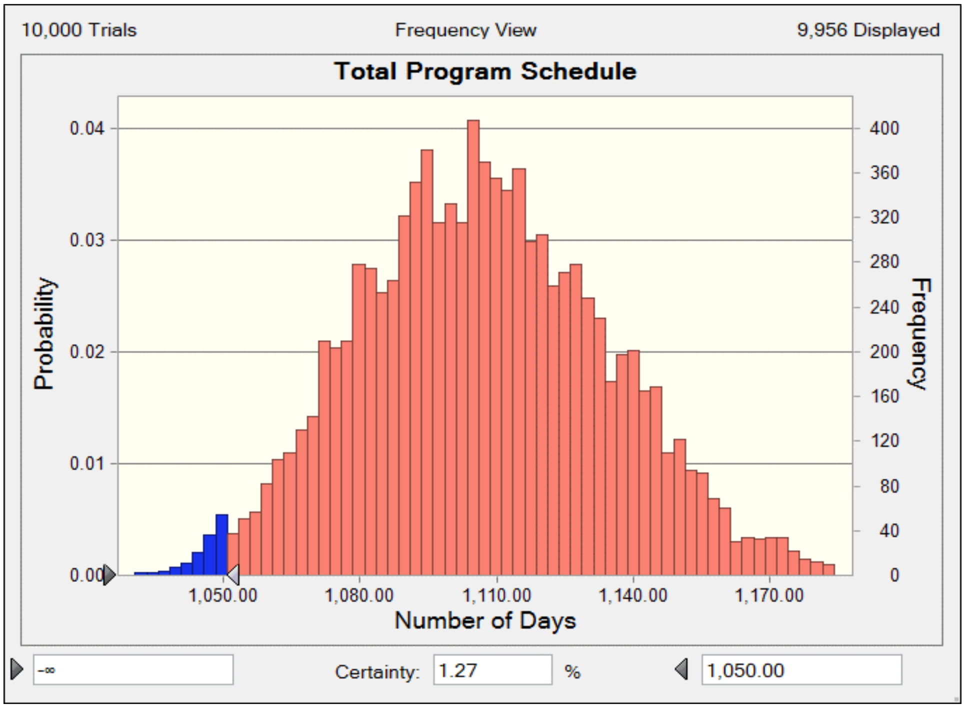

Figure 10.4: Probability of Success with No Risk Mitigation for Schedule Delay

Step III: Determine Probability of occurrence and Impact at various risk mitigation Levels

Refer Spreadsheet: Step III_POSE_Schedule (Snapshot in Appendix J)

In this step, we allocate a schedule delay risk mitigation to all the identified risks. We define the probability of occurrence of these risks and the impact of the risks under the allocated mitigation budget. After this allocation, the total schedule delay risk mitigation budget for the program sums up to be 48 days.

In this example, we formulated only one risk mitigation plan and assumed that this is the best possible risk mitigation. But we can formulate risk mitigation plans for various levels of schedule delay risk mitigation and then use them to simulate each of the plans to achieve the desired probability for the desired schedule thereby allowing us to trade various risk mitigation plans to achieve the required POS. So, risk mitigation becomes a powerful tool for reaching an acceptable program plan, provided you have a POSE tool available to study the trades.

Step IV: Perform Monte Carlo Simulation Using Oracle Crystal Ball

Refer Spreadsheet: Step IV_POSE_Schedule (Snapshot in Appendix J)

The Monte Carlo Simulation results to forecast the program schedule with the planned schedule delay risk mitigation are shown in Figure 10.5.

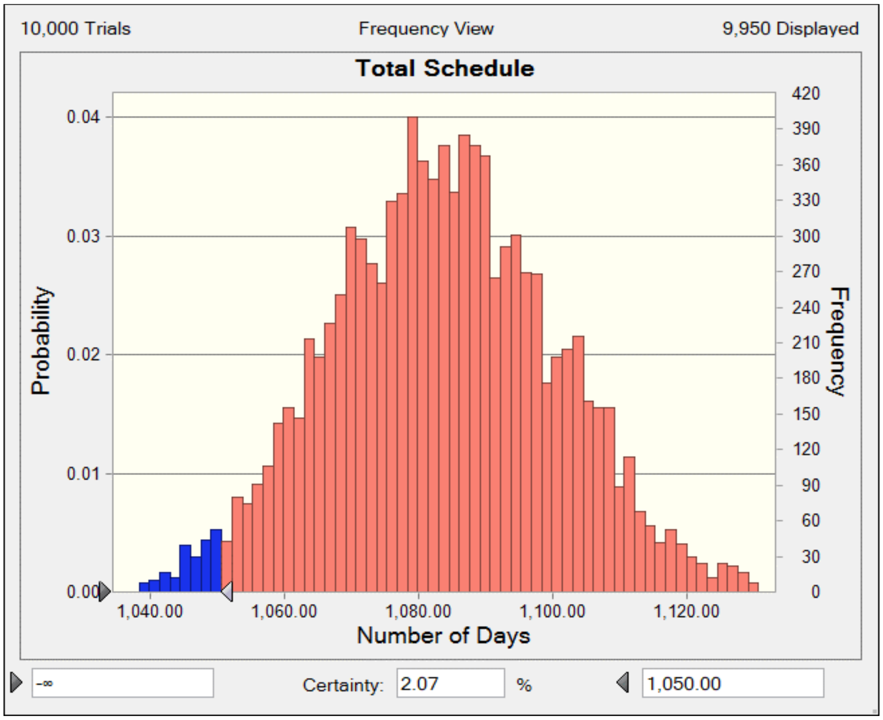

Figure 10.5: Probability of Success of Achieving the Desired Program Schedule with Schedule Delay Risk Mitigation

Step V: Determine the Probability of Success for Achieving the Desired Program Schedule with Risk Mitigation

After running the simulation in step IV, the output of the simulation is as shown in Figure 10.5. In this Figure we can see that the Probability of Success of achieving the desired cost has increased from 1.27% to 2.07%. Thus, more changes are needed to the program plan to achieve the desired probability for the desired schedule i.e. 80% Probability of Success for a schedule of 1050 days.

Step VI: Iterate combinations of Schedule Delay Risk Mitigation and Schedule Reserve

Since we assume that we have virtually finalized the risk mitigation plan and the schedule delay risk mitigation cannot be changed much further, we must now iterate between the risk mitigation (possible small changes only) and the schedule reserve to achieve the desired probability for the schedule of 1050 days. In this step, we decide the minimum acceptable schedule reserve. We assume that the minimum acceptable schedule reserve is 30 days based on our experience from previous similar programs.

To perform this iteration, we define the schedule reserve as a decision variable with a range of 30 – 50 days. (refer Section 6.3 for decision variables).

Refer Spreadsheet: Step VI_POSE_Schedule

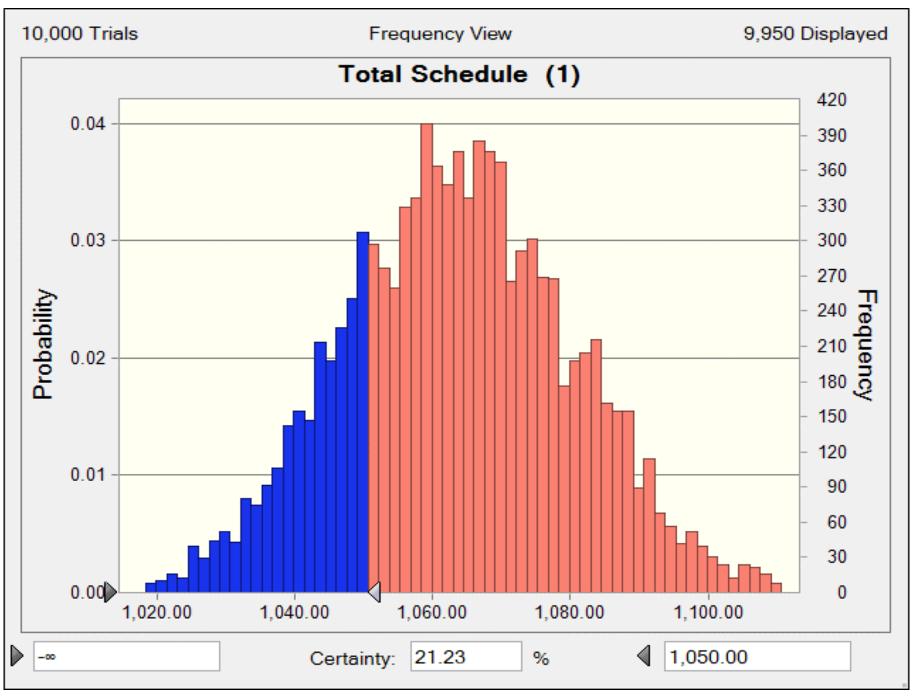

Figure 10.6: Probability of Success with Minimum Acceptable Schedule Reserve

After the simulation, we see that the Probability of Success of 80% is still not achieved. Even at the minimum acceptable schedule reserve of 30 days, the probability of achieving 1050 days is just 21.23%

Step VII: Best Value Solution for Desired Schedule and Desired Probability of Success

Before POSE, we had assumed a schedule reserve of 50 days. But after application of POSE, we have formulated a schedule delay risk mitigation of 48 days. Further in step IV, we derived a probability of 2.07% with the schedule delay risk mitigation and a schedule reserve of 50 days.

But after the iteration in Step VI, even after trading schedule reserve and adding mitigation plans to the program, we still have not achieved the desired probability for the desired schedule i.e 80% probability of completing the program in 1050 days.

This means that the baseline program plan requires re – planning in terms of schedule, so now the program manager must revisit the program plan, go through task by task and try and reduce the estimated schedule of the program. Then, we again run POSE to validate the revised schedule of the program.

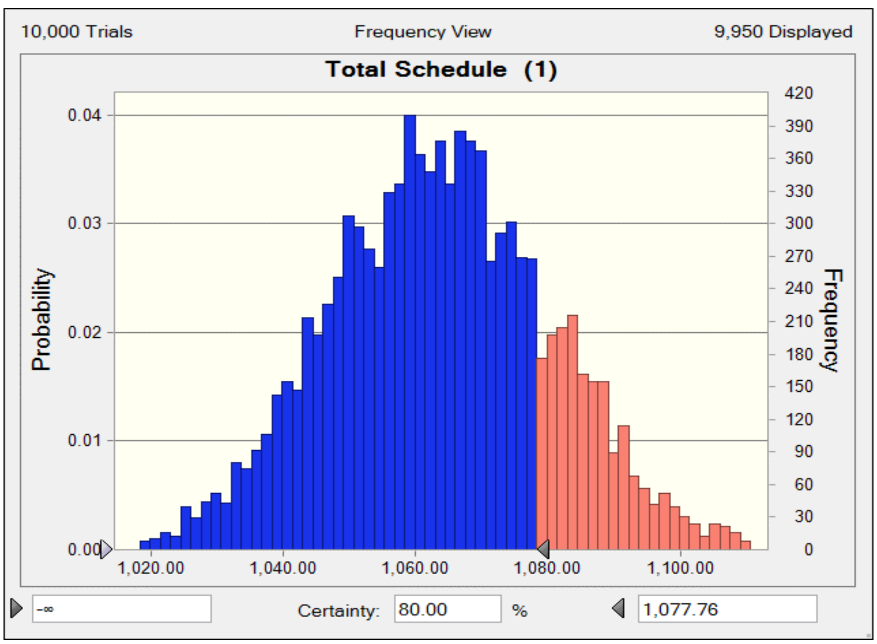

Figure 10.7: Acceptable Solution at 80% Probability of Success.

But for demonstrating POSE for managing program schedule, let us assume that we accept the 80% probability of completing the program in 1077 days. This means our new desired schedule is 1077 days, with a schedule delay risk mitigation of 48 days and a schedule reserve of 30 days.

The next obvious question is what should be critical path duration be, to maintain a risk mitigation duration of 48 days and a schedule reserve of 30 days. POSE cannot answer this question. As we discussed, the base assumption for POSE is that the Baseline Program plan has already been formulated. The risk mitigation and schedule reserve are a fall out of the baseline program plan. We cannot derive the baseline program plan using risk mitigation and schedule reserve.

Please Note: We have concluded that the program cannot achieve 80% probability for the desired schedule of 1050 days. So, in the real world, we will have to revise the whole baseline program plan. But, replanning a program is beyond the scope of this dissertation. So, for demonstrating POSE during execution, let us consider that the program manager begins the execution of this plan and which now has an 80% probability of being completed in 1077 days.

10.4 POSE to Manage the Program Cost during Execution

During the planning of the program, the program plan which provided 80% Probability of Success of achieving the desired cost of $525 million consists of a phase- wise estimate cost of $461,878,500, a risk mitigation budget of $18,728,415 and a management reserve of $35,500,000. We began the execution of the program with the above defined costs.

Now, let us assume that the first two phases of the program have been executed. After phase 2 and before phase 3, we want to assess the probability of achieving the cost of $525 million. During execution, we use the 4-step POSE process.

Refer Spreadsheet: POSE_Managing_Cost (Snapshot in Appendix J)

Step I: Determine the Risks occurred in the Program

The first two phases of the program have been executed. Now, we identify the risks which occurred in the first two phases of the program. Now, let us assume that all the risks we identified in the first two phases occurred. We change the probability of these risks to 1. Now, these risks consume the mitigation budget assigned to them from the risk mitigation budget. Therefore, the risk mitigation budget consumed by these risks is

$577,125. So out of the $18,728,415 risk mitigation budget, we are left with $18,151,290 as risk mitigation budget for the rest of the program.

Step II: Update the Cash flow of the program

The first two phases have been executed, so we know the exact expenditure for these two phases. The estimated cost of phase 1 and 2 was $6,880,000 and $7,057,500 respectively. Let us assume that we have incurred an expense of $7,000,000 and $7,200,000 for phase 1 and phase 2 respectively. We update the phase wise expense of these two phases as discussed, while the rest of the phase wise cost estimates remain the same.

Step III: Perform Monte Carlo using Crystal Ball

After updating the probability of occurrence of the risks, the risk mitigation budget and the phase wise expenses of the phases that have been executed, in this case, the first two phases. We run the Monte Carlo Simulation for the rest of the program.

The simulation output for the remaining program is as shown in Figure 10.8.

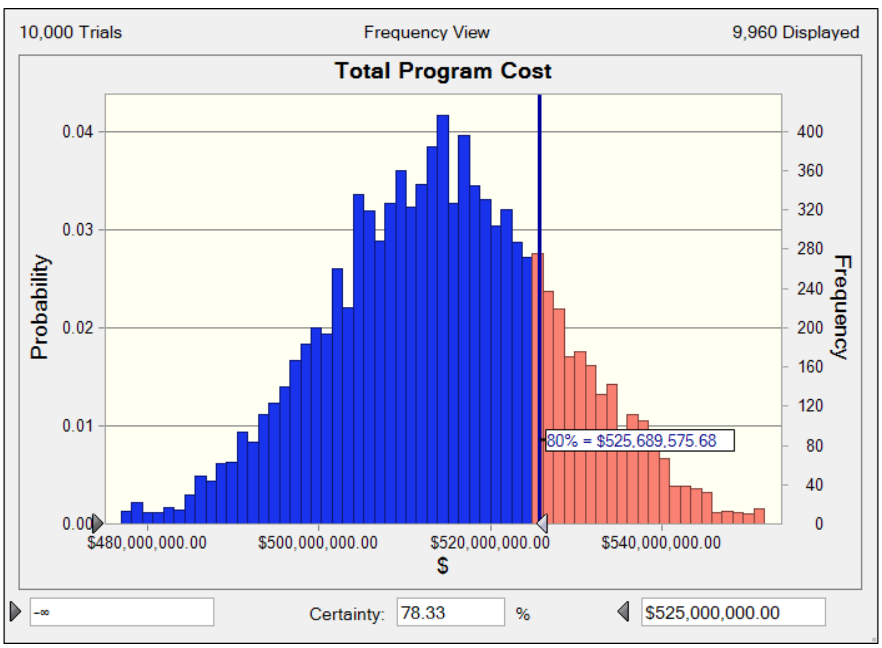

Figure 10.8: Probability of Success of the Achieving Desired Cost for the remaining Program

Step IV: Determine the POS for the Desired Program Cost

As we see in Figure 10.8, the Probability of Success of achieving the desired cost of $525 million has decreased from 80.15% to 78.33%. This means that the program execution of the first two phases has hurt the Probability of Success of the program.

Now, with a remaining risk mitigation budget of $18,151,290, a management reserve of $35.5 million and the rest of the estimated phase expense, the probability of achieving the desired cost of $525 million now is 78.33%.

10.5 POSE to Manage the Program Schedule during Execution

During this planning phase, we concluded that the program schedule needs to be re planned to achieve the desired Probability of Success for schedule of 1050 days. For this Section, let us assume that the program manager accepts the program that as seen in Step VII of Section 10.3 i.e. critical path of 1018 days with a schedule delay risk mitigation of 48 days and a schedule reserve of 30 days. This means we begin the execution of the program, with an 80% probability of completing the program in 1077 days.

Same as we did for cost, we have considered that the first two phases of the program have been executed. After phase 2 and before phase 3, we want to assess the probability of achieving the schedule of 1077 days. During execution, we use the 4-Step POSE process.

Refer Spreadsheet: POSE_Managing_Schedule (Snapshot in Appendix J)

Step I: Determine the Risks occurred in the Program

The first two phases of the program have been executed. Now, we identify the risks which occurred in the first two phases of the program. Now, let us assume that all the risks we identified in the first two phases occurred. We change the probability of these risks to 1. Now, these risks consume the mitigation budget assigned to them from the schedule delay risk mitigation. Therefore, the schedule delay risk mitigation consumed by these risks is 6 days. So out of the 48 days of schedule delay risk mitigation, we are left with only 42 days as schedule delay risk mitigation for the rest of the program.

Step II: Update the Schedule of the program

The first two phases have been executed, so we know the exact schedule for these two phases. The estimated schedule of critical tasks is now updated to the actual schedule these tasks took to be finished. We update the schedule of the critical tasks of these two phases as discussed, while the rest of the critical path schedule remains the same.

Step III: Perform Monte Carlo using Crystal Ball

After updating the probability of occurrence of the risks, the schedule delay risk mitigation and the schedule of the executed critical tasks, we run the Monte Carlo Simulation for the rest of the program.

The simulation output for the remaining program is as shown in Figure 10.9.

