APPROXIMATION OF NPV

FOR IT INVESTMENTS

A Research Report

presented to the

Graduate School of Business Leadership

University of South Africa

In partial fulfillment of the

requirements for the

MASTERS DEGREE IN BUSINESS LEADERSHIP,

UNIVERSITY OF SOUTH AFRICA

by

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01 December 2008

ABSTRACT

Companies must be able to adapt and evolve if they wish to survive in the highly competitive marketplace today. Businesses operate with the knowledge that their competitors will inevitably come to the market with a product that changes the basis of competition. The ability to change and adapt therefore is essential to survival. Changes in the technological landscape enable a number of new opportunities to be opened up in the marketplace. There is no need to emphasize the role of Information Technology (IT) in such endeavors.

However, great uncertainties surround the IT project landscape where unpredictability of costs as well as quantification of benefits remaining prominent. Although NPV is often used as the de facto standard for IT investment appraisal, calculating the confidence levels of the inputs thereto or the output thereof is not attempted as often as desired. The purpose of this study was to determine how to perform better Net Present Value (NPV) approximations by improving the accuracy of input values thereto, in order to make informed business decisions. The study focuses on finding a practical solution to the above problem than a purist approach towards developing a theory.

DECLARATION

I, Aruna Jude Rathugamage, declare that this research report is my own, unaided work. It is submitted in partial fulfillment of the requirements for the degree of Master of Business Leadership at the University of South Africa, School of Business Leadership, Midrand. It has not been submitted before for any degree or examination in this or any other university.

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Aruna Jude Rathugamage

31st October, 2008

ACKNOWLEDGEMENTS

I would like to thank the following people, without whom this research would not have been possible:

- my supervisor, Dr Jan Kruger, for his time, patience and encouragement;
- my fellow MBL students, for the support and encouragement;
- my wife Dulani and two sons Awadi and Asiri, for their enduring support;
- Finally, all the interviewees, for their help, support and cooperation.

Table of Contents

Index of Tables

Table of figures

Chapter 1 – Orientation

1.1 Introduction

Investment appraisal of projects involving Information Technology (IT) is a leadership challenge in organizations. (Bannister and Remenyi, 2000) sees a limit to what can be achieved by formal rational evaluation methods for IT that in mapping the set of evaluation methodologies on to what is termed the investment opportunity space. According to them, decision makers fall back on ‘gut feel’ and other non-formal and rigorous ways of making decisions with regard to IT investments.

The researcher intends to fill the gap on investment appraisal for business projects involving IT, providing a solution for the above problem by better application of net present value (NPV) method. NPV is defined as the total present value (PV) of a time series of future cash flows. It is a standard method that uses the time value of money to appraise long-term projects. Used for capital budgeting, and widely throughout economics, it measures the excess or shortfall of cash flows, in present value terms, once financing charges (and the intended returns according to the risk) are met.

The researcher would like to highlight the fact that NPV is a tool for evaluating cash flows of a business case, but not a forecasting method. As per (Connor, 2006), NPV is a rational objective to put cash flows on a common value basis for appraisal purposes. It is wrong, however, to consider the NPV rule or technique as a forecasting method. Function of NPV is to evaluate a project in terms of,

- Achieving rate of return better than the market could return for this class of investment.
- Earning a return greater than the cost of the capital invested.

- Earning a return that pays for the investment outlay, the interest charges associated with the finance and produce a net income to the business at current values. (Connor, 2006)

NPV is defined as

$$NPV = \sum_{t=1}^{T} \frac{C_t}{(1+r)^t} - C_o$$

The variables in the NPV equation could be analyzed as follows.

Variable	Description	Dimension
C_t	The net cash flow (cash inflow minus outflow for IT as well as other operational expenses) at time t	Value dimension(v)
C	Initial investment (for IT and other initial expenses)	Cost dimension(c)
T	Life span of the system.	Time dimension(t)
r	The discount rate (the rate of return that could be earned on an investment in the financial markets with similar risk.)	Risk dimension (r)

Table 1 Parameter Analysis

Therefore, NPV could be written as a function of: v = Value; c = Cost; t = Time and r = Risk. $NPV = f(v, c, t, r)$.

NPV approximation is not an exact science, but rather a measure for a given project relying on available cash flow figures within accuracy levels acceptable for the purpose. Therefore the researcher finds the following definition for *approximation* from American Heritage Dictionary most appropriate in the context of this research. “***Approximation is a result that is not necessarily exact, but is within the limits of accuracy required for a given purpose.***”
(Dictionary.com, 2008)
The researcher will use the term “*true NPV*” to denote the value that was realized at the end of the investment horizon. True NPV for a given project could deviate from its projected value at the beginning of the project, due to the level of accuracy of supplied inputs, which could result in 3 possible outcomes.

1. The True NPV is negative but the calculated NPV was positive, hence the project was pursued resulting in loss of value.
2. True NPV is positive, but the calculated NPV was negative, hence the project was dropped resulting in loss of opportunity.
3. All other scenarios where true NPV carries the same sign as the calculated NPV and differ just in quantity.

Especially the scenarios 1 and 2 above negatively affect business value creation process. Hence, improvisation of methodologies is critical.

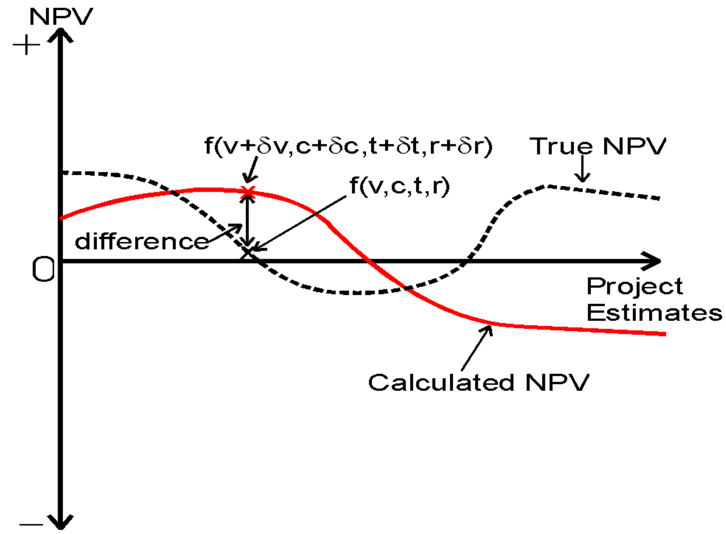

Figure 1 Gaps in NPV Calculations

As depicted in the graph, minimizing the difference between true and the calculated NPV could be described as NPV approximation. Hence the NPV approximation problem could be written as,

$$NPV \approx f(v+\delta v, c+\delta c, t+\delta t, r+\delta r)$$
$$when \quad \delta v \xrightarrow{\lim} 0; \quad \delta c \xrightarrow{\lim} 0; \quad \delta t \xrightarrow{\lim} 0; \quad \delta r \xrightarrow{\lim} 0.$$

1.2 Objectives of the Study

Since NPV approximation requires approximated inputs to add value to business, the purpose of this research is to improve the output from NPV by improving the accuracy of the input variables thereto. Obtaining acceptable level of accuracy for NPV according to the requirements forms the problem domain for this research. It is the objective of the researcher to improve existing IT investment cost appraisal methodologies by improving accuracy of input variable values in terms of time cost and risk profile as well as benefit quantification thus improving the overall benefits of the NPV evaluation, improving productivity in organizations and creating synergy.

IT projects are often considered with an element of uncertainty in terms of both time and financial cost. This has created mistrust between business and IT camps resulting in loss of synergy. Opportunities for productivity improvement by using IT is often lost due to this issue. Lack of common terms of reference which could be easily comprehended by both parties has been a main reason for this gap in communication between business and IT. In general, the researcher intends to find a reliable, plain language guideline for evaluating IT investments which could easily be acclimatized, comprehended and used by business and IT professionals alike for any environment with minimal effort.

1.3 The research problem: How to approximate NPV for IT investments?

<u>Sub problems are as follows:</u>

1.3.1 How to improve the value forecast for projects involving IT?

- How to quantify all the benefits?
- How to measure benefits in financial terms to be input to NPV equation?
- What level of confidence could be achieved?

1.3.2 How to improve the cost estimates for projects involving IT?

- What factors impact accuracy of estimates?
- How to improve the accuracy of IT cost estimates?
- What level of confidence could be achieved?

1.3.3 How to improve the quality of projects involving IT?

- What factors impact quality?

- What is the impact of quality on the accuracy of time and cost estimates?

1.3.4 How to approximate time estimate for projects involving IT?

- What factors impact the accuracy of estimate?
- How to improve the accuracy of time estimate for IT delivery and the productive life of the investment?
- What level of confidence could be achieved?

1.3.5 How to approximate the risk profile for IT projects involving IT?

- What factors impact the success of the project?
- How to improve the accuracy of the risk profile used?
- What level of confidence could be achieved?

1.4 Definitions

The term “Business” is used in a broader context to refer to all human endeavors including non profitable organizations and charities.

The term “Estimate” refers to both time and cost components of IT projects unless explicitly stated.

The term “Product” refers to an IT project or deliverable in context.

The term “IT investment” denotes the IT component of such an endeavor where IT plays a supporting function for a venture with a clear value proposition.

1.5 Assumptions

The researcher assumes proper estimation methods for non-IT components in the project. Sample data for quantitative analysis was taken from a large financial services organization, due its high dependency on IT systems in all areas of business activities. The size of the organization provided clearly demarcated functional areas for analysis as well as a broad range of projects.

1.6 Delimitations of the Study

The research does not attempt to evaluate the suitability of NPV as a cash flow evaluation tool for IT investments, but focus on finding accurate costing model. There are different opinions on the suitability of NPV as a project selection tool.

Arguments in favor of NPV are as follows. "The NPV and IRR methods make the same accept/reject decisions for independent projects, but for projects which are mutually exclusive, then ranking conflicts can arise. If conflicts do arise, the NPV method should be used. The NPV and IRR methods are both superior to the payback, but NPV is superior to IRR." (Garg, Joubert & Pellissier, 2005)
On the contrary, following arguments are against NPV. "When scheduling an uncertain project, project management can wait for additional (future) information to serve as the basis for rescheduling the project. This flexibility enhances the project's value by improving its upside potential while limiting downside losses relative to the initial expectations. Using Traditional techniques such as net present value (NPV) or decision tree analysis (DTA) can often lead to misleading results. Instead, a real options analysis should be preferred. The potentials of a real options approach to project management are discussed with an example and future research directions are highlighted."(Chulani, Boehm & Steece, 1998)

The strength of the business case for each project in question was assumed to exist and analysis of neither the accuracy of cash flow forecasts nor estimation of non-IT costs was not part of the focus of the study.

Infrastructure estimates are based on the volumes to be processed through the system. These capacity costs are relatively manageable due to commoditization. These services are generally handled by third party suppliers and costs could be contained by proper contracts. Hence infrastructure costing does not form part of the focus of this research project.

1.7 Outline of the research report

The researcher noticed an absence of literature on holistic approaches to the research in the problem domain of NPV approximation of IT investments, encompassing all its components such as time, cost, risk estimates as well as value quantification. This is quite remarkable given its importance to the success of all facets of businesses including non profit organizations. However, a rich archive of research publications on constituent fields does exist, which assisted the researcher in finding important insights regarding the problem domain.

Also, the forecasting of cash flows for a business value proposition is not an exact science, but a calculated guess using known market and economic data. NPV is a tool for evaluating the feasibility of the venture based on such forecasts, using inputs such as value forecast (v), cost estimate(c), time forecast (t), and project risk(r). However, there's an uncertainty in current appraisals for projects involving IT, which was the main motivator for this research. The literature review is divided in to six logical sections listed below.

1. Overview	Background to the problem and interrelationships between variables.

2. Value Approximation	Critical analysis of value quantification methods and constituent elements of value.
3. Cost Approximation	Critical analysis of IT cost estimation methods and contributing factors for accuracy thereof.
4.Time Approximation	Critical analysis of methods for time estimation and forecast of productive life for projects involving IT and contributing factors for deviations thereof.
5. Risk Approximation	Critical analysis of current approaches to determining risk for projects involving IT and additional factors to consider.
6. Conclusion	Summary and conclusion.

1.7.1 Overview

Importance of IT for business success is a widely accepted, yet much debated topic. Striking examples of IT project failures however have induced a climate of doubt. Lack of methods for forecasting and evaluation considered to be the main contributor for this situation. As per (Keil, Mixon, Saarinen & Virpituunainen, 1995), Information technology (IT) projects can fail for any number of reasons, and can result in considerable financial losses for the organizations that undertake them. (Keil, Mixon, Saarinen & Virpituunainen,1995) (Bannister & Remenyi , 2000) sees a limit to what can be achieved by formal rational evaluation methods for IT. The researcher however disagrees with this view and suggests this as a case of poor application instead. As per (Connor, 2006), the use of the net present value (NPV) rule in major investment decisions induces illusions of certainty and encourages over-confidence on the part of users is contested. In events where poor decisions are made and NPV rule has been used, it is argued that the causes will be behavioral and competence-centered rather than technique-based. From the literature, the researcher identified 5 main contributors for the above situation as listed below.

1. Lack of definition of scope and product parameters at inception.
2. Lack of clear definitions on scope and metrics of value proposition.
3. Lack of focus on reusability and adoption costs.
4. Lack of subjectivity in the risk analysis.
5. Lack of processes and non adherence to accepted project management principles.

The researcher intends to focus on these contributing factors due to their impact on approximation of four variables used in the NPV equation in sections to follow. Table below summarizes the impact on input variables by each factor.

Factor	**Value Impact**	**Cost Impact**	**Time Impact**	**Risk Impact**
Lack of definition of scope and product parameters at inception.	Yes	Yes	Yes	Yes
Lack of clear definitions on scope and metrics of value proposition	Yes			Yes
Lack of focus on reusability and adoption costs		Yes	Yes	
Generality instead of subjectivity in the risk analysis	Yes			Yes

Lack of processes and non adherence to accepted project management principles.	Yes	Yes	Yes	Yes

Table 2 Impact on Variables

According to (Lin, Huang, Cheng & Lin, 2007), forecasting accuracy also depends on predictability and repeatability of processes within an organization which depends on the level of maturity. The maturity level of an organization provides a way to predict the future performance of an organization within a given discipline or set of disciplines. Maturity levels consist of a predefined set of process areas. As adopted from (Carnegie Mellon Software Engineering Institute, 2002) IT Maturity Levels are defined as follows.

Maturity Level 1: Initial. Processes are usually ad hoc and chaotic. The organization usually does not provide a stable environment.

Maturity Level 2: Managed. Organization has ensured that requirements are managed and that processes are planned, performed, measured, and controlled.

Maturity Level 3: Defined. Processes are well characterized and understood, and are described in standards, procedures, tools, and methods.

Maturity Level 4: Quantitatively Managed. Organization has achieved all the specific goals of the process areas, and sub processes controlled by statistical and other quantitative techniques are in place that significantly contributes to overall process performance.

Maturity Level 5: Optimizing. Organization has achieved all the specific goals and the processes are continually improved based on a quantitative understanding of the common causes of variations inherent in processes. (Carnegie Mellon Software Engineering Institute, 2002)

With the current state on IT investment appraisal and its importance as well as the importance of IT maturity established, the researcher would like to focus on quantification and measurement of delivered value in the next section.

1.7.2 Value Approximation. ($\delta v \xrightarrow{\lim} 0$)

The researcher established the background to the problem in the previous section. The focus in this section is the quantification and value attribution of the delivered benefits including intangibles.

"If you can't measure it, you can't manage it!" often appear in most of the management literature especially that of notable scholars such as Pieter Drucker and Robert Kaplan, yet the researcher could not find enough less focus towards quantification and measurement of the value of IT benefits in organizations. However, some of the benefits could easily be measured than others such as intangible benefits, which form the majority and are critical for investment appraisal. In an effort to improve communications and to minimize omissions, a structured framework for measurement also needed.

According to (Dolins, 2006), Balanced Score Card (BSC) relates the enterprises' mission and strategic objectives to employees and external stakeholders using measures on each perspective. In BSC, measures are used to evaluate performance against expected results alongside organizational goals. Measures are used to gauge progress towards goals, to communicate progress to employees, and to set strategic direction for the organization. Measures are defined and classified using four different perspectives: financial, customer, internal process, and learning and growth. (Dolins, 2006) The researcher sees this creating a common frame of reference between business and IT across organizations.

Financial perspective	Are we meeting the expectations of our share holders?
Customer perspective	We delighting (or at least satisfying)

	our customers?
Business Process perspective	Are we doing the right things and doing things right?
Learning and Growth perspective	Are we prepared for the future?

Table 3 BSC Dimensions

With the broad categories for measurement established from BSC, the researcher intends to focus on candidate metrics for further analysis in this section. As described by (Kaplan, Norton,1992*)*, By measuring organizational performance across four balanced perspectives, the Balanced Scorecard complements traditional financial indicators with measures for customers, internal processes, and innovation and improvement activities. Some of BSC perspectives are intangible and there is a need to use non-traditional means for their measurement. The researcher intends to use Applied Information Economics (AIE) methods by Douglas W Hubbard for this purpose. As per (Hubbard, 2007), AIE is a synthesis of techniques from a variety of scientific and mathematical fields. The tools of economics, financial theory, and statistics are all major contributors to AIE. AIE also uses Decision Theory - the formulation of decisions into a mathematical framework - and Information Theory - the mathematical modeling of transmitting and receiving information. The researcher focused on the selection of a framework for measuring value and use of AIE for the quantification of intangible benefits. The next section focuses on cost estimation methods and challenges therein.

1.7.3 Cost Approximation. ($\delta c \xrightarrow{\lim} 0$)

The researcher established the importance of quantification and inclusion of all value components in the previous section. This section focuses on the field of IT cost estimation. The researcher sees four quadrants in the analysis of investment cost, as per the diagram below. The researcher only focuses on cost of IT for the shown in the right hand half of the diagram for the purposes of this study. It is assumed that non IT cost estimates has been adequately dealt with.

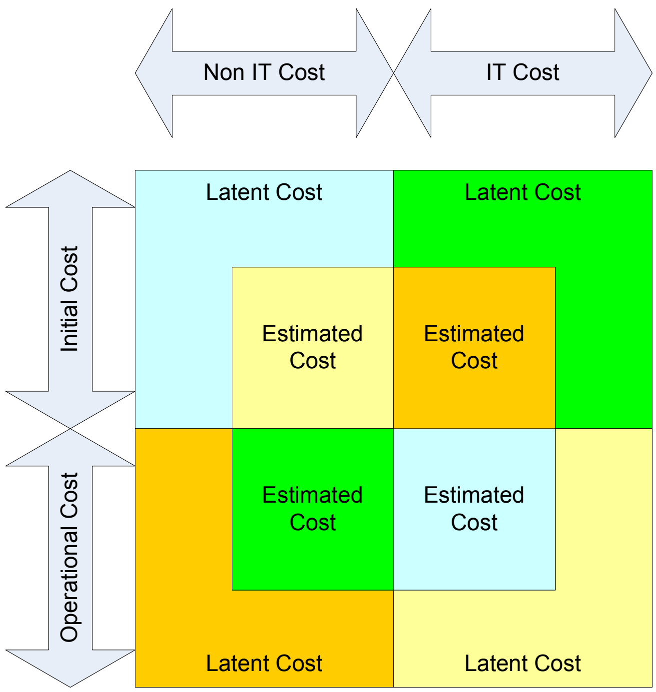

Figure 2 Cost Components Matrix

The researcher would like to separate cost into two components for analysis.

1. **Estimated Costs** Estimated expenses for personnel and software for the build and the operation of IT solution.

2. **Latent Costs** Costs incurred as a result of variances in estimations and the Cost of Quality (CoQ), and any other

unforeseen cost element.

1.7.3.1 Estimated Costs.

Estimated costs refer to the expected investment for the IT deliverable calculated according to available methods and guidelines. However the levels of accuracy obtained from these are not satisfactory. As per (Ayyıldız, Kalıpsız & Yavuz, 2006), since software becomes increasingly expensive to develop and is a major cost factor in any information system budget. Software development costs often get out of control due to lack of measurement and estimation methodologies. (Ayyıldız, Kalıpsız & Yavuz, 2006)

Various methods for software cost estimation have been developed as a resulting from the above situation. According to (Hu, Plant & Hertz*,* 1998), one of the major difficulties in controlling software development project cost overruns and schedule delays has been developing practical and accurate software cost models. Researcher had to seek information from earlier research for their technical details for most of these estimation methods except COCOMO as they are proprietary thus details are not available in the public domain. The researcher observed four approaches to software cost estimation.

1. Empirical Methods.
2. Methods based on mathematical models.
3. Methods based on theories from other disciplines.
4. Cost Estimation based on Expert Judgment.

1. Empirical Methods

These methods use historical data from vendors' proprietary databases to identify trends in software costs and need acclimatization to the local environment. COCOMO II is such a model based on Object Points. Object Points are a count of the screens, reports and third-generation-language modules developed in the application.

2. Methods based on Mathematical models

These methods use existing statistical or productivity models for software cost estimation. One such example is SLIM by Putnam, details of which are proprietary.

The researcher used literature by (Boehm, Abts & Chulani, 1998) for details thereof. SLIM is based on Putnam's analysis of the life-cycle in terms of a so-called Rayleigh distribution of project personnel level versus time. It makes use of Rayleigh curve to estimate project effort, schedule and defect rate. SLIM can record and analyze data from previously completed projects which are used to calibrate the model.

3. Methods based on Theories from other disciplines

(Hu *et al,*1998), proposed a theoretical approach to software cost modeling named Minimum Software Cost Model (MSCM), derived from economic production theory and systems optimization. The MSCM model is based on the proposition that software systems development processes are economic productions.

4. Cost Estimation based on Expert Judgment

These methods use the knowledge of an expert with the domain knowledge for the estimation of software cost. These methods appear to have been more reliable in some applications, especially in the reusability of software as discussed later in this study.

1.7.3.2 Latent Costs.

The researcher would like to classify the biggest problem experienced by projects involving IT is the unforeseen cost element, under latent cost. As per (Keil, Mixon, Saarinen & Virpituunainen,1995), IT projects can fail for any number of reasons, and can result in considerable financial losses to the organizations that undertake them. One pattern of failure that has been observed but seldom studied is the runaway project that takes on a life of its own. Such projects exhibit characteristics those are consistent with the broader phenomenon known as escalating commitment lo a failing course of action. Several theories have been offered to explain this phenomenon, including self-justification theory and the so-called sunk cost effect which can be explained by prospect theory. High level of sunk cost may influence decision makers to escalate their commitment to an IT project. From available literature, the researcher found 3 contributors to the latent cost as per the list below.

1. Unforeseen events,
2. Cost of Quality (CoQ), and
3. Variances in estimated costs.

1.7.3.2.1 Unforeseen Events.

Due to the rapid growth in IT as well as normal economic cycles, project scope could deviate from its estimates. Adequate risk provision is required in order to manage such situations. This is analyzed in a later under risk approximation section of this report.

1.7.3.2.2 Cost of Quality (CoQ).

The researcher also would like to investigate the cost of quality in detail in the hope of studying it further during research. Quality impacts defect resolution and detection as well as ongoing maintenance after implementation. As per (Houston and Keats, 1998), the basis for CoQ is the accounting of two kinds of costs.

1. Those which are incurred due to a lack of quality, which are further divided into the following.
    - Costs of internal failures and
    - Costs of external failures.
2. Those which are incurred in the achievement of quality, which are further divided into the following.

- Appraisal cost and
- Defect prevention costs.

Category	Definition	Typical Costs for Software
Internal failures	Quality failures detected prior to product shipment	Defect management, rework, retesting
External failures	Quality failures detected after product shipment	Technical support, complaint investigation, defect notification
Appraisal	Discovering the condition of the product	Testing and associated activities, product quality audits
Prevention	Efforts to ensure product quality	SQA administration, inspections, process improvements, metrics collection and analysis

Table 4 Cost Elements of Quality (Adopted from Houston & Keats 1998)

1.7.3.2.3 Variances in Estimated Costs.

The researcher would like to analyze previous work on IT cost variances from the estimated in this section. (Hu *et al*,1998), in their analysis have found that like many other software cost models, the COCOMO and SLIM models are empirical in nature, and their performances tend to vary significantly from one environment to another. (Chulani, Boehm & Steece, 1998) confirmed this view by proving the need for local calibrations. They found that the predictive performance of the Bayesian approach (i.e. COCOMO II.1998) is significantly better than that of the multiple regressions approach (i.e. COCOMO II.1997). COCOMO II.1998 gives predictions that are within 30% of the actual 71% of the time where as COCOMO II.1997 gives predictions within 30% of the actual only 52% of the time. If the model's multiplicative coefficient is calibrated to each of the major sources of project data, the resulting model produces estimates within 30% of the actual 76% of the time. It is therefore recommended that organizations using the model calibrate it using their own data to increase model accuracy and produce a local optimum estimate for similar type projects. However the researcher finds these levels of accuracy (i.e. best case of 30%) as unacceptable given the capital deployment, and intends to research on improvements thereto.

IT Cost Variation Drivers.

In view of gaps established in the previous section with the existing cost estimation methods, the researcher intends to analyze factors impacting cost variation. According to the existing literature, the researcher found 4 contributing factors for IT cost variance. They are listed below for analysis.

1. Product Factors
2. Resource Factors
3. Technological Factors
4. Environmental Factors

1. Product Factors

Due to rapid advancements in technology and customer needs, IT projects often have to change during development to still be relevant. This is particularly true for longer running projects. As per (Kadiyala and Kleiner, 2005), In order to meet customers needs in the competitive market, businesses need to continuously up grade their existing in formation systems and adopt new technologies in order to adapt to the changing trends. As per (Jones, 2006) among the technical issues that contribute to project failures are the lack of modern estimating approaches and the failure to plan for requirements growth during development.

<u>Granularity of Specification</u>

Definition of requirements takes longer in IT projects, yet estimates are attempted. According to Dr. Barry Boehm, who was involved in legendary COCOMO and COCOMO II methods of IT cost estimation, the granularity of the software cost estimation model used needs to be consistent with the granularity of the information available to support software cost estimation. In the early stages of a software project, very little may be known about the size of the product to be developed, hence accuracy will be limited.

Software Reusability and Integration

A unique feature of IT applications is its reusability. Each application needs to be integrated into existing systems as well as some code from existing code may be usable for new applications. This is an area where local expert knowledge becomes crucial. As per (Selby, 1988) of reuse costs across nearly 3000 reused modules in the NASA Software Engineering Laboratory indicates that the reuse cost function is nonlinear in two significant ways. There is generally a cost of about 5% for assessing, selecting, and assimilating the reusable component. Small modifications generate disproportionately large costs. This is primarily due to two factors: the cost of understanding the software to be modified, and the relative cost of interface checking. This is one of the main reasons for the failure of software cost estimation methods.

2. Resource Factors

Availability and quality of technical resources is dependant on the market demand, quality of training, and ease of adaptability. According to (Boehm *et al,* 1998) analyst capability, application experience, programming capability, platform experience, language and tool experience, personnel continuity are key factors impacting project delivery.

3. Technological Factors

Researcher is aware of the impact of rapid growth in technology in IT projects. In addition to the introduction of new technologies, existing technologies become obsolete or unsupported. This will demand compulsory realignment which can cost time, money and even impact the quality. As per (Skok and Tan, 2007) Strategic change is often enabled by the use of modern technology. However, one of the biggest problems faced by business managers and executives is how to keep up with the rapid changes in computing, communications and associated technology. Following famous quotes are included to illustrate the phenomenal growth in technology adaptation, especially in IT. *"640K (computer memory) ought to be enough for anybody"* Bill Gates, 1981

4. Environmental Factors

The researcher found literature related to the impact of environmental success factors. According to (Boehm *et al,* 1998), Multi-site development; use of software tool; required development schedule. The above factors are not necessarily independent, and most of them are hard to quantify. In many models, some of the factors appear in combined form and some are simply ignored. Also some factors take discrete values, resulting in an estimation function with a piece-wise form.

The researcher found literature related to the impact of environmental success factors. (Graham and Englund, 2004) lists generic environmental success factors for projects as follows.

- Strategic Emphasis – Projects need to be selected based on contribution to business strategy.
- Upper management support – Upper management needs to support the project management process and behave in ways that increase project success.
- Customer / end user input – Degree to which customer and end user input was considered during project planning and execution. This will remove ambiguities and define clear requirements in the beginning.

- Project Team Development – Degree to which organizational practices support project team development creating an environment which motivates the project team.
- Communications and information systems – Availability of key information within the project team and across the organization.

1.7.4 Time Approximation ($\delta t \xrightarrow{\lim} 0$)

In business, "*Time is Money*". Hence the cost dimension has a strong dependency on time in its forecasts for informed decision making, which is the focus of this section. Shortening of expense cycle as well as increasing income cycle is a definite provider of value. Therefore the researcher wishes to investigate the optimization of the time dimension in this section. This would involve concepts such as time value of money, as well as practical guidelines on forecasting accuracy, making the maximum use of time by delivering more in less time as well as making the value to last longer. As per (Omitaomu and Badiru, 2007), the timing of costs and benefits across different streams is an important factor. If the development takes longer, there will be a delay in accruing benefits and it is possible that the benefits may not be as originally anticipated. Thus, the researcher sees the importance of the speed and accuracy of forecast and delivery schedule. Delay in time means an opportunity lost. As per (Gleeson, 2004), currently businesses are experiencing more volatile marketplaces, global competition, shortened product life cycles, customer pressures for tailored offerings and tighter performance standards. They increasingly depend on new information systems to gain or maintain competitive advantage.

1.7.5 Risk Approximation ($\delta r \xrightarrow{\lim} 0$)

The researcher established the optimization of time, value and cost dimensions in the previous sections. No business initiative is immune to risk. Hence the researcher intends to focus on risk in this section.

In most IT projects, only the cost of capital is considered. The researcher intends to analyze other factors that can influence the success of IT projects such as,

- People risk,
- Technology risk,
- Environment risk, and
- Product risk.

As per (Omitaomu & Badiru, 2007), the financial risk analysis techniques are also usually used to evaluate information system projects. However, the amount of risk involved needs to be measured in some special way since the possibility that if desired benefits will not be achieved due to deviations from original budget, time schedules or change of priorities. These deviations from the ideal or expected situations require a more integrated approach for analyzing.

1.7.6 Conclusion

The researcher could not find a holistic approach to cost benefit analysis for IT investments, but focusing on either benefit evaluation or cost estimation. Omission of intangible benefits of IT is seen as a significant factor in the inability to evaluation of IT projects. Therefore the researcher sees opportunities for exploration in this field. Researcher also found some errors in cost estimation approaches with regards to reusability. Time estimation is impacted by the inaccuracies in cost and value calculations. Another observation is the lack of provision to the other risks other than using interest rate for discounted rate. The researcher sees opportunities to add to the existing literature, outcomes of this research.

1.7.7 Research Methodology

On assumption that the IT cost and benefit evaluation is best told by the practitioners of the field, individuals with extensive experience on project execution such as,

- Senior IT professionals (Technical Leads),
- IT project managers, and
- Business managers,

With considerable experience in delivering projects of varying sizes were interviewed in the qualitative phase of the research. The research was divided into two sections, where two forms of analysis methods was employed.

1. **Quantification of Value.**

Qualitative interviews were conducted with business sponsors to identify candidate metrics for IT value measurement. This essentially forms part of

Phase 0: Identifying Experts and

Phase 1: Initial Estimate of AIE, which is proposed by researcher for identifying and defining metrics.

2. **Approximation of Cost/Time and Risk estimates.**

Post de facto analysis of cost and quality data from project were analyzed for the determination of other impacting variables.

1.7.7.1 Qualitative interviews

In-person interviews were conducted with each experienced professional guided by the questions listed in Appendix A. The roles of groups interviewed and focus areas listed in the question focus matrix appear below.

Role	**Role Description**	**Interview focus**
Business Sponsor	Project Sponsorship in both financial and social terms in the organization. Responsible for cost benefit evaluation.	Benefits measurement metric identification and quantification
Project Manager	Overall responsibility for the financial and social aspects of project delivery, qualified in project management methodology.	Cost and time estimates, environmental, resource and product aspects of project(s).

Technical Lead	Expert in the IT application domain with over 7 years experience. Responsible for software development cost estimation.	Filling in the project manager on the size and complexity of above project(s).

Table 5 Interviewee Selection Matrix

Historical data from 50 projects where they are involved will be used in post de facto analysis for the survey. These projects will be selected using the criteria explained in the next section to obtain a good spread.

1.7.7.2 Quantitative Analysis

Historic data from completed projects was used for analysis. Stratified samples were selected from a variety of projects as per the table below to have an even distribution. Selections of candidates for interviews were done in such a way to represent more than 2 data selection criteria for an unbiased result.

Dimension	**Category**	**Criteria**
Environmental Diversity	Narrow	Single functional area within the organization
	Medium	Multiple functional areas within the organization.
	Wide	Multiple functional areas

		involving external organizations
IT Budget	Small	Less than R200,000,00
	Medium	Greater Than R200, 000, 00 but less than R 1, 000, 000, 00.
	Large	Over R 1,000,000,00
Novelty	Low	Project team has members who implemented similar projects in the same organization
	Medium	Project team has members who implemented similar projects in other organizations
	High	No one in the project team has done a similar project before
Significance	Low	Nice to have feature
	Medium	Enhancement for better usability
	High	Compliance, Strategic
Complexity	Low	Less than 20 interfaces

	Medium	20 – 100 interfaces
	High	Over 100 interfaces

Table 6 Project Selection Matrix

An ex-post facto analysis will be conducted using historical data selected according to the above criteria and correlation between cost variance, time variance, risk variance and the following variables will be analyzed using Kendall's Tau and Spearman's correlation methods.

Spearman's Correlation

As per (Diamantopoulos and Schlegelmilch, 2004), Spearman's correlation is calculated by applying the Pearson correlation formula to the ranks of the data rather than to the actual data values themselves. Pearson correlation measures the strength of linear relationship between variables, in the case of nonlinear, but monotonic relationships.

Kendall's Tau

As per (Diamantopoulos and Schlegelmilch, 2004), Kendall's *Tau* is equivalent to Spearman'*s Rho*, with regard to the underlying assumptions, but Spearman's *Rho* and Kendall's *Tau* are not identical in magnitude, since their underlying logic and computational formulae are quite different. Kendall's *Tau* and Spearman's *Rho* imply different interpretations. Spearman's *Rho* is considered as the regular Pearson's correlation coefficient in terms of the proportion of variability accounted for, whereas Kendall's *Tau* represents a probability, *i.e.*, the difference between the probabilities that the observed data are in the same order *versus* the probability that the observed data are not in the same order.

Values for both Spearman's R and Kendall's Tau range from -1 (100% negative association, or perfect inversion) to +1 (100% positive association, or perfect agreement). A value of zero indicates the absence of association.

Gamma

Tests the strength of association of the cross tabulations when both variables are measured at the ordinal level. It makes no adjustment for either table size or ties. Values range from -1 (100% negative association, or perfect inversion) to +1 (100% positive association, or perfect agreement). A value of zero indicates the absence of association.

Applied Information Economics (AIE)

Steps	Description	Artifacts
Unit Of Measure	Clarify the problem by defining observable	The result is a decision model

	phenomenon	
Calibrated Probability Assessments	Document the current state of uncertainty	The result is a decision model populated with initial calibrated estimates
Calculation of the Economic Value Of Information	Compute the value of additional information for each variable in a business case	The result is economically selected and prioritized measurements
IT Investment as an Investment Portfolio	Optimize the decision based on new measurement information	The result is a recommendation to improve the decision and the portfolio it is part of

As per (Hubbard, 2007), AIE is a synthesis of techniques from a variety of scientific and mathematical fields. The tools of economics, financial theory, and statistics are all major contributors to AIE. But in addition to these more familiar fields, AIE includes Decision Theory - the formulation of decisions into a mathematical framework - and Information Theory - the mathematical modeling of transmitting and receiving information. It is important to emphasize, however, that even though AIE is a theoretically well-founded set of techniques, it is a very practical approach. Every proper application of AIE keeps the bottom line squarely in mind. All output from the AIE project is in support of specific practical business objectives. Applied Information Economics steps are summarized in this following table.

AIE suggests that instead of choosing a single point value of any set of variables, rather realistic results could be achieved by ascribing the probabilities on them. For this reason, AIE derives the probability distribution graph of the net benefits of a particular type of investment.

Table 7 AIE Steps

Chapter 2: Literature Review

Introduction

In this chapter, the researcher intends to critically analyze available literature on IT cost estimation as well as value quantification. Most material points towards "intangible" view of IT benefits but the researcher found few exceptions, which formed base for value quantification study.

Forecasting of cash flows for a business proposition is not an exact science, but a calculated guess using known market and economic data. NPV is a tool to evaluate the feasibility of the venture based on such forecasts using inputs such as value forecast (v), cost estimate (c), time forecast (t), and project risk (r). However, there's an uncertainty surrounding projects involving IT, which was the main motivator for this research. The researcher could not find a holistic approach, but rather a focus on constituent fields in the problem domain of NPV approximation of IT investments. This is quite remarkable, given its influence and importance to the success of all facets of business including both profit seeking and non-profitable organizations. However, the researcher has benefited from intensified focus in constituent subject areas such as value quantification of intangible benefits; software cost estimation, project management, and risk containment etc., providing a rich repository of inputs.

The envisaged study involves the obtainment of optimum value for four dimensional NPV function ***f (v, c, t, r).*** In order to approximate NPV, the difference between actual and estimated values for four input variables v(value), c(cost), t(time), and r(risk) must be minimized, or the NPV approximation problem could be written as,

$$NPV \approx f(v + \delta v, c + \delta c, t + \delta t, r + \delta r)$$
$$when \quad \delta v \xrightarrow{\lim} 0; \quad \delta c \xrightarrow{\lim} 0; \quad \delta t \xrightarrow{\lim} 0; \quad \delta r \xrightarrow{\lim} 0.$$

This section includes detailed analysis and researcher's analysis of available literature on the subject area. The literature review is divided in to six logical sections as listed below.

1.Overview	Overview of the literature review and interrelationships of variables. Background to the problem
2. Value Approximation	Impact of value in the overall NPV and quantification and optimization thereof.
3. Cost Approximation	Impact of Cost on NPV and its approximation.
4.Time Approximation	Impact of time on the NPV and optimization thereof.
5. Risk Approximation	Risk containment on IT investments.
6. Conclusion	Summary and conclusion.

2.1 Overview

Importance of IT for business success is a widely accepted, yet the detail of which is much debated. Striking examples of IT project failures however have induced a climate of doubt. Lack of methods for forecasting and evaluation considered to be the main contributor for this situation. As per (Keil, Mixon, Saarinen & Virpituunainen, 1995), Information technology (IT) projects can fail for any number of reasons, and can result in considerable financial losses for the organizations that undertake them. One pattern of failure that has been observed but seldom studied is the runaway project that takes on a life of its own. Such projects exhibit characteristics those are consistent with the broader phenomenon known as escalating commitment lo a failing course of action. Several theories have been pursued to explain this phenomenon, including self-justification theory and the so-called sunk cost effect which can be explained by prospect theory. High level of sunk cost may influence decision makers to escalate their commitment to an IT project. (Keil, Mixon, Saarinen & Virpituunainen, 1995) The researcher sees this as a direct consequence of the lack of evaluation and monitoring tools. This is referred to as the 'gut feel' investment strategy. (Bannister & Remenyi , 2000) sees a limit to what can be achieved by formal rational evaluation methods for IT that, in mapping the set of evaluation methodologies on to what is termed the investment opportunity space. According to them, decision makers fall back on `gut feel' and other non-formal and rigorous ways of making decisions with regard to IT investments. The researcher however disagrees with this view and would think this is a case of poor application instead. As per (Connor,2006), the use of the net present value (NPV) rule in major investment decisions induces illusions of certainty and encourages over-confidence on the part of users is contested. In the event that poor decisions are made when the NPV rule has been used, it is argued here that the causes will be behavioral and competence-centered rather than technique-based. From the literature, the researcher identified 5 main contributors for the above situation as listed below.

1. Lack of definition of scope and product parameters at inception.
2. Lack of clear definitions on scope and metrics of value proposition.
3. Lack of focus on reusability and adoption costs.
4. Lack of subjectivity in the risk analysis.
5. Non adherence to accepted project management principles.

The researcher intends to focus on these contributing factors and their impact on approximation of four variables used in the NPV equation in sections to follow. Table below summarizes the researcher's findings on the impact of input variables by various factors from available literature.

Factor	Value Impact	Cost Impact	Time Impact	Risk Impact
Lack of definition of scope and product parameters at inception.	Yes	Yes	Yes	Yes
Lack of clear definitions on scope and metrics of value proposition	Yes			Yes
Lack of focus on reusability and adoption costs		Yes	Yes	
Generality but lack of subjectivity in the risk analysis	Yes			Yes
Non adherence to accepted project management principles	Yes	Yes	Yes	Yes

Table 8 General Concerns and their impact on input variables

Incorrect value forecasts for IT projects are often justified by attributing them to inflation, bloated intangible benefits, technology changes and any other conceivable economic factor, or errors with forecasting tools, and the unpredictability prevails. The situation hardly ever draws attention due to lack of post deployment reviews. As per (Thomas, 2002), although ROI might be the acronym du jour during budget-conscious times, 68% of the respondents denied the measurement of return on investment of IT projects six months after their completion at a poll conducted among participants at Computerworld's annual premier-100 conference. They acknowledged the fact that they focus on costs and cost savings during financially tough periods, but rather focus on customer service when financial conditions are good. (Thomas, 2002) As a result, a clear guideline for the evaluation of IT projects is weak or non existent. A delayed delivery which does not have the same original value anticipated has become a standard. Thus project delays are however accepted as a certainty for IT projects. As (Bannister and Remenyi ,2000) found in their study, relatively a small subset of over 1000 published journal articles, conference papers, books, technical notes etc., have been written on the subject of evaluation or IT investment appraisal. They have found that the highly complex issue of value of IT systems is simplified, ignored or assumed. According to available literature, they have found much of the research focus is set on evaluation methodologies where there are different strands of thought which they classified as partisan, composite and Meta approaches to evaluation. (Bannister and Remenyi, 2000) Therefore an objective quantification for value added (or destroyed) by IT is badly needed. Also, the researcher sees a need for a post-investment review just like any other investment for IT. This would create an archive of information which could be used as best practices. Accurate forecasting also involves predictability and repeatability of processes in an organization, which is referred to as IT maturity. According to (Lin, Huang, Cheng & Lin, 2007), there is a positive impact by using Limits-to-Value model to examine the relationship between the levels of IT maturity and the adoption of IT investment evaluation and benefits realization methodologies as well as its effect on the management of business-to-business (B2B) electronic commerce(EC) benefits. (Lin C, Huang Y, Cheng M, Lin W,2007) The maturity level of an organization provides a way to predict the future performance of an organization within a given discipline or set of disciplines. The maturity levels are measured by the achievement of the specific and generic goals that apply to each predefined set of process areas.

As adopted from (Carnegie Mellon Software Engineering Institute, 2002) IT Maturity Levels are defined as follows.

Maturity Level 1: Initial. Processes are usually ad hoc and chaotic. The organization usually does not provide a stable environment.

Maturity Level 2: Managed. Organization has ensured that requirements are managed and that processes are planned, performed, measured, and controlled.

Maturity Level 3: Defined. Processes are well characterized and understood, and are described in standards, procedures, tools, and methods.

Maturity Level 4: Quantitatively Managed. Organization has achieved all the specific goals of the process areas, and sub processes controlled by statistical and other quantitative techniques are in place that significantly contributes to overall process performance.

Maturity Level 5: Optimizing. Organization has achieved all the specific goals and the processes are continually improved based on a quantitative understanding of the common causes of variations inherent in processes. (Carnegie Mellon Software Engineering Institute, 2002)

As per (Omitaomu and Badiru, 2007), the selection of the right project based on its economic analysis cannot be overemphasized. However, information system projects have numerous uncertainties and several distinguished characteristics that make their analyses, a challenging task. Information system project costs are tangible, but many of the benefits are intangible. Intangible benefits are important and should be accounted for adequately. The researcher does not agree with this view and would see this as lack of application instead. Non-accounting for intangibles, the researcher sees as one of the main gaps in IT investment analysis, hence wish to focus research on the subject. Since four variables in question, value, cost, time and risk are interdependent, an omission or an oversight of one impacts the overall output. Therefore following focused attention on each variable involves many overlapping discussions.

2.2 Value Approximation. ($\delta v \xrightarrow{\lim} 0$)

The researcher established the background to the problem domain in the previous section. The focus in this section is the quantification and value attribution for intangibles, thus improving inputs to the calculation of value. As discussed in the previous section, value is either unaccounted or often bloated due to lack of quantification methods for intangible benefits.

The only unit used in the NPV equation is the unit of currency (e.g. the Rand, the Dollars etc). Therefore it is imperative to expect the only other quantity, C_t in the same unit, for proper evaluation. (Time is taken only as a repetition factor hence no unit is considered.) However the researcher finds that in most of the literature, benefits of IT is considered intangible and excluded from calculations or given in a unit incompatible with the equation forcing omission. In some instances, it is just an unqualified quantity. The researcher sees this as a fundamental error in the application of NPV equation, hence would wish to pursue detailed research on the topic. Although, *"If you can't measure it, you can't manage it!"* often appear in management literature especially that of notable scholars such as Pieter Drucker and Robert Kaplan, the researcher finds relatively less focus towards quantification and measurement of the value of IT benefits in organizations.

Some of the benefits could not easily be measured as others such as intangible benefits, and metrics are unclear. For example, measuring the benefits of building a decision support system and utilizing its decisions, or the benefits of installing and making software packages operational, are not as straightforward as measuring increased number of units sold. In many cases these benefits do not directly contribute to the enterprise's bottom line, but rather play a supporting role. However value attribution is possible in these situations using techniques such as Applied Information Economics (AIE) by William Hubbard. As per (Hubbard, 2007), AIE applies mathematical models and scientific measurements to solve problems in information systems investments.

(Lin, Huang, Cheng & Lin, 2007), found that although those organizations that employ IT benefits evaluation methodologies would be likely to employ IT investment evaluation methodologies, the converse might not be true. One of the fundamental observations which concerned them was the contribution of underlying IT maturity of an organization to its willingness and cultural capability to use semi-formal processes explicitly as part of its decision making. In other words, the organizations that are more mature in IT are more likely to display more willingness to use evaluation processes and reap benefits thereof. (Lin *et al, 2007)*

In order to minimize omissions and to gain confidence of other business areas, adaptation of a common framework across the business is required. According to (Dolins, 2006), Balanced Score Card (BSC) relates the enterprises' mission and strategic objectives to employees and external stakeholders using measures on each perspective. In BSC, measures are used to evaluate performance against expected results alongside organizational goals. Such measures are defined and classified along financial, customer, internal process, and learning and growth perspectives. (Dolins, 2006)

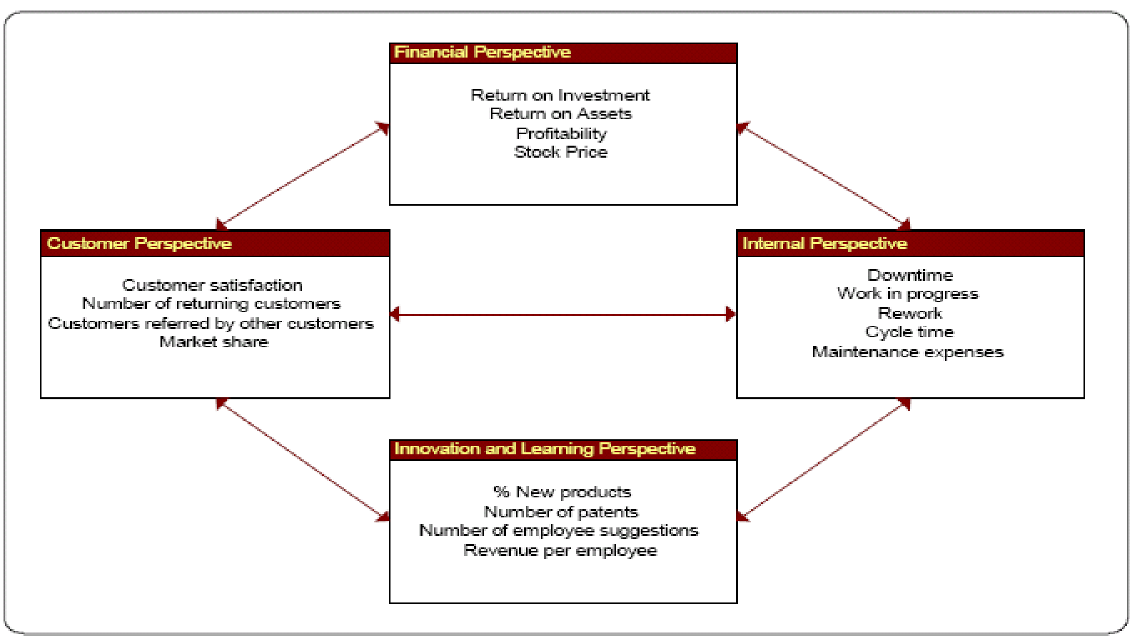

Figure 3 Using BSC perspectives for IT Value Quantification

Adopted from (Gleeson, 2004)

The researcher intends to conduct further investigations on the possibility of practical application of the above with the use of AIE. With the quantification of value established in this section, approximation of cost estimations forms scope for the next section.