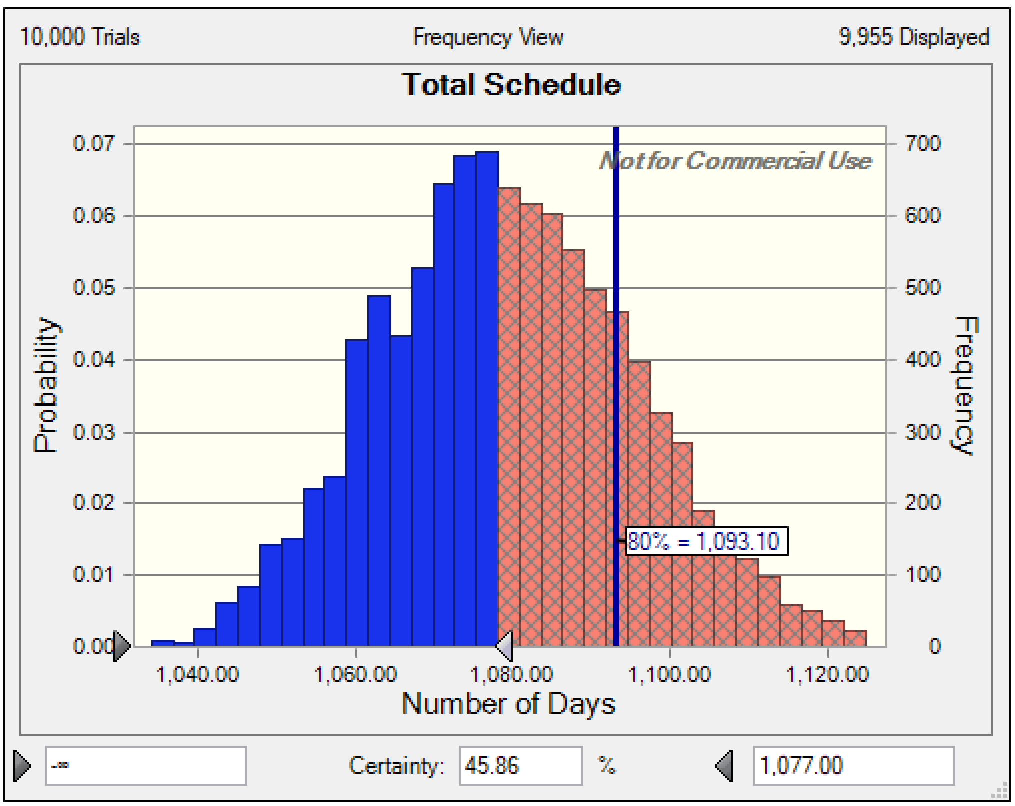

Figure 10.9: Probability of Success of the Achieving Desired Schedule for the remaining Program

Step IV: Determine the POS for the Desired Program Schedule

As we see in Figure 10.9, the Probability of Success of achieving the desired schedule of 1077 days has decreased from 80% to 45.86%.

Let us summarize the schedule conclusions. We desired schedule of 1050 days. But considering the program plan, only trading with risk mitigation and schedule reserve was not enough to achieve the required probability. This means that the baseline program plan needs to be revised thoroughly.

But for the demonstration, we accept that the program began execution with an 80% Probability of Success of achieving 1077 days as seen in Figure 10.7. But even under this program schedule, after executing the first two phases, the probability of finishing the program in 1077 days fell to 45.86% from 80%.

10.6 Conclusion

Program Cost: We began our POSE application with no mitigation plan and a management reserve of $40 million. At the end of the 7 step POSE application, we acquired the desired Probability of Success of 80% for a cost of $525 million, with a management reserve of 35.5 million and a risk mitigation budget of $18.72 million. Further, during managing the program, we applied the 4 Step POSE after the first two phases were executed and we concluded that the program cost has overrun, and the probability of desired cost now is 78.33%

Program Schedule: We began POSE application with no mitigation plan and a schedule reserve of 50 days. At the end of the 7 step POSE application, we concluded that even with a risk mitigation of 48 days and the minimum acceptable schedule reserve, we were still not able to achieve the desired probability. This means that the baseline program plan needs to be revised to achieve the desired schedule of 1050 days. In real life the program would not begin execution but for POSE demonstration purposes, we assume that we begin execution with 80% probability of achieving 1077 days. After the 4-step POSE process, we saw that the probability of achieving even 1077 days on schedule fell to 45.86%. So, when we began execution, we knew that the program could not be completed in 1050 days and it will be delayed. But now, even with a delayed schedule after POSE, we realize that the program has only a 45.86% probability of even achieving the delayed schedule.

Further, an important aspect of POSE is the simultaneous application to cost and schedule of the program. During POSE for schedule, we saw that the baseline program plan needs to be revised. If the program manager, decides to do that and revises the whole baseline program plan, then this revised program plan, we also vary from the cost of the program. If the plan is revised, then we again through POSE for cost and schedule to achieve 80% Probability of Success for desired cost and desired schedule.

Chapter 11

RESEARCH CONCLUSIONS AND FUTURE RESEARCH

Overview: In this Chapter Section 11.1 we summarize the conclusions reached in Chapters 7, 8, 9, and 10. In Section 11.2, we discuss some of the potential opportunities for further research in the field of project/program management that have become apparent from this dissertation effort. In Section 11.3, we discuss how POSE has addressed the 4 major reasons for program failures as identified in the Chapter 1 and Chapter 2 of this dissertation.

11.1 Research Conclusions

In this dissertation, we have explained and applied the POSE methodology. The POSE methodology is an 11-step methodology, out of which, the first 7 steps are applied to baseline program plans during the planning phase and the remaining 4 steps are applied to programs during execution. The POSE methodology, demonstrates the trades that can be done with the help of risk mitigation plans, to achieve a desired Probability of Success of achieving the desired program cost and schedule for a program. Very importantly this research also indicates that when the trades of risk mitigation and reserves cannot achieve the desired Probability of Success, the baseline program plan is needs to be revised and the whole program needs to be re- planned and/or the POS goals need to be adjusted downward.

In this research, we have demonstrated the application of POSE to achieving the desired Probability of Success for the cost and schedule of a program.

But, the basic assumption to the version of POSE in this dissertation is that the desired program performance requirements for the program remain unchanged. In real life we may also have the possibility of trading program performance requirements with cost and schedule requirements to achieve an acceptable, best value program solution. So it is important to apply POSE simultaneously to cost, schedule and performance of a program to derive the best value total program solution for the desired probabilities of each attribute. This means that the best value solution requirement for our program might require a POS of 80% for all three attributes or whatever mixes of POS requirements the sponsoring organization specifies. It is important to remember that for a particular program plan that achieves 80% probability of desired cost and does not achieve 80% for schedule needs to be re-planned if that is the organizations requirements. Thus, this becomes an iterative process, with trading between cost and schedule until we receive an acceptable solution on all the fronts of the program

11.2 Future Research

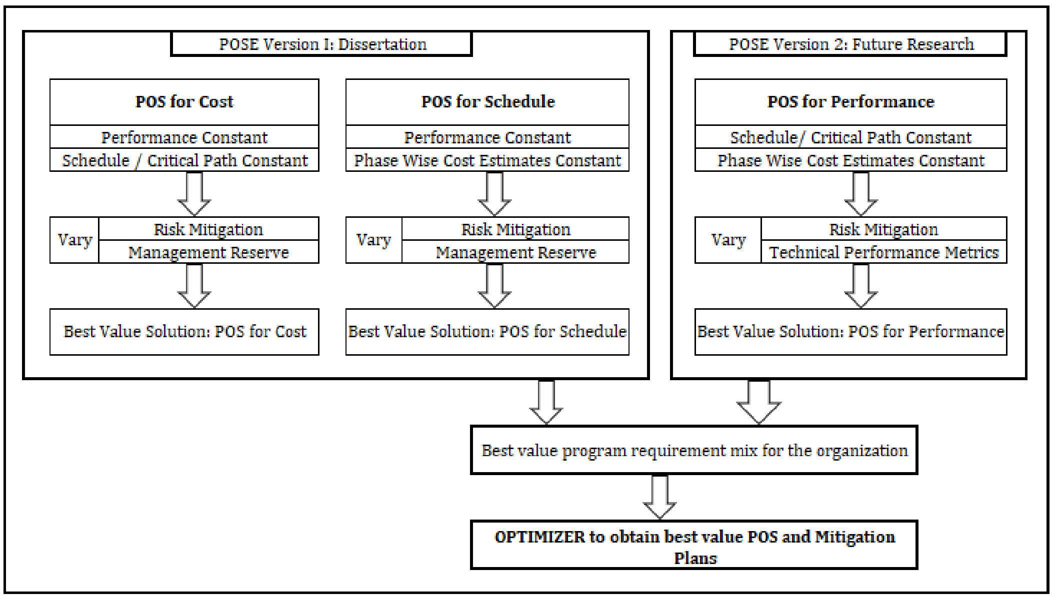

Figure 11.1: Optimization of Cost, Schedule and Performance of a Program

As shown in Figure 11.1, this dissertation version of POSE, POSE 1, demonstrates the calculation of Probability of Success of achieving the desired program cost and schedule only. As we have seen in Chapter 4.0, the analysis of our survey of experts in the field of program management showed that the performance parameter of a program is more important than the cost of the program. In this version of POSE, we have calculated the Probability of Success of achieving the desired program cost and schedule of the program under this assumption that the performance of the program is constant and cannot be changed. The next POSE research topic should be the development of the POSE 2 tool to allow determining the probability of achieving a desired program performance metrics with for a given program cost or schedule so that we ultimately can have a POSE tool that can allow better visibility into trading cost, schedule, and performance to derive the best value program at any time during the program. A major next step in developing the Performance version of POSE will be in determining how to quantify and the “Technical Performance Metrics (TPM)” to be used for a particular program and determine the performance related risk occurrences and impacts.

After the POSE 2 tool for performance of program a program has been developed, we now can calculate Probability of Success for achieving all of the attributes of a program. As depicted in Figure 11.1, after calculating the probability for all the attributes with POSE 1 and POSE 2, we can also add an optimization capability for trading, cost, schedule, performance, risk, and reserves to get the Best- Value POS- based program solutions for the whole program.

Also, in the whole POSE Cost/Schedule methodology we have discussed in this dissertation, we did not focus on the program management decision making process that is needed to deal with the problems that come in running the program, even though we now have a very powerful POSE tool that indicates the magnitude of the problems that are there and even allows trading solutions to the problems. But we have not harnessed the POSE tool directly tool to an automated. To extend the value of POSE further, we need to create an automated decision support tool which will derive its inputs from the outputs of POSE (and other systems like EVMS, etc.) to rapidly help the Program Manager determine the best value solution for the program. For example, consider when the Probability of Success of achieving the desired cost falls below 80%, then what is to be done to increase the probability back to 80%? In the survey conducted for this research, we had also asked this question to the respondents regarding the value of an automated decision support tool. (reminder: total responses: 91)

Question in Survey (Q. No. 8): It is necessary to design an automated decision support tool for managing programs to provide the best value suggestion. (mark only one answer)

☐ Strongly Disagree

☐ Disagree

☐ Neither Agree or Disagree

☐ Agree

☐ Strongly Agree

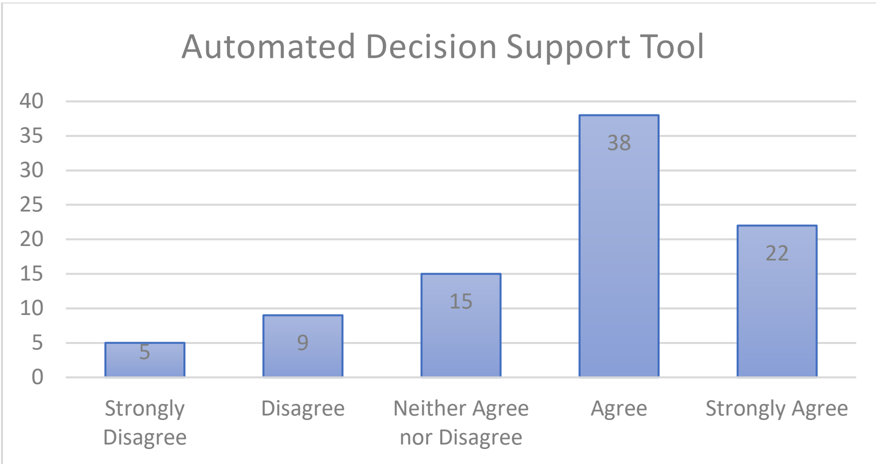

Figure 11.2: Responses for Automated Decision Support Tool(Q8)

So, from the survey, we can see that 60 respondents out of 91 (66%) are in favor of designing an automated decision support tool to compliment POSE. Further, we notice that during planning and executing a program, there is a gamut of tools currently used to calculate various metrics. Thus, it becomes important to present the necessary information in a structured format for the decision makers. The automated decision support tool which can suggest the best value solution, but human intervention and experience is needed to analyze the suggested decision and gauge the feasibility of implementation of the solution. For this purpose, we need have all the data analyzed and structured in a manner as demanded by the program manager.

In the survey, we also asked about creation of management dashboards to structure data and metrics of program.

Question in Survey (Q. No. 9): It is necessary to design program management dashboards to capture decisions in a user-friendly format. (mark only one answer)

- ☐ Strongly Disagree
- ☐ Disagree
- ☐ Neither Agree or Disagree
- ☐ Agree

☐ Strongly Agree

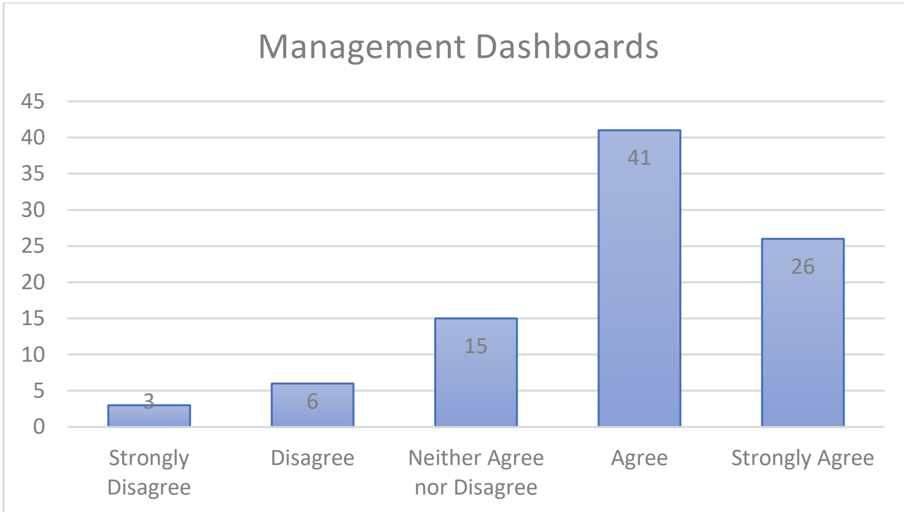

Figure 11.3: Responses for Management Dashboards(Q9)

We can see from the above response, that 66 of 91 (66%) respondents are in favor of designing management dashboards for decision making in a user-friendly format for program management. These management dashboards have to be easily modifiable in order to cater the needs of different users.

To summarize, we have defined the version of POSE for Cost and Schedule of a Program. The future research is to create a version of POSE for Performance and then combine all the versions. Then we can use optimization to come up with the best value solution for the program on all the three fronts. Once, POSE is complete, we use the automated decision support system to make decisions using POSE and then display the results of the process on management dashboards in a user-friendly format.

11.3 Conclusion

74% of programs fail (Mulcahy, Rita, 1999).

In the beginning of the dissertation, we pointed out 4 reasons for program failure: Poor Planning, Scope creep, poor execution and lack of risk management. The objective of developing POSE is to avoid these failures. POSE is designed to address each of these failures as follows:

(i) **Poor Planning**: The 7-Step POSE process is applied to a baseline program plan during the planning phase. Under the current program plan, POSE defines the trades between risk mitigation and contingency reserves that can be performed to increase the probability of the program plan achieving the required Probability of Success levels for the cost and schedule of the program, Further, if the trades between risk mitigation and contingency reserves are not enough to achieve the required program Probability of Success, POSE can be used to determine whether the baseline program plan can be modified sufficiently to achieve the desired Probability of Success for cost and schedule **.**

(ii) **Scope Creep**: Scope creep is defined as adding features and functionality (project scope) without addressing the effects on time, cost and resources. We apply POSE before beginning program execution and calculate a desired Probability of Success. Any changes in the cost or schedule of the program, will directly affect this Probability of Success for the program. So, if the program experiences scope creep for whatever reason, this version of POSE will address the effect of these changes on cost and schedule and calculate the change in Probability of Success of the program

(iii) **Poor Execution:** The 4 Step POSE methodology can be applied during program execution on a regular basis to calculate the change in Probability of Success of the program as the program progresses. POSE provides an integrated metric incorporating all of the risks that have occurred, the expenses incurred, and schedule spent which helps us define the quality of execution of the program.

(iv) **Lack of Risk Management:** In the 7-step methodology of POSE, we have incorporated a step that calculates the Probability of Success of the program, under no risk mitigation. Then POSE is used to calculate the probability with a risk mitigation plan. These steps have been especially incorporated to quantify the effect and demonstrate the importance of risk management in program success. Further, once a mitigation plan is formulated, POSE also analyzes the effectiveness of the risk mitigation plan, indicates whether it should be incorporated in the program plan or, whether a new risk mitigation plan should be formulated.

So, POSE does address all of these major reasons cited for program failure by addressing in this version of POSE the Probability of Successfully achieving the required cost and schedule for the program for a specified program performance. Future versions of will address determining program POS for cost, schedule and performance.

Appendix A

Detailed Program Planning process

In reference to Figure 2.1;

A.1 Requirements Gathering

Before a program is planned, it is very important to get the requirements that drive the program. These requirements include the technical specifications, terms and conditions, goals and priorities and if any technical prior work is needed for the program. One of the most important output of requirements gathering is Statement of Work (SOW). PMI defines Statement of Work as “a narrative description of products or services to be supplied under contract”. The SOW identifies responsibilities of all the parties involved. It establishes the ground work upon which the services or products are to be delivered. It will define the beginning and ending date of the program, estimated cost and the performance to be delivered.

A.2 Top Level Program Plan

The formulation of a top-level program plan follows the below process flow:

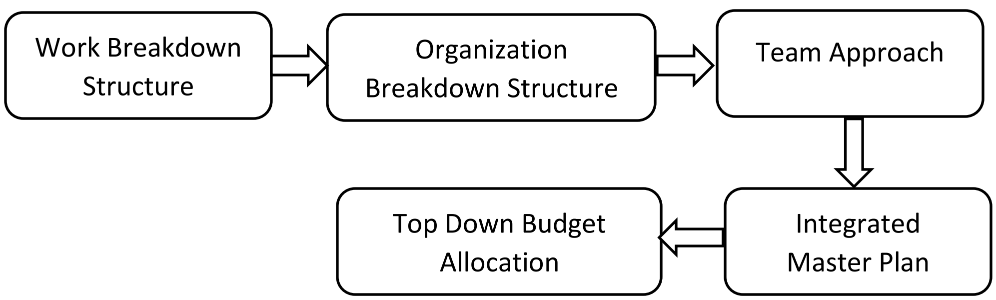

Figure A.1: Top Level Program Plan

- Work Breakdown Structure (WBS): PMI defines a WBS as “a deliverable-oriented hierarchical decomposition of work to be executed by the program team to accomplish the program objectives and create the required deliverables. It organizes and defines the total scope of the program. Each descending level represents an increasing detailed definition of the program work. The WBS is decomposed into work packages. The deliverable orientation of the hierarchy includes both internal and external deliverables.” Basically, it defines all the work to be performed and managed to deliver the program objectives as mentioned in the SOW.

- Organizational Breakdown Structure(OBS): After the WBS is formulated, an OBS is used to show which work package has been assigned to which organizational unit.
- Team Approach: All organizational units are grouped into teams, and the workflow of the program is defined across various teams in the organization. It defines the sequence of the work execution and the inputs/outputs of each team.
- Integrated Master Plan (IMP): An IMP is an event based plan consisting of a hierarchy of program events, with each event being supported by specific accomplishments, each accomplishment associated with specific criteria to be satisfied for its completion. It is plan used across the organization as scheduling constraint to integrate the individual schedules to the program schedule.
- Top Down Budget Allocation: The top down budget allocations are done by the program manager based on program costs. This helps guide the bottom up budget allocation. In this phase, we define the contingency reserves and Management Reserve. Contingency reserve and management reserve are options to respond to risks so that these risks do not compromise the program. As stated above, management reserve is kept aside to cover “unknown unknowns,” or risks that occur but were not accounted for. For the “known unknowns,” or risks that have been kept in the risk register, contingency reserve can be part of the overall risk response strategy. (Shrivastava, N. K. (2014). A model to develop and use risk contingency reserve. Paper presented at PMI® Global Congress 2014—North America, Phoenix, AZ. Newtown Square, PA: Project Management Institute.)