2.3 Cost Approximation. ($\delta c \xrightarrow{\lim} 0$ *)*

The researcher established the importance of quantification and inclusion of value components in the previous section. This section focuses on field of IT cost estimation. The researcher would like to divide project costs to four quadrants as per the diagram below for analysis. This research focus is only on the cost of IT or the right hand half of the diagram. It is assumed that the left half, or the non IT cost estimates has been adequately dealt with and falling outside the scope of this research.

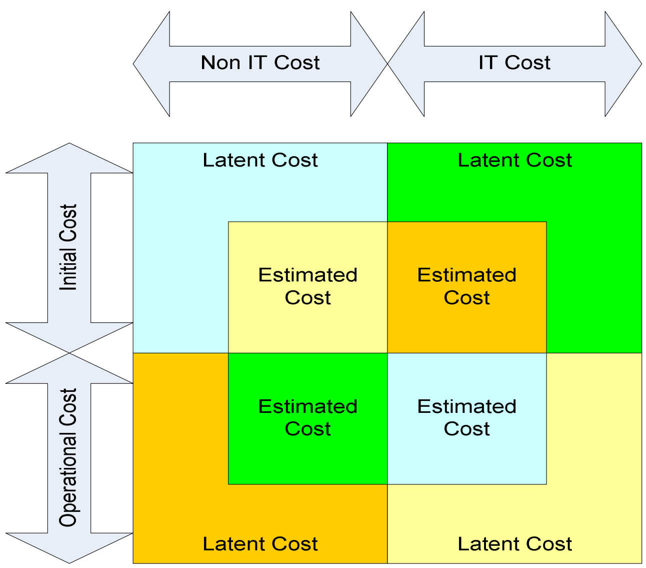

Figure 4 Cost Distribution Matrix

The difference between initial and the operational cost is their occurrence in timeline, and flexibility thereof will be analyzed in the next section on the time variable. In this section the researcher would like to focus on the following two cost components, which are amongst the most expensive, unpopular and disputed in business decision making involving IT. The researcher intends to analyze estimated and latent costs separately for added focus.

1. Estimated Costs	Costs estimated for infrastructure and personnel for the build and operation of IT investment.
2. Latent Costs	Costs incurred as a result of unforeseen events, Cost of quality (CoQ) and variances in estimations.

2.3.1 Estimated Costs.

Estimated costs refer to the expected investment for the IT deliverable calculated using available methods and guidelines, at the inception of the project. This encompasses all items such as software, maintenance as well as personnel costs for the development and maintenance of the system during its perceived life. Attention to such detail as build, test and deployment stages as well as provision for any cost escalations is fundamental for successful deployment of an IT project. As per (Ayyıldız, Kalıpsız & Yavuz, 2006), since software becomes increasingly expensive to develop, it is a major cost factor in any information system budget. Software development costs often get out of control due to lack of measurement and estimation methodologies. (Ayyıldız, Kalıpsız & Yavuz, 2006)

2.3.1.1 IT Cost Estimation Methods.

Due to the subjectivity of the individual application domains, software cost estimation is more complex than infrastructure or hardware cost estimation. According to (Hu *et al,* 1998), one of the major difficulties in controlling software development project cost overruns and schedule delays has been developing practical and accurate software cost models. As per (Jones, 2005), due to the complexity of software cost estimation, there is a growing commercial industry of companies that are marketing software estimation tools. As of calendar year 2000 there are approximately 50 commercial software estimating tools marketed in the United States, and another 25 marketed abroad. About one new software estimating tool has entered the commercial market almost every month since 1992. The software cost estimation market was created by researchers who were employed by large enterprises that built large and complex software systems such as, IBM, RCA, TRW, and the U.S. Air Force. These organizations led the development of commercial cost estimating tools. The software estimation business dates back to the early 1970's. In 1973 the PRICE-S software estimation model designed by Frank Freiman and his colleagues was put on the market as the first software commercial estimation tool in the United States, and perhaps the world. (Jones, 2005) As per (Leung, 2006), most cost estimation methods give estimates in terms of person-months. Accurate software cost estimates are critical to both developers and customers. They can be used for generating request for proposals, contract negotiations, scheduling, monitoring and control. Underestimating the costs may result in management approving proposed systems that then exceed their budgets, with underdeveloped functions and poor quality, and failure to complete on time. Overestimating may result in too many resources committed to the project, or, during contract bidding, result in not winning the contract, which can lead to business failure and loss of jobs. (Leung, 2006) Therefore it's a concern of both business and social relevance. (Hu *et al*, 1998) has highlighted the significant challenge faced by the software industry due to growing software cost, not only to adapt to the ever-evolving software technologies, but also to develop software application systems more efficiently with sound software project management practices, which has been a major impetus behind the move toward software engineering since the late 1960s. The effort so far has produced mixed results. On one hand, integrated CASE tools, fourth-generation languages (4GLs), and object-oriented programming technology have forever changed the way in which software systems are constructed at the micro level. On the other hand, managing software development projects with engineering precision at the macro level is still far from reality. Some significant problems that plagued the software projects in the 1960s and 1970s still exist and may even have intensified due to the increasing scale and complexity of new computer applications. (Hu, Plant & Hertz, 1998)

The researcher found 4 major approaches to software cost estimation in the available literature. Researcher had to use 3rd party information from earlier research for their technical details as most of these estimation methods except COCOMO are proprietary commercial products thus details are not available in the public domain.

1. **Empirical Methods.**
2. **Methods based on mathematical models.**
3. **Methods based on theories from other disciplines.**
4. **Cost Estimation based on Expert Judgment.**

2.3.1.1.1 *Empirical Methods*

These methods use historical data to identify trends in software costs. They need acclimatization to the local environment before use. Recent methods such as COCOMO II provide models for modern scenarios such as estimation of Application Generator, System Integration, and Infrastructure software projects. As per (Boehm *et al,* 1998) COCOMO II model, the latest derivative of COCOMO for the Application Composition sector is based on Object Points. Object Points are a count of the screens, reports and third-generation-language modules developed in the application, each weighted by a three-level (simple, medium, difficult) complexity factor. This is commensurate with the level of information generally known about an Application Composition product during its planning stages, and the corresponding level of accuracy needed for its software cost estimates (such applications are generally developed by a small team in a few weeks to months). Regression-based estimation approaches dominate. Regression-based estimation approaches include most common parametric estimation models, e.g., the COCOMO model. Roughly half of all estimation methods have tried to build, improve or compare with regression model-based estimation methods. They have seen an increase in the proportion of papers on analogy-based estimation models. The popularity of research on the function-point based estimation approaches was at its highest in the 1990s. In that period, almost one-third of the papers tried to improve upon, or make comparisons with, function point-based estimation methods.

2.3.1.1.2 Methods based on Mathematical models

These methods use existing statistical or productivity models as basis for software cost estimation. One such example is SLIM by Putnam, details of which are proprietary. The researcher used literature by (Boehm, Abts & Chulani, 1998) for details thereof. SLIM is based on Putnam's analysis of the life-cycle in terms of a so-called Rayleigh distribution of project personnel level versus time. It supports most of the popular size estimating methods including ballpark techniques, source instructions, function points, etc. It makes use of a so-called Rayleigh curve to estimate project effort, schedule and defect rate. A Manpower Buildup Index (MBI) and a Technology Constant or Productivity factor (PF) are used to influence the shape of the curve. SLIM can record and analyze data from previously completed projects which are then used to calibrate the model.

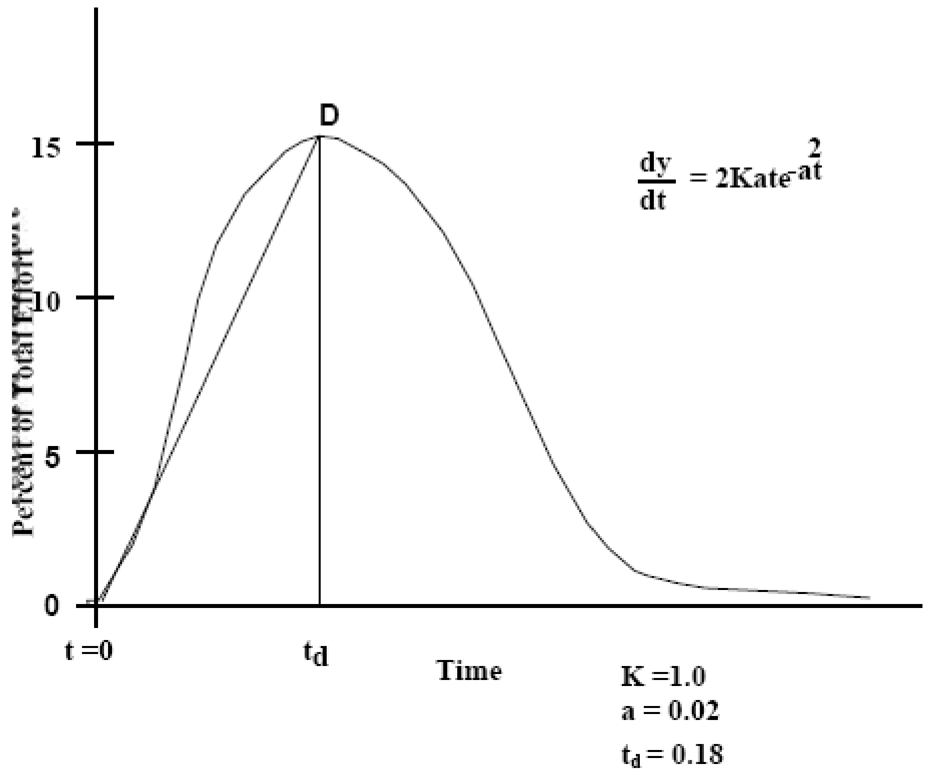

Figure 5 Rayleigh Curve adopted from (Chulani, 1998)

Theory-based estimation approaches, e.g., the SLIM model and Halstead's software science, were initially very popular, but research interest has faded considerably since 1990.

2.3.1.1.3 Methods based on Theories from other disciplines

According to (Hu *et al,* 1998), one of the major difficulties in controlling software development project cost overruns and schedule delays has been developing practical and accurate software cost models. They proposed a theoretical approach to software cost modeling named Minimum Software Cost Model (MSCM), derived from economic production theory and systems optimization. The MSCM model is based on the proposition that software systems development processes are economic productions. While software systems development usually involves multiple stages, it is premature to develop a mathematical software production model that addresses all stages of the development process concurrently without first having a model that addresses the individual stages. The model we propose here focuses on one individual stage of a multistage production process. If software production is considered as a single stage process, then this model applies to the entire process.

2.3.1.1.4 Cost Estimation based on Expert Judgment

These methods use the knowledge of an expert in the application domain for the estimation of software cost. In spite of the fact that formal estimation models have existed for many years, the dominant estimation method is based on expert judgment. Further, available evidence does not suggest that the estimation accuracy improves with use of formal estimation models. Despite these factors, current research on expert estimation is relatively sparse and we believe that it deserves more research effort. Currently, a typical evaluation of an estimation method is based on an arbitrarily chosen data set, where the representativeness and other properties are not analyzed or much discussed. Even worse, quite a few papers are based on data sets that are clearly too old to be representative for more recent or future projects. We recommend that researchers on software cost estimation change their focus from the availability of project data sets to understanding the relationship between project characteristics (data set properties) and estimation methods. (Jorgensen and Sheppard, 2007)

However, a common assumption prevails in all above approaches except for the cost estimations based on expert judgment, in that the software development effort is considered proportional to the functionality delivered. This assumption, the researcher observes as the main reason for inaccuracy. The researcher intends to explore this further during this research study.

2.3.2 Latent Costs.

The researcher intends to classify all unforeseen events, cost of quality and variances from the estimates, which is caused by lack of accurate estimation methodologies under latent costs. These costs in some instances have caused major financial impact to organizations. Therefore, minimizing the *latent cost* with improved cost estimations is one of the main aims of this research. As per (Keil, Mixon, Saarinen & Virpituunainen, 1995), Information technology (IT) projects can fail for any number of reasons, and can result in considerable financial losses for the organizations that undertake them. One pattern of failure that has been observed but seldom studied is the runaway project that takes on a life of its own. Such projects exhibit characteristics those are consistent with the broader phenomenon known as escalating commitment lo a failing course of action. Several theories have been offered to explain this phenomenon, including self-justification theory and the so-called sunk cost effect which can be explained by prospect theory. High level of sunk cost may influence decision makers to escalate their commitment to an IT project. The researcher would like to explore latent cost elements in the following order.

1. Unforeseen events,
2. Cost of Quality (CoQ), and
3. Variances in estimated costs.

2.3.2.1 Unforeseen Events.

Due to the rapid growth in IT as well as normal economic cycles, project costs could deviate from its estimates. These are beyond the control or predictability of organization; hence the researcher would not focus on the same. However, accurate time estimates could help in damage control. It’s a conventional business decision of realignment to the change. Adequate risk focus could minimize the impact of this.

2.3.2.2 Cost of Quality (CoQ).

The researcher also would like to investigate the cost of quality in detail in the hope of studying it further during research. Quality impacts defect resolution and detection as well as ongoing maintenance after implementation. Quality impacts defect resolution and detection as well as ongoing maintenance after implementation. As per (Houston and Keats, 1998) the basis for CoQ is the accounting of two kinds of costs.

- Those which are incurred due to a lack of quality, which are further divided into:
    - Costs of internal failures and
    - Costs of external failures.
- Those which are incurred in the achievement of quality, which are further divided into:
    - Appraisal cost and
    - Defect prevention costs.

Category	Definition	Typical Costs for Software
Internal failures	Quality failures detected prior to product shipment	Defect management, rework, retesting
External failures	Quality failures detected after product shipment	Technical support, complaint investigation, defect notification
Appraisal	Discovering the condition of the product	Testing and associated activities, product quality audits
Prevention	Efforts to ensure product quality	SQA administration, inspections, process improvements, metrics collection and analysis

Table 9 Component Costs of Quality adopted from (Houston and Keats, 1998)

The costs of achieving quality and the costs due to lack of quality have an inverse relationship to one another: as the investment in achieving quality increases, the costs due to lack of quality decrease.

2.3.2.3 Variances in Estimated Costs.

With the wealth of knowledge existing in the field of software cost estimation explored in a previous section, the researcher would like to analyze reasons for IT cost variance from estimates in this section. (Hu, Plant & Hertz,1998), in their analysis have found that like many other software cost models, the COCOMO and SLIM models are empirical in nature, and their performances tend to vary significantly from one environment to another. (Chulani, Boehm & Steece, 1998) confirmed this view by proving the need for local calibrations. They found that the predictive performance of the Bayesian approach (i.e. COCOMO II.1998) is significantly better than that of the multiple regression approach (i.e. COCOMO II.1997) for calibration. COCOMO II.1998 gives predictions that are within 30% of the actual 71% of the time where as COCOMO II.1997 gives predictions within 30% of the actual only 52% of the time. If the model's multiplicative coefficient is calibrated to each of the major sources of project data, the resulting model produces estimates within 30% of the actual 76% of the time. It is therefore recommended that organizations using the model calibrate it using their own data to increase model accuracy and produce a local optimum estimate for similar type projects. From table below, it is clear that the prediction accuracy of the COCOMO II.1998 model is better than the prediction accuracy of the COCOMO II.1997 model.

The researcher saw a bias on this calibration exercise as the same dataset is used. It is therefore logical to assume higher variances in real-life scenarios.

As per (Hu *et al,* 1998), The COCOMO II 1998 Bayesian calibration discussed above uses the complete dataset of 161 data points. Thus, the prediction accuracies of COCOMO II.1998 are based on the same dataset of 161 data points. That is, the calibration and validation datasets are the same. A natural question that arises in this context is how well will the model predict new software development projects? To address this issue, they randomly selected 121 observations for their calibration dataset with the remaining 40 becoming assigned to the validation dataset (i.e. "new" data). They repeated this process 15 times creating 15 calibration and 15 validation datasets each of size 121 and 40 respectively. They then developed a prediction equation for each of the 15 calibration datasets. They used the resulting a posteriori models to predict the development effort of the 40 "new" projects in the validation datasets. This validation approach, known as out-of-sample validation, provides a true measure of the model's predictive abilities. This out-of-sample test yielded an average PRED(.30) of 69%; indicating that on average, the out of sample validation results produced estimates within 30% of the actual 69% of the time. They concluded that Bayesian model has reasonably good predictive qualities. However, the researcher sees a definite need for improvement, as best case estimate of 30% accuracy for a high budget estimate is less than what a business decision could rely on. The researcher feels that either the accuracy should be improved or an appropriate level of risk should be loaded to facilitate better decision making.

As per (Boehm, Abts & Chulani, 1998) as software grew in size and importance it also grew in complexity, making it very difficult to accurately predict the cost of software development. This dynamic field of software estimation sustained the interests of these researchers who succeeded in setting the stepping-stones of software engineering cost models. Just like in any other field, the field of software engineering cost models has had its own pitfalls. The fast changing nature of software development has made it very difficult to develop parametric models that yield high accuracy for software development in all domains. Software development costs continue to increase and practitioners continually express their concerns over their inability to accurately predict the costs involved. One of the most important objectives of the software engineering community has been the development of useful models that constructively explain the development life-cycle and accurately predict the cost of developing a software product. To that end, many software estimation models have evolved in the last two decades based on the pioneering efforts of the above mentioned researchers. The most commonly used techniques for these models include classical multiple regression approaches. However, these classical model-building techniques are not necessarily the best when used on software engineering data as illustrated in this paper. The subjective nature of cost estimation is another reason for the accuracy levels of current methods *(*Kemerer, 1987) compared several major software models (COCOMO. SLIM. ESTIMACS, and Function Points) and revealed that the average magnitude of relative errors (MRE) of the estimates using these models ranged from 85 to 772 percent, with many in the 500-600 percent range. Varying approaches to software cost estimation and their accuracy levels in the literature shows certain uncertainties surrounding software cost estimation methods. (Hu et al, 1998) conjecture that the empirical foundations for these models may have contributed to and resulted in unpredictable performance when used for software cost estimation. The researcher intends to analyze reasons for the aforesaid unpredictability in the next section.

IT Cost Variation Drivers.

In view of variances established in the previous section with the existing cost estimation methods, the researcher intends to analyze factors impacting cost variation. The researcher sees multiple factors contributing to IT cost variations, which could be divided to four main groups as listed below. Literature review will follow in that order.

1. **Product Factors**
2. **Resource Factors**
3. **Technological Factors**
4. **Environmental Factors**

2.3.2.3.1 Product Factors

Changes to Requirements Specification

Changes in requirements during development can obviously nullify estimates. Due to rapid advancements in technology and customer needs, IT projects often have to change during development to still be relevant. This is particularly true for longer running projects. As per (Kadiyala and Kleiner, 2005), In order to meet customer needs in the competitive market, businesses need to continuously up grade their existing in formation systems and adopt new technologies in order to adapt to the changing trends.

As per (Jones, 2006)*, a*mong the technical issues that contribute to project failures are the lack of modern estimating approaches and the failure to plan for requirements growth during development. However, it is not a law of nature that software projects will run late, be cancelled, or be unreliable after deployment. A careful program of risk analysis and risk abatement can lower the probability of a major software disaster.

Due to changes in market and customer needs, IT projects often have to adopt to change during development. This is particularly true for longer running projects. According to (Kadiyala and Kleiner, 2005), In order to meet customers' needs in the competitive market, businesses need to continuously up grade their existing in formation systems and adopt new technologies in order to adapt to the changing trends. As per (Jones, 2006), one of the issues that contribute to project failures is the failure to plan for requirements growth during development.

Granularity of Information Available

Initial estimates are being sought from IT at the conceptual stage of a project and these estimates often used to assess project feasibility. According to Dr. Barry Boehm, who was involved in legendary COCOMO and COCOMO II methods of IT cost estimation, the granularity of the software cost estimation model used needs to be consistent with the granularity of the information available to support software cost estimation. In the early stages of a software project, very little may be known about the size of the product to be developed, the nature of the target platform, the nature of the personnel to be involved in the project, or the detailed specifics of the process to be used. As depicted in the figure below, the effect of project uncertainties on the accuracy of software size and cost estimates. In the very early stages, one may not know the specific nature of the product to be developed to better than a factor of 4. As the life cycle proceeds and product decisions are made, the nature of the products and its consequent size are better known, and the nature of the process and its consequent cost drivers are better known.

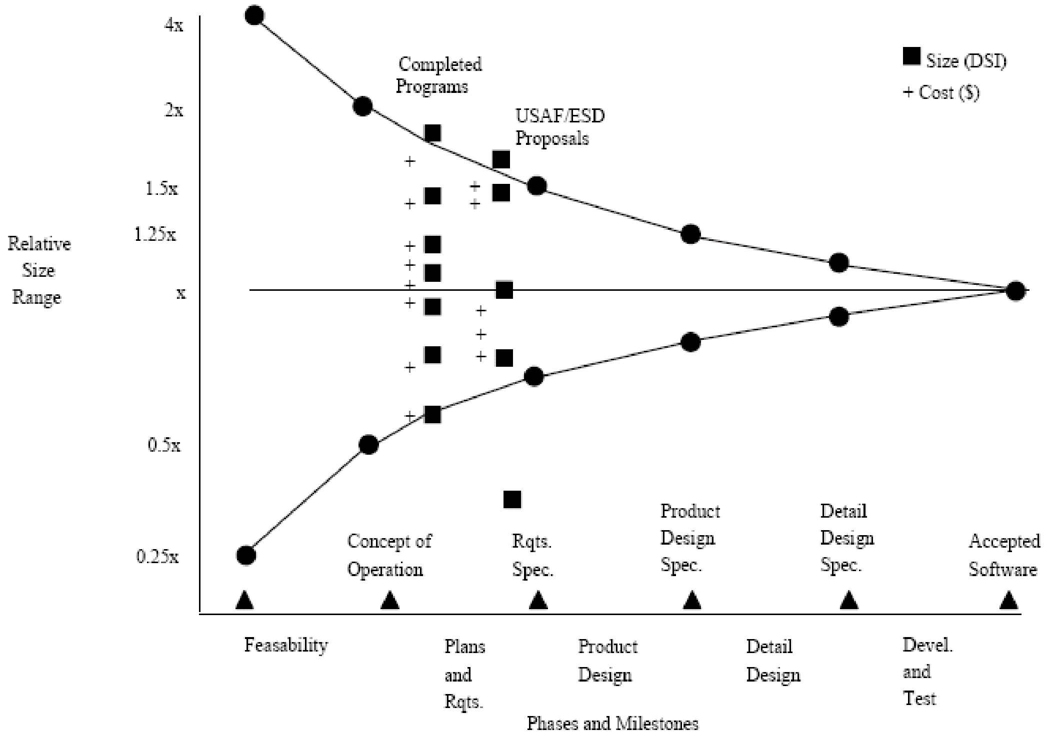

Figure 6 Cost Estimation Accuracy during various project phases
Adopted from (Boehm, Abts, Clark & Chulani, 1998)

Reusability

Unlike most technologies IT has the unique features of integration and reuse with other projects and systems. Impact of which depends on the so called degree of coupling. (Systems coupling is an IT term used to denote the interdependency of systems at application program level) Loosely coupled systems, enhances the integration capability. Therefore software development cost varies depending on the degree of software coupling in the organization; hence the discount rate should be loaded appropriately to compensate for the risk.

Most estimation methods assume IT projects as brand new, but this rarely is the case. It projects are largely enhancement or at least integration to existing systems. This needs local knowledge to estimate. Reusability component is subjective local knowledge.

Nonlinear Reuse Effect

The researcher finds a common flaw in all 3 of these methods in the assumption that software development having a linear relationship with the functionality anticipated. The reusability aspect is somewhat ignored. This exaggerated hypothetical view is negated by earlier research by (Selby, 1988) in his research into *Nonlinear Reuse Effects.* As per (Selby, 1988), analysis of reuse costs across nearly 3000 reused modules in the NASA Software Engineering Laboratory indicates that the reuse cost function is nonlinear in two significant ways as per the graph below.

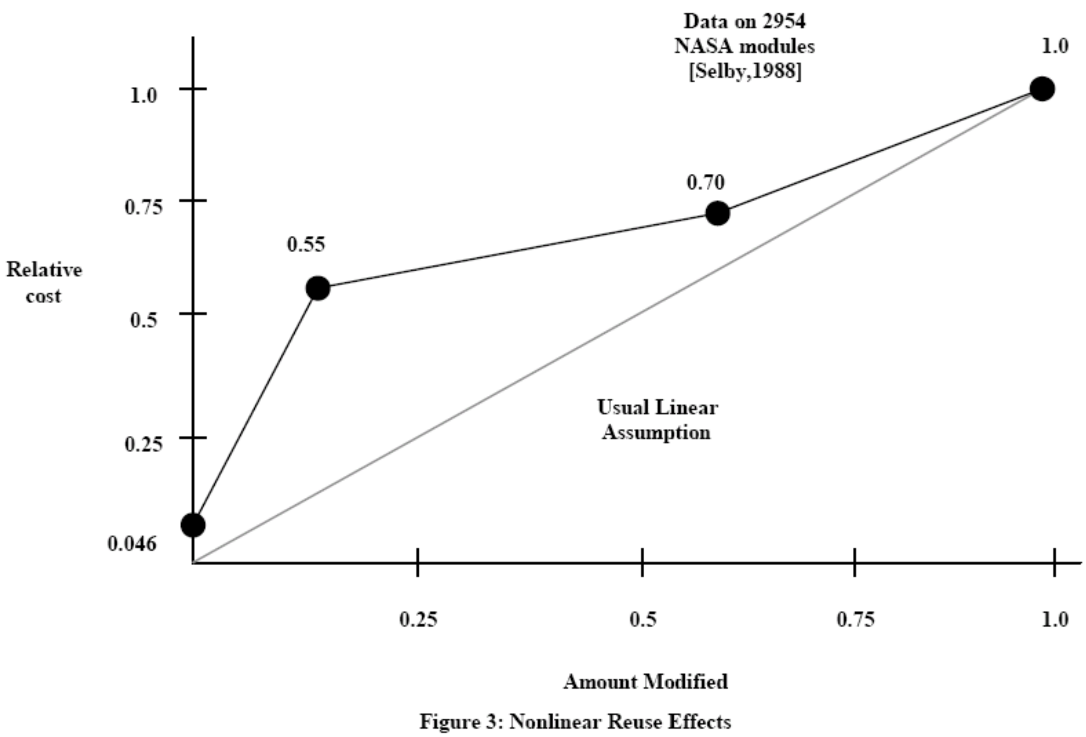

Figure 7 Nonlinear Reuse Effect (adopted from Selby, 1988)

1. The graph does not go through the origin. There is generally a cost of about 5% for assessing, selecting, and assimilating the reusable component.
2 Small modifications generate disproportionately large costs. This is primarily due to two factors: the cost of understanding the software to be modified, and the relative cost of interface checking.

Modern estimation methods uses penalties to compensate this effect however this indicates the nonlinear effects involved in the module interface checking which occurs during the design, code, integration, and test of modified software.

However the complete modular design enabling direct coupling is predominantly an academic concept yet to realize. Therefore the researcher believes informed input from a local expert for accuracy. This view is proven by the magnitude of variance in the analysis into estimation variances in a section to follow.

2.3.2.3.2 Resource Factors

Productivity, capability and motivation of resources are a local parameter of the IT project. According to (Boehm *et al,* 1998) factors such as analyst capability, application experience, programming capability, platform experience, language and tool experience, personnel continuity also have an impact on the duration of the development task. The researcher will perform quantitative analysis on the impact of such factors and hope to derive correction coefficients from research findings.

2.3.2.3.3 Technological Factors

Researcher is aware of the impact of rapid growth in technology in IT projects. In addition to the introduction of new technologies, existing technologies become obsolete or unsupported. This will demand compulsory realignment which can cost time, money and even impact the quality. As per (Skok and Tan, 2007) Strategic change is often enabled by the use of modern technology. However, one of the biggest problems faced by business managers and executives is how to keep up with the rapid changes in computing, communications and associated technology. Following famous quotes are included to illustrate the phenomenal growth in technology adaptation, especially in IT.

"I think there is a world market for maybe five computers"

Thomas Watson, IBM Chairman, 1943

"There is no reason anyone would want a computer in their home"

Ken Olson, President and Founder, Digital Equipment Corporation, 1977

"640K (computer memory) ought to be enough for anybody"

Bill Gates, 1981

2.3.2.3.4 Environmental Factors

The researcher understands the impact of environmental success factors in the execution of IT projects. Impact of these will be analyzed in the intended quantitative research to follow. According to (Boehm *et al,* 1998), Multi-site development, use of software tool, required development schedule. The above factors are not necessarily independent, and most of them are hard to quantify. In many models, some of the factors appear in combined form and some are simply ignored. Also some factors take discrete values, resulting in an estimation function with a piece-wise form. (Graham and Englund, 2004) lists ten generic environmental success factors for successful projects as follows. This view is confirmed by (Jones, 2006).

1. **Change to project based organizations (PBO)**. To run projects successfully, organizations must become PBOs. PBOs need both supporting structures and cultures.

2. **Emphasize the Link between Strategy and Projects**

Need to link projects to strategy. Strategic emphasis motivates team members.

3. **Understand Upper Management Influence**

Upper managers are unaware of how their behaviour influences project success. Therefore must implement a project support system in terms of negotiating the project deadline, supporting the creative process, changing the reward system to support project work, and not to interfere with project execution.

4. Develop Core Team process

Setting up and keeping a core team of people representing various departments necessary to complete a project. This helps smooth project execution across functional areas (silos).

5. Organize for Project Management

Use a suitable structure for the project. This could be matrix, or an enclosed project group depending on the project size and significance.

6. Develop a Project Management Information System (PMIS)

PMIS is a key for information sharing as well as monitoring project progress.

7. Develop a plan for Project Manager Selection and Development

Using a project manager familiar with project management methodology and best practices is important to the success of a project.

8. Develop a Learning organization

Use experience from previous projects for improving.

9. Develop a Project Management Initiative

Continually improve project management practices and knowledge in the organization.

10. Develop Project Management in Your Organization

Applying the above concepts is needed in organizations with different cultures in order to become a PBO.

2.4 Time Approximation ($\delta t \xrightarrow{\lim} 0$)

In business, "*Time is Money*". Hence the cost dimension has a strong dependency on time in its forecasts for informed decision making, which is the focus of this section. Shortening or delaying of expense cycle, increasing income cycle is a definite provider of value. Therefore the researcher would investigate the optimization of the time dimension in this section. This would involve concepts such as time value of money, as well as practical guidelines on forecasting accuracy, making the maximum use of time by delivering more in less time as well as making the value to last longer. As per (Omitaomu & Badiru, 2007), the timing of costs and benefits across different streams is an important factor. If the development takes longer, there will be a delay in accruing benefits and it is possible that the benefits may not be as originally anticipated. Thus, the researcher sees the importance of the speed and accuracy of forecast and delivery schedule. Delay in time means an opportunity lost. As per (Boehm *et al,* 1998) competitive advantage is increasingly dependent on the development of smart, tailored products and services, and on the ability to develop and adapt these products and services more rapidly than competitors' adaptation times. (Boehm *et al*, 1998) Dramatic reductions in computer hardware platform costs and the prevalence of commodity software solutions have indirectly put downward pressure on systems development costs. This situation makes cost-benefit calculations even more important in selecting the correct components for construction and life cycle evolution of a system, and in convincing skeptical financial management of the business case for software investments. It also highlights the need for concurrent product and process determination, and for the ability to conduct trade-off analyses among software and system life cycle costs, cycle times, functions, performance, and qualities. Concurrently, a new generation of software processes and products is changing the way organizations develop software. These new approaches-evolutionary, risk-driven, and collaborative software processes; fourth generation languages and application generators; commercial off-the-shelf (COTS) and reuse-driven software approaches; fast-track software development approaches; software process maturity initiatives-lead to significant benefits in terms of improved software quality and reduced software cost, risk, and cycle time. (Boehm *et al*, 1998)

Current need for agility in companies for quick response to dynamic business needs, and IT cost containment by reusability has created potential business opportunities for IT vendors, clouding the horizon with various commercial initiatives. At the same time, it has created a significant influx of funds and focus which is a positive outcome. Following brief summary is intended to provide current developments in this field. As per (Gleeson, 2004), currently businesses are experiencing more volatile marketplaces, global competition, shortened product life cycles, customer pressures for tailored offerings and tighter performance standards. They increasingly depend on new information systems to gain or maintain competitive advantage. The IS components in business solutions must be constructed rapidly and effectively despite the massive changes in information systems product capability, a restructured supply industry, potential shifts in system development approaches, and new ambiguities in terms of what should be regarded as a business-side versus a technical specialist task. Over the years such methodologies such as waterfall method, object oriented design has evolved. However these methodologies were mainly intended to be used by IT professionals. In order to bridge the increasing gap between business and IT, a common ground was needed.

Reusability of systems allows businesses to use available time more efficiently as well as saving time (and cost) on future endeavors. As seen in the literature, a considerable time is spent on requirements specification. Service Oriented Architecture (SOA) is notable development promising to save time in terms of both specification and reusability. According to Merrifield, Calhoun & Stevens (2008), with SOA It is becoming possible to design many business activities as Lego-like software components that can be easily put together and taken apart. It’s a relatively new way of designing and deploying the software that supports a business activity. The beauty of SOA is that it allows activities or processes built from such activities to be accessed using the now ubiquitous internet in a standardized fashion. Whether the capabilities that make up an activity are manual, fully automated, or somewhere in between, the SOA-based design of their underlying software or electronic user interface allows the activity to be turned into a de facto web service. This transformation makes it vastly easier to share discrete activities and entire processes internally, to buy or sell them externally, to delegate their execution to suppliers or customers, and to update and maintain IT systems. Most companies that have embraced SOA have applied it without first rethinking the design of their businesses. Unfortunately, few companies are using SOA to create more productive and focused organizations or to slash costs by purging duplicative operations and technologies. They are not revisiting the fundamental design of their operations. This omission means they have overlooked SOA's greatest value: the opportunity to create much more focused, efficient, and flexible organizational structures. Adopting this new model requires a new mind-set for those who have been at the nexus of process improvement and technology. We compare it to the change that architects and engineers in the mid-1800s had to make after the arrival of the two biggest construction technology breakthroughs of that century: high-strength steel and electric elevators. They took 30 years to realize that these great advances meant they could build skyscrapers.

According to (Zhang, Lin & Hsu, 2007), SOA using Web services has emerged as a major software architecture in the past few years and has provided a powerful paradigm to compose service processes using individual atomic services. Using SOA, enterprise systems can define and execute transactions across multiple server domains at distributed locations. Companies can use service-oriented computing's (SOC's) plug-and-play interoperability to compose business processes and integrate different services on the fly to enable dynamic cooperation among business partners.

According to (Schlier, 2008), Service-Oriented Architecture (SOA) offer the promise of increased logic segment and data structure reuse. This promise is especially attractive to banks, because it has the possibility of dramatically reduced time and cost to transform application portfolios to maintain alignment with the rapidly changing and increasingly competitive banking industry. SOA-enabled reuse also provides reduced redundancy, complexity and portfolio size, which are critical to reducing total bank IT expense as a percent of revenue while increasing IT use in the bank (to do more with less). However, implementing a successful SOA program in the bank is a high-risk investment in time, money and trust. Because the investments and risks are high, SOA-enabled reuse programs must be strategic initiatives that achieve a high level of reuse and financial return. More enterprises worldwide limit investments in SOA to those that can be justified primarily on improved integration capabilities and not on SOA-enabled reuse, because they have been unable to achieve the high levels of reuse required to justify investments in SOA-enabled reuse. While improved integration is a valuable use of SOA, it does not provide the potential financial benefits Of a successful SOA-enabled reuse program. However, SOA-enabled integration can be applied tactically to an existing problem (integration), while a successful SOA-enabled reuse program requires strategic vision and investment.

2.5 Risk Approximation ($\delta r \xrightarrow{\lim} 0$)

The researcher established the optimization of time, value and cost dimensions in the previous sections. No business initiative is immune to risk. Hence the researcher intends to focus on risk in this section. Usually in IT projects, only the cost of capital is considered, which is not adequate. As per (Omitaomu & Badiru, 2007), the risk analysis techniques are also usually used to evaluate information system projects. However, the amount of risk involved needs to be measured in some special way since the possibility that if desired benefits will not be achieved due to deviations from original budget, time schedules or change of priorities. These deviations from the ideal or expected situations require a more integrated approach for analyzing the risks involved. Therefore the researcher will conduct quantitative analysis to determine the appropriate loading of discount rates based on contributions from,

1. Technological Risk,
2. Resource Risk,
3. Product Risk, as well as
4. Environmental (Economic) Risk.

As per (Slywotsky and Vasilash, 2007), rather than starting out with "We've got to take a risk," there should be a more focused approach, one essentially predicated on the answers to two questions:

- What are the odds of success?
- What things can I do to change the odds of success?

The difference is between being a "risk taker" and being a "risk shaper." The former choice tends to lead to failure while the latter increases odds for project success. The researcher sees that the latter could bring more credibility to the process.

2.6 Conclusion

As seen in the previous sections, gaps in capabilities of calculation of cost, time, and risk estimates as well as quantifying value is hindering the accuracy of NPV output for projects involving IT. The best case variance of 30% for cost estimates leaves much to be desired, considering the size of IT budgets. Therefore, the importance of accuracy in IT project cost estimation, components of the cost equation and calibration thereof are key success factors for approximation of NPV for IT investments.

The researcher sees IT component as part of an ecosystem encompassing the business unit, which eventually become part of the bigger ecosystem encompassing the organization. Hence a holistic approach is sought as opposed to current focus on individual contributing elements. The researcher found a total absence of focus on value quantification combined with following gaps in current approaches to project estimation.

1. Most organizations of today have a sizable legacy elements is their software stack. These systems have evolved over the years and usually represent various stages of technological development. Reusability and integration thereto is therefore a complex and very subjective and could only be quantified by thorough examination by a local expert. This effect does not considered enough in available methodologies.

2. There is no evidence of Global standards in IT governance hence it is impossible to build estimates on time spent on governance tasks and frequency of team meetings to the cost equation.
3. Local work ethics such as working hours and days per week unspecified, a calculation of man months does not give a proper cost estimate. This is quite relevant in globally outsourced projects. Man hours would have been better.
4. Decision delays and resource contention, challenges in adaptation to new Technologies are not considered. Further, these estimates do not give indications to any catalysts for productivity improvement process.
5. Needs calibration for each new programming language that come up.
6. Methods for quantification and measurement of value are non existent.

The researcher intends to investigate these weaknesses and would like to find a solution for abovementioned problems. It is hoped that this would empower business leaders for better investment decisions for projects involving IT.

Chapter 3: Research Methodology

Introduction

In this chapter, the researcher will detail the problem statement and related hypothesis involved. Intended research methodologies will be explained towards the end of this chapter. The two phase approach to the study will also be justified within context. Due to uncertainties in the problem domain, all conceivable factors that could impact IT projects were analyzed for correlation.

3.1 The research problem: How to approximate NPV for IT Investments?

<u>Sub Problem 1:</u> How to improve the value quantification for projects involving IT?

The researcher intends to will conduct qualitative interviews based on BSC framework with business managers to collect data. This data will form phase 1 of AIE methodology. Typical questions are as follows.

- What measurements would you use to measure financial benefits of an IT project?
- What measurements would you use to measure benefits to internal processes from an IT project?
- What measurements would you use to measure customer benefits of an IT project?
- What measurements would you use to measure learning and growth benefits of an IT project?

The complete questionnaire appear in appendix A-1.

<u>Sub problem 2:</u> What factors contribute to the IT cost variance?

<u>Product Characteristics</u>

Hypothesis 1 – Product Complexity correlates to cost variance

Hypothesis 2 – Product Significance correlates to cost variance

Hypothesis 3 – Product Budget correlates to cost variance

Hypothesis 4 – Product Requirements Change correlates to cost variance

<u>Technology Characteristics</u>

Hypothesis 5 – Maturity of Technology correlates to cost variance

Hypothesis 6 – Continuity of Technology throughout the project correlates to cost variance

Hypothesis 7 – Technology Spread (popularity) correlates to cost variance

Hypothesis 8 – Technology Progression Rate correlates to cost variance

<u>People Characteristics</u>

Hypothesis 9 – Experience of team members correlates to cost variance

Hypothesis 10 – Personnel continuity correlates to cost variance

Hypothesis 11 – Focus of the Team members correlates to cost variance

Hypothesis 12 – Team size correlates to cost variance

<u>Environmental Characteristics</u>

Hypothesis 13 – Executive Pressure on estimates correlates to cost variance

Hypothesis 14 – Business Complexity correlates to cost variance

Hypothesis 15 – Business Geographical Spread correlates to cost variance

Hypothesis 16 – Project Structure correlates to cost variance

<u>Execution Characteristics</u>

Hypothesis 17 – Task inter-dependence correlates to cost variance

Hypothesis 18 – Resource doubling response correlates to cost variance

Hypothesis 19 – Progress Monitoring frequency correlates to cost variance

Hypothesis 20 – Project priority changes correlates to cost variance

Quality Characteristics

Hypothesis 21 – Defects in Definition correlates to cost variance

Hypothesis 22 – Defects in Construction (software development) correlates to cost variance

Hypothesis 23 – Defects in Design (alignment to user requirements) correlates to cost variance

Hypothesis 24 – Defects in quality control prior to deployment correlates to cost variance

A post de facto analysis using historical data from the same projects will be used to identify correlation between cost variance (ratio scale) and each element (ordinal scale). Kendall's Tau will be used for analyzing correlation. A regression analysis will be conducted for correlated variables and a coefficient will be derived, which will be used in a new cost estimation formulae.

Sub problem 3: What impacts the quality of projects involving IT?

Product Characteristics

Hypothesis 25 – Product Complexity correlate to defects in Product definition.

Hypothesis 26 – Product Complexity correlate to defects in construction.

Hypothesis 27 – Product Complexity correlate to defects in Design alignment to user requirements.

Hypothesis 28 – Product Complexity correlate to defects in Quality Control prior to deployment.

Hypothesis 29 – Requirements change during project execution correlate to defects in definition.

Hypothesis 30 – Requirements Change during project execution correlate to defects in construction.

Hypothesis 31 – Requirements change during project execution correlate to defects in Design alignment to user requirements.

Hypothesis 32 – Requirements Change during project execution correlate to defects in Quality Control.

People Characteristics

Hypothesis 33 – Resource Experience correlate to defects in definition.

Hypothesis 34 – Resource Experience correlate to defects in construction.

Hypothesis 35 – Resource Experience correlate to defects in Design alignment to user requirements.

Hypothesis 36 – Resource Experience correlate to defects in Quality Control prior to deployment.

Hypothesis 37 – Resource Continuity throughout the project correlate to defects in definition.

Hypothesis 38 – Resource Continuity throughout the project correlate to defects in construction.

Hypothesis 39 – Resource Continuity throughout the project correlate to defects in Design alignment to user requirements.

Hypothesis 40 – Resource Continuity throughout the project correlate to defects in Quality Control.

Hypothesis 41 – Resource Focus Level correlate to defects in definition.

Hypothesis 42 – Resource Focus Level correlate to defects in construction.

Hypothesis 43 – Resource Focus Level correlate to defects in Design alignment to user requirements.

Hypothesis 44 – Resource Focus Level correlate to defects in Quality Control.

Environmental Characteristics

Hypothesis 45 – Executive Pressure on Time /Cost Estimates correlate to defects in definition.

Hypothesis 46 – Executive Pressure on Time/Cost Estimates correlate to defects in construction.

Hypothesis 47 – Executive Pressure on Time/Cost Estimates correlate to defects in Design alignment to user requirements.

Hypothesis 48 – Executive Pressure on Time/Cost Estimates correlate to defects in Quality Control.

<u>Sub problem 4:</u> What factors influence time variance for projects involving IT?

<u>Product Characteristics</u>

Hypothesis 49 – Product Complexity correlates to time variance

Hypothesis 50 – Product Significance correlates to time variance

Hypothesis 51 – Product Budget correlates to time variance

Hypothesis 52 – Requirements Change during project execution correlates to time variance

<u>Technology Characteristics</u>

Hypothesis 53 – Maturity level of Technology used correlates to time variance

Hypothesis 54 – Continuance of Technology throughout the project correlates to time variance

Hypothesis 55 – Technology Spread (popularity) correlates to time variance

Hypothesis 56 – Technology Progression Rate correlates to time variance

<u>People Characteristics</u>

Hypothesis 57 – Experience of Team members correlate to time variance

Hypothesis 58 – Personnel Continuity correlate to time variance

Hypothesis 59 – Focus of the Team members on the project correlate to Time variance.

Hypothesis 60 – Team Size correlate to Time variance.

<u>Environmental Characteristics</u>

Hypothesis 61 – Executive Pressure on Time/Time Estimates correlate to Time variance.

Hypothesis 62 – Business Complexity correlate to Time variance.

Hypothesis 63 – Business Geographical Spread correlate to Time variance.

Hypothesis 64 – Project Structure correlate to Time variance.

<u>Execution Characteristics</u>

Hypothesis 65 – Task inter-dependence correlate to Time variance.

Hypothesis 66 – Resource doubling influence on timeline correlate to Time variance.

Hypothesis 67 – Progress Monitoring Frequency correlate to Time variance.

Hypothesis 68 – Priority increase of Project during execution correlate to Time variance.

<u>Quality Characteristics</u>

Hypothesis 69 – Defects in Product Definition correlate to Time variance.

Hypothesis 70 – Defects in Product Build correlate to Time variance.

Hypothesis 71 – Defects in Product Design Alignment to User Requirements correlate to time variance.

Hypothesis 72 – Defects in Quality Control correlate to time variance.

A post de facto analysis using historical data from the same projects will be used to identify correlation between time variance (ratio scale) and each element (ordinal scale). Kendall's Tau will be used for analyzing correlation. A regression analysis will be conducted for correlated variables and a coefficient will be derived, which will be used in a new cost estimation formulae.

<u>Sub problem 5:</u> How adequate is the risk profile for IT projects

Hypothesis 73 – Risk profile correlate to Product Complexity.

Hypothesis 74 – Risk profile correlate to Product Significance.

Hypothesis 75 – Risk profile correlate to Product Budget.