A.3 Develop Detailed Cost/Schedule Plan.

- Detail out the WBS, OBS, assign work and establish Budget structure: After the initial WBS and OBS plans integrate to IMP and it meets all the program objectives of cost, schedule and performance, further detailing is carried out to lowest level.
- Developing detailed schedules: In this step, 70% of program managers use critical path method (Pollack-Johnson and Liberatore, 2005) to define the initial schedule. We will discuss the various methods used to detail schedule in Literature review II under Schedule Risk analysis. This step leads to an

integrated, networked schedule containing all the detailed discrete work packages necessary to support all the events, accomplishments and criteria of IMP termed as Integrated Master Schedule (IMS).

- Establish Resource and Budget: This is the finalization of initially defined resources and budget. Here we verify the budget bottom up with the help of the IMS, to prove the congruence between the Top-bottom and bottom-top cost allocations.
- Baseline Cash Flow Model: All the steps above lead to a baseline model with a define cash flow for the program. At this stage, the model that we have is termed as "Pre-mitigated Baseline Model". The application of this research starts after the program managers have reached this stage of formulating a baseline model.

A.4 Risk Management:

Every Program plan is subject to risk. PMI defines risk as "An uncertain event or condition that if it occurs has a positive or negative effect on a program's objectives". The events which have a positive impact are termed as opportunities; those with a negative impact are termed "risks". Over decades there have been several definitions of risk in programs example: Risk implies a lack of predictability about the outcomes of a plan or decision (Hertz & Thomas 1983). But all of them refer to uncertainty and the impact it has on the program.

Risk Management is the systematic process of identifying, analyzing and responding to program risk. It includes maximizing the probability and consequences of positive events and minimizing the probability and consequences of adverse events to the program objectives. (PMBOK). Many scholars have defined various process of risk management and all of them can be correlated in some way or the other. For this dissertation, we employ the risk management cycle as below: (adaptation of Lockheed Martin Program Management)

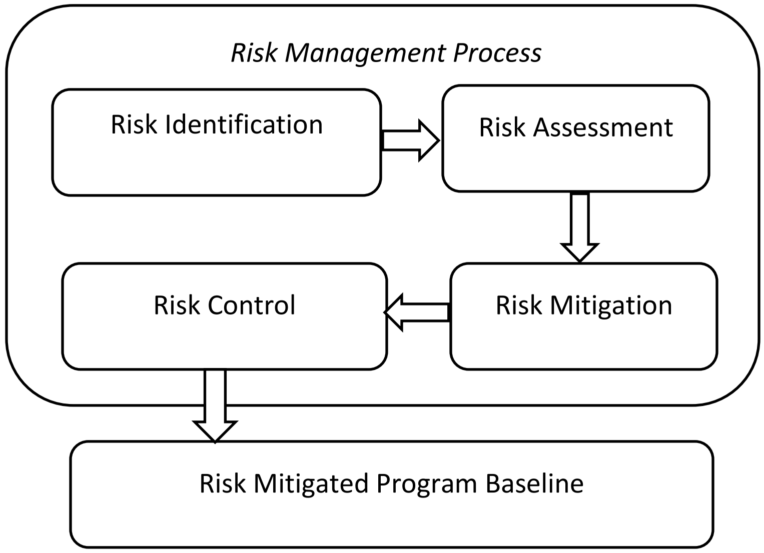

Figure A.2: Risk Management Process

- Risk Identification: In this step, we enlist all the risks the program can face during execution. Usually, risk identification is first done at a team level followed by program level. Risk can be identified and categorized as per the industry, but all the risks are connected to one or more of the three attributes of a program i.e. cost, schedule and performance.
- Risk Assessment: After listing possible risks a program can face; the risks are analyzed using qualitative and quantitative methods. Risk Assessment can be categorized into: Qualitative and Quantitative

  Qualitative Assessment: the most common method used for qualitative risk analysis is the Probability and impact description. There are several other common methodologies that are used in this assessment, for example: Checklists, Flowcharts, Cause and effect diagrams (Journal of construction engineering and management, Cano, Cruz, December 2002). This dissertation will be using the Probability-impact description method.

  Probability-Impact Description method: The probability refers to the percent chance of occurrence of a given risk surfacing. Impact can be defined in 3 ways: financial ($), schedule (days/weeks/months) or performance (technical requirements). The product of probability and impact is termed as Risk Value or

Risk Priority Number (RPN). This risk value is used to prioritize risk in order of attention needed.

Quantitative Risk Management: There are three elements of program risk analysis: Cost, schedule and performance. All the risk that the program faces will affect either one or more than one of these elements. Thus, by the definition of risk we need to perform risk analysis (quantitative or qualitative) on these elements. (Galway 2004). The qualitative and quantitative risk assessment lead to a list of prioritized risks, which need to be mitigated to increase the Probability of Success of the program. Since, POSE is aimed at quantitative risk analysis, we discuss quantitative risk analysis, in detail in the Appendix B.

- Step III: Risk Mitigation: Risk Mitigation seeks to reduce the probability and/or consequences of an adverse risk event to an acceptable threshold. Taking early action to reduce the probability of the risk's occurring or its impact on the program is more effective than trying to repair the consequences after it has occurred. Mitigation costs are an approximation, given the likely probability of the risk and its consequences. (PMBOK, 5th Edition). This research also focuses on validating the mitigation cost that has been calculated by risk analysis methods.
- Risk Control: Risk control is the process of keeping track of the identified risks, monitoring the residual risks and identifying new risks, ensuring execution of risk plans and evaluating their effectiveness to reducing risk. As the program matures, the risks change, new risk develop, or anticipated risk disappear. Thus, risk control is paramount to maintain and enhance the program success. (PMBOK, 5th Edition)

A.5 Business Case with Risk Mitigation: After risk management is carried on the initial program baseline and the results of the analysis have been incorporated into the program plan, the new program plan is termed as Risk mitigated program baseline. This baseline incorporates contingency reserves and the management reserves in the resulting cash flow. The process of getting from a pre-mitigated baseline model to a risk mitigated baseline model will be discussed in Chapter 4 of the dissertation. One of the applications of the POSE tool, is to derive a risk mitigated baseline, and validate the assumptions of the contingency reserves or also termed as risk mitigation budget.

A.6 Iteration: We run this iteration of Detailed Cost/Schedule Plan to Risk analysis to Risk mitigated baseline over and over again till we arrive at an acceptable business solution.

A.7 Management Methods

- Defining core metrics: In this Section, we define how the cost and schedule management systems will be Statused and reports will be generated. Some typical reports are: Cost /schedule performance status and Technical performance metrics.
- Program Baseline: There are no changes to be program baseline as compared to the “Pre-Mitigate Program Baseline”. The addition to the baseline in this phase, it has defined the critical points where data is to be collected to calculate certain metrics to evaluate the performance of the program.

Appendix B

Quantitative Risk Analysis

B.1 Schedule Risk Analysis

The first quantitative technique developed was the Gantt chart in 1917. It provides a graphical summary of the activities in the program. Gantt charts did not have an analytical approach to the program plan, it was just a representation methodology. To analyze program schedules two techniques were developed in the late 1950's: Critical Path Method (CPM) and Program Evaluation and Review Technique(PERT). CPM invented by Du Pont, calculates the longest path of planned activities to end of the program and contains the earliest and latest that each activity can start and finish without delaying the whole program. This technique assumes absolute values of start and finish dates thus not accommodating for variability in the schedule. Although this technique is old, a survey suggests that still 70% of program managers use critical path method (Pollack-Johnson and Liberatore, 2005).

Following CPM, the US federal government developed the techniques of Program Evaluation and Review Technique (PERT) in the late 1950's itself. This technique was developed to incorporate variability and statistical deviations into schedule planning and estimation. In this technique, we define the program task duration by a beta distribution with mean and variance as below:

Mean (meu i) = 1/6(minimum + 4 most likely + Maximum)

Variance (sigma square) = 1/36(max – min)^2

Here, mean denotes the ideal duration of a task while variance is the expected square of the deviation in the schedule.

Following PERT, another widely used technique called GERT (Graphical evaluation and review technique) (Pritsker & Happ, 1966, Wiest & Levy, 1977) was developed to model probabilistic networks. Due to challenging nature of GERT and difficulty to use, the technique was widely discredited but many of its functions are now available in a simulation packages (Pollack-Johnson and Liberatore, 2005).

Another technique which is widely applied is scenario analysis. In this analysis, the uncertain network structure is expressed through a set of network scenarios, each having a specific probability of occurrence. This method can also be used to create loops or probabilistic branching. (Pollack-Johnson and Liberatore, 2005).

Extensive sets of techniques and tools which can be used by individuals as well as in groups are available to simplify the process of uncertainty modeling (Clemen, 1996; Hill, 1982). A survey published in international journal of project management list 38 tools that can be used for risk management in programs. (use and benefits of tools for project risk management, Raz, Micheal, 2001, Volume 19, issue 1, pg 9-17).

In recent years, Monte Carlo Simulation has been increasingly gaining application in the field of risk analysis and program management. Researchers criticize that PERT/CPM does not statistically account for path convergence and tends to underestimate program duration (PMBOK) and consequently no longer suitable for risk analysis (Simon et.al.1997). MCS supersedes PERT/CPM as it enables program managers to achieve better estimates.

Although PERT/CPM and MCS are widely taught in academic courses, the latter is favorable. In MCS, the manager assigns a probability distribution function to each of the task durations, often a three-point estimate: most likely, minimum and maximum durations of each task. Once the simulation is complete, probability distribution function of the completing the program is available. (Kwak and Ingall, 2007).

B.2 Cost Risk Analysis

Most quantitative cost risk analysis has been done with techniques largely separate from those used for schedule risk analysis. (Galway 2004). Cost analysis is based on the Work Breakdown Structure (WBS). The WBS breaks a complex program Statement of Work (SOW) down into components/tasks by major categories of product or service component and/ or and functional task (e.g. Marketing, Engineering, Manufacturing, Support, etc.) with each supporting task defined in a hierarchical level of finer and finer detail. WBS cost estimation builds on the WBS by simply determining a cost for each task and summing to a total. For a quantitative risk analysis in program planning, experts in relevant areas are asked to specify a probability of occurrence and consequence of occurrence (impact in $) distribution for each risk assessed for every task in the WBS. A risk mitigation plan is determined for the risks that are deemed critical enough to warrant mitigation and the costs of these mitigation plans are estimated and included in the total estimated program cash flow model. Then a Monte Carlo simulation is used to estimate the probability distribution for accomplishing the total program for the estimated price or cost (Kwak and Ingall, 2007).

B.3 Performance Risk Analysis:

Unlike schedule and cost risk analysis, where methodologies are stereotypical and can be applied across all types of programs in a similar manner, methods of performance risk analysis tend to be tied tightly to the subject area. (Galway 2004). Each PRA will typically have a different model structure, application of probability distributions, and resulting outputs, depending upon the engineering discipline and specific application. (DoD Risk, Issue and Opportunity Management Guide for Defense Acquisition Programs). Due to the subjectively of Performance Risk Analysis, all organizations usually have their own method depending on the sector and the kind of program being executed.

Appendix C

Recent Developments

In the wake of a lack of integrated methods for schedule and cost risk analysis, Hulett (2010) proposed an integrated cost-schedule risk analysis using risk drivers. This method argues that schedule and cost risk should be directly driven by the risk already in the risk register. For each risk, practitioners will specify the probability of occurrence and its impact on schedule and cost, in terms of multiplicative factors, will be identified. Hulett divides risk into three types: Uncertainties (bound to change example labor productivity), Ambiguities (Accuracy of cost and schedule) and risk events (may or may not occur). This method puts emphasis on the risks themselves and not on their impact. The argument for this approach is that a prioritized list of risks imbibes bias in the program plan hence also in mitigation plans. Hulett proposes that schedule risk analysis is performed first and then the cost risk analysis, which is used for defining distributions to run a Monte Carlo simulation on the entire baseline plan.

Another standard method recently defined is the event chain methodology. This method is designed to mitigate the negative impact of cognitive and motivational biases related to estimation. The assumption to this method is that an event cannot be easily translated into duration, finish time, etc. They base their estimates on the best-case scenario, and they base the probability of events occurring on relative frequency; i.e., the probability of occurrence equals the number of times an event occurs divided by the total number of possible outcomes. Once all the event chains and probabilities have been defined, Monte Carlo simulation is conducted over the possible event chains as defined, to quantify the cumulative impact of all the events. (European journal for the informatics Professional, Micheal Trumper, Lev Virine, Volume 12, issue 5, December 2011, pg 22-33).

Appendix D:

Installing Oracle Crystal Ball

This appendix has three Sections: Purchasing the Oracle Crystal Ball, Installing Oracle Crystal Ball and Licensing Oracle Crystal Ball.

A.1 Purchasing Oracle Crystal Ball

Crystal Ball can be purchased in two ways: Online software download or purchasing a CD

For Online Software download:

1. Visit www.oracle.com/technetwork/middleware/crystalball/downloads/index.html
2. Accept the OTN license agreement and select the correct version of Crystal Ball as per your computer configuration
3. Sign up for a Free Oracle Account. After all the information has been entered, hit create button at the bottom of the page.
4. Choose Crystal Ball version (32-bit or 64 bit) from the dropdown list and download the setup file. Run.

For a CD purchase: Crystal Ball can be purchase in form of a CD. Once you put the CD in the CD-ROM of the computer, the installation follows similar steps as an online download. These steps are listed below.

A.2 Installing the Software:

1. Once you run the file, it will uncompress the compressed contents.
2. The CD or folder where you unzipped the folder will have the following files:
    - Crystal Ball Installation Guide.pdf: The Oracle Crystal Ball Installation and Licensing Guide in Adobe Acrobat .pdf format.
    - License Key Request Process.html—The *Oracle Crystal Ball License Key Request Process*, which describes how to obtain and activate a Crystal Ball license code for use after the initial time-limited trial license expires.
    - README.htm—An overview document that introduces Crystal Ball, describes how to display the latest Crystal Ball README (release notes) file on Oracle Technology Network, and lists third party license and copyright information.

- A bit-specific (32 or 64) setup execuTable file—The setup launcher for Crystal Ball.

3. If the installation does not start automatically, double click the setup execuTable file
4. When requested, select a setup language. The default language is English (United States).
5. After this a message will be seen, which states that the installation .msi file is being extracted. This can take several minutes. When the extraction is complete, the Crystal Ball launcher will show the below image (this is image is for installation of 32 bit):

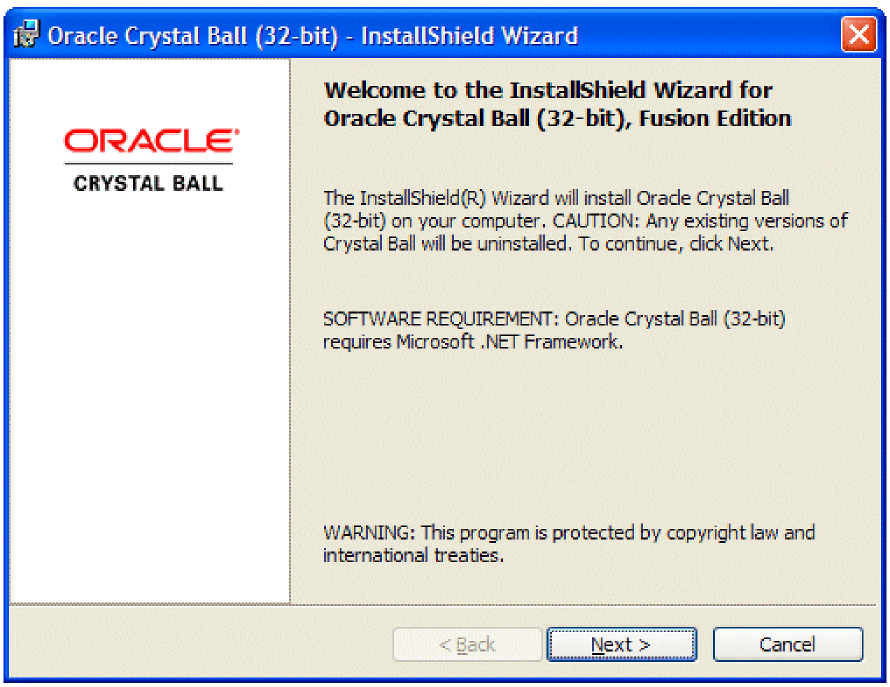

Figure D.1: Oracle Crystal Ball: Start Installation

6. In the installation wizard welcome dialog box, notice that any existing versions of Crystal Ball will be uninstalled, and Microsoft .NET framework is required. If your computer does not have Microsoft .NET framework, the installation process will guide you to the Microsoft website to get it installed.
7. Click Next to continue

8. If you are prompted to uninstall a previous version of Crystal Ball, click Yes both to uninstall and to confirm the uninstallation. If you are prompted to uninstall shared files, select No To All. When the uninstallation has successfully completed, click OK.
9. In the customer information dialog box, enter your name and organization (company or school)
10. In the setup type dialog, select either complete(Typical) or custom setup. Typical selects the default installation folder while custom helps you choose a difference installation folder.
11. Click NEXT
12. In the Ready to Install the program dialog, review the settings you have selected, click install.
13. The below Figure shows the dialog box when the installation is complete. When it opens, click Finish.

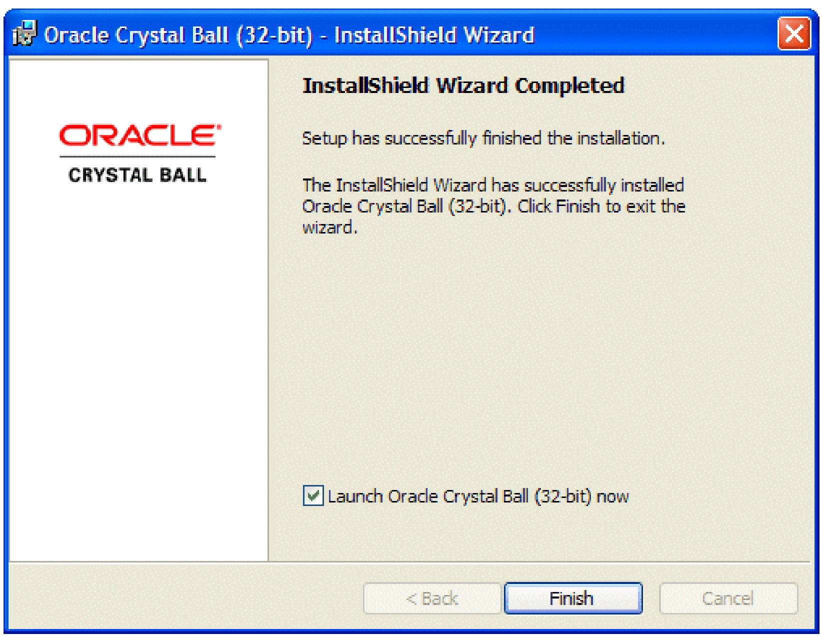

Figure D.2: Oracle Crystal Ball: Finish Installation

Crystal Ball is Ready to Use. You can use Crystal Ball without a license for 30 days. At that time, a username and serial number is required to continue.

A.3 Licensing the software

You can use Crystal Ball for 15 days without activating a license. During this time, Crystal Ball runs with a trial license. All features are available during the trial. The Crystal Ball Welcome screen is displayed each time you start Crystal Ball and indicates how many days remain on the trial license before it expires.