Hypothesis 76 – Risk profile correlate to Technological Risk.

Hypothesis 77 – Risk profile correlate to Resource Risk.

Hypothesis 78 – Risk profile correlate to Business Risk.

A post de facto analysis using historical data from the same projects will be used to identify the correct discount rate for the actual variance. A correlation analysis will be done between discount factor and each variable following this.

3.2 Sample Selection

On assumption that the IT cost and benefit evaluation is best told by the practitioners of the field, individuals with extensive experience on project execution such as,

- Technical Leads,
- IT project managers, and
- Business managers

with considerable experience in delivering projects of varying sizes were interviewed in the qualitative phase of the research. In-person interviews were conducted with each person guided by the questions listed in Appendix A-2. The roles of three groups interviewed and focus areas listed in Table below.

Role	Role Description	Interview focus
Business Manager	Project Sponsorship in both financial and social terms in the organization. Responsible for cost benefit evaluation.	Benefits measurement metric identification and quantification
Project Manager	Overall responsibility for the financial and social aspects of project delivery, qualified in project management methodology.	Environmental, People and Product aspects of the project .
Technical Lead	Expert in the IT application domain with over 7 years experience. Responsible for software development cost estimation.	Cost and time estimation for software development, impact of reusability

Table 10 Interviewee Selection Matrix

Historic data from 40 projects where they are involved will be used in post de facto analysis for the survey. Historic data from completed projects was used for analysis. Stratified samples were selected from a variety of projects as per the table below to have an even distribution. Selection of candidates for interview was done in such a way to represent more than 2 project dimensions (listed in the table below) for an unbiased result.

Dimension	Category	Criteria
Environmental Diversity	Narrow	Single functional area within the organization
	Medium	Multiple functional areas within the organization.
	Wide	Multiple functional areas involving external organizations
IT Budget	Small	Less than R200,000,00
	Medium	Greater Than R200, 000, 00 but less than R 1, 000, 000, 00.
	Large	Over R 1,000,000,00
Novelty	Low	Project team has members who implemented similar projects in the same organization
	Medium	Project team has members who implemented similar projects in other organizations

	High	No one in the project team has done a similar project before
Significance	Low	Nice to have
	Medium	Enhancement for better usability
	High	Compliance, Strategic
Complexity	Low	Less than 20 interfaces
	Medium	20 – 100 interfaces
	High	Over 100 interfaces

Table 11 Project Selection Matrix

An ex-post facto analysis will be conducted using historical data selected according to the above criteria and correlation between cost variance, time variance, risk variance and the following variables will be analyzed using Kendall's Tau and Spearman's correlation methods.

3.3 Measurement Instruments

Two types of measurement instrument will be used in this research.

1. Questionnaires, schedules and guidelines for interviews, and standardized tests and scales. To obtain an objective measure on variables, nominal and ratio scale was used in structured questions. Respondent's confidence level was also recorded to support such measurements.

2. Analysis of existing excel documents for historical data on project estimates on time, cost and manpower allocations vs. actual.

3.4 Data Analysis

The research was divided into two sections as follows.

1. Correlation Analysis of variables.
2. Quantification of intangibles.

1. Correlation Analysis between variables.

Spearman's Correlation

As per (Diamantopoulos and Schlegelmilch, 2004), Spearman's Correlation is calculated by applying the Pearson correlation formula to the ranks of the data rather than to the actual data values themselves. In so doing, many of the distortions that plague the Pearson correlation are reduced considerably. Pearson correlation measures the strength of linear relationship between variables. In the case of nonlinear, but monotonic relationships, a useful measure is *Spearman's* rank correlation coefficient, *Rho,* which is a *Pearson's* type correlation coefficient, computed on the ranks of values.

Kendall's Tau

As per (Diamantopoulos and Schlegelmilch, 2004), Kendall's Tau is a measure of correlation between two ordinal-level variables. It is most appropriate for square tables. Kendall's *Tau* is equivalent to Spearman'*s Rho*, with regard to the underlying assumptions, but Spearman's *Rho* and Kendall's *Tau* are not identical in magnitude, since their underlying logic and computational formulae are quite different. In most cases, resultant values are very similar, and when discrepancies occur, it is probably safer to interpret the lower value. More importantly, Kendall's *Tau* and Spearman's *Rho* imply different interpretations. Spearman's *Rho* is considered as the regular Pearson's correlation coefficient in terms of the proportion of variability accounted for, whereas Kendall's *Tau* represents a probability, *i.e.*, the difference between the probabilities that the observed data are in the same order *versus* the probability that the observed data are not in the same order.

Gamma

As per (Diamantopoulos and Schlegelmilch, 2004), Gamma Tests the strength of association of the cross tabulations when both variables are measured at the ordinal level. It makes no adjustment for either table size or ties. Values range from -1 (100% negative association, or perfect inversion) to +1 (100% positive association, or perfect agreement). A value of zero indicates the absence of association.

2. Quantification of Intangibles

Applied Information Economics

As per (Hubbard, 2007), AIE is a synthesis of techniques from a variety of scientific and mathematical fields. The tools of economics, financial theory, and statistics are all major contributors to AIE. But in addition to these more familiar fields, AIE includes Decision Theory - the formulation of decisions into a mathematical framework - and Information Theory - the mathematical modeling of transmitting and receiving information. It is important to emphasize, however, that even though AIE is a theoretically well-founded set of techniques, it is a very practical approach. Every proper application of AIE keeps the bottom line squarely in mind. All output from the AIE project is in support of specific practical business objectives.

Applied Information Economics steps are summarized in this following table:

Steps	**Description**	**Artifacts**
Unit Of Measure	Clarify the problem by defining observable phenomenon	The result is a decision model
Calibrated Probability Assessments	Document the current state of uncertainty	The result is a decision model populated with initial calibrated estimates
Calculation of the Economic Value Of Information	Compute the value of additional information for each variable in a business case	The result is economically selected and prioritized measurements
IT Investment as an Investment Portfolio	Optimize the decision based on new measurement information	The result is a recommendation to improve the decision and the portfolio it is part of

Table 12 AIE Steps

AIE suggests that instead of choosing a single point value of any set of variables, rather realistic results could be achieved by ascribing the probabilities on them. For this reason, AIE derives the probability distribution graph of the net benefits of a particular type of investment.

3.5 Ethical Considerations

Researcher would not expose details of his respondents to protect privacy. Neither would he expose participants to undue stress, embarrassment or lose of self-esteem by this study, especially who participated in a failed project. Also the names and descriptions of projects are disguised to protect organizational confidentiality requirements.

Informed consent from partakers will be obtained and their participation will be strictly voluntary. They should be told the nature of the research to allow them to make up their minds as to whether they would like to take part or not. They will also have the right to withdraw at any time without being subjected to any feelings of guilt.

Also misrepresentation of findings to support the intended conclusions will not be attempted. Research findings will either confirm or reject the researcher's hypothesis. The true situation will be presented.

Chapter 4: Research results

Introduction

Included in this chapter are extracts and statistical analysis results of responses for questionnaires listed in appendix A. Full details of responses appear in Appendix C. In this chapter, the researcher has listed responses for IT value questionnaire followed by the cost time and risk approximation data. The researcher has included testing of all hypotheses forming basis for analysis of the results in the next chapter.

4.1 IT Value Quantification

4.1.1 Sub Problem 1: How to improve the value quantification for projects involving IT?

The results were collected from interviews with Business Sponsors on metrics on IT value. In general there was a lack of understanding on appreciation for value metrics for IT benefits, as seen in the literature. Data collection was based on BSC framework and essentially fulfilled requirements of the following phases of AIE methodology.

Phase 0 : Preparation

1. Initial research.
2. Expert identification.

Phase 1 : Decision Model

1. Decision Problem Definition.
2. Decision Model Detail.
3. Initial Calibrated Estimates.

Initial calibrated estimates could not be collected as it was part of classified business critical information. This would not impact the results of his research as the intended output being a generalization.

Below is a summary of information gathered during interviews with project Sponsors representing multiple industries on financial perspective of IT project benefits.

Financial Perspective	
Measurement	**Metric**
Increase in Revenue (sales)	new accounts created by the system
Increase in Revenue (sales)	new sale created by the system
Increase in Revenue (sales)	new service appointment created by the system
Increase in Revenue (sales)	repeat /additional account, sale, service appointment by the systems
Increase in Revenue (sales)	new account, sale, service appointment
Increase in Efficiency (more with less) – Systems	additional customer served by new system (infrastructure capacity improvement)
Increase in efficiency (more with less) – People	additional customer served by existing staff using the new system (people capacity improvement)
Increase in Revenue (sales)	Cross sell of products
Increase in Revenue (sales)	Increased transactions - cost of sale – ATM footprint

Table 13 Metrics for Financial Perspective

Below is a summary of information gathered during interviews with project Sponsors representing multiple industries on customer perspective of IT project benefits.

Customer Perspective	
Measurement	**Metric**
Number of complaints received per month	Staff Time/Cost to Resolve the complaint with the new system
Number of complaints received per month	Loss of customer due to time and inconvenience due to delays in resolving the complaint with current system (branch)
Percentage of customers that repeat business	new accounts
Percentage of customers that repeat business	new services used
Percentage of customers that repeat business	new customers gained
Improved processes	Satisfied customer - faster turnaround through optimal service
Reduction in production costs	Benefit for customer for lower fees

Table 14 Metrics for Customer Perspective

Appearing next is a summary of information gathered during interviews with project Sponsors representing multiple industries on internal process perspective of IT project benefits.

Internal Process Perspective	
Measurement	**Metric**
Reduced cost of servicing customers at branch	Cost reduction per engagement
Less volumes at branch	Additional capacity created(cost per session)
Reduced Downtime	Average cost of downtime per minute
Reduced Rework	cost per unit per rework
decrease in cycle times;	cost per minute times saved time
Maintenance expenses	Average maintenance cost per month times % reduction
more service with less bodies	cost per body times number of bodies reduced
Decreased time to make certain decisions	loss of interest per day; average % deals lost in the past month
Revenue per employee	total income / new head count
Reduced Paperwork	cost per print times number of prints reduced
Improved processes	Improved competitiveness – faster turnaround e.g.: Vehicle finance on dealer floors
Reduced headcount	Increased profitability through reduced headcount

Table 15 Metrics on Internal Process Perspective

Appearing next is a summary of information gathered during interviews with project Sponsors representing multiple industries on internal process perspective of IT project benefits.

Learning and Growth Perspective	
Measurement	**Metric**
Decreased employees turnover	Cost to hire
Decreased employees turnover	Cost to train
Employee Attraction	Cost to hire
Decreased supervisory overhead	supervisory overhead
New products introduced	profit per product
Number of patents	profit per patent
Number of employee suggestions	value per suggestion
Handling more complex queries	supervisory overhead
Increased job satisfaction	happy employees

Table 16 Metrics on Learning and Growth Perspective

The qualitative interviews for gathering value quantification interviews were extremely challenging, due to the novelty of the concept. Most benefits were considered intangible and there were no reference models available. AIE prescribes a couple of workshops with experts for this step for a specific project, but the researcher could not afford to have such workshops. Further, the requirements for a generalized metrics would have taken more work shops than a locally focused project. However, the researcher managed to get a good sample of metrics.

4.2 *Time, Cost and Risk Approximation*

4.2.1 Survey results

The survey results were collected from interviews with Project Managers and Technical Leads on cost approximation. Inputs were directly input to Excel worksheets in the presence of the interviewee to improve efficiency of the process and to eliminate any possible data capturing errors. A total of 30 projects were considered by interviewing 15 Project Managers.

Descriptive Statistics:

The project budgets were representative sample of projects in large organization. Below is a graphical representation of the project budgets of the sample. Projects with budgets between R1.2 million and R10 million has a 33% representation while projects below R 250,000 and above R 20 million are represented 17% and 16% respectively.

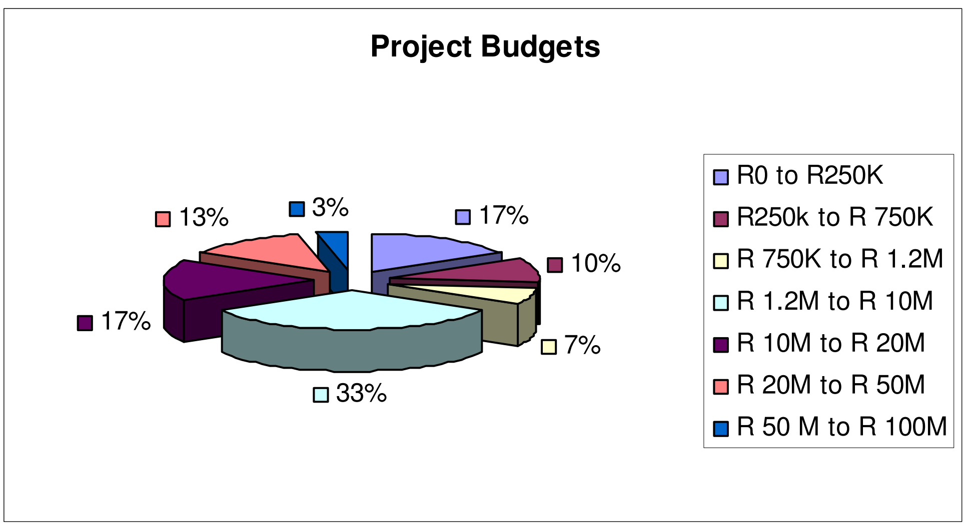

Figure 8 Project Value Distribution

Time and Cost Variance

	Cost Variance % from Concept to Actual	*Time Variance % from Concept to Actual*
Mean	57.11560229	38.65677482
Standard Error	17.80868888	7.784802032
Median	30.65656566	26.49122807
Mode	20	25
Standard Deviation	97.5422062	42.63911678
Sample Variance	9514.48199	1818.09428
Kurtosis	24.3453371	8.912490842
Skewness	4.732611557	2.897913615
Range	550	200
Minimum	0	0
Maximum	550	200
Sum	1713.468069	1159.703244
Count	30	30
Largest(1)	550	200
Smallest(1)	0	0
Confidence Level(95.0%)	36.42285784	15.92170763

Table 17 Descriptive Statistics on Time and Cost Variance

Mean value for cost variance is 57% while time variance is 38%. These figures align with literature on time and cost variances for IT projects. All time cost estimates were expert estimates. There was a lack of tool usage due to cost and the need for customization using local data.

Project (Product) Characteristics

	Project Complexity	*Project Significance*	*Project Budget*	*Requirements change during Project execution*
Mean	3.2	3.5	3.6	2.7
Standard Error	0.221800366	0.157202556	0.269524912	0.180357244
Median	3	3	4	2.5
Mode	3	3	4	2
Standard Deviation	1.214850636	0.861033861	1.476248741	0.987857312
Sample Variance	1.475862069	0.74137931	2.179310345	0.975862069
Kurtosis	-1.062340649	-0.491436813	-0.77417195	-0.441471165
Skewness	0.331346672	0.173630409	-0.829591593	0.432306404
Range	4	3	4	4
Minimum	1	2	1	1
Maximum	5	5	5	5
Sum	96	105	108	81
Count	30	30	30	30
Largest(1)	5	5	5	5
Smallest(1)	1	2	1	1
Confidence Level(95.0%)	0.453632676	0.321515323	0.551240331	0.368871977

Table 18 Product Characteristics

Mean value for project complexity is 3.2 and Median is 3, which means the projects included in the survey had around 25 interfaces (i.e. screens, reports, files etc) which is a fair representation of IT projects in large organization.

Mean value for project significance is 3.5 and Median is 3, which means the projects included in the survey are either of operational or strategic importance, hence they had due focus from the relevant organizations.

Mean value for project budget is 3.6 and Median is 4, which represents a typical project scenarios in large organizations.

Change in requirements during project execution is below 25% for most projects as represented by a Mean value of 2.7.

Technology Landscape

	Maturity of Technology used	Continuity of Technology from concept to realization	Technology Spread (popularity)	Progression Rate(rate of adoption by others)
Mean	3.233333333	3.166666667	4.066666667	4.033333333
Standard Error	0.183724765	0.258569599	0.143305263	0.237241491
Median	4	3	4	4.5
Mode	4	5	4	5
Standard Deviation	1.006301982	1.416244021	0.784915253	1.29942516
Sample Variance	1.012643678	2.005747126	0.616091954	1.688505747
Kurtosis	-0.924530201	-1.213391398	-1.331846896	0.394116086
Skewness	-0.505328483	-0.15896486	-0.120882769	-1.278028301
Range	4	4	2	4
Minimum	1	1	3	1
Maximum	5	5	5	5
Sum	97	95	122	121
Count	30	30	30	30
Largest(1)	5	5	5	5
Smallest(1)	1	1	3	1
Confidence Level(95.0%)	0.37575933	0.5288342	0.293092168	0.485213322

Table 19 Technology Landscape

Mean value for the maturity of Technologies involved is 3.23 and Median is 4, which means the technologies have been in the respective organizations for more than a year. Therefore, distortion due to novelty of technologies has been eliminated.

Mean value for continuance of technologies throughout the projects is 3.16 denoting minimal disturbances from technological evolution or errors in technology selection. The only impact was from new releases, which is commonplace in IT projects.

Mean value for Technology Spread is 4.06 denotes a fair supply of resources. This together with Progression rate for technologies where the mean value of 4.03, eliminate any extravagant resource cost due to scarcity.

<u>Resource Allocation Characteristics</u>

	Experience of Team Members	*Personnel Continuity*	*Resource Focus on the Project (descending order off Sharing among other projects)*	*Team size*
Mean	3.233333333	3.9	3.2	2.633333333
Standard Error	0.16388483	0.154250133	0.264357821	0.200478355
Median	3	4	4	2.5
Mode	3	4	4	2
Standard Deviation	0.897634183	0.844862772	1.447947418	1.098065174
Sample Variance	0.805747126	0.713793103	2.096551724	1.205747126
Kurtosis	1.103495051	0.013858189	-1.253400772	-0.212375826
Skewness	-0.803915655	-0.536674315	-0.373876411	0.472771454
Range	4	3	4	4
Minimum	1	2	1	1
Maximum	5	5	5	5
Sum	97	117	96	79
Count	30	30	30	30
Largest(1)	5	5	5	5
Smallest(1)	1	2	1	1
Confidence Level(95.0%)	0.335182107	0.315476939	0.540672443	0.410024268

Table 20 Resource Perspectives

Established organizations are generally functional hence do not have dedicated project teams. It is also common for resources to move from one organization due to natural attrition.

Experience of team members for the projects concerned has a mean value of 3.23, denoting majority are familiar with the technologies used and are used to the environment.

Personnel continuity has a mean value of 3.9 and a mode of 4 denoting a low turnaround, eliminating possible project delays caused by knowledge transfer.

Resource sharing among other projects has a mean value of 3.2 and a mode of 4, denoting at least 50% focus from the resources, which is usual for large projects, which have a bigger impact on cost. Most team sizes concerned were below 25, denoted by the mean value of 2.6 and the mode 2.

Project Environment

	Executive pressure on Time/cost estimates	*Business (product) Complexity*	*Business (geographical) complexity*	*Project Friendliness of Structure*
Mean	3.233333333	3.3	2.933333333	3.133333333
Standard Error	0.233333333	0.209816559	0.239411795	0.247903083
Median	3	4	3	3
Mode	2	4	4	3
Standard Deviation	1.278019301	1.149212624	1.311312407	1.357821108
Sample Variance	1.633333333	1.320689655	1.71954023	1.843678161
Kurtosis	-1.241498308	-1.148243985	-1.277205218	-1.09103577
Skewness	-0.044916569	-0.201555381	-0.06583133	0.008002301
Range	4	4	4	4
Minimum	1	1	1	1
Maximum	5	5	5	5
Sum	97	99	88	94
Count	30	30	30	30
Largest(1)	5	5	5	5
Smallest(1)	1	1	1	1
Confidence Level(95.0%)	0.477220243	0.42912304	0.489652093	0.507018727

Table 21 Organizational Environment

Executive pressure on time cost estimates has a mode of 3, but a mean value of 3.2 denoting a balance tilted away from autonomy for the project team, which is a fair representation of the real world situation.

Business complexity has a mode of 4, and a mean value of 3.3 representing the real world situation where tacit knowledge dictating business processes.

Business geographical complexity has a mean value of 2.93 and a mode of 4, denoting the distributed and silo based organizational structures.

Most project structures are matrix with resources sourced from functional units as denoted by a mean value of 3.13, and a mode of 3. This reflects the real world situation.

<u>Project Execution Characteristics</u>

	Ascending level of project activity Interdependence	*Ascending order of time benefit by doubling resources*	*Ascending order of project progress monitoring frequency*	*Ascending level of Priority Increase for project during execution*
Mean	3.033333333	2.9	4.333333333	3.133333333
Standard Error	0.131160456	0.161530041	0.087537622	0.201906621
Median	3	3	4	3
Mode	3	3	4	4
Standard Deviation	0.718395402	0.88473647	0.479463301	1.105888107
Sample Variance	0.516091954	0.782758621	0.229885057	1.222988506
Kurtosis	2.868544445	-0.071554714	-1.553571429	-0.657824071
Skewness	-0.049603246	0.204858817	0.744880486	-0.116309357
Range	4	4	1	4
Minimum	1	1	4	1
Maximum	5	5	5	5
Sum	91	87	130	94
Count	30	30	30	30
Largest(1)	5	5	5	5
Smallest(1)	1	1	4	1
Confidence Level(95.0%)	0.268253248	0.330366022	0.179034536	0.4129454

Table 22 Project Execution Characteristics

Project activity interdependence has a mean value of 3.03 and a mode of 3. This is a fair reflection of project interdependencies in modern organizations. Possible time benefits achieved by doubling of resources has a mean value of 2.9, denoting a below 25% improvement supporting the previous point on task interdependence.

Majority of projects are monitored weekly with a mean value of 4.3 and a mode of 4. This is a fair representation of the real world, where projects are budgeted and executed in weekly cycles. Priorities of projects under study were either high throughout or of the increasing priority, denoted by a mean of 3.13 and a mode of 4. This eliminates time distortions due to decreases in priority.

<u>Risk Considerations</u>

	Risks considered in calculation of the discount rate	*Technological Risk of the Project*	*Resource Risks for the project*	*Business Risk of the product*
Mean	1.233333333	1.766666667	2.566666667	1.966666667
Standard Error	0.114302818	0.1329016	0.114302818	0.264719905
Median	1	2	2.5	1
Mode	1	2	2	1
Standard Deviation	0.626062316	0.727932042	0.626062316	1.449930636
Sample Variance	0.391954023	0.529885057	0.391954023	2.102298851
Kurtosis	4.848611799	-0.957344047	- 0.452831626	- 0.215375898
Skewness	2.508681102	0.396332676	0.635032906	1.152640605
Range	2	2	2	4
Minimum	1	1	2	1
Maximum	3	3	4	5
Sum	37	53	77	59
Count	30	30	30	30
Largest(1)	3	3	4	5
Smallest(1)	1	1	2	1
Confidence Level(95.0%)	0.233775507	0.271814287	0.233775507	0.541412989

Table 23 Risk Consideration

Risk consideration for the calculation has a mean of 1.23 and a mode of 1 highlighting the fact that in most situations, only the cost of capital is considered. This is a fair reflection of real world situation.

Technological risk has a mean of 1.76 and a mode of 2. This represents fairly a low level of technological risk undertaken. Since most companies tend to use established technologies, this is a fair reflection of reality.

Resource risk is moderate with a mean value of 2.5 and a mode of 2. This is in line with the practices of large organizations. Business risk has a mean of 1.96 and a mode of 1 denoting the lack of innovation which is a fair representation of the South African situation.