To activate a purchased Crystal Ball license, you must obtain an Oracle license code and enter the code into Crystal Ball. To obtain a License Code follow the below steps:

1. Contact Oracle at licensecodes_ww@oracle.com to request a Crystal Ball license code.
2. In your e-mail, include your name, e-mail address, organization, Oracle Customer Support Identifier (CSI), or other unique identifier such as your Oracle customer ID number. If you are eligible for a license, you will receive a user name and serial number (the Crystal Ball license code).
3. Describe the environment where you will be installing Crystal Ball (desktop only or a multiuser computer). Also, if your corporation has a generic username, indicate this in the e-mail.
4. Check your e-mail for mail from Oracle with your Crystal Ball license code.
5. The e-mail from licensecodes_ww@oracle.com will include your Crystal Ball user name and serial number.
6. When you receive your Crystal Ball license code, follow these steps to license Crystal Ball:
    - Locate the username and serial number you received from Oracle and start Crystal Ball.
    - In the Crystal Ball Welcome screen, click Activate License.
    - In the Username box of the Activate a License dialog, enter the username provided by Oracle. This is usually the e-mail address you provided when you downloaded Crystal Ball.
    - In the Serial Number boxes, enter the serial number provided by Oracle.
    - The easiest way to do this is to copy the serial number from an e-mail and paste it into the first Serial Number box (at the left). It automatically pastes correctly into the other boxes.

- Click OK.

7. If you entered the serial number correctly, the license is activated instantly, and a confirmation message is displayed. When you click OK in the confirmation message, the Crystal Ball Welcome screen is displayed. You can click Use Crystal Ball to start using Crystal Ball, or click another link. The Oracle Crystal Ball User's Guide describes the other links. Notice that you can click View Existing Licenses in the Activate a License dialog to review feature and expiration information for your license.
8. If you need to open the Activate a License dialog after you have either started Crystal Ball or activated your license, select Help, then Crystal Ball, and then Licensing in the Microsoft Excel menu bar. For Microsoft Excel 2007 or later, select Resources, and then Licensing in the Help group at the end of the Crystal Ball ribbon (following the Tools group).
9. The Crystal Ball licensed version is activated and ready to use.

Appendix E

One-Sided and Two-Sided Confidence Intervals in Crystal Ball

Crystal Ball gives us two options of conducting probability analysis using Monte Carlo Simulation. By default, Crystal Ball provides us with a two-sided confidence interval. In this dissertation, we will be discussing one sided confidence interval.

Suppose we run the simulation as described in Section 4.2, below is the initial forecast chart that we get:

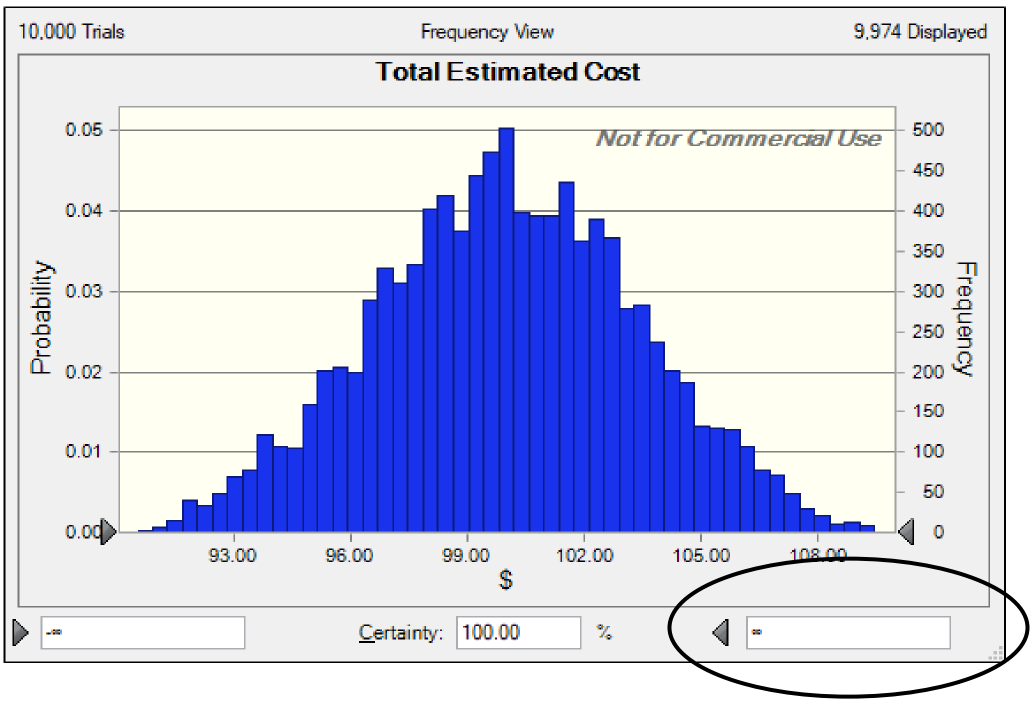

Figure E.1: Initial Forecast Chart

- Now, we have to assess the Probability of Success of the estimated total cost to be $100. In order to do this, we enter 100 in the bottom right corner of the output as circled in Figure B.1. Once you enter $100 and hit enter, the forecast shows the Figure B.2. This is a one-sided interval. From this is can definitely conclude that the Probability of Success of $100 is 50.51%.
- But the issue rises, when are assessing the cost to achieve a particular probability. This means, we want to know how much should my estimated total cost be in order to achieve a Probability of Success of 80%. In this case, we enter 80% in the certainty box in the bottom center and hit enter, we will see the Figure B.3. From Figure B.3 we can conclude that to achieve a Probability of Success of 80%, we need our estimated total cost to be between $95.54 and

$104.39. Now, with a range of estimated total cost, decision making becomes difficult because we do not have a particular number to achieve to receive the targeted probability.

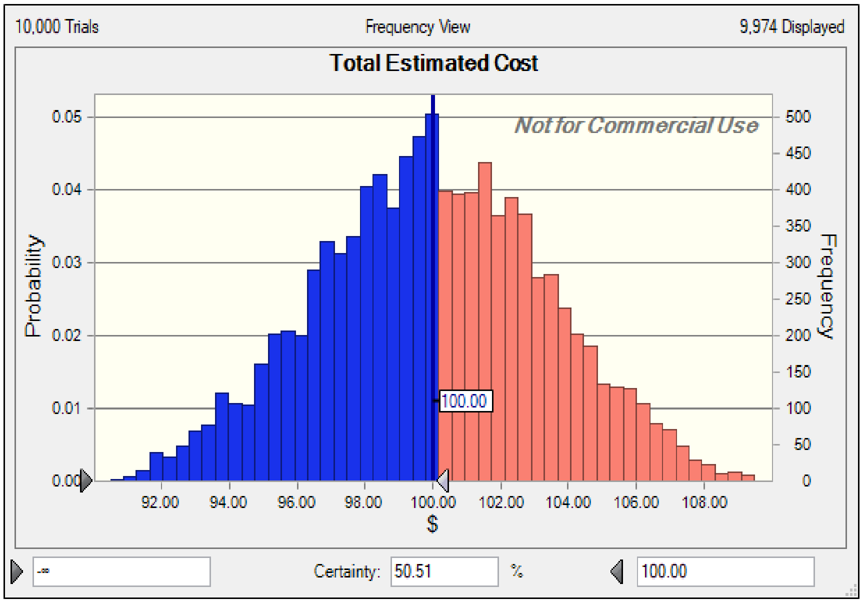

Figure E.2: Probability of Success for $100 estimated total cost

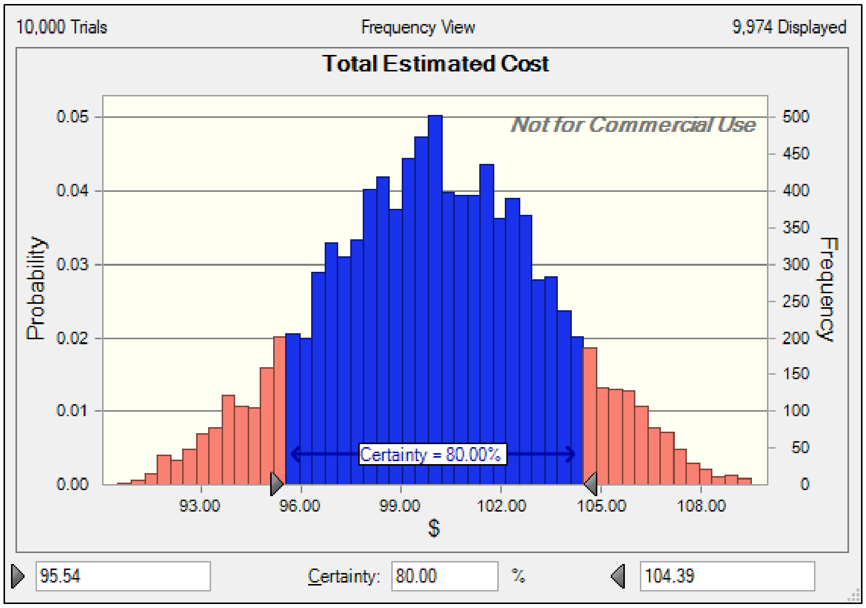

Figure E.3: Assessing cost at 80% Probability of Success

In this case, what do we do?

If you look at Figure E.4, you can see there are two black markers that are circled. These arrows can be two colors: black and white. There are three types of confidence intervals we can have:

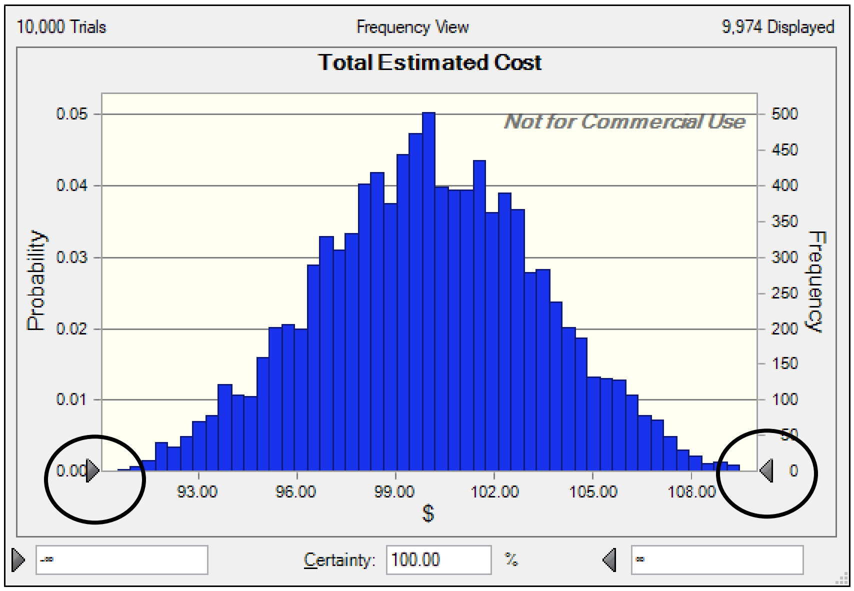

Figure E.4: One Sided Confidence Interval (Upper Bound)

- Two-sided Confidence Intervals: If both the arrows are black, it means that both the arrows can move. In this case, if we enter 80.00 in the certainty box and hit enter, we receive an output similar to Figure B.3.

- One-sided confidence interval (Lower Bound): To achieve this kind of a confidence interval, you click on the marker on the right. The marker will change its color to white. This means that the marker on the right will not move while only the one on the left will move. After doing this, if we enter 80.00 in the certainty box, we receive a Figure as seen in B.5. Please notice the color of the arrow on the right, it is white. In this case we conclude that at 80% probability, the estimated total cost can range between $97.06 to infinity. This type of conclusion does not help in anyway if one the limits to my cost is infinity. Further, one of the reasons we perform Monte Carlo analysis to understand a practical worst at a certain probability.

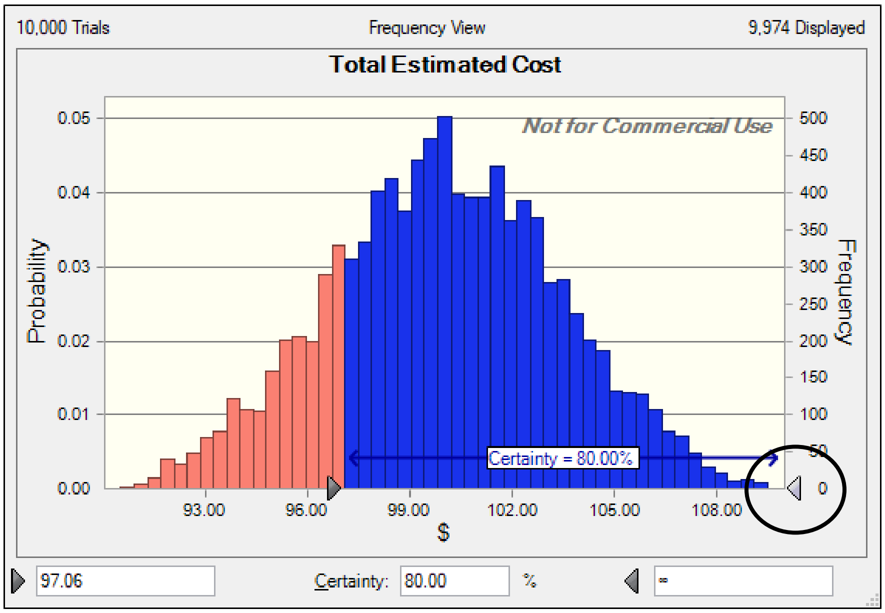

Figure E.5: One Sided Confidence Interval (Lower Bound)

- One-sided confidence interval (Upper Bound): This is the confidence interval that will be used throughout the dissertation. In this case, we click on the marker as circled in Figure E.4 on the left and only the marker on the right moves. In this case, we enter 80.00 in the certainty box; we receive a Figure similar to B.6. In this case we conclude that at 80% probability, the estimated total cost will range between 0 – $102.89. This conclusion describes a practical scenario which can be used for decision making. The worst-case cost of my product under a certain probability can be derived using this approach.

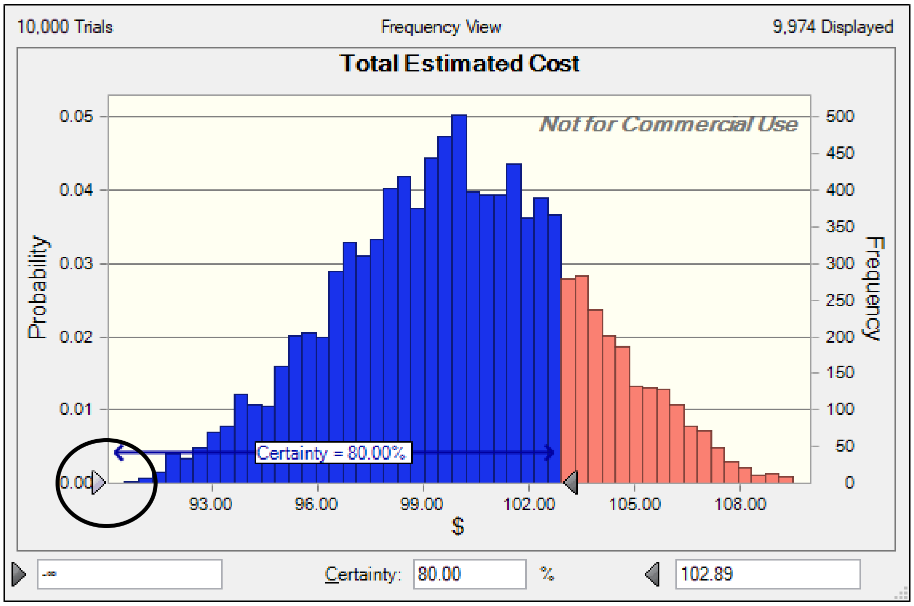

Figure E.6: One Sided Confidence Interval (Upper Bound)

Conclusion: In this dissertation, we will be using the one-sided confidence interval (Upper Bound). Before you assess cost for a certain probability, it is important to click on the marker on the right. This fixes the marker to the zero position. When we enter the probability in the certainty box in the bottom center of the output, we receive a one-sided upper bound confidence interval.

Appendix F

Verification of Crystal Ball Results by other Softwares

In this appendix, we will run Monte Carlo Simulations using three softwares: Oracle Crystal Ball, @Risk, and Python. Oracle Crystal ball and @Risk are Excel based software which we can use directly to perform Monte Carlo Simulations while we have been required to actually will write the software to perform the Monte Carlo Simulation algorithm in the Python Software language to prove that we understand how the Monte Carlo process works using multiple tools and verifying the validity of each tool. An Example Problem is shown below to demonstrate how each tool is used for Monte Carlo Simulation and POSE application.

Example Problem:

We are to build a product that has 5 parts. The cost of each of these 5 parts is $10,000, $15,000, $30,000, $25,000 and $20,000 respectively. The cost of all the parts follows a normal distribution with a standard deviation of 10%. The mean cost of the product is $100,000. This product will be sold at $150,000 (fixed selling price). Thus, the expected profit is $50,000 (before tax). We must calculate the probability of making a minimum of $50,000 profit (before tax) considering the variations in the cost elements of the product.

Oracle Crystal Ball Results:

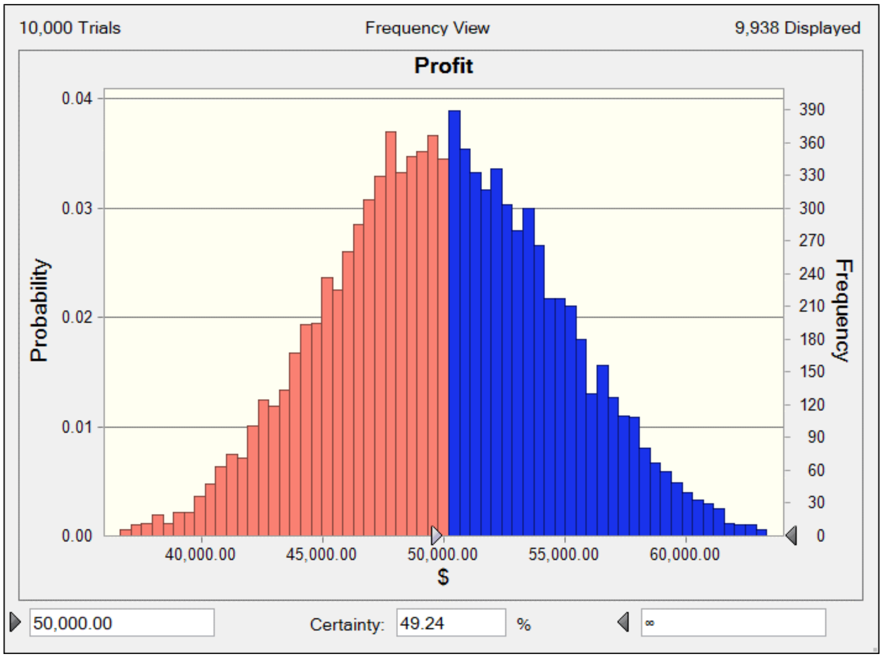

Figure F.1: Oracle Crystal Ball result

The simulation in Oracle Crystal Ball shows that the probability of achieving a minimum profit of $50,000 is 49.24%.

@Risk Results:

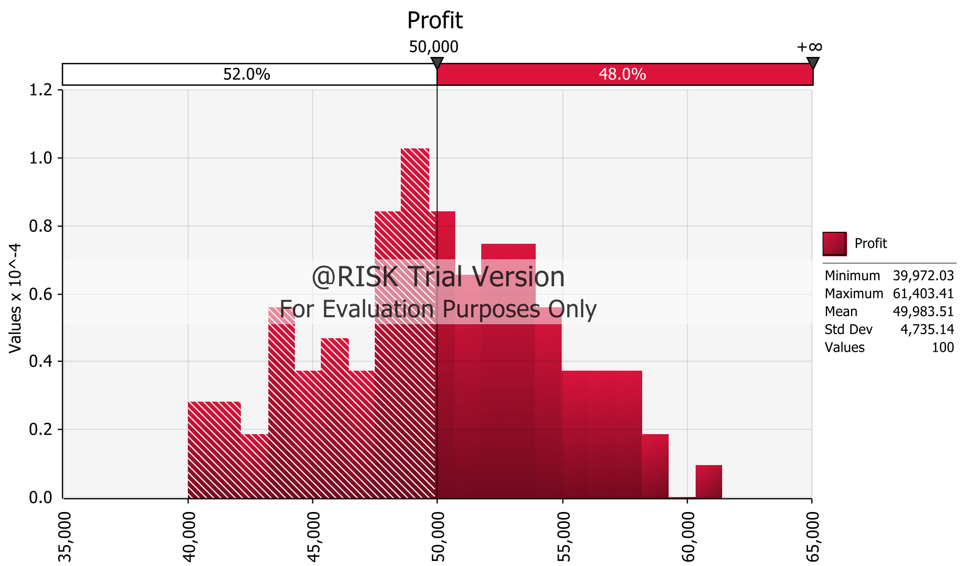

Figure F.2: @Risk Result

If we run the simulation in @Risk, the probability of achieving minimum profit of $50000 is 48%.

Python Results

In this section, we write the algorithm that is used by Crystal Ball to perform Monte Carlo Simulation. Each line in the algorithm is numbered on the extreme left, we will discuss the algorithm line by line.

```
import random                                              //1
from scipy.stats import norm                               //2
```

```
import matplotlib.pyplot as plt                                    //3

mean = [10000,15000,30000,25000,20000]                             //4
N = 10000                                                          //5

def profit(mean):                                                 //6

 lst = []                                                          //7
    for i in mean:                                                 //8
        a = random.uniform(0,1)                                    //9
        lst.append(norm.ppf((a),loc=i,scale=(0.1*i)))             //10
    l_sum = sum(lst)                                              //11
    profit = 150000 - l_sum                                       //12
    return profit                                                 //13

b = [profit(mean) for i in range(N)]                              //14

plt.hist(b,bins = 500)                                            //15
probability = len(list(filter(lambda x: x >= 50000, b)))/10000
//16

print("The probability of achieving a minimum profit of 50,000
is: "+
      str(probability))                                           //17
```

Explanation of the code line by line

1 : Import a predefined function in python to generate random numbers

package “random” to use the random number generator from it.

2: import a predefined function in python to describe normal distribution from package “scipy.stats” the class norm is imported to find the inverse of a normal distribution

3: import a predefined function in python to plot the histogram of the output

package “matplotlib.pyplot” is imported to plot the histogram of the simulation

4: We define the 5 costs of the product with their mean value

5: We define the number of iterations

6: Since Profit is the output variable, we define a function called profit.

7: We create an empty list to store the values of the individual cost

8: In this case, i will assume values (10000, 15000, 30000, 25000 and 20000) and create a for loop, i is not defined. i is just used to iterate in the for loop.

9: we define a variable “a” that chooses a random number between 0 and 1.

10: we use the random number “a” to use the inverse function to find the value of the cost corresponding to that random number and store the value in the list define in step 7

11: We sum up all the values in the list to receive the possible output cost

12: we define profit

13: we calculate profit with respect to the calculated cost, this is one possible value of profit

14: We run the simulation of 10000 iterations

15: we plot the histogram

16: We calculate the probability of achieving minimum 50000 of profit.

17. Printing the probability of achieving $50000 profit

Explanation: we start with an empty list (line 7). We start executing the for loop as defined in line 8. For i = 10000, we generate a random number between 0 and 1. We find the inverse value of the distribution with mean 10000 and standard deviation of 1000. We put this value in the previously defined empty list. This procedure is done for all the mean values i.e. 15000, 30000, 25000 and 20000. That the end of this, we have 5 values in the list, which was previously empty. Now, we sum up these 5 values to receive on possible cost of the product (line 11). This possible value of cost is subtracted from the selling price of 150,000 to generate profit. Here, we receive one of the possible values of profit.

Now, we run this iteration from line 7 to line 13, 10000 times. Then we plot the histogram of the 10000 possible values of profit.

Output:

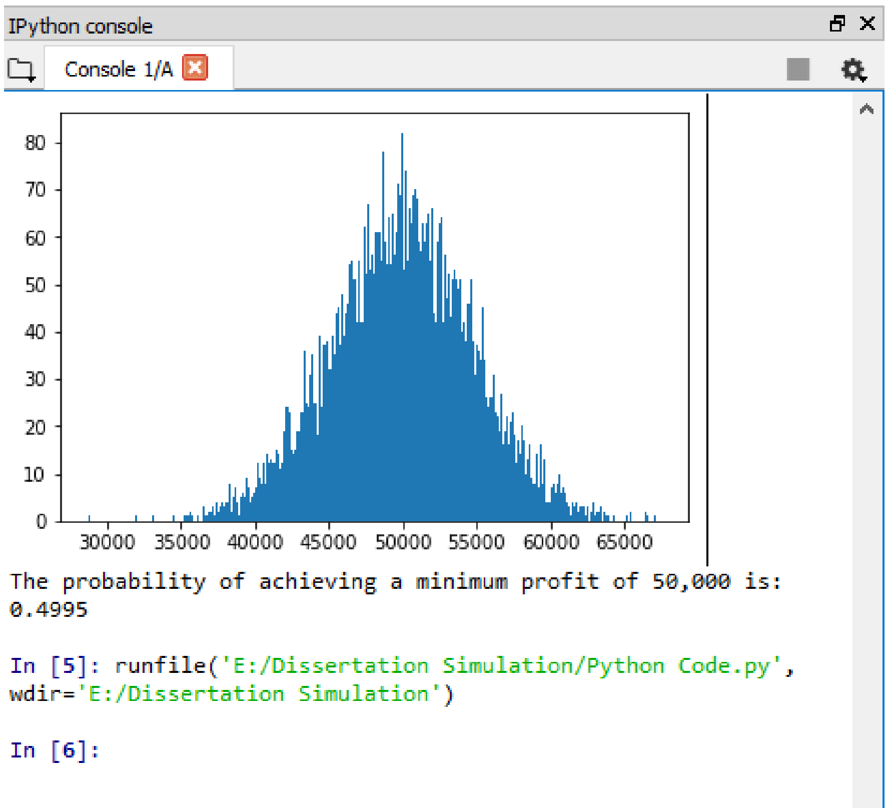

Figure F.3: Python Output

The python code shows that the probability of achieving minimum profit of $50000 is 49.95%.

Conclusion:

In the above three results, we can conclude that the results of the 3 software tools give approximately the same answer. To summarize, Crystal Ball has a probability of 49.24%; @Risk has a probability of 48%; and Python has a probability of 49.95%. The slight difference in their outputs is attributed to the random sampling. Since, Monte Carlo Simulations are based on the principle of random sampling, different software will use different sampling methods which explains the difference in the output. But the point to be noted is that we are running 10000 iterations. As per Bernoulli's Law of large numbers, if we were to run infinite iterations, all of the sampling methods would generate the same probability.

Appendix G

Chapter 6

ORACLE CRYSTAL BALL

	Minimum Cost	Estimated Cost	Maximum Cost
Estimated Cost of Raw Material	35	40	45
Estimated Cost of Labor	27	30	33
Estimated Cost of Machinery	24	30	36
Total Estimated Cost		100	

Figure G.1: Chapter 6_Initial Estimates

	Minimum Cost	Estimated Cost	Maximum Cost
Estimated Cost of Raw Material	35	40	45
Estimated Cost of Labor	27	30	33
Estimated Cost of Machinery	24	29	36
Total Estimated Cost		99	

Figure G.2: Chapter 6_Revised Estimates_Machinery Cost

	Minimum Cost	Estimated Cost	Maximum Cost
Estimated Cost of Raw Material	35	40	45
Estimated Cost of Labor	27	30	33
Estimated Cost of Machinery	24	29	36
Total Estimated Cost		99	

Figure G.3: Chapter 6_Revised Estimates_Labor Cost

Appendix H

Chapter 8

POSE FOR PROGRAM PLANNING

Phase	Task	Probability of Occurrence	Impact when Risk Mitigation Budget is zero				Minimum	Estimated Cost of the Phase	Maximum
			Minimum	Most Likely	Maximum				
Phase 1	Task 1	0.9	2250	2500	2750	0	4500	5000	5200
Phase 2	Task 2	0.7	2520	2800	3080	0	7000	7500	8250
Phase 3	Task 3	0.1	2880	3200	3520	0	9000	10000	12000
Phase 4	Task 4	0.2	2160	2400	2640	0	10000	12500	15000
Phase 5	Task 5	0.5	2160	2400	2640	0	14500	15000	15500
Phase 6	Task 6	0.8	3420	3800	4180	0	17000	17500	19000
Phase 7	Task 7	0.3	4500	5000	5500	0	16000	17500	19000
Phase 8	Task 8	0.15	4860	5400	5940	0	18000	20000	22000
Phase 9	Task 9	0.24	4050	4500	4950	0	14500	15000	16500
Phase 10	Task 10	0.25	4950	5500	6050	0	4500	5000	7500
Total				**37500**		**0**		**125,000**	
Management Reserve		15000							
Total Program Cost		140,000							

Figure H.1: POS_No Risk Mitigation_Cost.

Phase	Task	Probability of Occurrence	Mitigation Cost		Impact when Risk Mitigation Budget is zero				Minimum	Estimated Cost of the Phase	Maximum
					Minimum	Most Likely	Maximum				
Phase 1	Task 1	0.5	1200	0	1080	1200	1320	0	4500	5000	5200
Phase 2	Task 2	0.7	950	0	1080	1200	1320	0	7000	7500	8250
Phase 3	Task 3	0.1	1400	0	3240	3600	3960	0	9000	10000	12000
Phase 4	Task 4	0.15	950	0	1125	1250	1375	0	10000	12500	15000
Phase 5	Task 5	0.4	1000	0	1125	1250	1375	0	14500	15000	15500
Phase 6	Task 6	0.6	1250	0	2520	2800	3080	0	17000	17500	19000
Phase 7	Task 7	0.25	1175	0	3420	3800	4180	0	16000	17500	19000
Phase 8	Task 8	0.1	1050	0	2700	3000	3300	0	18000	20000	22000
Phase 9	Task 9	0.24	75	0	135	150	165	0	14500	15000	16500
Phase 10	Task 10	0.25	1100	0	1575	1750	1925	0	4500	5000	7500
Total			**10150**	0		**20000**		0		**125,000**	
Management Reserve		15000									
Total Program Cost		140,000									

Figure H.2: POS_Risk Mitigation_Cost.

Phase	Task	Probability of Occurrence	Mitigation Cost		Impact when Risk Mitigation Budget is zero				Minimum	Estimated Cost of the Phase	Maximum
					Minimum	Most Likely	Maximum				
Phase 1	Task 1	0.5	1200	0	1080	1200	1320	0	4500	5000	5200
Phase 2	Task 2	0.7	950	0	1080	1200	1320	0	7000	7500	8250
Phase 3	Task 3	0.1	1400	0	3240	3600	3960	0	9000	10000	12000
Phase 4	Task 4	0.15	950	0	1125	1250	1375	0	10000	12500	15000
Phase 5	Task 5	0.4	1000	0	1125	1250	1375	0	14500	15000	15500
Phase 6	Task 6	0.6	1250	0	2520	2800	3080	0	17000	17500	19000
Phase 7	Task 7	0.25	1175	0	3420	3800	4180	0	16000	17500	19000
Phase 8	Task 8	0.1	1050	0	2700	3000	3300	0	18000	20000	22000
Phase 9	Task 9	0.24	75	0	135	150	165	0	14500	15000	16500
Phase 10	Task 10	0.25	1100	0	1575	1750	1925	0	4500	5000	7500
Total			**10150**	0		**20000**		0		**125,000**	
Management Reserve		15000									
Total Program Cost		140,000									

Figure H.3: RM_MR_Iteration_Cost

Phase	Task	Probability of Occurrence	Impact when Risk Mitigation Budget is zero				Minimum	Estimated Cost of the Phase	Maximum
			Minimum	Most Likely	Maximum				
Phase 1	Task 1	0.9		1		0	3	4	6
Phase 2	Task 2	0.7		2		0	3	5	6
Phase 3	Task 3	0.1		2		0	4	6	7
Phase 4	Task 4	0.2		2		0	4	5	8
Phase 5	Task 5	0.5		2		0	5.5	7	8
Phase 6	Task 6	0.8		2		0	6	9	10
Phase 7	Task 7	0.3		1		0	10	11	11
Phase 8	Task 8	0.15		1		0	9	10	10
Phase 9	Task 9	0.24		2		0	12	15	16
Phase 10	Task 10	0.25		1		0	7	8	9
Total				16		**0**		**80**	
Schedule Reserve		10							
Total Program schedule		106							

Figure H.4: POS_No Risk Mitigation_Schedule

Phase	Task	Probability of Occurrence	Mitigation schedule	Impact considering Risk Mitigation Plan				Minimum	Estimated Cost of the Phase	Maximum
				Minimum	Most Likely	Maximum				
Phase 1	Task 1	0.5	1	0.9	1	1.1	0	3	4	6
Phase 2	Task 2	0.7	0.5	1.8	2	2.2	0	3	5	6
Phase 3	Task 3	0.1	1	1.8	2	2.2	0	4	6	7
Phase 4	Task 4	0.15	1	1.8	2	2.2	0	4	5	8
Phase 5	Task 5	0.4	0.5	0.9	1	1.1	0	5.5	7	8
Phase 6	Task 6	0.6	1	1.8	2	2.2	0	6	9	10
Phase 7	Task 7	0.25	1	1.8	2	2.2	0	10	11	11
Phase 8	Task 8	0.1	1	1.8	2	2.2	0	9	10	10
Phase 9	Task 9	0.24	1	1.8	2	2.2	0	12	15	16
Phase 10	Task 10	0.25	2	0.9	1	1.1	0	7	8	9
Total			**10**		**17**		0		**80**	
Schedule Reserve		10								
Total Program Schedule		90								

Figure H.5: POS_Risk Mitigation_Schedule

Appendix I

Chapter 9

POSE FOR MANAGING A PROGRAM

Phase	Task	Probability of Occurrence	Mitigation Cost		Impact when Risk Mitigation Budget is zero				Minimum	Estimated Cost of the Phase	Maximum
					Minimum	Most Likely	Maximum				
Phase 1	Task 1	1	1200	1200	810	900	990	900	4500	5000	5200
Phase 2	Task 2	1	950	950	1080	1200	1320	1200	7000	7700	8250
Phase 3	Task 3	0	1400	0	3240	3600	3960	0	9000	11000	12000
Phase 4	Task 4	0.15	950	0	1125	1250	1375	0	10000	12500	15000
Phase 5	Task 5	0.4	1000	0	1125	1250	1375	0	14500	15000	15500
Phase 6	Task 6	0.6	1250	0	2520	2800	3080	0	17000	17500	19000
Phase 7	Task 7	0.25	1175	0	3375	3750	4125	0	16000	17500	19000
Phase 8	Task 8	0.1	1050	0	2250	2500	2750	0	18000	20000	22000
Phase 9	Task 9	0.24	75	0	135	150	165	0	14500	15000	16500
Phase 10	Task 10	0.25	1100	0	1575	1750	1925	0	4500	5000	7500
Total			**10150**	2150		**19150**		2100		**126,200**	
Management Reserve		14450									
Total Program Cost		142,750									

Figure I.1: POS_Managing_Cost

Phase	Task	Probability of Occurrence	Mitigation schedule	Impact considering Risk Mitigation Plan				Minimum	Estimated Cost of the Phase	Maximum
				Minimum	Most Likely	Maximum				
Phase 1	Task 1	1	1	0.9	1	1.1	1	3	5	6
Phase 2	Task 2	1	0.5	1.8	2	2.2	2	3	5	6
Phase 3	Task 3	0	1	1.8	2	2.2	0	4	6	7
Phase 4	Task 4	0.15	1	1.8	2	2.2	0	4	5	8
Phase 5	Task 5	0.4	0.5	0.9	1	1.1	0	5.5	7	8
Phase 6	Task 6	0.6	1	1.8	2	2.2	0	6	9	10
Phase 7	Task 7	0.25	1	1.8	2	2.2	0	10	11	11
Phase 8	Task 8	0.1	1	1.8	2	2.2	0	9	10	10
Phase 9	Task 9	0.24	1	1.8	2	2.2	0	12	15	16
Phase 10	Task 10	0.25	2	0.9	1	1.1	0	7	8	9
Total			**10**		**17**		3		**81**	
Schedule Reserve		10								
Total Program Schedule		94								

Figure I.2: POS_Managing_Schedule

Appendix J

Chapter 10

APPLICATION OF POSE TO COMPLEX PROGRAM

Risk	Phase	Risk	Probabil	Minimum	Most Likely	Maximum	Risk Value	Risk
1.1	Market Planning	Loss in market share	0.25	$180,000.00	$200,000.00	$220,000.00	$50,000.00	Low
1.2	Market Planning	30% profit is not attained	0.1	$405,000.00	$450,000.00	$495,000.00	$45,000.00	Low
1.3	Market Planning	Competitor launches similar phone	0.2	$450,000.00	$500,000.00	$550,000.00	$100,000.00	Low
1.4	Market Planning	Change in taxes & cost	0.3	$450,000.00	$500,000.00	$550,000.00	$150,000.00	Low
1.5	Market Planning	Failed Market Research	0.1	$225,000.00	$250,000.00	$275,000.00	$25,000.00	Low
2.1	Placement &	Reduction in budget allocation	0.2	$450,000.00	$500,000.00	$550,000.00	$100,000.00	Low
2.2	Placement &	Resource over/under allocation	0.4	$180,000.00	$200,000.00	$220,000.00	$80,000.00	Low
2.3	Placement &	Unsatisfied customers	0.2	$360,000.00	$400,000.00	$440,000.00	$80,000.00	Low
2.4	Placement &	Customer shift to different brands	0.1	$405,000.00	$450,000.00	$495,000.00	$45,000.00	Low
2.5	Placement &	Shorter product life cycle than anticipated	0.05	$675,000.00	$750,000.00	$825,000.00	$37,500.00	Low
3.1	Project Definition	Delay in critical path	0.7	$180,000.00	$200,000.00	$220,000.00	$140,000.00	Low
3.2	Project Definition	Vendor issues	0.2	$135,000.00	$150,000.00	$165,000.00	$30,000.00	Low
3.3	Project Definition	Intellectual property legal issues	0.1	$90,000.00	$100,000.00	$110,000.00	$10,000.00	Low
3.4	Project Definition	Improper capacity, capability assessment	0.1	$90,000.00	$100,000.00	$110,000.00	$10,000.00	Low
3.5	Project Definition	Scope creep	0.1	$126,000.00	$140,000.00	$154,000.00	$14,000.00	Low
4.1	Implementation	Procurement and estimation	0.25	$5,850,000.00	$6,500,000.00	$7,150,000.00	$1,625,000.00	High
4.2	Implementation	Failed prototype testing	0.2	$6,750,000.00	$7,500,000.00	$8,250,000.00	$1,500,000.00	High
4.3	Implementation	Manufacturing and Design incompatibility	0.1	$4,050,000.00	$4,500,000.00	$4,950,000.00	$450,000.00	Low
4.4	Implementation	software and hardware integration	0.2	$4,275,000.00	$4,750,000.00	$5,225,000.00	$950,000.00	Medium
4.5	Implementation	Testing protocols & resource are delayed	0.1	$3,150,000.00	$3,500,000.00	$3,850,000.00	$350,000.00	Low
5.1	Launch and Close out	Preorder is higher than inventory	0.5	$4,050,000.00	$4,500,000.00	$4,950,000.00	$2,250,000.00	High
5.2	Launch and Close out	Product software failure	0.3	$1,350,000.00	$1,500,000.00	$1,650,000.00	$450,000.00	Low
5.3	Launch and Close out	Delayed launch of product	0.3	$2,250,000.00	$2,500,000.00	$2,750,000.00	$750,000.00	Medium
5.4	Launch and Close out	Product hardware failure	0.1	$2,250,000.00	$2,500,000.00	$2,750,000.00	$250,000.00	Low
5.5	Launch and Close out	Disposition of Obsolete/excess material	0.2	$585,000.00	$650,000.00	$715,000.00	$130,000.00	Low
6.1	Production	Production capability less than	0.5	$8,100,000.00	$9,000,000.00	$9,900,000.00	$4,500,000.00	High
6.2	Production	Over production	0.3	$6,750,000.00	$7,500,000.00	$8,250,000.00	$2,250,000.00	High
6.3	Production	Cost of raw material increases	0.1	$3,600,000.00	$4,000,000.00	$4,400,000.00	$400,000.00	Low
6.4	Production	Defective products	0.2	$4,050,000.00	$4,500,000.00	$4,950,000.00	$900,000.00	Medium
6.5	Production	Equipment failure	0.1	$4,500,000.00	$5,000,000.00	$5,500,000.00	$500,000.00	Low
6.6	Production	Natural Disaster	0.01	$6,750,000.00	$7,500,000.00	$8,250,000.00	$75,000.00	Low
6.7	Production	Defective packing	0.1	$2,025,000.00	$2,250,000.00	$2,475,000.00	$225,000.00	Low
6.8	Production	Workers strike	0.01	$9,000,000.00	$10,000,000.00	$11,000,000.00	$100,000.00	Low
7.1	Customer Support	Access to service centers	0.3	$4,050,000.00	$4,500,000.00	$4,950,000.00	$1,350,000.00	High
7.2	Customer Support	Inefficient staff	0.5	$3,150,000.00	$3,500,000.00	$3,850,000.00	$1,750,000.00	High
7.3	Customer Support	Not fulfilling customer commitment	0.2	$3,150,000.00	$3,500,000.00	$3,850,000.00	$700,000.00	Medium
7.4	Customer Support	Lack of integration of service centers	0.1	$6,750,000.00	$7,500,000.00	$8,250,000.00	$750,000.00	Medium
					$112,040,000.00			