<u>Product Quality at different stages of Projects</u>

	Defect Index at Product Definition	*Defect Index at Component Integration*	*Defect Index at User Acceptance Testing*	*Defect Index during first month in Production*
Mean	2.866666667	3.133333333	3.133333333	3
Standard Error	0.190180394	0.149584354	0.133333333	0.16609096
Median	3	3	3	3
Mode	3	4	3	3
Standard Deviation	1.04166092	0.819307249	0.730296743	0.909717652
Sample Variance	1.085057471	0.671264368	0.533333333	0.827586207
Kurtosis	-0.871029466	-1.457171675	-1.01908867	1.12202381
Skewness	-0.501503978	-0.259156461	-0.214164916	0
Range	3	2	2	4
Minimum	1	2	2	1
Maximum	4	4	4	5
Sum	86	94	94	90
Count	30	30	30	30
Largest(1)	4	4	4	5
Smallest(1)	1	2	2	1
Confidence Level(95.0%)	0.388962574	0.30593435	0.272697281	0.339694149

Table 24 Defect Index at Various Stages of projects

Defects index is defined for the purposes of this study as follows.

Level 1 – No time or cost impact.

Level 2 – Time/Cost impact less than 1 project day.

Level 3 – Time/Cost impact less than 1 project week.

Level 4 – Time/Cost impact more than 1 project week.

Level 5 – The defect caused the project or business activity to cease functioning.

(Project days is defined as number of resources in the project X no of days lost)

Product Definition Defects has a mean value of 2.86 and a mode of 3. This denotes an average cost of 1 project week. This is a slight underestimation, but at least highlights an often ignored factor in time/cost estimations.

Component Integration Defects has a mean value of 3.13 and a mode of 4. This denotes an average cost of over 1 project week. This again is a slight underestimation, but highlight a common issue in software development involving multiple function areas.

User Acceptance Defects has a mean value of 3.13 and a mode of 3. This denotes an average cost of around 1 project week. This again is a slight underestimation, but highlight a common issue in software development where user requirements are not properly understood.

Defects during the first month in production have a mean value of 3 and a mode of 3. This denotes an average cost of around 1 project week. This is a fair reflection of the true situation, as on average plus minus 1 week is spent on fixing production issues caused by the product or as a result of surfacing of undetected errors of the existing systems.

4.2.2 Sub problem 2: What factors contribute to the IT cost variance?

Hypothesis 1 – Product Complexity correlates to cost variance

Null Hypothesis H0 – Product Complexity does not correlate to cost variance.

In this case Kendall's Tau = 0.01586, which is closer to 0.
Hence we can conclude that product complexity does not correlate to the cost variance. Therefore accept the null hypothesis.

Spearman R	***0.02593***
Rank Difference Squares Sum	*4,210.50000*
t-test value for hypothesis r = 0	*0.13726*
p-level	*89.18050%*
Kendall Tau	***0.01586***
Inversions Count	*160*
Z	*0.12310*
p-level	*90.20291%*
Gamma	***1.84049%***
Pearson Correlation Coefficient	*12.85483%*

Hypothesis 2 – Product Significance correlates to cost variance

Null Hypothesis H0 – Product Significance does not correlate to cost variance.

In this case Kendall's Tau = -0.07111, which is closer to 0.
Hence we can conclude that product significance does not correlate to the cost variance. Therefore accept the null hypothesis.

Spearman R	***-0.09324***
Rank Difference Squares Sum	*4,616.50000*
t-test value for hypothesis r = 0	*-0.49556*
p-level	*62.40735%*
Kendall Tau	***-0.07111***
Inversions Count	*164*
Z	*0.55190*
p-level	*58.10152%*
Gamma	***-8.60927%***
Pearson Correlation Coefficient	*3.92176%*

Hypothesis 3 – Product Budget correlates to cost variance

Null Hypothesis H0 – Product Budget does not correlate to cost variance.

In this case Kendall's Tau = -0.12915, which is closer to 0.
Hence we can conclude that product significance does not correlate to the cost variance. Therefore accept the null hypothesis.

Spearman R	***-0.15587***
Rank Difference Squares Sum	*4,958.50000*
t-test value for hypothesis r = 0	*-0.83499*
p-level	*41.07905%*
Kendall Tau	***-0.12915***
Inversions Count	*182*
Z	*1.00229*
p-level	*31.62030%*
Gamma	***-15.18987%***
Pearson Correlation Coefficient	*-13.33012%*

Hypothesis 4 – Requirements Change during project execution correlates to cost variance

Null Hypothesis H0 – Requirements Change during project execution does not correlate to cost variance.

In this case Kendall's Tau = 0.36096, which is not close enough to 0.
Hence we can conclude that requirement change during project execution weakly correlate to the cost variance. Therefore reject the null hypothesis.

Spearman R	***0.44182***
Rank Difference Squares Sum	*2,377.00000*
t-test value for hypothesis r = 0	*2.60602*
p-level	*1.45106%*
Kendall Tau	***0.36096***
Inversions Count	*88*
Z	*2.80135*
p-level	*0.50890%*
Gamma	***43.04207%***
Pearson Correlation Coefficient	*2.68637%*

Impact of Technology Characteristics

Hypothesis 5 – Maturity level of Technology used correlates to cost variance

Null Hypothesis H0 – Maturity level of Technology used does not correlate to cost variance.

In this case Kendall's Tau = 0.00840, which is close enough to 0. Hence we can conclude that maturity level of technology does not correlate to the cost variance. Therefore accept the null hypothesis.

Spearman R	***-0.00578***
Rank Difference Squares Sum	*4,187.00000*
t-test value for hypothesis r = 0	*-0.03060*
p-level	*97.58025%*
Kendall Tau	***0.00840***
Inversions Count	*143*
Z	*0.06522*
p-level	*94.79992%*
Gamma	***1.03806%***
Pearson Correlation Coefficient	*10.02717%*

Hypothesis 6 – Continuance of Technology throughout the project correlates to cost variance

Null Hypothesis H0 – Continuance of Technology throughout the project does not correlate to cost variance.

In this case Kendall's Tau = -0.24179, which is not close enough to 0. Hence we can conclude that continuance of technology throughout the project has a weak inverse correlation to the cost variance. Therefore reject the null hypothesis.

Spearman R	***-0.31315***
Rank Difference Squares Sum	*5,779.50000*
t-test value for hypothesis r = 0	*-1.74476*
p-level	*9.19946%*
Kendall Tau	***-0.24179***
Inversions Count	*224*
Z	*1.87651*
p-level	*6.05850%*
Gamma	***-26.91218%***
Pearson Correlation Coefficient	*9.72747%*

Hypothesis 7 – Technology Spread (popularity) correlates to cost variance

Null Hypothesis H0 – Technology Spread does not correlate to cost variance.

In this case Kendall's Tau = -0.06956, which is close enough to 0. Hence we can conclude that technology spread does not correlate to the cost variance. Therefore accept the null hypothesis.

Spearman R	***-0.09149***
Rank Difference Squares Sum	*4,613.50000*
t-test value for hypothesis r = 0	*-0.48616*
p-level	*63.06371%*
Kendall Tau	***-0.06956***
Inversions Count	*159*
Z	*0.53985*
p-level	*58.93016%*
Gamma	***-8.53242%***
Pearson Correlation Coefficient	*13.55225%*

Hypothesis 8 – Technology Progression Rate correlates to cost variance

Null Hypothesis H0 – Technology Progression rate does not correlate to cost variance.

In this case Kendall's Tau = -0.05085, which is close enough to 0. Hence we can conclude that technology progression rate does not correlate to the cost variance. Therefore accept the null hypothesis.

Spearman R	***-0.06699***
Rank Difference Squares Sum	*4,426.50000*
t-test value for hypothesis r = 0	*-0.35526*
p-level	*72.50547%*
Kendall Tau	***-0.05085***
Inversions Count	*151*
Z	*0.39468*
p-level	*69.30819%*
Gamma	***-6.33803%***
Pearson Correlation Coefficient	*-5.09938%*

Hypothesis 9 – **Experience of Team members correlate to cost variance**

Null Hypothesis H0 – **Experience of Team members does not correlate to cost variance.**

In this case Kendall's Tau = -0.17748, which is close enough to 0. Hence we can conclude that experience of team members does not correlate to the cost variance. Therefore accept the null hypothesis.

Spearman R	***-0.22015***
Rank Difference Squares Sum	*5,068.50000*
t-test value for hypothesis r = 0	*-1.19420*
p-level	*24.24172%*
Kendall Tau	***-0.17748***
Inversions Count	*174*
Z	*1.37740*
p-level	*16.83894%*
Gamma	***-22.10526%***
Pearson Correlation Coefficient	*-46.93041%*

Hypothesis 10 – **Personnel Continuity correlate to cost variance**

Null Hypothesis H0 – **Personnel Continuity does not correlate to cost variance.**

In this case Kendall's Tau = -0.27203, which is not close enough to 0. Hence we can conclude that personnel continuity throughout the project has a weak inverse correlation to the cost variance. Therefore reject the null hypothesis.

Spearman R	***-0.33781***
Rank Difference Squares Sum	*5,573.00000*
t-test value for hypothesis r = 0	*-1.89914*
p-level	*6.78940%*
Kendall Tau	***-0.27203***
Inversions Count	*193*
Z	*2.11121*
p-level	*3.47543%*
Gamma	***-33.56401%***
Pearson Correlation Coefficient	*-26.25035%*

Hypothesis 11 – **Focus of the Team members on the project correlate to Cost variance.**

Null Hypothesis H0 – **Focus of the Team members on the project does not correlate to cost variance.**

In this case Kendall's Tau = -0.04120, which is close enough to 0.
Hence we can conclude that focus of the team members on the project does not correlate to the cost variance. Therefore accept the null hypothesis.

Spearman R	***-0.08704***
Rank Difference Squares Sum	*4,747.50000*
t-test value for hypothesis r = 0	*-0.46235*
p-level	*64.74066%*
Kendall Tau	***-0.04120***
Inversions Count	*180*
Z	*0.31971*
p-level	*74.91880%*
Gamma	***-4.65116%***
Pearson Correlation Coefficient	*9.90470%*

Hypothesis 12 – **Team Size correlate to Cost variance.**

Null Hypothesis H0 – **Team size does not correlate to cost variance.**

In this case Kendall's Tau = -0.09715, which is close enough to 0.
Hence we can conclude that team size does not correlate to the cost variance. Therefore accept the null hypothesis.

Spearman R	***-0.13385***
Rank Difference Squares Sum	*4,891.50000*
t-test value for hypothesis r = 0	*-0.71471*
p-level	*48.07045%*
Kendall Tau	***-0.09715***
Inversions Count	*183*
Z	*0.75395*
p-level	*45.08771%*
Gamma	***-11.24620%***
Pearson Correlation Coefficient	*-15.02515%*

Hypothesis 13 – **Executive Pressure on Time/Cost Estimates correlate to Cost variance.**

Null Hypothesis H0 – **Executive Pressure on Time/Cost Estimates does not correlate to cost variance.**

In this case Kendall's Tau = 0.02859, which is close enough to 0.
Hence we can conclude that executive pressure on time/cost estimates does not correlate to the cost variance.
Therefore accept the null hypothesis.

Spearman R	***0.06945***
Rank Difference Squares Sum	*4,062.00000*
t-test value for hypothesis r = 0	*0.36837*
p-level	*71.53706%*
Kendall Tau	***0.02859***
Inversions Count	*164*
Z	*0.22190*
p-level	*82.43892%*
Gamma	***3.24484%***
Pearson Correlation Coefficient	*-0.09164%*

Hypothesis 14 – **Business Complexity correlate to Cost variance.**

Null Hypothesis H0 – **Business Complexity does not correlate to cost variance.**

In this case Kendall's Tau = 0.12126, which is close enough to 0.
Hence we can conclude that business complexity does not correlate to the cost variance. Therefore accept the null hypothesis.

Spearman R	***0.16017***
Rank Difference Squares Sum	*3,597.00000*
t-test value for hypothesis r = 0	*0.85863*
p-level	*39.78375%*
Kendall Tau	***0.12126***
Inversions Count	*135*
Z	*0.94111*
p-level	*34.66483%*
Gamma	***14.28571%***
Pearson Correlation Coefficient	*29.41701%*

Hypothesis 15 – **Business Geographical Spread correlate to Cost variance.**

Null Hypothesis H0 – **Business Geographical Spread does not correlate to cost variance.**

In this case Kendall's Tau = 0.22881, which is not close enough to 0. Hence we can conclude that Business Geographical Spread has a weak correlation to the cost variance. Therefore reject the null hypothesis.

Spearman R	***0.31256***
Rank Difference Squares Sum	*2,993.50000*
t-test value for hypothesis r = 0	*1.74113*
p-level	*9.26398%*
Kendall Tau	***0.22881***
Inversions Count	*125*
Z	*1.77574*
p-level	*7.57764%*
Gamma	***26.03550%***
Pearson Correlation Coefficient	*23.87665%*

Hypothesis 16 – **Project Structure correlate to Cost variance.**

Null Hypothesis H0 – **Project Structure does not correlate to cost variance.**

In this case Kendall's Tau = -0.10281, which is close enough to 0. Hence we can conclude that project structure does not correlate to the cost variance. Therefore accept the null hypothesis.

Spearman R	***-0.14482***
Rank Difference Squares Sum	*5,013.50000*
t-test value for hypothesis r = 0	*-0.77446*
p-level	*44.51516%*
Kendall Tau	***-0.10281***
Inversions Count	*193*
Z	*0.79793*
p-level	*42.49123%*
Gamma	***-11.56069%***
Pearson Correlation Coefficient	*-29.12290%*

Hypothesis 17 – **Task inter-dependence correlate to Cost variance.**

Null Hypothesis H0 – Task inter-dependence does not correlate to cost variance.

In this case Kendall's Tau =0.04911, which is close enough to 0.
Hence we can conclude that task inter-dependence does not correlate to the cost variance. Therefore accept the null hypothesis.

Spearman R	***0.06243***
Rank Difference Squares Sum	*3,491.00000*
t-test value for hypothesis r = 0	*0.33101*
p-level	*74.31017%*
Kendall Tau	***0.04911***
Inversions Count	*98*
Z	*0.38110*
p-level	*70.31307%*
Gamma	***7.10900%***
Pearson Correlation Coefficient	*-3.87136%*

Hypothesis 18 – Resource doubling influence on timeline correlate to Cost variance.

Null Hypothesis H0 – Resource doubling influence on timeline does not correlate to cost variance.

In this case Kendall's Tau =0.09633, which is close enough to 0.
Hence we can conclude that resource doubling influence on timeline does not correlate to the cost variance.
Therefore accept the null hypothesis.

Spearman R	***0.13081***
Rank Difference Squares Sum	*3,682.50000*
t-test value for hypothesis r = 0	*0.69817*
p-level	*49.08263%*
Kendall Tau	***0.09633***
Inversions Count	*133*
Z	*0.74761*
p-level	*45.46967%*
Gamma	***11.62791%***
Pearson Correlation Coefficient	*23.52870%*

Hypothesis 19 – **Progress Monitoring Frequency correlate to Cost variance.**

Null Hypothesis H0 – **Progress Monitoring Frequency does not correlate to cost variance.**

In this case Kendall's Tau =-0.02692, which is close enough to 0.
Hence we can conclude that progress monitoring frequency does not correlate to the cost variance.
Therefore accept the null hypothesis.

Spearman R	***-0.02451***
Rank Difference Squares Sum	*3,837.50000*
t-test value for hypothesis r = 0	*-0.12973*
p-level	*89.77108%*
Kendall Tau	***-0.02692***
Inversions Count	*103*
Z	*0.20890*
p-level	*83.45257%*
Gamma	***-4.04040%***
Pearson Correlation Coefficient	*-12.09497%*

Hypothesis 20 – **Priority increase of Project during execution correlate to Cost variance.**

Null Hypothesis H0 – **Priority increase of project during execution does not correlate to cost variance.**

In this case Kendall's Tau =-0.00525, which is close enough to 0.
Hence we can conclude that priority increase of project during execution does not correlate to the cost variance.
Therefore accept the null hypothesis.

Spearman R	***0.00668***
Rank Difference Squares Sum	*4,315.50000*
t-test value for hypothesis r = 0	*0.03534*
p-level	*97.20567%*
Kendall Tau	***-0.00525***
Inversions Count	*167*
Z	*0.04076*
p-level	*96.74859%*
Gamma	***-0.60241%***
Pearson Correlation Coefficient	*-16.52857%*

Hypothesis 21 – Defects in Product Definition correlate to Cost variance.

Null Hypothesis H0 – Defects in Product definition does not correlate to cost variance.

In this case Kendall's Tau =0.15783, which is close enough to 0.

Hence we can conclude that defects in product definition do not correlate to the cost variance. Therefore accept the null hypothesis.

Spearman R	***0.20356***
Rank Difference Squares Sum	*3,431.50000*
t-test value for hypothesis r = 0	*1.10017*
p-level	*28.06277%*
Kendall Tau	***0.15783***
Inversions Count	*130*
Z	*1.22486*
p-level	*22.06292%*
Gamma	***18.49530%***
Pearson Correlation Coefficient	*-8.53440%*

Hypothesis 22 – Defects n Product Build correlate to Cost variance.

Null Hypothesis H0 – Defects in Product Build does not correlate to cost variance.

In this case Kendall's Tau = 0.47850, which is close enough to 1.

Hence we can conclude that Defects in Product Build has a strong correlation to the cost variance. Therefore reject the null hypothesis.

Spearman R	***0.60820***
Rank Difference Squares Sum	*1,661.50000*
t-test value for hypothesis r = 0	*4.05434*
p-level	*0.03632%*
Kendall Tau	***0.47850***
Inversions Count	*60*
Z	*3.71358*
p-level	*0.02043%*
Gamma	***58.76289%***
Pearson Correlation Coefficient	*36.93391%*

Hypothesis 23 – **Defects in Product Design Aligned to User Requirements correlate to cost variance.**

Null Hypothesis H0 – **Defects in Product Design Aligned to User Requirements does not correlate to cost variance.**

In this case Kendall's Tau = 0.37597, which is not close enough to 0. Hence we can conclude that defects in Design Alignment to User requirements have a weak correlation to the cost variance. Therefore reject the null hypothesis.

Spearman R	***0.47754***
Rank Difference Squares Sum	*2,183.50000*
t-test value for hypothesis r = 0	*2.87604*
p-level	*0.76152%*
Kendall Tau	***0.37597***
Inversions Count	*74*
Z	*2.91784*
p-level	*0.35247%*
Gamma	***47.14286%***
Pearson Correlation Coefficient	*33.91513%*

Hypothesis 24 – **Defects in Quality Control correlate to cost variance.**

Null Hypothesis H0 – **Defects in Quality Control does not correlate to Cost variance.**

In this case Kendall's Tau = 0.22865, which is not close enough to 0. Hence we can conclude that defects in Quality Control have a weak correlation to the cost variance. Therefore reject the null hypothesis.

Spearman R	***0.28926***
Rank Difference Squares Sum	*2,851.50000*
t-test value for hypothesis r = 0	*1.59900*
p-level	*12.10451%*
Kendall Tau	***0.22865***
Inversions Count	*93*
Z	*1.77453*
p-level	*7.59756%*
Gamma	***29.54545%***
Pearson Correlation Coefficient	*-5.92448%*

4.2.3 Sub problem 3: What impacts the quality of projects involving IT?

Hypothesis 25 – Product Complexity correlate to defects in definition.

Null Hypothesis H0 – Product Complexity does not correlate to defects in definition.

In this case Kendall's Tau = 0.52861, which is close enough to 1.
Hence we can conclude that Product Complexity has a strong correlation to the defects in definition. Therefore reject the null hypothesis.

Spearman R	***0.58953***
Rank Difference Squares Sum	*1,764.00000*
t-test value for hypothesis r = 0	*3.86194*
p-level	*0.06077%*
Kendall Tau	***0.52861***
Inversions Count	*39*
Z	*4.10248*
p-level	*0.00409%*
Gamma	***71.42857%***
Pearson Correlation Coefficient	*66.25872%*

Hypothesis 26 – Product Complexity correlate to defects in construction.

Null Hypothesis H0 – Product Complexity does not correlate to defects in construction.

In this case Kendall's Tau = 0.10417, which is close enough to 0.
Hence we can conclude that Product Complexity does not have a correlation to the defects in construction. Therefore accept the null hypothesis.

Spearman R	***0.04379***
Rank Difference Squares Sum	*3,974.00000*
t-test value for hypothesis r = 0	*0.23195*
p-level	*81.82647%*
Kendall Tau	***0.10417***
Inversions Count	*94*
Z	*0.80846*
p-level	*41.88238%*
Gamma	***16.07143%***
Pearson Correlation Coefficient	*11.08619%*

Hypothesis 27 – **Product Complexity correlate to defects in Design alignment to user requirements.**

Null Hypothesis H0 – **Product Complexity does not correlate to defects in Design alignment to user requirements.**

In this case Kendall's Tau = 0.20962, which is not close enough to 0. Hence we can conclude that Product Complexity have a weak correlation to the defects in Design Alignment to user requirements. Therefore we reject the null hypothesis.

Spearman R	***-0.02251***
Rank Difference Squares Sum	*4,299.14286*
t-test value for hypothesis r = 0	*-0.11915*
p-level	*90.60062%*
Kendall Tau	***0.20962***
Inversions Count	*74*
Z	*1.62687*
p-level	*10.37656%*
Gamma	***33.03167%***
Pearson Correlation Coefficient	*24.09747%*

Hypothesis 28 – **Product Complexity correlate to defects in Quality Control.**

Null Hypothesis H0 – **Product Complexity does not correlate to defects in Quality Control.**

In this case Kendall's Tau = 0.07951, which is close enough to 0. Hence we can conclude that Product Complexity does not correlate to the defects in quality control. Therefore we accept the null hypothesis.

Spearman R	***0.12803***
Rank Difference Squares Sum	*3,706.44444*
t-test value for hypothesis r = 0	*0.68311*
p-level	*50.01490%*
Kendall Tau	***0.07951***
Inversions Count	*89*
Z	*0.61705*
p-level	*53.72015%*
Gamma	***13.17073%***
Pearson Correlation Coefficient	*9.36039%*

Hypothesis 29 – Requirements change during project execution correlate to defects in definition.

Null Hypothesis H0 – Requirements change during project execution does not correlate to defects in definition.

In this case Kendall's Tau = 0.52608, which is close enough to 1. Hence we can conclude that Requirements Change during project execution has a strong correlation to the defects in definition. Therefore we reject the null hypothesis.

Spearman R	***0.37263***
Rank Difference Squares Sum	*2,595.20238*
t-test value for hypothesis r = 0	*2.12478*
p-level	*4.25674%*
Kendall Tau	***0.52608***
Inversions Count	*26*
Z	*4.08285*
p-level	*0.00445%*
Gamma	***78.24268%***
Pearson Correlation Coefficient	*62.99981%*

Hypothesis 30 – Requirements Change during construction correlate to defects in construction.

Null Hypothesis H0 – Requirements change during construction does not correlate to defects in construction.

In this case Kendall's Tau = 0.27505, which is not close enough to 0. Hence we can conclude that Requirements Change during construction have a weak correlation to the defects in construction. Therefore we reject the null hypothesis.

Spearman R	***0.25136***
Rank Difference Squares Sum	*3,059.50000*
t-test value for hypothesis r = 0	*1.37418*
p-level	*18.02860%*
Kendall Tau	***0.27505***
Inversions Count	*60*
Z	*2.13460*
p-level	*3.27938%*
Gamma	***44.18605%***
Pearson Correlation Coefficient	*34.93613%*

Hypothesis 31 – **Requirements change during construction correlate to defects in Design alignment to user requirements.**

Null Hypothesis H0 – **Requirements change during construction does not correlate to defects in Design alignment to user requirements.**

In this case Kendall's Tau = 0.36496, which is not close enough to 0. Hence we can conclude that Requirements change during construction have a weak correlation to the defects in Design Alignment to user requirements. Therefore we reject the null hypothesis.

Spearman R	***0.27388***
Rank Difference Squares Sum	*3,003.00000*
t-test value for hypothesis r = 0	*1.50688*
p-level	*14.30429%*
Kendall Tau	***0.36496***
Inversions Count	*45*
Z	*2.83239*
p-level	*0.46202%*
Gamma	***59.09091%***
Pearson Correlation Coefficient	*43.97403%*

Hypothesis 32 – **Requirements Change during construction correlate to defects in Quality Control.**

Null Hypothesis H0 – **Requirements Change during construction does not correlate to defects in Quality Control.**

In this case Kendall's Tau = 0.23771, which is not close enough to 0. Hence we can conclude that Requirements change during construction weakly correlate to the defects in quality control. Therefore we reject the null hypothesis.

Spearman R	***0.23359***
Rank Difference Squares Sum	*3,205.16667*
t-test value for hypothesis r = 0	*1.27121*
p-level	*21.41127%*
Kendall Tau	***0.23771***
Inversions Count	*58*
Z	*1.84480*
p-level	*6.50673%*
Gamma	***41.11675%***
Pearson Correlation Coefficient	*26.85958%*

Hypothesis 33 – **Resource Experience correlate to defects in definition.**

Null Hypothesis H0 – **Resource Experience does not correlate to defects in definition.**

In this case Kendall's Tau = -0.00893, which is close enough to 0. Hence we can conclude that Resource Experience during project execution has no correlation to the defects in definition. Therefore we accept the null hypothesis.

Spearman R	***0.13494***
Rank Difference Squares Sum	*3,573.13889*
t-test value for hypothesis r = 0	*0.72062*
p-level	*47.71185%*
Kendall Tau	***-0.00893***
Inversions Count	*105*
Z	*0.06930*
p-level	*94.47547%*
Gamma	***-1.44928%***
Pearson Correlation Coefficient	*-0.24586%*

Hypothesis 34 – **Resource Experience correlate to defects in construction.**

Null Hypothesis H0 – **Resource Experience does not correlate to defects in construction.**

In this case Kendall's Tau = 0.06168, which is close enough to 0. Hence we can conclude that Resource Experience during construction have no correlation to the defects in construction. Therefore we accept the null hypothesis.

Spearman R	***0.21035***
Rank Difference Squares Sum	*3,151.50000*
t-test value for hypothesis r = 0	*1.13852*
p-level	*26.45521%*
Kendall Tau	***0.06168***
Inversions Count	*88*
Z	*0.47868*
p-level	*63.21631%*
Gamma	***10.65990%***
Pearson Correlation Coefficient	*9.69006%*

Hypothesis 35 – **Resource Experience correlate to defects in Design alignment to user requirements.**

Null Hypothesis H0 – **Resource Experience does not correlate to defects in Design alignment to user requirements.**

In this case Kendall's Tau = 0.15657, which is close enough to 0. Hence we can conclude that Resource Experience does not correlate to the defects in Design Alignment to user requirements. Therefore accept the null hypothesis.

Spearman R	***0.25458***
Rank Difference Squares Sum	*3,011.92857*
t-test value for hypothesis r = 0	*1.39298*
p-level	*17.45866%*
Kendall Tau	***0.15657***
Inversions Count	*68*
Z	*1.21515*
p-level	*22.43081%*
Gamma	***28.04233%***
Pearson Correlation Coefficient	*16.13132%*

Hypothesis 36 – **Resource Experience correlate to defects in Quality Control.**

Null Hypothesis H0 – **Resource Experience does not correlate to defects in Quality Control.**

In this case Kendall's Tau = 0.11337, which is close enough to 0. Hence we can conclude that Resource Experience does not correlate to the defects in quality control. Therefore we accept the null hypothesis.

Spearman R	***0.33366***
Rank Difference Squares Sum	*2,724.55556*
t-test value for hypothesis r = 0	*1.87291*
p-level	*7.15559%*
Kendall Tau	***0.11337***
Inversions Count	*66*
Z	*0.87986*
p-level	*37.89373%*
Gamma	***21.89349%***
Pearson Correlation Coefficient	*16.89102%*

Hypothesis 37 – Resource Continuity throughout the project correlate to defects in definition.

Null Hypothesis H0 – Resource Continuity throughout the project does not correlate to defects in definition.

In this case Kendall's Tau = -0.255557, which is not close enough to 0. Hence we can conclude that Resource Continuity throughout the project during project execution has a weak inverse correlation to the defects in definition. Therefore we reject the null hypothesis.

Spearman R	***-0.15377***
Rank Difference Squares Sum	*4,673.69048*
t-test value for hypothesis r = 0	*-0.82349*
p-level	*41.71880%*
Kendall Tau	***-0.25557***
Inversions Count	*158*
Z	*1.98341*
p-level	*4.73215%*
Gamma	***-39.82301%***
Pearson Correlation Coefficient	*-25.07664%*

Hypothesis 38 – Resource Continuity throughout the project correlate to defects in construction.

Null Hypothesis H0 – Resource Continuity throughout the project does not correlate to defects in construction.

In this case Kendall's Tau = -0.17725, which is close enough to 0. Hence we can conclude that Resource Continuity throughout the project during construction have no correlation to the defects in construction. Therefore we accept the null hypothesis.

Spearman R	***-0.28030***
Rank Difference Squares Sum	*5,123.50000*
t-test value for hypothesis r = 0	*-1.54514*
p-level	*13.35422%*
Kendall Tau	***-0.17725***
Inversions Count	*129*
Z	*1.37564*
p-level	*16.89319%*
Gamma	***-30.30303%***
Pearson Correlation Coefficient	*-17.93377%*

Hypothesis 39 – **Resource Continuity throughout the project correlate to defects in Design alignment to user requirements.**

Null Hypothesis H0 – **Resource Continuity throughout the project does not correlate to defects in Design alignment to user requirements.**

In this case Kendall's Tau = -0.08273, which is close enough to 0. Hence we can conclude that Resource Continuity throughout the project does not correlate to the defects in Design Alignment to user requirements. Therefore accept the null hypothesis.

Spearman R	***-0.13943***
Rank Difference Squares Sum	*4,615.07143*
t-test value for hypothesis r = 0	*-0.74505*
p-level	*46.24484%*
Kendall Tau	***-0.08273***
Inversions Count	*110*
Z	*0.64202*
p-level	*52.08617%*
Gamma	***-14.58333%***
Pearson Correlation Coefficient	*-3.35326%*

Hypothesis 40 – **Resource Continuity throughout the project correlate to defects in Quality Control.**

Null Hypothesis H0 – **Resource Continuity throughout the project does not correlate to defects in Quality Control.**

In this case Kendall's Tau = 0.00000. Hence Resource Continuity throughout the project does not correlate to the defects in quality control. Therefore we accept the null hypothesis.

Spearman R	***0.12249***
Rank Difference Squares Sum	*3,596.11111*
t-test value for hypothesis r = 0	*0.65309*
p-level	*51.90249%*
Kendall Tau	***0.00000***
Inversions Count	*97*
Z	*0.00000*
p-level	*100.00000%*
Gamma	***0.00000%***
Pearson Correlation Coefficient	*0.00000%*

Hypothesis 41 – Resource Focus Level correlate to defects in definition.

Null Hypothesis H0 – Resource Focus Level does not correlate to defects in definition.

In this case Kendall's Tau = -0.00893, which is close enough to 0.
Hence we can conclude that Resource Focus Level during project execution has no correlation to the defects in definition. Therefore we accept the null hypothesis.

Spearman R	***0.12676***
Rank Difference Squares Sum	*3,711.27381*
t-test value for hypothesis r = 0	*0.67620*
p-level	*50.44597%*
Kendall Tau	***0.03633***
Inversions Count	*123*
Z	*0.28198*
p-level	*77.79612%*
Gamma	***5.01931%***
Pearson Correlation Coefficient	*6.40149%*

Hypothesis 42 – Resource Focus Level correlate to defects in construction.

Null Hypothesis H0 – Resource Focus Level does not correlate to defects in construction.

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In this case Kendall's Tau = 0.10344, which is close enough to 0.
Hence we can conclude that Resource Focus Level during construction have no correlation to the defects in construction. Therefore we accept the null hypothesis.

Spearman R	***-0.00500***
Rank Difference Squares Sum	*4,222.00000*
t-test value for hypothesis r = 0	*-0.02645*
p-level	*97.90839%*
Kendall Tau	***0.10344***
Inversions Count	*100*
Z	*0.80278*
p-level	*42.21038%*
Gamma	***15.25424%***
Pearson Correlation Coefficient	*15.11492%*

Hypothesis 43 – **Resource Focus Level correlate to defects in Design alignment to user requirements.**

Null Hypothesis H0 – **Resource Focus Level does not correlate to defects in Design alignment to user requirements.**

In this case Kendall's Tau = 0.15657, which is close enough to 0.
Hence we can conclude that Resource Focus Level does not correlate to the defects in Design Alignment to user requirements. Therefore accept the null hypothesis.

Spearman R	***-0.02963***
Rank Difference Squares Sum	*4,375.42857*
t-test value for hypothesis r = 0	*-0.15688*
p-level	*87.64681%*
Kendall Tau	***0.15629***
Inversions Count	*87*
Z	*1.21291*
p-level	*22.51648%*
Gamma	***23.68421%***
Pearson Correlation Coefficient	*20.21816%*

Hypothesis 44 – **Resource Focus Level correlate to defects in Quality Control.**

Null Hypothesis H0 – **Resource Focus Level does not correlate to defects in Quality Control.**

In this case Kendall's Tau = 0.10161, which is close enough to 0.
Hence we can conclude that Resource Focus Level does not correlate to the defects in quality control. Therefore we accept the null hypothesis.

Spearman R	***0.10771***
Rank Difference Squares Sum	*3,832.88889*
t-test value for hypothesis r = 0	*0.57326*
p-level	*57.10447%*
Kendall Tau	***0.10161***
Inversions Count	*88*
Z	*0.78857*
p-level	*43.03645%*
Gamma	***16.19048%***
Pearson Correlation Coefficient	*10.47135%*

Hypothesis 45 – **Executive Pressure on Time /Cost Estimates correlate to defects in definition.**

Null Hypothesis H0 – **Executive Pressure on Time/Cost Estimates does not correlate to defects in definition.**

Inn this case Kendall's Tau = 0.28464, which is not close enough to 0. Hence we can conclude that Executive Pressure on Time/Cost Estimates during project execution has weak correlation to the defects in definition. Therefore reject the null hypothesis.

Spearman R	***0.47275***
Rank Difference Squares Sum	*2,239.48810*
t-test value for hypothesis r = 0	*2.83885*
p-level	*0.83351%*
Kendall Tau	***0.28464***
Inversions Count	*78*
Z	*2.20906*
p-level	*2.71708%*
Gamma	***39.53488%***
Pearson Correlation Coefficient	*38.68076%*

Hypothesis 46 – **Executive Pressure on Time/Cost Estimates correlate to defects in construction.**

Null Hypothesis H0 – **Executive Pressure on Time/Cost Estimates does not correlate to defects in construction.**

In this case Kendall's Tau = 0.06168, which is close enough to 0. Hence we can conclude that Executive Pressure on Time/Cost Estimates during construction have no correlation to the defects in construction. Therefore we accept the null hypothesis.

Spearman R	***0.30250***
Rank Difference Squares Sum	*2,928.50000*
t-test value for hypothesis r = 0	*1.67936*
p-level	*10.42083%*
Kendall Tau	***0.34125***
Inversions Count	*59*
Z	*2.64840*
p-level	*0.80875%*
Gamma	***50.42017%***
Pearson Correlation Coefficient	*43.03112%*

Hypothesis 47 – Executive Pressure on Time/Cost Estimates correlate to defects in Design alignment to user requirements.

Null Hypothesis H0 – Executive Pressure on Time/Cost Estimates does not correlate to defects in Design alignment to user requirements.

In this case Kendall's Tau = 0.20874, which is not close enough to 0.

Hence we can conclude that Executive Pressure on Time/Cost Estimates weakly correlate to the defects in Design Alignment to user requirements. Therefore reject the null hypothesis.

Spearman R	***0.05328***
Rank Difference Squares Sum	*4,020.71429*
t-test value for hypothesis r = 0	*0.28234*
p-level	*77.97591%*
Kendall Tau	***0.20874***
Inversions Count	*75*
Z	*1.62000*
p-level	*10.52316%*
Gamma	***32.12670%***
Pearson Correlation Coefficient	*26.10837%*

Hypothesis 48 – Executive Pressure on Time/Cost Estimates correlate to defects in Quality Control.

Null Hypothesis H0 – Executive Pressure on Time/Cost Estimates does not correlate to defects in Quality Control.

In this case Kendall's Tau = 0.37023, which is not close enough to 0.

Hence we can conclude that Executive Pressure on Time/Cost Estimates weakly correlate to the defects in quality control. Therefore we reject the null hypothesis.

Spearman R	***0.46847***
Rank Difference Squares Sum	*2,282.05556*
t-test value for hypothesis r = 0	*2.80582*
p-level	*0.90275%*
Kendall Tau	***0.37023***
Inversions Count	*44*
Z	*2.87330*
p-level	*0.40621%*
Gamma	***58.87850%***
Pearson Correlation Coefficient	*47.45456%*

4.2.4 Sub problem 4: What factors influence time variance for projects

involving IT?

Hypothesis 49 – Product Complexity correlates to time variance

Null Hypothesis H0 – Product Complexity does not correlate to time variance.

In this case Kendall's Tau = 0.03457, which is closer to 0.
Hence we can conclude that product complexity does not correlate to the time variance. Therefore accept the null hypothesis.

Spearman R	***0.05220***
Rank Difference Squares Sum	*4,095.16667*
t-test value for hypothesis r = 0	*0.27657*
p-level	*78.41435%*
Kendall Tau	***0.03457***
Inversions Count	*154*
Z	*0.26827*
p-level	*78.84884%*
Gamma	***4.04984%***
Pearson Correlation Coefficient	*-5.31017%*

Hypothesis 50 – Product Significance correlates to time variance

Null Hypothesis H0 – Product Significance does not correlate to time variance.

In this case Kendall's Tau = -0.18208, which is closer to 0.
Hence we can conclude that product significance does not correlate to the time variance. Therefore accept the null hypothesis.

Spearman R	***-0.24053***
Rank Difference Squares Sum	*5,234.83333*
t-test value for hypothesis r = 0	*-1.31127*
p-level	*20.04180%*
Kendall Tau	***-0.18208***
Inversions Count	*181*
Z	*1.41306*
p-level	*15.76367%*
Gamma	***-22.29730%***
Pearson Correlation Coefficient	*-13.19592%*

Hypothesis 51 – Product Budget correlates to time variance

Null Hypothesis H0 – Product Budget does not correlate to time variance.

In this case Kendall's Tau = 0.16019, which is closer to 0.

Hence we can conclude that product budget does not correlate to the time variance. Therefore accept the null hypothesis.

Spearman R	***0.22597***
Rank Difference Squares Sum	*3,320.50000*
t-test value for hypothesis r = 0	*1.22748*
p-level	*22.98618%*
Kendall Tau	***0.16019***
Inversions Count	*128*
Z	*1.24325*
p-level	*21.37763%*
Gamma	***18.98734%***
Pearson Correlation Coefficient	*6.36936%*

Hypothesis 52 – Requirements Change during project execution correlates to time variance

Null Hypothesis H0 – Requirements Change during project execution does not correlate to time variance.

In this case Kendall's Tau = 0.33121, which is not close enough to 0.

Hence we can conclude that requirement change during project execution weakly correlate to the time variance. Therefore reject the null hypothesis.

Spearman R	***0.44947***
Rank Difference Squares Sum	*2,343.33333*
t-test value for hypothesis r = 0	*2.66250*
p-level	*1.27077%*
Kendall Tau	***0.33121***
Inversions Count	*92*
Z	*2.57050*
p-level	*1.01552%*
Gamma	***39.86928%***
Pearson Correlation Coefficient	*28.39888%*

Hypothesis 53 – Maturity level of Technology used correlates to time variance

Null Hypothesis H0 – Maturity level of Technology used does not correlate to time variance.

In this case Kendall's Tau = -0.06462, which is close enough to 0.
Hence we can conclude that maturity level of technology does not correlate to the time variance. Therefore accept the null hypothesis.

Spearman R	***-0.08792***
Rank Difference Squares Sum	*4,525.66667*
t-test value for hypothesis r = 0	*-0.46702*
p-level	*64.41018%*
Kendall Tau	***-0.06462***
Inversions Count	*154*
Z	*0.50150*
p-level	*61.60206%*
Gamma	***-8.07018%***
Pearson Correlation Coefficient	*-10.93567%*

Hypothesis 54 – Continuance of Technology throughout the project correlates to time variance

Null Hypothesis H0 – Continuance of Technology throughout the project does not correlate to time variance.

In this case Kendall's Tau = -0.00507, which is close enough to 0.
Hence we can conclude that continuance of technology throughout the project does not correlate to the time variance. Therefore accept the null hypothesis.

Spearman R	***-0.00015***
Rank Difference Squares Sum	*4,400.16667*
t-test value for hypothesis r = 0	*-0.00080*
p-level	*99.93658%*
Kendall Tau	***-0.00507***
Inversions Count	*177*
Z	*0.03933*
p-level	*96.86249%*
Gamma	***-0.56818%***
Pearson Correlation Coefficient	*2.26653%*

Hypothesis 55 – Technology Spread (popularity) correlates to time variance

Null Hypothesis H0 – Technology Spread does not correlate to time variance.

In this case Kendall's Tau = -0.11007, which is close enough to 0. Hence we can conclude that technology spread does not correlate to the time variance. Therefore accept the null hypothesis.

Spearman R	***-0.13801***
Rank Difference Squares Sum	*4,807.50000*
t-test value for hypothesis r = 0	*-0.73732*
p-level	*46.70593%*
Kendall Tau	***-0.11007***
Inversions Count	*167*
Z	*0.85423*
p-level	*39.29770%*
Gamma	***-13.60544%***
Pearson Correlation Coefficient	*-11.55032%*

Hypothesis 56 – Technology Progression Rate correlates to time variance

Null Hypothesis H0 – Technology Progression rate does not correlate to time variance.

In this case Kendall's Tau = 0.10454, which is close enough to 0. Hence we can conclude that technology progression rate does not correlate to the time variance. Therefore accept the null hypothesis.

Spearman R	***0.13395***
Rank Difference Squares Sum	*3,593.83333*
t-test value for hypothesis r = 0	*0.71527*
p-level	*48.03671%*
Kendall Tau	***0.10454***
Inversions Count	*122*
Z	*0.81132*
p-level	*41.71833%*
Gamma	***13.16726%***
Pearson Correlation Coefficient	*15.29985%*

Hypothesis 57 – Experience of Team members correlate to time variance

Null Hypothesis H0 – Experience of Team members does not correlate to time variance.

In this case Kendall's Tau = -0.27565, which is not close enough to 0. Hence we can conclude that experience of team members inversely correlate to the time variance. Therefore reject the null hypothesis.

Spearman R	***-0.35089***
Rank Difference Squares Sum	*5,607.50000*
t-test value for hypothesis r = 0	*-1.98284*
p-level	*5.72739%*
Kendall Tau	***-0.27565***
Inversions Count	*188*
Z	*2.13928*
p-level	*3.24129%*
Gamma	***-34.76703%***
Pearson Correlation Coefficient	*-38.76119%*

Hypothesis 58 – Personnel Continuity correlate to time variance

Null Hypothesis H0 – Personnel Continuity does not correlate to time variance.

Spearman R	***-0.26221***
Rank Difference Squares Sum	*5,256.33333*
t-test value for hypothesis r = 0	*-1.43781*
p-level	*16.15714%*
Kendall Tau	***-0.20638***
Inversions Count	*181*
Z	*1.60166*
p-level	*10.92302%*
Gamma	***-25.69444%***

In this case Kendall's Tau = -0.20638, which is not close enough to 0.

Pearson Correlation Coefficient	-30.64003%

Hence we can conclude that personnel continuity throughout the project has a weak inverse correlation to the time variance. Therefore reject the null hypothesis.

Hypothesis 59 – Focus of the Team members on the project correlate to Time variance.

Null Hypothesis H0 – Focus of the Team members on the project does not correlate to time variance.

In this case Kendall's Tau = 0.03100, which is close enough to 0.
Hence we can conclude that focus of the team members on the project does not correlate to the time variance. Therefore accept the null hypothesis.

Spearman R	***0.03987***
Rank Difference Squares Sum	*4,191.50000*
t-test value for hypothesis r = 0	*0.21116*
p-level	*83.42889%*
Kendall Tau	***0.03100***
Inversions Count	*164*
Z	*0.24056*
p-level	*80.98964%*
Gamma	***3.52941%***
Pearson Correlation Coefficient	*-3.90619%*

Hypothesis 60 – Team Size correlate to Time variance.

Null Hypothesis H0 – Team size does not correlate to time variance.

In this case Kendall's Tau = 0.14789, which is close enough to 0.
Hence we can conclude that team size does not correlate to the time variance. Therefore accept the null hypothesis.

Spearman R	***0.20485***
Rank Difference Squares Sum	*3,429.83333*
t-test value for hypothesis r = 0	*1.10746*
p-level	*27.75184%*
Kendall Tau	***0.14789***
Inversions Count	*134*
Z	*1.14776*
p-level	*25.10656%*
Gamma	***17.28395%***
Pearson Correlation Coefficient	*5.13156%*

Hypothesis 61 – **Executive Pressure on Time/Time Estimates correlate to Time variance.**

Null Hypothesis H0 – **Executive Pressure on Time/Cost Estimates does not correlate to time variance.**

In this case Kendall's Tau = 0.02347, which is close enough to 0. Hence we can conclude that executive pressure on time/cost estimates does not correlate to the time variance. Therefore accept the null hypothesis.

Spearman R	***0.03837***
Rank Difference Squares Sum	*4,195.66667*
t-test value for hypothesis r = 0	*0.20318*
p-level	*84.04629%*
Kendall Tau	***0.02347***
Inversions Count	*163*
Z	*0.18215*
p-level	*85.54683%*
Gamma	***2.68657%***
Pearson Correlation Coefficient	*-12.75580%*

Hypothesis 62 – **Business Complexity correlate to Time variance.**

Null Hypothesis H0 – **Business Complexity does not correlate to time variance.**

Spearman R	***0.36033***
Rank Difference Squares Sum	*2,739.66667*
t-test value for hypothesis r = 0	*2.04399*
p-level	*5.04634%*
Kendall Tau	***0.33968***
Inversions Count	*93*

Z	*2.63617*
p-level	*0.83847%*
Gamma	***40.38462%***
Pearson Correlation Coefficient	*14.57232%*

In this case Kendall's Tau = 0.33968, which is not close enough to 0. Hence we can conclude that business complexity does correlate to the time variance. Therefore reject the null hypothesis.

Hypothesis 63 – Business Geographical Spread correlate to Time variance.

Null Hypothesis H0 – Business Geographical Spread does not correlate to time variance.

In this case Kendall's Tau = 0.20553, which is not close enough to 0. Hence we can conclude that Business Geographical Spread has a weak correlation to the time variance. Therefore reject the null hypothesis.

Spearman R	***0.25223***
Rank Difference Squares Sum	*3,254.50000*
t-test value for hypothesis r = 0	*1.37925*
p-level	*17.87351%*
Kendall Tau	***0.20553***
Inversions Count	*128*
Z	*1.59509*
p-level	*11.06928%*
Gamma	***23.58209%***
Pearson Correlation Coefficient	*28.99602%*

Hypothesis 64 – Project Structure correlate to Time variance.

Null Hypothesis H0 – Project Structure does not correlate to time variance.

Spearman R	***-0.00853***

In this case Kendall's Tau = -0.00257, which is close enough to 0.
Hence we can conclude that project structure does not correlate to the time variance. Therefore accept the null hypothesis.

Rank Difference Squares Sum	*4,414.83333*
t-test value for hypothesis r = 0	*-0.04515*
p-level	*96.43120%*
Kendall Tau	***-0.00257***
Inversions Count	*172*
Z	*0.01996*
p-level	*98.40741%*
Gamma	***-0.29155%***
Pearson Correlation Coefficient	*-25.32222%*

Hypothesis 65 – Task inter-dependence correlate to Time variance.

Null Hypothesis H0 – Task inter-dependence does not correlate to time variance.

In this case Kendall's Tau =0.21583, which is not close enough to 0.
Hence we can conclude that task inter-dependence weakly correlate to the time variance. Therefore reject the null hypothesis.