Figure J.1: Step I_POSE_Cost

Risk no	Phase	Risk	Probability	Minimum Impact	Most Likely Impact	Maximum Impact	Impact	Risk Value	Risk Prioritization	Phase Vise Estimated
1.1	Market Planning	Loss in market share	0.5	$140,400.00	[illegible]	$171,600.00	$0.00	$78,000.00	Low	[illegible]
1.2	Market Planning	30% profit is not attained	[illegible]	$315,900.00	[illegible]	$386,100.00	$0.00	$70,200.00	Low	
1.3	Market Planning	Competitor launches similar phone	0.25	$351,000.00	[illegible]	$429,000.00	$0.00	$97,500.00	Low	
1.4	Market Planning	Change in taxes & cost	[illegible]	$351,000.00	[illegible]	$429,000.00	$0.00	$117,000.00	Low	
1.5	Market Planning	Failed Market Research	0.15	$175,500.00	[illegible]	$214,500.00	$0.00	$29,250.00	Low	
2.1	Placement &	Reduction in budget allocation	[illegible]	$351,000.00	[illegible]	$429,000.00	$0.00	$78,000.00	Low	[illegible]
2.2	Placement &	Resource over/under allocation	0.4	$140,400.00	[illegible]	$171,600.00	$0.00	$62,400.00	Low	
2.3	Placement &	Unsatisfied customers	[illegible]	$280,800.00	[illegible]	$343,200.00	$0.00	$62,400.00	Low	
2.4	Placement &	Customer shift to different brands	[illegible]	$315,900.00	[illegible]	$386,100.00	$0.00	$70,200.00	Low	
2.5	Placement &	Shorter product life cycle than	0.05	$526,500.00	[illegible]	$643,500.00	$0.00	$29,250.00	Low	
3.1	Project Definition	Delay in critical path	[illegible]	$140,400.00	[illegible]	$171,600.00	$0.00	$109,200.00	Low	[illegible]
3.2	Project Definition	Vendor issues	[illegible]	$105,300.00	[illegible]	$128,700.00	$0.00	$23,400.00	Low	
3.3	Project Definition	Intellectual property legal issues	0.15	$70,200.00	[illegible]	$85,800.00	$0.00	$11,700.00	Low	
3.4	Project Definition	Improper capacity, capability	0.25	$70,200.00	[illegible]	$85,800.00	$0.00	$19,500.00	Low	
3.5	Project Definition	Scope creep	[illegible]	$98,280.00	[illegible]	$120,120.00	$0.00	$32,760.00	Low	
4.1	Implementation	Procurement and estimation	0.5	$4,563,000.00	[illegible]	$5,577,000.00	$0.00	$2,535,000.00	High	[illegible]
4.2	Implementation	Failed prototype testing	[illegible]	$5,265,000.00	[illegible]	$6,435,000.00	$0.00	$1,170,000.00	High	
4.3	Implementation	Manufacturing and Design	0.15	$3,159,000.00	[illegible]	$3,861,000.00	$0.00	$526,500.00	Medium	
4.4	Implementation	software and hardware integration	0.5	$3,334,500.00	[illegible]	$4,075,500.00	$0.00	$1,852,500.00	High	
4.5	Implementation	Testing protocols & resource are	0.25	$2,457,000.00	[illegible]	$3,003,000.00	$0.00	$682,500.00	Medium	
5.1	Launch and Close out	Preorder is higher than inventory	0.5	$3,159,000.00	[illegible]	$3,861,000.00	$0.00	$1,755,000.00	High	[illegible]
5.2	Launch and Close out	Product software failure	0.5	$1,053,000.00	[illegible]	$1,287,000.00	$0.00	$585,000.00	Medium	
5.3	Launch and Close out	Delayed launch of product	[illegible]	$1,755,000.00	[illegible]	$2,145,000.00	$0.00	$585,000.00	Medium	
5.4	Launch and Close out	Product hardware failure	0.5	$1,755,000.00	[illegible]	$2,145,000.00	$0.00	$975,000.00	Medium	
5.5	Launch and Close out	Disposition of Obsolete/excess	[illegible]	$456,300.00	[illegible]	$557,700.00	$0.00	$101,400.00	Low	
6.1	Production	Production capability less than	[illegible]	$6,318,000.00	[illegible]	$7,722,000.00	$0.00	$3,510,000.00	High	[illegible]
6.2	Production	Over production	[illegible]	$5,265,000.00	[illegible]	$6,435,000.00	$0.00	$1,755,000.00	High	
6.3	Production	Cost of raw material increases	[illegible]	$2,808,000.00	[illegible]	$3,432,000.00	$0.00	$1,560,000.00	High	
6.4	Production	Defective products	0.2	$3,159,000.00	[illegible]	$3,861,000.00	$0.00	$702,000.00	Medium	
6.5	Production	Equipment failure	0.2	$3,510,000.00	[illegible]	$4,290,000.00	$0.00	$780,000.00	Medium	
6.6	Production	Natural Disaster	0.01	$5,265,000.00	[illegible]	$6,435,000.00	$0.00	$58,500.00	Low	
6.7	Production	Defective packing	[illegible]	$1,579,500.00	[illegible]	$1,930,500.00	$0.00	$438,750.00	Low	
6.8	Production	Workers strike	0.01	$7,020,000.00	[illegible]	$8,580,000.00	$0.00	$78,000.00	Low	
7.1	Customer Support	Access to service centers	[illegible]	$3,159,000.00	[illegible]	$3,861,000.00	$0.00	$1,755,000.00	High	[illegible]
7.2	Customer Support	Inefficient staff	[illegible]	$2,457,000.00	[illegible]	$3,003,000.00	$0.00	$1,365,000.00	High	
7.3	Customer Support	Not fulfilling customer commitment	0.2	$2,457,000.00	[illegible]	$3,003,000.00	$0.00	$546,000.00	Medium	
7.4	Customer Support	Lack of integration of service centers	[illegible]	$5,265,000.00	[illegible]	$6,435,000.00	$0.00	$1,755,000.00	High	
					$87,391,200.00		$0.00			$461,878,000.00
								Management Reserve	40000000	
								Total Program	$501,878,000.00	

Figure J.2: Step II_POSE_Cost

Risk	Phase	Risk	Mitigation Plan	Probabil	Minimum	Most Likely	Maximum	Risk Mitigation
1.1	Market Planning	Loss in market share	Branding &advertising campaign	0.25	$45,000.00	$50,000.00	$55,000.00	$40,500.00
1.2	Market Planning	30% profit is not attained	Low skilled labor, Offshoring	0.1	$40,500.00	$45,000.00	$49,500.00	$36,450.00
1.3	Market Planning	Competitor launches similar phone	Focus in MS brand rather than product	0.2	$90,000.00	$100,000.00	$110,000.00	$81,000.00
1.4	Market Planning	Change in taxes & cost	re-visit budget allocation	0.3	$135,000.00	$150,000.00	$165,000.00	$121,500.00
1.5	Market Planning	Failed Market Research	Re-invent	0.1	$22,500.00	$25,000.00	$27,500.00	$20,250.00
2.1	Placement &	Reduction in budget allocation	Revisit the financial objective & profit	0.2	$90,000.00	$100,000.00	$110,000.00	$81,000.00
2.2	Placement &	Resource over/under allocation	Revisit WBS &OBS,	0.4	$72,000.00	$80,000.00	$88,000.00	$64,800.00
2.3	Placement &	Unsatisfied customers	Promotion, additional software features	0.2	$72,000.00	$80,000.00	$88,000.00	$64,800.00
2.4	Placement &	Customer shift to different brands	Customer loyalty program & incentives	0.1	$40,500.00	$45,000.00	$49,500.00	$36,450.00
2.5	Placement &	Shorter product life cycle than anticipated	Reevaluate vendor/suppliers	0.05	$33,750.00	$37,500.00	$41,250.00	$30,375.00
3.1	Project Definition	Delay in critical path	Revisit IMS/ develop new critical paths,	0.7	$126,000.00	$140,000.00	$154,000.00	$113,400.00
3.2	Project Definition	Vendor issues	Stringent service legal agreement	0.2	$27,000.00	$30,000.00	$33,000.00	$24,300.00
3.3	Project Definition	Intellectual property legal issues	periodic legal assament	0.1	$9,000.00	$10,000.00	$11,000.00	$8,100.00
3.4	Project Definition	Improper capacity, capability assessment	Revisit turnaround cycle time of product	0.1	$9,000.00	$10,000.00	$11,000.00	$8,100.00
3.5	Project Definition	Scope creep	Scope Creep Methodology	0.1	$12,600.00	$14,000.00	$15,400.00	$11,340.00
4.1	Implementation	Procurement and estimation	Reserve inventory of raw material (buffer	0.25	$1,462,500.00	$1,625,000.00	$1,787,500.00	$1,316,250.00
4.2	Implementation	Failed prototype testing	Revisit product design	0.2	$1,350,000.00	$1,500,000.00	$1,650,000.00	$1,215,000.00
4.3	Implementation	Manufacturing and Design incompatibility	Design for six sigma	0.1	$405,000.00	$450,000.00	$495,000.00	$364,500.00
4.4	Implementation	software and hardware integration	Evaluate compatibility options	0.2	$855,000.00	$950,000.00	$1,045,000.00	$769,500.00
4.5	Implementation	Testing protocols & resource are delayed	outsource testing	0.1	$315,000.00	$350,000.00	$385,000.00	$283,500.00
5.1	Launch and Close out	Preorder is higher than inventory	Re-schedule shipments	0.5	$2,025,000.00	$2,250,000.00	$2,475,000.00	$1,822,500.00
5.2	Launch and Close out	Product software failure	Offer software update	0.3	$405,000.00	$450,000.00	$495,000.00	$364,500.00
5.3	Launch and Close out	Delayed launch of product	Increase resources	0.3	$675,000.00	$750,000.00	$825,000.00	$607,500.00
5.4	Launch and Close out	Product hardware failure	Review technical specifications	0.1	$225,000.00	$250,000.00	$275,000.00	$202,500.00
5.5	Launch and Close out	Disposition of Obsolete/excess material	Maintaining inventory for repair	0.2	$117,000.00	$130,000.00	$143,000.00	$105,300.00
6.1	Production	Production capability less than	Outsource, Hire a consultant	0.5	$4,050,000.00	$4,500,000.00	$4,950,000.00	$3,645,000.00
6.2	Production	Over production	Acquire space/ rent public warehouse	0.3	$2,025,000.00	$2,250,000.00	$2,475,000.00	$1,822,500.00
6.3	Production	Cost of raw material increases	Offshore procurement	0.1	$360,000.00	$400,000.00	$440,000.00	$324,000.00
6.4	Production	Defective products	Implement Six Sigma, Automation, Q&A	0.2	$810,000.00	$900,000.00	$990,000.00	$729,000.00
6.5	Production	Equipment failure	Outsource, Overhauling of machinery	0.1	$450,000.00	$500,000.00	$550,000.00	$405,000.00
6.6	Production	Natural Disaster	Insurance	0.01	$67,500.00	$75,000.00	$82,500.00	$60,750.00
6.7	Production	Defective packing	New vendor, Redesign, Outsource	0.1	$202,500.00	$225,000.00	$247,500.00	$182,250.00
6.8	Production	Workers strike	Give incentives	0.01	$90,000.00	$100,000.00	$110,000.00	$81,000.00
7.1	Customer Support	Access to service centers	Collaborate with local Servicing	0.3	$1,215,000.00	$1,350,000.00	$1,485,000.00	$1,093,500.00
7.2	Customer Support	Inefficient staff	Training programs	0.5	$1,575,000.00	$1,750,000.00	$1,925,000.00	$1,417,500.00
7.3	Customer Support	Not fulfilling customer commitment	Training programs	0.2	$630,000.00	$700,000.00	$770,000.00	$567,000.00
7.4	Customer Support	Lack of integration of service centers	Use CRM and Salesforce	0.1	$675,000.00	$750,000.00	$825,000.00	$607,500.00
						$23,121,500.00		$18,728,415.00

Figure J.3: Step III_POSE_Cost

Risk no	Phase	Risk	Mitigation Plan	Probability	Minimum Impact	Most Likely Impact	Maximum Impact	Impact	Risk Mitigation	Phase Wise Cost Estimates
1.1	Market Planning	Loss in market share	Branding &advertising campaign	[illegible]	$90,585.00	[illegible]	$110,715.00	$0.00	$40,500.00	[illegible]
1.2	Market Planning	30% profit is not attained	Low skilled labor, Offshoring	[illegible]	$81,526.50	[illegible]	$99,643.50	$0.00	$36,450.00	
1.3	Market Planning	Competitor launches similar phone	Focus in MS brand rather than	[illegible]	$181,170.00	[illegible]	$221,430.00	$0.00	$81,000.00	
1.4	Market Planning	Change in taxes & cost	re-visit budget allocation	[illegible]	$271,755.00	[illegible]	$332,145.00	$0.00	$121,500.00	
1.5	Market Planning	Failed Market Research	Re-invent	[illegible]	$45,292.50	[illegible]	$55,357.50	$0.00	$20,250.00	
2.1	Placement &	Reduction in budget allocation	Revisit the financial objective & profit	[illegible]	$181,170.00	[illegible]	$221,430.00	$0.00	$81,000.00	[illegible]
2.2	Placement &	Resource over/under allocation	Revisit WBS &OBS,	[illegible]	$144,936.00	[illegible]	$177,144.00	$0.00	$64,800.00	
2.3	Placement &	Unsatisfied customers	Promotion, additional software	[illegible]	$144,936.00	[illegible]	$177,144.00	$0.00	$64,800.00	
2.4	Placement &	Customer shift to different brands	Customer loyalty program &	[illegible]	$81,526.50	[illegible]	$99,643.50	$0.00	$36,450.00	
2.5	Placement &	Shorter product life cycle than	Reevaluate vendor/suppliers	[illegible]	$67,938.75	[illegible]	$83,036.25	$0.00	$30,375.00	
3.1	Project Definition	Delay in critical path	Revisit IMS/ develop new critical	[illegible]	$253,638.00	[illegible]	$310,002.00	$0.00	$113,400.00	[illegible]
3.2	Project Definition	Vendor issues	Stringent service legal agreement	[illegible]	$54,351.00	[illegible]	$66,429.00	$0.00	$24,300.00	
3.3	Project Definition	Intellectual property legal issues	periodic legal assament	[illegible]	$18,117.00	[illegible]	$22,143.00	$0.00	$8,100.00	
3.4	Project Definition	Improper capacity, capability	Revisit turnaround cycle time of	[illegible]	$18,117.00	[illegible]	$22,143.00	$0.00	$8,100.00	
3.5	Project Definition	Scope creep	Scope Creep Methodology	[illegible]	$25,363.80	[illegible]	$31,000.20	$0.00	$11,340.00	
4.1	Implementation	Procurement and estimation	Reserve inventory of raw material	[illegible]	$2,944,012.50	[illegible]	$3,598,237.50	$0.00	$1,316,250.00	[illegible]
4.2	Implementation	Failed prototype testing	Revisit product design	[illegible]	$2,717,550.00	[illegible]	$3,321,450.00	$0.00	$1,215,000.00	
4.3	Implementation	Manufacturing and Design	Design for six sigma	[illegible]	$815,265.00	[illegible]	$996,435.00	$0.00	$364,500.00	
4.4	Implementation	software and hardware integration	Evaluate compatibility options	[illegible]	$1,721,115.00	[illegible]	$2,103,585.00	$0.00	$769,500.00	
4.5	Implementation	Testing protocols & resource are	outsource testing	[illegible]	$634,095.00	[illegible]	$775,005.00	$0.00	$283,500.00	
5.1	Launch and Close out	Preorder is higher than inventory	Re-schedule shipments	[illegible]	$4,076,325.00	[illegible]	$4,982,175.00	$0.00	$1,822,500.00	[illegible]
5.2	Launch and Close out	Product software failure	Offer software update	[illegible]	$815,265.00	[illegible]	$996,435.00	$0.00	$364,500.00	
5.3	Launch and Close out	Delayed launch of product	Increase resources	[illegible]	$1,358,775.00	[illegible]	$1,660,725.00	$0.00	$607,500.00	
5.4	Launch and Close out	Product hardware failure	Review technical specifications	[illegible]	$452,925.00	[illegible]	$553,575.00	$0.00	$202,500.00	
5.5	Launch and Close out	Disposition of Obsolete/excess	Maintaining inventory for repair	[illegible]	$235,521.00	[illegible]	$287,859.00	$0.00	$105,300.00	
6.1	Production	Production capability less than	Outsource, Hire a consultant	[illegible]	$8,152,650.00	[illegible]	$9,964,350.00	$0.00	$3,645,000.00	[illegible]
6.2	Production	Over production	Acquire space/ rent public warehouse	[illegible]	$4,076,325.00	[illegible]	$4,982,175.00	$0.00	$1,822,500.00	
6.3	Production	Cost of raw material increases	Offshore procurement	[illegible]	$724,680.00	[illegible]	$885,720.00	$0.00	$324,000.00	
6.4	Production	Defective products	Implement Six Sigma, Automation,	[illegible]	$1,630,530.00	[illegible]	$1,992,870.00	$0.00	$729,000.00	
6.5	Production	Equipment failure	Outsource, Overhauling of machinery	[illegible]	$905,850.00	[illegible]	$1,107,150.00	$0.00	$405,000.00	
6.6	Production	Natural Disaster	Insurance	[illegible]	$135,877.50	[illegible]	$166,072.50	$0.00	$60,750.00	
6.7	Production	Defective packing	New vendor, Redesign, Outsource	[illegible]	$407,632.50	[illegible]	$498,217.50	$0.00	$182,250.00	
6.8	Production	Workers strike	Give incentives	[illegible]	$181,170.00	[illegible]	$221,430.00	$0.00	$81,000.00	
7.1	Customer Support	Access to service centers	Collaborate with local Servicing	[illegible]	$2,445,795.00	[illegible]	$2,989,305.00	$0.00	$1,093,500.00	[illegible]
7.2	Customer Support	Inefficient staff	Training programs	[illegible]	$3,170,475.00	[illegible]	$3,875,025.00	$0.00	$1,417,500.00	
7.3	Customer Support	Not fulfilling customer commitment	Training programs	[illegible]	$1,268,190.00	[illegible]	$1,550,010.00	$0.00	$567,000.00	
7.4	Customer Support	Lack of integration of service centers	Use CRM and Salesforce	[illegible]	$1,358,775.00	[illegible]	$1,660,725.00	$0.00	$607,500.00	
						$46,543,579.50		$0.00	$18,728,415.00	$461,878,000.00
									Management Reserve	40000000
									Total Program	$501,878,000.00

Figure J.4: Step IV_POSE_Cost

Risk no	Phase	Risk	Mitigation Plan	Probability	Minimum Impact	Most Likely Impact	Maximum Impact	Impact	Risk Mitigation	Phase Wise Cost
1.1	Market Planning	Loss in market share	Branding &advertising campaign	0.25	$90,585.00	[illegible]	$110,715.00	$0.00	$40,500.00	[illegible]
1.2	Market Planning	30% profit is not attained	Low skilled labor, Offshoring	[illegible]	$81,526.50	[illegible]	$99,643.50	$0.00	$36,450.00	
1.3	Market Planning	Competitor launches similar phone	Focus in MS brand rather than	[illegible]	$181,170.00	[illegible]	$221,430.00	$0.00	$81,000.00	
1.4	Market Planning	Change in taxes & cost	re-visit budget allocation	[illegible]	$271,755.00	[illegible]	$332,145.00	$0.00	$121,500.00	
1.5	Market Planning	Failed Market Research	Re-invent	[illegible]	$45,292.50	[illegible]	$55,357.50	$0.00	$20,250.00	
2.1	Placement &	Reduction in budget allocation	Revisit the financial objective & profit	[illegible]	$181,170.00	[illegible]	$221,430.00	$0.00	$81,000.00	[illegible]
2.2	Placement &	Resource over/under allocation	Revisit WBS &OBS,	[illegible]	$144,936.00	[illegible]	$177,144.00	$0.00	$64,800.00	
2.3	Placement &	Unsatisfied customers	Promotion, additional software	[illegible]	$144,936.00	[illegible]	$177,144.00	$0.00	$64,800.00	
2.4	Placement &	Customer shift to different brands	Customer loyalty program &	[illegible]	$81,526.50	[illegible]	$99,643.50	$0.00	$36,450.00	
2.5	Placement &	Shorter product life cycle than	Reevaluate vendor/suppliers	0.05	$67,938.75	[illegible]	$83,036.25	$0.00	$30,375.00	
3.1	Project Definition	Delay in critical path	Revisit IMS/ develop new critical	[illegible]	$253,638.00	[illegible]	$310,002.00	$0.00	$113,400.00	[illegible]
3.2	Project Definition	Vendor issues	Stringent service legal agreement	[illegible]	$54,351.00	[illegible]	$66,429.00	$0.00	$24,300.00	
3.3	Project Definition	Intellectual property legal issues	periodic legal assament	[illegible]	$18,117.00	[illegible]	$22,143.00	$0.00	$8,100.00	
3.4	Project Definition	Improper capacity, capability	Revisit turnaround cycle time of	[illegible]	$18,117.00	[illegible]	$22,143.00	$0.00	$8,100.00	
3.5	Project Definition	Scope creep	Scope Creep Methodology	[illegible]	$25,363.80	[illegible]	$31,000.20	$0.00	$11,340.00	
4.1	Implementation	Procurement and estimation	Reserve inventory of raw material	0.25	$2,944,012.50	[illegible]	$3,598,237.50	$0.00	$1,316,250.00	[illegible]
4.2	Implementation	Failed prototype testing	Revisit product design	[illegible]	$2,717,550.00	[illegible]	$3,321,450.00	$0.00	$1,215,000.00	
4.3	Implementation	Manufacturing and Design	Design for six sigma	[illegible]	$815,265.00	[illegible]	$996,435.00	$0.00	$364,500.00	
4.4	Implementation	software and hardware integration	Evaluate compatibility options	[illegible]	$1,721,115.00	[illegible]	$2,103,585.00	$0.00	$769,500.00	
4.5	Implementation	Testing protocols & resource are	outsource testing	0.15	$634,095.00	[illegible]	$775,005.00	$0.00	$283,500.00	
5.1	Launch and Close out	Preorder is higher than inventory	Re-schedule shipments	0.5	$4,076,325.00	[illegible]	$4,982,175.00	$0.00	$1,822,500.00	[illegible]
5.2	Launch and Close out	Product software failure	Offer software update	[illegible]	$815,265.00	[illegible]	$996,435.00	$0.00	$364,500.00	
5.3	Launch and Close out	Delayed launch of product	Increase resources	[illegible]	$1,358,775.00	[illegible]	$1,660,725.00	$0.00	$607,500.00	
5.4	Launch and Close out	Product hardware failure	Review technical specifications	[illegible]	$452,925.00	[illegible]	$553,575.00	$0.00	$202,500.00	
5.5	Launch and Close out	Disposition of Obsolete/excess	Maintaining inventory for repair	[illegible]	$235,521.00	[illegible]	$287,859.00	$0.00	$105,300.00	
6.1	Production	Production capability less than	Outsource, Hire a consultant	[illegible]	$8,152,650.00	[illegible]	$9,964,350.00	$0.00	$3,645,000.00	[illegible]
6.2	Production	Over production	Acquire space/ rent public warehouse	[illegible]	$4,076,325.00	[illegible]	$4,982,175.00	$0.00	$1,822,500.00	
6.3	Production	Cost of raw material increases	Offshore procurement	[illegible]	$724,680.00	[illegible]	$885,720.00	$0.00	$324,000.00	
6.4	Production	Defective products	Implement Six Sigma, Automation,	[illegible]	$1,630,530.00	[illegible]	$1,992,870.00	$0.00	$729,000.00	
6.5	Production	Equipment failure	Outsource, Overhauling of machinery	[illegible]	$905,850.00	[illegible]	$1,107,150.00	$0.00	$405,000.00	
6.6	Production	Natural Disaster	Insurance	0.01	$135,877.50	[illegible]	$166,072.50	$0.00	$60,750.00	
6.7	Production	Defective packing	New vendor, Redesign, Outsource	[illegible]	$407,632.50	[illegible]	$498,217.50	$0.00	$182,250.00	
6.8	Production	Workers strike	Give incentives	0.01	$181,170.00	[illegible]	$221,430.00	$0.00	$81,000.00	
7.1	Customer Support	Access to service centers	Collaborate with local Servicing	[illegible]	$2,445,795.00	[illegible]	$2,989,305.00	$0.00	$1,093,500.00	[illegible]
7.2	Customer Support	Inefficient staff	Training programs	[illegible]	$3,170,475.00	[illegible]	$3,875,025.00	$0.00	$1,417,500.00	
7.3	Customer Support	Not fulfilling customer commitment	Training programs	[illegible]	$1,268,190.00	[illegible]	$1,550,010.00	$0.00	$567,000.00	
7.4	Customer Support	Lack of integration of service centers	Use CRM and Salesforce	[illegible]	$1,358,775.00	[illegible]	$1,660,725.00	$0.00	$607,500.00	
						$46,543,579.50		$0.00	$18,728,415.00	$461,878,000.00
									Management Reserve	$40,000,000.00
									Total Program	$501,878,000.00

Figure J.6: Step VI_POSE_Cost

Risk no	Phase	Risk	Probability	Minimum Impact	Most Likely Impact	Maximum Impact	Risk Value	Risk Prioritization
1.1	Market Planning	Loss in market share	0.25	4	5	6	1.25	Medium
1.3	Market Planning	Competitor launches similar phone	0.2	6	8	9	1.6	Medium
2.1	Placement & Acceptance	Reduction in budget allocation	0.2	6	8	9	1.6	Medium
2.5	Placement & Acceptance	Shorter product life cycle than anticipated	0.05	6	7	9	0.35	Low
3.3	Project Definition	Intellectual property legal issues	0.1	4	6	7	0.6	Low
3.4	Project Definition	Improper capacity, capability assessment	0.1	1	3	3	0.3	Low
4.1	Implementation	Procurement and estimation	0.25	16	18	20	4.5	High
4.2	Implementation	Failed prototype testing	0.2	18	20	21	4	High
5.3	Launch and Close out	Delayed launch of product	0.3	4	5	6	1.5	Medium
5.4	Launch and Close out	Product hardware failure	0.1	6	7	7	0.7	Low
5.1	Launch and Close out	Preorder is higher than inventory	0.5	22	24	25	12	High
5.2	Launch and Close out	Product software failure	0.3	20	24	25	7.2	High
4.4	Implementation	software and hardware integration	0.2	20	22	25	4.4	High
7.4	Customer Support	Lack of integration of service centers	0.1	18	20	21	2	Medium
7.2	Customer Support	Inefficient staff	0.01	5	7	8	0.07	Low
7.1	Customer Support	Access to service centers	0.3	18	20	21	6	High
7.3	Customer Support	Not fulfilling customer commitment	0.2	18	22	22	4.4	High
					226			

Figure J.7: Step I_POSE_Schedule

Risk no	Phase	Risk	Probability	Minimum Impact	Most Likely Impact	Maximum Impact	Impact
1.1	Market Planning	Loss in market share	0.25	4	5	6	0
1.3	Market Planning	Competitor launches simila	0.2	6	8	9	0
2.1	Placement &	Reduction in budget alloca	0.2	6	8	9	0
2.5	Placement &	Shorter product life cycle th	0.05	6	7	9	0
3.3	Project Definition	Intellectual property legal	0.1	4	6	7	0
3.4	Project Definition	Improper capacity, capabili	0.1	1	3	3	0
4.1	Implementation	Procurement and	0.25	16	18	20	0
4.2	Implementation	Failed prototype testing	0.2	18	20	21	0
5.3	Launch and Close out	Delayed launch of product	0.3	4	5	6	0
5.4	Launch and Close out	Product hardware failure	0.1	6	7	7	0
5.1	Launch and Close out	Production capability less	0.5	22	24	25	0
5.2	Launch and Close out	Over production	0.3	20	24	25	0
4.4	Implementation	Defective products	0.2	20	22	25	0
7.4	Customer Support	Equipment failure	0.1	18	20	21	0
7.2	Customer Support	Inefficient staff	0.01	5	7	8	0
7.1	Customer Support	Access to service centers	0.3	18	20	21	0
7.3	Customer Support	Not fulfilling customer commitment	0.2	18	22	22	0
					226		0
		Schedule Reserve	50				
		Total Number of Days	1068				

Task Name	Minimum	Duration	Maximum
Market Planning		6	
SWOT Analysis		12	
Opportunity Analysis		18	
Conceptual Product	15	18	20
Marketing Plan		10	
Financial Analysis	20	24	25
Legal Assessment		3	
Resource Strategy		10	
Control Charts	16	25	28
Technology and Architecture	18	21	24
Conceptual Design	18	20	25
Budget Estimates		18	
Review		1	
Staffing Plan		10	
Product Specification		10	
Intellectual Property		3	
Manufacturing Requirements Allocation		9	
Sourcing		7	
Logistics and Supply Chain		45	
System Specification	35	40	45
Inventory Management		5	
Prototyping	90	110	120
Testing Prototype		25	
Design Finalization		15	
Production System Finalization		7	
Project Staffing		70	
Manufacuring Inception		1	
Training and Development		85	
Customer Service		330	
Project Close out	40	60	60
Critical Path Duration		1018	

Figure J.8: Step II_POSE_Schedule

Risk no	Phase	Risk	Probability	Minimum Impact	Most Likely Impact	Maximum Impact		Schedule Delay Risk Mitigation
1.1	Market Planning	Loss in market share	0.25	1	2	3	0	1
1.3	Market Planning	Competitor launches similar p	0.2	3	5	6	0	2
2.1	Placement & Acceptance	Reduction in budget allocatio	0.2	3	5	6	0	1
2.5	Placement & Acceptance	Shorter product life cycle than	0.05	3	4	6	0	2
3.3	Project Definition	Intellectual property legal issu	0.1	1	3	4	0	1
3.4	Project Definition	Improper capacity, capability	0.1	1	2	2	0	1
4.1	Implementation	Procurement and estimation	0.25	13	15	17	0	4
4.2	Implementation	Failed prototype testing	0.2	15	17	18	0	5
5.3	Launch and Close out	Delayed launch of product	0.3	1	2	3	0	1
5.4	Launch and Close out	Product hardware failure	0.1	3	4	4	0	2
5.1	Launch and Close out	Production capability less	0.5	19	21	22	0	4
5.2	Launch and Close out	Over production	0.3	17	21	22	0	5
4.4	Implementation	Defective products	0.2	17	19	22	0	5
7.4	Customer Support	Equipment failure	0.1	15	17	18	0	5
7.2	Customer Support	Inefficient staff	0.01	2	4	5	0	1
7.1	Customer Support	Access to service centers	0.3	15	17	18	0	4
7.3	Customer Support	Not fulfilling customer commitment	0.2	15	19	19	0	4
					177		0	48
		Schedule Reserve	50					

Figure J.9: Step III_POSE_Schedule

Risk no	Phase	Risk	Probability	Minimum Impact	Most Likely Impact	Maximum Impact	Impact	Schedule Delay Risk	Task Name	Minimum	Duration	Maximum
1.1	Market Planning	Loss in market share	0.25	1	2	3	0	1	Market Planning		6	
1.3	Market Planning	Competitor launches similar	0.2	3	5	6	0	2	SWOT Analysis		12	
2.1	Placement &	Reduction in budget allocati	0.2	3	5	6	0	1	Opportunity Analysis		18	
2.5	Placement &	Shorter product life cycle tha	0.05	3	4	6	0	2	Conceptual Product	15	18	20
3.3	Project Definition	Intellectual property legal iss	0.1	1	3	4	0	1	Marketing Plan		10	
3.4	Project Definition	Improper capacity, capability	0.1	1	2	2	0	1	Financial Analysis	20	24	25
4.1	Implementation	Procurement and	0.25	10	12	14	0	4	Legal Assessment		3	
4.2	Implementation	Failed prototype testing	0.2	10	12	14	0	5	Resource Strategy		10	
5.3	Launch and Close out	Delayed launch of product	0.3	1	2	3	0	1	Control Charts	16	25	28
5.4	Launch and Close out	Product hardware failure	0.1	3	4	4	0	2	Technology and Arch	18	21	24
5.1	Launch and Close out	Production capability less	0.5	12	14	15	0	4	Conceptual Design	18	20	25
5.2	Launch and Close out	Over production	0.3	10	11	12	0	5	Budget Estimates		18	
4.4	Implementation	Defective products	0.2	10	11	12	0	5	Review		1	
7.4	Customer Support	Equipment failure	0.1	9	10	12	0	5	Staffing Plan		10	
7.2	Customer Support	Inefficient staff	0.01	2	4	5	0	1	Product Specification		10	
7.1	Customer Support	Access to service centers	0.3	9	11	14	0	4	Intellectual Property		3	
7.3	Customer Support	Not fulfilling customer commitment	0.2	8	9	11	0	4	Manufacturing Requirements A		9	
					121		0	48	Sourcing		7	
									Logistics and Supply Chain		45	
									System Specification	35	40	45
		Schedule Reserve	50						Inventory Management		5	
		Total Number of Days	1068						Prototyping	90	110	120
									Testing Prototype		25	
									Design Finalization		15	
									Production System Finalization		7	
									Project Staffing		70	
									Manufacuring Inception		1	
									Training and Development		85	
									Customer Service		330	
									Project Close out	40	60	60
									Critical path Duration		1018	

Figure J.10: Step IV_POSE_Schedule

Risk no	Phase	Risk	Probability	Minimum Impact	Most Likely Impact	Maximum Impact	Impact	Schedule Delay Risk Mitigation	Task Name	Minimum	Duration	Maximum
1.1	Market Planning	Loss in market share	0.25	1	2	3	0	1	Market Planning		6	
1.3	Market Planning	Competitor launches simila	0.2	3	5	6	0	2	SWOT Analysis		12	
2.1	Placement &	Reduction in budget alloca	0.2	3	5	6	0	1	Opportunity Analysis		18	
2.5	Placement &	Shorter product life cycle th	0.05	3	4	6	0	2	Conceptual Product	15	18	20
3.3	Project Definition	Intellectual property legal	0.1	1	3	4	0	1	Marketing Plan		10	
3.4	Project Definition	Improper capacity, capabili	0.1	1	2	2	0	1	Financial Analysis	20	24	25
4.1	Implementation	Procurement and	0.25	10	12	14	0	4	Legal Assessment		3	
4.2	Implementation	Failed prototype testing	0.2	10	12	14	0	5	Resource Strategy		10	
5.3	Launch and Close out	Delayed launch of product	0.3	1	2	3	0	1	Control Charts	16	25	28
5.4	Launch and Close out	Product hardware failure	0.1	3	4	4	0	2	Technology and Arch	18	21	24
5.1	Launch and Close out	Production capability less	0.5	12	14	15	0	4	Conceptual Design	18	20	25
5.2	Launch and Close out	Over production	0.3	10	11	12	0	5	Budget Estimates		18	
4.4	Implementation	Defective products	0.2	10	11	12	0	5	Review		1	
7.4	Customer Support	Equipment failure	0.1	9	10	12	0	5	Staffing Plan		10	
7.2	Customer Support	Inefficient staff	0.01	2	4	5	0	1	Product Specification		10	
7.1	Customer Support	Access to service centers	0.3	9	11	14	0	4	Intellectual Property		3	
7.3	Customer Support	Not fulfilling customer commitment	0.2	8	9	11	0	4	Manufacturing Requirements		9	
					121		0	48	Sourcing		7	
									Logistics and Supply Chain		45	
									System Specificatior	35	40	45
		Schedule Reserve	50						Inventory Management		5	
		Total Number of Days	1068						Prototyping	90	110	120
									Testing Prototype		25	
									Design Finalization		15	
									Production System Finalizatio		7	
									Project Staffing		70	
									Manufacuring Inception		1	
									Training and Development		85	
									Customer Service		330	
									Project Close out	40	60	60
									Critical path Duration		1018	

Figure J.11: Step VI_POSE_Schedule

Risk no	Phase	Risk	Mitigation Plan	Probability	Minimum Impact	Most Likely	Maximum Impact	Impact	Risk Mitigation	Phase Vise Cost Estimates
1.1	Market Planning	Loss in market share	Branding &advertising campaign	1	$90,585.00	$100,650.00	$110,715.00	$100,650.00	$40,500.00	$7,000,000.00
1.2	Market Planning	30% profit is not attained	Low skilled labor, Offshoring	1	$81,526.50	$90,585.00	$99,643.50	$90,585.00	$36,450.00	
1.3	Market Planning	Competitor launches similar phone	Focus in MS brand rather than	1	$181,170.00	$201,300.00	$221,430.00	$201,300.00	$81,000.00	
1.4	Market Planning	Change in taxes & cost	re-visit budget allocation	1	$271,755.00	$301,950.00	$332,145.00	$301,950.00	$121,500.00	
1.5	Market Planning	Failed Market Research	Re-invent	1	$45,292.50	$50,325.00	$55,357.50	$50,325.00	$20,250.00	
2.1	Placement &	Reduction in budget allocation	Revisit the financial objective & profit	1	$181,170.00	$201,300.00	$221,430.00	$201,300.00	$81,000.00	$7,200,000.00
2.2	Placement &	Resource over/under allocation	Revisit WBS &OBS,	1	$144,936.00	$161,040.00	$177,144.00	$161,040.00	$64,800.00	
2.3	Placement &	Unsatisfied customers	Promotion, additional software	1	$144,936.00	$161,040.00	$177,144.00	$161,040.00	$64,800.00	
2.4	Placement &	Customer shift to different brands	Customer loyalty program &	1	$81,526.50	$90,585.00	$99,643.50	$90,585.00	$36,450.00	
2.5	Placement &	Shorter product life cycle than	Reevaluate vendor/suppliers	1	$67,938.75	$75,487.50	$83,036.25	$75,487.50	$30,375.00	
3.1	Project Definition	Delay in critical path	Revisit IMS/ develop new critical	[illegible]	$253,638.00	[illegible]	$310,002.00	$0.00	$113,400.00	[illegible]
3.2	Project Definition	Vendor issues	Stringent service legal agreement	[illegible]	$54,351.00	[illegible]	$66,429.00	$0.00	$24,300.00	
3.3	Project Definition	Intellectual property legal issues	periodic legal assament	[illegible]	$18,117.00	[illegible]	$22,143.00	$0.00	$8,100.00	
3.4	Project Definition	Improper capacity, capability	Revisit turnaround cycle time of	[illegible]	$18,117.00	[illegible]	$22,143.00	$0.00	$8,100.00	
3.5	Project Definition	Scope creep	Scope Creep Methodology	[illegible]	$25,363.80	[illegible]	$31,000.20	$0.00	$11,340.00	
4.1	Implementation	Procurement and estimation	Reserve inventory of raw material	0.25	$2,944,012.50	[illegible]	$3,598,237.50	$0.00	$1,316,250.00	[illegible]
4.2	Implementation	Failed prototype testing	Revisit product design	[illegible]	$2,717,550.00	[illegible]	$3,321,450.00	$0.00	$1,215,000.00	
4.3	Implementation	Manufacturing and Design	Design for six sigma	[illegible]	$815,265.00	[illegible]	$996,435.00	$0.00	$364,500.00	
4.4	Implementation	software and hardware integration	Evaluate compatibility options	[illegible]	$1,721,115.00	[illegible]	$2,103,585.00	$0.00	$769,500.00	
4.5	Implementation	Testing protocols & resource are	outsource testing	[illegible]	$634,095.00	[illegible]	$775,005.00	$0.00	$283,500.00	
5.1	Launch and Close out	Preorder is higher than inventory	Re-schedule shipments	[illegible]	$4,076,325.00	[illegible]	$4,982,175.00	$0.00	$1,822,500.00	[illegible]
5.2	Launch and Close out	Product software failure	Offer software update	[illegible]	$815,265.00	[illegible]	$996,435.00	$0.00	$364,500.00	
5.3	Launch and Close out	Delayed launch of product	Increase resources	[illegible]	$1,358,775.00	[illegible]	$1,660,725.00	$0.00	$607,500.00	
5.4	Launch and Close out	Product hardware failure	Review technical specifications	[illegible]	$452,925.00	[illegible]	$553,575.00	$0.00	$202,500.00	
5.5	Launch and Close out	Disposition of Obsolete/excess	Maintaining inventory for repair	[illegible]	$235,521.00	[illegible]	$287,859.00	$0.00	$105,300.00	
6.1	Production	Production capability less than	Outsource, Hire a consultant	[illegible]	$8,152,650.00	[illegible]	$9,964,350.00	$0.00	$3,645,000.00	[illegible]
6.2	Production	Over production	Acquire space/ rent public warehouse	[illegible]	$4,076,325.00	[illegible]	$4,982,175.00	$0.00	$1,822,500.00	
6.3	Production	Cost of raw material increases	Offshore procurement	[illegible]	$724,680.00	[illegible]	$885,720.00	$0.00	$324,000.00	
6.4	Production	Defective products	Implement Six Sigma, Automation,	[illegible]	$1,630,530.00	[illegible]	$1,992,870.00	$0.00	$729,000.00	
6.5	Production	Equipment failure	Outsource, Overhauling of machinery	[illegible]	$905,850.00	[illegible]	$1,107,150.00	$0.00	$405,000.00	
6.6	Production	Natural Disaster	Insurance	[illegible]	$135,877.50	[illegible]	$166,072.50	$0.00	$60,750.00	
6.7	Production	Defective packing	New vendor, Redesign, Outsource	[illegible]	$407,632.50	[illegible]	$498,217.50	$0.00	$182,250.00	
6.8	Production	Workers strike	Give incentives	[illegible]	$181,170.00	[illegible]	$221,430.00	$0.00	$81,000.00	
7.1	Customer Support	Access to service centers	Collaborate with local Servicing	[illegible]	$2,445,795.00	[illegible]	$2,989,305.00	$0.00	$1,093,500.00	[illegible]
7.2	Customer Support	Inefficient staff	Training programs	[illegible]	$3,170,475.00	[illegible]	$3,875,025.00	$0.00	$1,417,500.00	
7.3	Customer Support	Not fulfilling customer commitment	Training programs	[illegible]	$1,268,190.00	[illegible]	$1,550,010.00	$0.00	$567,000.00	
7.4	Customer Support	Lack of integration of service centers	Use CRM and Salesforce	[illegible]	$1,358,775.00	[illegible]	$1,660,725.00	$0.00	$607,500.00	
						$46,543,579.50		$1,434,262.50	$18,151,290.00	$462,141,000.00
									Management Reserve	$35,500,000.00
									Total Program	$499,075,262.50

Figure J.12: POSE_Managing_Cost

Risk no	Phase	Risk	Probability	Minimum Impact	Most Likely Impact	Maximum Impact	Impact	Schedule Delay Risk Mitigation	Task Name	Minimum	Duration	Maximum
1.1	Market Planning	Loss in market share	1	1	2	3	2	1	Market Planning		6	
1.3	Market Planning	Competitor launches simila	1	3	5	6	5	2	SWOT Analysis		12	
2.1	Placement & Acceptance	Reduction in budget alloca	1	3	5	6	5	1	Opportunity Analysis		18	
2.5	Placement & Acceptance	Shorter product life cycle th	1	3	4	6	4	2	Conceptual Product		16	
3.3	Project Definition	Intellectual property legal	0.1	1	3	4	0	1	Marketing Plan		10	
3.4	Project Definition	Improper capacity, capabili	0.1	1	2	2	0	1	Financial Analysis		24	
4.1	Implementation	Procurement and	0.25	10	12	14	0	4	Legal Assessment		3	
4.2	Implementation	Failed prototype testing	0.2	10	12	14	0	5	Resource Strategy		10	
5.3	Launch and Close out	Delayed launch of product	0.3	1	2	3	0	1	Control Charts		26	
5.4	Launch and Close out	Product hardware failure	0.1	3	4	4	0	2	Technology and Architecture		22	
5.1	Launch and Close out	Production capability less	0.5	12	14	15	0	4	Conceptual Design		20	
5.2	Launch and Close out	Over production	0.3	10	11	12	0	5	Budget Estimates		18	
4.4	Implementation	Defective products	0.2	10	11	12	0	5	Review		1	
7.4	Customer Support	Equipment failure	0.1	9	10	12	0	5	Staffing Plan		10	
7.2	Customer Support	Inefficient staff	0.01	2	4	5	0	1	Product Specification		10	
7.1	Customer Support	Access to service centers	0.3	9	11	14	0	4	Intellectual Property		3	
7.3	Customer Support	Not fulfilling customer commitment	0.2	8	9	11	0	4	Manufacturing Requirements		9	
					121		16	48	Sourcing		7	
									Logistics and Supply Chain		45	
									System Specificatior	35	40	45
		Schedule Reserve	30						Inventory Management		5	
		Total Number of Days	1064						Prototyping	90	110	120
									Testing Prototype		25	
									Design Finalization		15	
									Production System Finalizatic		7	
									Project Staffing		70	
									Manufacuring Inception		1	
									Training and Development		85	
									Customer Service		330	
									Project Close out	40	60	60
									Critical Path Duration		1018	

Figure J.13: POSE_Managing_Schedule

Appendix K

Template for POSE Application

This appendix provides an outline to use the Excel Spreadsheet template to apply POSE. This template can be accessed in the link as below:

https://www.dropbox.com/sh/fx3ilox3u6hqhdl/AAAYI3CpF3Yvffh4O7JVomREa?dl=0

The template is in the folder named “POSE Template”.

Pre- Requisite: This template can be used for Cost and Schedule of the Program. Only the units of input will change i.e. for Cost all inputs will be $ while for Schedule it will be in Days, Months or Years. Before application of POSE the following is to be filled in the template:

- Cost: The cost distribution for each activity/phase must be estimated by the program manager. The most common cost distribution used is the triangular distribution. IF the user plans on defining cost of each phase as a triangular then the three-point estimated should be filled. In the template, the user needs to filled data in Columns C, D and E with minimum, most likely and maximum estimated cost per phase or per activity.
- Schedule: In case of Schedule, only tasks on the critical path are to be listed in the template. The corresponding three-point estimates for each of these tasks is to be formulated. The data needs to be entered in Column C, D and E as minimum, most likely and maximum time required to complete the activity.

Cell number C15 is the management reserve. This should be defined as per the initial requirement before application of POSE. The cell “C16” is the forecast variable. The template shows the name “Total Program Cost”. This same template can be used for POSE for Schedule also. The only changes will be the units of the impact, schedule reserves and the forecast variable name as “Estimated Total Schedule”.

Step I: In this step, the user identifies the risk and enters them in the corresponding phase under the column “Risk”. The user further needs to input the data in columns: F: probability of occurrence, G: Minimum Impact, H: Most Likely Impact and I is Maximum Impact. Please Note: Do not enter any data in the temp column, it is only there to explain the simulation process. Further, the risk value will be calculated by the template. The Risk prioritization threshold for risk categorization must be decided by the user. The threshold value needs to be changed in the formula in the column of “Risk Prioritization”.

Step II: Depending on the risk priority, if the user wants to acknowledge only high risks, then all the rows of risks should be deleted before proceeding. Once it is deleted, please enter the value of the required “Management Reserve” in cell “C15”. Your spreadsheet is ready for simulation. Execute Step II.

Step III: In this Step, we fill out column “M: Mitigation Cost”. This is the risk mitigation for each of the listed risks. The summation of this risk mitigation at the end of the column is the “Risk Mitigation Budget” for the Program. This step will change the probability of occurrence (Column F) and impact of each of the risk (Columns G, H and I), thus corresponding changes should be made in those columns too. Do not enter any data in the column “Temp” or “Risk Mitigation Spent”. Now, we have defined risk mitigation at one level of Risk Mitigation Budget.

Step IV: Run the Simulation

Step V: As we defined in Step III, risk mitigation at one particular level. If the user has defined more than one level of risk mitigation, we do a comparative analysis of the probability of success under various levels of risk mitigation in this step

Step VI: Define the Management Reserve as decision variable if required.

Step VII: Best Value Solution.

The Figure K.1 shows a snapshot of the template that is to be used for POSE application.

Task	Risk	Minimum Estimated Cost of Phase	Most Likely Estimated Cost of the Phase	Maximum Estimated Cost of Phase	Probability of Occurrence	Impact when Risk Mitigation				Risk Value	Risk Prioritization	Mitigation Cost	Risk Mitigation Spent
						Minimum	Most Likely	Maximum	Temp				
Task 1	Risk 1					0		0	0	0	Low		0
Task 2	Risk 2					0		0	0				0
Task 3	Risk 3					0		0	0				0
Task 4	Risk 4					0		0	0				0
Task 5	Risk 5					0		0	0				0
Task 6	Risk 6					0		0	0				0
Task 7	Risk 7					0		0	0				0
Task 8	Risk 8					0		0	0				0
Task 9	Risk 9					0		0	0				0
Task 10	Risk 10					0		0	0				0
Total			**0**				**0**		0			**0**	**0**

Management Reserve	
Total Program Cost	**0**

Figure K.1: POSE Template

References

Cooke-Davies, T. & Arzymanov, A. (2003) The maturity of project management in different industries: An investigation into variations between project management models. International Journal of Project Management, 21, pp 471-478

Tzvi Raz, Aaron Shenhar and Dov Dvir(2002) Risk management, project success and technological uncertainty. Risk Management, Project Success and Technological Uncertainty. R & D Management.

Integrated cost and schedule Risk analysis, Hulett David, 2010. Ashgate Publication

Micheal Trumper, Lev Virine, Event Chain Methodology in Project Management. European journal for the informatics Professional, Volume 12, issue 5, December 2011, pg. 22-33

Kwak, Ingall. Exploring Monte Carlo Simulation Applications for Project Management, Risk Management, Vol 9, No. 1 (Feb 2007)

Barreras Anthony J (2011) Risk Management- Monte Carlo Simulation in Cost Estimating. Risk Management, 2011.

Shrivastava, N. K. (2014). A model to develop and use risk contingency reserve. Paper presented at PMI® Global Congress 2014—North America, Phoenix, AZ. Newtown Square, PA: Project Management Institute.)

Pollack-Johnson, (2006) Incorporating Quality considerations into project time/cost tradeoff analysis and Decision making, Liberatore M.J. IEEE transactions on Engineering Management, Volume 53, Issue 4, 2006

Pollack-Johnson, Liberatore M.J. (2005). Project Planning under uncertainty using scenario analysis. Project Management Journal, Volume 36, Issue 1.

Mulcahy, Rita (1999) Top Reasons projects fail. Risk Management. Conference Paper

High Cost of Low Performance (2016) Pulse of the Profession, 2016. Project Management Institute

Black, Ken, 1996. Causes of Project failure: A survey of professional engineers.

Hertz, David; Thomas, Howard (1983) Risk Analysis: Important New Tool for Business Planning, Journal of Business Strategy, Volume 3, pg23-29, 1983.

Cano, Cruz, (2002) Integrated Methodology for Project Risk Management, Journal of construction engineering and management.

Galway Lionel (2004) Quantitative Risk Analysis for Project Management: A critical Review. RAND Corporation.

Raz, Michael (2001) Use and Benefits of tools for project risk management, International Journal of Project Management, Volume 19, issue 1, page 9-17.

DoD Risk, Issue and Opportunity Management Guide for Defense Acquisition Programs. June 2015

Risk Management Guide for DoD Acquisition, Sixth Edition. August 2006.

Grauber, Schmidt & Proske: Practical use of Monte Carlo Simulation for Risk Management within the International Construction Industry. Proceedings of the 6th International Probabilistic Workshop, Darmstadt, 2008.

Perminova Olga, Gustafsson Magnus (2008), Defining Uncertainty in projects: A new Perspective. International Journal of Project Management. Vol 26. Pg &3-79.

Kutsch, Hall (2009) Deliberate Ignorance in Project Risk Management. International Journal of Project Management. Vol 28, pg 245-255.

Choudhry, Iqbal. Identification of Risk Management System in Construction Industry in Pakistan. Journal of Management in Engineering. January 2013. Pg 42-49.

Nguyen Tan Loc (2010), Integrated schedule and cost risk analysis using risk drivers in construction projects in Vietnam, Master's thesis, Royal Institute of Technology, Stockholm.

Kishk, M and Ukaga,C (2008) The impact of effective risk management on project success. Procs 24th annual ARCOM Conference. Cardiff UK. Association of Researchers in Construction Management. 799 – 808.

Virine Lev (2013), Integrated Qualitative and Quantitative Risk Analysis of Project Portfolios, Casualty Actuarial society, Professional Risk Manager's International Association, Society of Actuaries.

Hulett David (2010), Project Schedule Risk analysis, Monte Carlo Simulation or PERT? Risk Management. February 2000.

Cook Michael S (2001), Real World Monte Carlo Analysis. Risk Management.

Meyer, W. G. (2015). Quantifying risk: measuring the invisible. Paper presented at PMI® Global Congress 2015—EMEA, London, England. Newtown Square, PA: Project Management Institute.

Kramer, S. W. & Jenkins, J. L. (2006). Understanding the basics of CPM calculations: what is scheduling software really telling you? Paper presented at PMI® Global Congress 2006—North America, Seattle, WA. Newtown Square, PA: Project Management Institute

Bernoulli, J Wahrscheinlichkeitsrechnung (Ars conjectandi, 1713). Ostwalds Klassiker der exakten Wissenschaften, W. Engelmann, Leipzig, 1899)

Williams, T. (2003). The Contribution of Mathematical Modeling to the Practice of Project Management. IMA Journal of Management Mathematics. 14(1), p. 3.

Eckhardt, Roger. Stan Ulam, John Von Neumann and Monte Carlo Method. Los Alamos Special Issue. 1987

Metropolis, N (1987). The beginning of Monte Carlo Method. Los Alamos Sci. 15 Special issue 125-130

C Robert and G Casella. A short history of Markov Chain Monte Carlo: Subjective Recollections of incomplete data. Statistical Science, 2011. Vol 26 no.1, 102-115.

Financial Modelling with Oracle Crystal Ball and Excel by John Charnes.2010.

McKay, Beckman, and Conover, Technometrics, Vol 21., No.2 May 1979 pp 239 -245

Herman Kahn, Applications of Monte Carlo, RAND corporation, 1956

Halton (1970), A retrospective and Prospective survey of the Monte Carlo Method

Metropolis N. and Ulam S. (1949). The Monte Carlo Method. J.Amer. Statist. Assoc. 44, 335-341

Larson, Richard and Larson, Elizabeth, Conference Paper, Skill Development. 2009

Matta, Ashkenas (2003), Harvard Business Review, Why Good Projects fail Anyway. September

Piney, C. (2007). Integrated portfolio and program management: discovering organizational project management. Paper presented at PMI® Global Congress 2007—EMEA, Budapest, Hungary. Newtown Square, PA: Project Management Institute.

Bodych, M. A. (2012). Integrated project management in the organization. Paper presented at PMI® Global Congress 2012—EMEA, Marsailles, France. Newtown Square, PA: Project Management Institute.

https://docs.oracle.com/cd/E17236_01/epm.1112/cb_installation_1112200/frameset.htm?ch02s02.html

https://docs.oracle.com/cd/E17236_01/epm.1112/cb_user/frameset.htm?ch01s04.html

Biographical Information

The author Tejas Pawar got his PhD in Industrial Engineering and Master's Degree in Engineering Management from the University of Texas at Arlington. His Doctoral dissertation was on "Probability of Success in Program Management". Mr. Tejas Pawar is the co -founder of American Society of Engineering Management at UTA. He has a Six Sigma Green Belt Certification.

Mr. Tejas Pawar worked briefly with Foxconn as an Intern for Data Analysis. Prior to his Master's Degree, he worked as an Analyst for CTS Consulting in India for 3 years.

He is passionate about project/program management and looks forward to work in the consulting industry.