Spearman R	***0.29699***
Rank Difference Squares Sum	*2,636.66667*
t-test value for hypothesis r = 0	*1.64576*
p-level	*11.09945%*
Kendall Tau	***0.21583***
Inversions Count	*71*
Z	*1.67501*
p-level	*9.39325%*
Gamma	***31.73077%***
Pearson Correlation Coefficient	*9.45253%*

Hypothesis 66 – Resource doubling influence on timeline correlate to Time variance.

Null Hypothesis H0 – Resource doubling influence on timeline

does not correlate to time variance.

In this case Kendall's Tau =0.13289, which is close enough to 0.
Hence we can conclude that resource doubling influence on timeline does not correlate to the time variance.
Therefore accept the null hypothesis.

Spearman R	***0.18940***
Rank Difference Squares Sum	*3,433.16667*
t-test value for hypothesis r = 0	*1.02068*
p-level	*31.61465%*
Kendall Tau	***0.13289***
Inversions Count	*124*
Z	*1.03130*
p-level	*30.23982%*
Gamma	***16.21622%***
Pearson Correlation Coefficient	*6.40147%*

Hypothesis 67 – Progress Monitoring Frequency correlate to Time variance.

Null Hypothesis H0 – Progress Monitoring Frequency does not correlate to time variance.

In this case Kendall's Tau =-0.04368, which is close enough to 0.
Hence we can conclude that progress monitoring frequency does not correlate to the time variance. Therefore accept the null hypothesis.

Spearman R	***-0.06575***
Rank Difference Squares Sum	*3,986.83333*
t-test value for hypothesis r = 0	*-0.34866*
p-level	*72.99511%*
Kendall Tau	***-0.04368***
Inversions Count	*104*
Z	*0.33899*
p-level	*73.46185%*
Gamma	***-6.66667%***
Pearson Correlation Coefficient	*-17.96741%*

Hypothesis 68 – Priority increase of Project during execution correlate to Time variance.

Null Hypothesis H0 – Priority increase of project during execution

does not correlate to time variance.

In this case Kendall's Tau =-0.23262, which is not close enough to 0.
Hence we can conclude that priority increase of project during execution has a weak inverse correlation to the time variance. Therefore reject the null hypothesis.

Spearman R	***-0.29601***
Rank Difference Squares Sum	*5,627.16667*
t-test value for hypothesis r = 0	*-1.63982*
p-level	*11.22312%*
Kendall Tau	***-0.23262***
Inversions Count	*210*
Z	*1.80536*
p-level	*7.10181%*
Gamma	***-26.88822%***
Pearson Correlation Coefficient	*-32.37656%*

Hypothesis 69 – Defects in Product Definition correlate to Time variance.

Null Hypothesis H0 – Defects in Product definition does not correlate to time variance.

In this case Kendall's Tau =0.16682, which is close enough to 0.
Hence we can conclude that defects in product definition do not correlate to the time variance. Therefore accept the null hypothesis.

Spearman R	***0.22674***
Rank Difference Squares Sum	*3,330.16667*
t-test value for hypothesis r = 0	*1.23189*
p-level	*22.82345%*
Kendall Tau	***0.16682***
Inversions Count	*126*
Z	*1.29469*
p-level	*19.54283%*
Gamma	***19.74522%***
Pearson Correlation Coefficient	*13.13734%*

Hypothesis 70 – Defects in Product Build correlate to Time variance.

Null Hypothesis H0 – Defects in Product Build does not correlate to time variance.

Spearman R	***0.15113***

Rank Difference Squares Sum	3,588.16667
t-test value for hypothesis r = 0	0.80899
p-level	42.53415%
Kendall Tau	**0.10385**
Inversions Count	125
Z	0.80593
p-level	42.02825%
Gamma	**12.89199%**
Pearson Correlation Coefficient	-0.65610%

In this case Kendall's Tau = 0.10385, which is not close enough to 0. Hence we can conclude that Defects in Product Build does not correlate to the time variance. Therefore accept the null hypothesis.

Hypothesis 71 – Defects in Product Design Alignment to User Requirements correlate to time variance.

Null Hypothesis H0 – Defects in Product Design Alignment to User Requirements does not correlate to time variance.

In this case Kendall's Tau = 0.23504, which is not close enough to 0. Hence we can conclude that defects in Design Alignment to User requirements have a weak correlation to the time variance. Therefore reject the null hypothesis.

Spearman R	**0.27564**
Rank Difference Squares Sum	3,020.83333
t-test value for hypothesis r = 0	1.51733
p-level	14.03944%
Kendall Tau	**0.23504**
Inversions Count	98
Z	1.82412
p-level	6.81335%
Gamma	**29.74910%**
Pearson Correlation Coefficient	3.68372%

Hypothesis 72 – Defects in Quality Control correlate to time variance.

Null Hypothesis H0 – Defects in Quality Control does not correlate to Time variance.

In this case Kendall's Tau = -0.03787, which is close enough to 0.
Hence we can conclude that defects in Quality Control do not have correlation to the time variance. Therefore reject the null hypothesis.

Spearman R	***-0.03613***
Rank Difference Squares Sum	*4,140.83333*
t-test value for hypothesis r = 0	*-0.19132*
p-level	*84.96569%*
Kendall Tau	***-0.03787***
Inversions Count	*138*
Z	*0.29393*
p-level	*76.88118%*
Gamma	***-4.94297%***
Pearson Correlation Coefficient	*-24.81691%*

4.2.5 Sub problem 4: How adequate is the Risk Profile for IT projects?

Hypothesis 73 – Risk profile correlate to Product Complexity.
Null Hypothesis H0 – Risk profile does not correlate to Product Complexity.

In this case Kendall's Tau = 0.10920, which is close enough to 0.
Hence we can conclude that Risk Profile does not correlate to Product Complexity.
Therefore reject the null hypothesis.

Spearman R	***0.22732***
Rank Difference Squares Sum	*2,901.66667*
t-test value for hypothesis r = 0	*1.23520*
p-level	*22.70201%*
Kendall Tau	***0.10920***
Inversions Count	*25*
Z	*0.84745*
p-level	*39.67439%*
Gamma	***37.50000%***
Pearson Correlation Coefficient	*25.38923%*

Hypothesis 74 – Risk profile correlate to Product Significance.
Null Hypothesis H0 – Risk profile does not correlate to Product Significance.

In this case Kendall's Tau = 0.14489, which is close enough to 0.
Hence we can conclude that Risk Profile does not correlate to Product Complexity.
Therefore accept the null hypothesis.

Spearman R	***0.06767***
Rank Difference Squares Sum	*3,403.83333*
t-test value for hypothesis r = 0	*0.35893*
p-level	*72.23435%*
Kendall Tau	***0.14489***
Inversions Count	*17*
Z	*1.12444*
p-level	*26.08266%*
Gamma	***55.26316%***
Pearson Correlation Coefficient	*28.78570%*

Hypothesis 75 – Risk profile correlate to Product Budget.

Null Hypothesis H0 – Risk profile does not correlate to Product Budget.

In this case Kendall's Tau = 0.08943, which is close enough to 0.
Hence we can conclude that Risk Profile does not correlate to Product Budget.
Therefore accept the null hypothesis.

Spearman R	***0.00410***
Rank Difference Squares Sum	*3,701.83333*
t-test value for hypothesis r = 0	*0.02170*
p-level	*98.28423%*
Kendall Tau	***0.08943***
Inversions Count	*27*
Z	*0.69407*
p-level	*48.76402%*
Gamma	***31.64557%***
Pearson Correlation Coefficient	*17.90879%*

Hypothesis 76 – Risk profile correlate to Technological Risk.

Null Hypothesis H0 – Risk profile does not correlate to Technological Risk.

Spearman R	***0.09222***
Rank Difference Squares Sum	*3,256.50000*
t-test value for hypothesis r = 0	*0.49005*

In this case Kendall's Tau = 0.06028, which is close enough to 0.
Hence we can conclude that Risk Profile does not correlate to Technological Risk.
Therefore accept the null hypothesis.

p-level	*62.79176%*
Kendall Tau	***0.06028***
Inversions Count	*26*
Z	*0.46786*
p-level	*63.98845%*
Gamma	***25.71429%***
Pearson Correlation Coefficient	*4.79210%*

Hypothesis 77 – Risk profile correlate to Resource Risk.

Null Hypothesis H0 – Risk profile does not correlate to Resource Risk.

In this case Kendall's Tau = 0.07450, which is close enough to 0.
Hence we can conclude that Risk Profile does not correlate to Resource Risk.
Therefore accept the null hypothesis.

Spearman R	***0.05206***
Rank Difference Squares Sum	*3,279.00000*
t-test value for hypothesis r = 0	*0.27588*
p-level	*78.46691%*
Kendall Tau	***0.07450***
Inversions Count	*19*
Z	*0.57820*
p-level	*56.31281%*
Gamma	***37.70492%***
Pearson Correlation Coefficient	*9.09091%*

Hypothesis 78 – Risk profile correlate to Business Risk.

Null Hypothesis H0 – Risk profile does not correlate to Business Risk.

In this case Kendall's Tau = 0.03492, which is close enough to 0.
Hence we can conclude that Risk Profile does not correlate to Business Risk.
Therefore accept the null hypothesis.

Spearman R	***0.03896***
Rank Difference Squares Sum	*3,214.66667*
t-test value for hypothesis r = 0	*0.20633*
p-level	*83.80239%*
Kendall Tau	***0.03492***
Inversions Count	*29*
Z	*0.27098*
p-level	*78.64067%*
Gamma	***15.94203%***
Pearson Correlation Coefficient	*0.88637%*

Chapter 5: Discussion, Conclusions And Recommendations

Introduction

In this chapter, the analysis of research findings forming basis for the proposed improvements to NPV approximation for IT projects is included. Improvements to the current methodology as well as a changed mindset towards quantification of IT value is proposed. A practical process making financial sense yet is simple enough to be implemented in any organization is suggested towards the end.

The researcher would like to refer back to the research problem forming context to this chapter. The objective was to improve accuracy of inputs to the NPV equation.

$$\mathrm{NPV} = \sum_{t=1}^{T} \frac{C_t}{(1+r)^t} - C_0$$

NPV could be written as a function of: v = Value; c = Cost; t = Time and r = Risk.

$$NPV = f(v, c, t, r)$$

Hence the NPV approximation problem could be written as,

$$NPV \approx f(v + \delta v, c + \delta c, t + \delta t, r + \delta r)$$

$$when \quad \delta v \xrightarrow{\lim} 0; \quad \delta c \xrightarrow{\lim} 0; \quad \delta t \xrightarrow{\lim} 0; \quad \delta r \xrightarrow{\lim} 0.$$

5.1 Value Approximation ($\delta v \xrightarrow{\lim} 0$)

Benefits of IT is often considered intangible, thus most benefits gets excluded from financial equations. This is a major gap in NPV calculations. Intention of this research was to find practical guidelines and a framework for valuing IT benefits. The researcher sought a resolution for this issue using AIE and BSC. Although AIE is a project focused measurement exercise, a generalized approach is taken for the purposes of this research. Following templates derived from interview responses provide guidelines for application for a practical situation. The templates are grouped under four BSC perspectives namely,

	Unit of Measurement	Minimum value per Unit	No of units per month at 90% confidence	Max Value per unit	No of units per month at 90% confidence	Minimum Value	Maximum Value

1. Financial Perspective
2. Customer Perspective
3. Internal Process Perspective
4. Learning and Growth Perspective.

Financial Perspective	Increase in Revenue (sales)	new account, sale, service appointment created by the system						
	Increase in Revenue (sales)	repeat /additional account, sale, service appointment by the systems						
	Increase in Revenue (sales)	new account, sale, service appointment						
	Increase in Efficiency (more with less) – Systems	additional customer served by new system (infrastructure capacity improvement)						
	Increase in efficiency (more with less) – People	additional customer served by existing staff using the new system (people capacity improvement)						

Table 25 Template for Financial Metrics

		Unit of Measurement	Minimum value per Unit	No of units per month at 90% confidence	Max Value per unit	No of units per month at 90% confidence	Minimum Value	Maximum Value
Customer Perspective	Number of complaints received per month	Staff Time/Cost to Resolve the complaint with the new system						
	Number of complaints received per month	Loss of customer due to time and inconvenience due to delays in resolving the complaint with current system (branch)						
	Percentage of customers that repeat business	new accounts						
	Percentage of customers that repeat business	new services used						
	Percentage of customers that repeat business	new customers gained						

Table 26 Template for Customer Perspective Metrics

		Unit of Measurement	Minimum value per Unit	No of units per month at 90% confidence	Max Value per unit	No of units per month at 90% confidence	Minimum Value	Maximum Value
Internal Process Perspective	Reduced cost of servicing customers at branch	Cost reduction per engagement						
	Less volumes at branch	Additional capacity created(cost per session)						
	Reduced Downtime	Average cost of downtime per minute						
	Reduced Rework	cost per unit per rework						
	Decrease in cycle times;	cost per minute times saved time						
	Maintenance expenses	Average maintenance cost per month times % reduction						
	more service with less bodies	cost per body times number of bodies reduced						
	Decreased time to make certain decisions	loss of interest per day; average % deals lost in the past month						
	Revenue per employee	total income / new head count						
	Reduced Paperwork	cost per print times number of prints reduced						

Table 27 Template for Internal Process Metrics

		Unit of Measurement	Minimum value per Unit	No of units per month at 90% confidence	Max Value per unit	No of units per month at 90% confidence	Minimum Value	Maximum Value
Learning and Growth Perspective	Decreased employees turnover	Cost to hire						
	Decreased employees turnover	Cost to train						
	Employee Attraction	Cost to hire						
	Decreased supervisory overhead	supervisory overhead						
	New products introduced	profit per product						
	Number of patents	profit per patent						
	Number of employee suggestions	value per suggestion						
	Handling more complex queries	supervisory overhead						

Table 28 Template for Learning and Growth Metrics

The researcher made a conscious effort to generalize templates. Therefore in order to find project specific values, a series of workshops need to be held involving subject matter experts (SMEs). Inputs from these workshops need to be improved using statistical techniques such as Monte Carlo simulations for calibration and improvement prior to application.

5.2 *Cost and Time Approximation* ($\delta c \xrightarrow{\lim} 0; \delta t \xrightarrow{\lim} 0$)

Research findings provided insights to the current situation in this context. The researcher sees two aspects to this problem in the reverse order of occurrence.

1. Minimizing Variances from Estimates.
2. Improving Estimation Accuracy.

5.2.1 Minimizing Variances from Estimates

In search of causes for the widespread problem of IT cost variance, data was collected on every conceivable aspect of projects and were analyzed for possible correlations. The result was a useful insight into the impact of organizational factors on time and cost variance in contrast to the popular belief on estimation inaccuracies. All projects considered used expert judgment for estimations. This represented the South African situation. The variance between estimations at conception and completion observed was 60% which was within observations found in the literature. The impact of environmental pressures on quality of delivery was featured heavily in the findings.

Contributing factors for Cost Variance

In this research, correlation between cost variance and various project characteristics were analyzed. Research findings are summarized in the table below.

	Kendall's Tau	Degree of Correlation
Defect Index during Build	*0.47850*	*Strong correlation*
Technology Continuity	*-0.24179*	*weak inverse correlation*
Personnel Continuity	*-0.27203*	*weak inverse correlation*
Requirements Change During Project	*0.36096*	*Weak correlation*
Business Geography	*0.22881*	*Weak correlation*
Defect index at Solution Alignment	*0.37597*	*Weak correlation*
Defect Index in Production	*0.22865*	*Weak correlation*
Project Complexity	*0.01586*	*insignificant*
Project Significance	*-0.07111*	*insignificant*
Project Budget	*-0.12915*	*Insignificant*
Technology Maturity	*0.00840*	*Insignificant*
Technology Spread	*-0.06956*	*Insignificant*
Technology Progression Rate	*-0.05085*	*Insignificant*
Experience of Team Members	*-0.17748*	*Insignificant*
Personnel Focus	*-0.04120*	*Insignificant*
Team Size	*-0.09715*	*Insignificant*
Executive Pressure	*0.02859*	*Insignificant*
Business Complexity	*0.12126*	*Insignificant*
Project Structure	*-0.10281*	*Insignificant*
Activity Interdependence	*0.04911*	*Insignificant*
Resource Doubling Impact	*0.09633*	*Insignificant*
Progress Monitoring Frequency	*-0.02692*	*Insignificant*
Increase in Priority	*-0.00525*	*Insignificant*
Defect Index at Definition	*0.15783*	*Insignificant*

Table 29 Cost Variance Correlation Summary

Defects in quality during various stages are seen as one of the main contributors for cost variance. Other factors include changes in Technology, Resources and Scope as well as geographical complexity of the business.

Factors Influencing Quality.

In order for projects to maintain low levels of defects, it is important to maintain high level of quality standards. In the analysis, the researcher found the following.

	Kendall's Tau	Degree of Correlation
Project Complexity	*0.52861*	*strong correlation*
Requirements Change During Project	*0.52608*	*strong correlation*
Personnel Continuity	*-0.25557*	*weak inverse Correlation*
Executive Pressure	*0.28464*	*weak correlation*
Experience of Team Members	*-0.00893*	*Insignificant*
Personnel Focus	*0.03633*	*Insignificant*

Table 30 Variable impact for Defects at Product Definition

Project Complexity, Requirement Changes, Personnel Continuity and Executive Pressure on time/cost estimates are seen as a contributor for poor quality at project definition (initiation) stage.

	Kendall's Tau	Degree of Correlation
Requirements Change During Project	*0.27505*	*weak correlation*
Executive Pressure	*0.34125*	*weak correlation*
Project Complexity	*0.10417*	*Insignificant*
Experience of Team Members	*0.06168*	*Insignificant*
Personnel Continuity	*-0.17725*	*Insignificant*
Personnel Focus	*0.10344*	*Insignificant*

Table 31 Variable impact for defects during Software development

	Kendall's Tau	Degree of Correlation
Requirements Change During Project	*0.23771*	*weak correlation*
Executive Pressure	*0.37023*	*weak correlation*
Project Complexity	*0.07951*	*Insignificant*
Experience of Team Members	*0.11337*	*Insignificant*
Personnel Continuity	*0.00000*	*Insignificant*
Personnel Focus	*0.10161*	*Insignificant*

Table 32 Variable impact on defects at Solution Alignment

Requirement Changes and Executive Pressure on time/cost estimates is seen as a contributor for poor quality during development and solutions alignment review stages.

	Kendall's Tau	Degree of Correlation
Project Complexity	*0.20962*	*weak correlation*
Requirements Change During Project	*0.36496*	*weak correlation*
Executive Pressure	*0.20874*	*weak correlation*
Experience of Team Members	*0.15657*	*Insignificant*
Personnel Continuity	*-0.08273*	*Insignificant*
Personnel Focus	*0.15629*	*Insignificant*

Table 33 Variable impact on defects at Quality Control

Project Complexity, Requirement Changes and Executive Pressure on time/cost estimates are seen as a contributor for poor quality at the Quality Control prior to deployment.

Requirement Changes and Executive Pressure on time/cost estimates is seen as a contributor for poor quality at the product specification stage. According to the research findings, the most influential factors for cost variance is defects, and changes. Executive pressure on time cost estimates correlates with defect index. The researcher sees these are more behavioral issues caused by lack of project management maturity in organizations. The researcher also found influence of environment such as business complexity and geography.

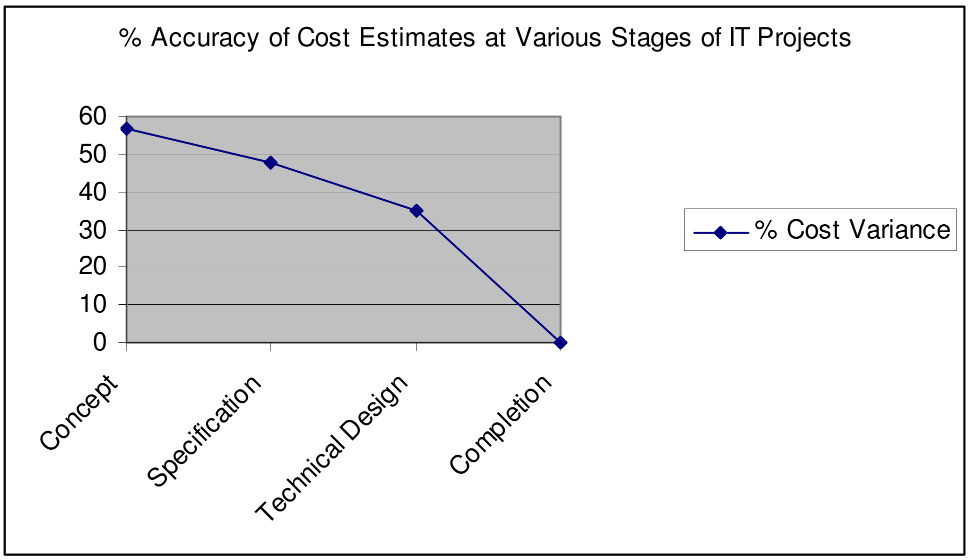

Figure 9 Estimation Accuracy at Various Stages of an IT project

Accuracy of estimates at various stages of the project agrees with (Boehm *et al*, 1998) studies on estimation accuracy and granularity of information available. Above graph was plotted using research results.

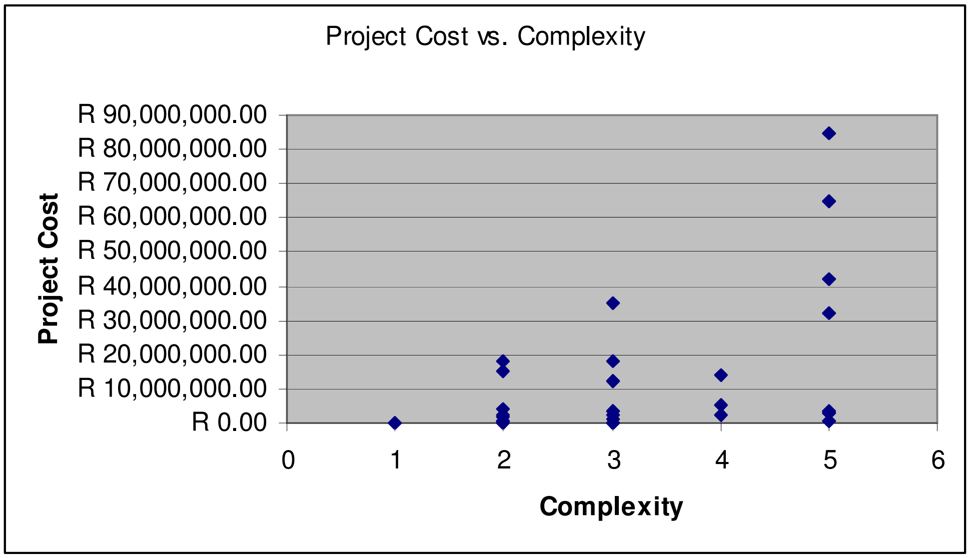

Figure 10 Correlations between Project Cost and Complexity

Researcher also noticed a non linear relationship between project cost and the complexity of the product. This shows the cost of technology and non-linear reuse effect (Selby, 1988). It also gives insights into the use of appropriate technology and leads to the debate on adequacy vs. speculation.

Time Estimate Approximation

	Kendall's Tau	Degree of Correlation
Experience of Team Members	*-0.27565*	weak inverse correlation
Personnel Continuity	*-0.20638*	weak inverse correlation
Increase in Priority	*-0.23262*	weak inverse correlation
Requirements Change During Project	*0.33121*	weak correlation
Business Complexity	*0.33968*	weak correlation
Business Geography	*0.20553*	weak correlation
Activity Inter-dependence	*0.21583*	weak correlation
Defect index at Solution Alignment	*0.23504*	weak correlation
Project Complexity	*0.03457*	Insignificant
Project Significance	*-0.18208*	Insignificant
Project Budget	*0.16019*	Insignificant
Technology Maturity	*-0.06462*	Insignificant
Technology Continuity	*-0.00507*	Insignificant
Technology Spread	*-0.11007*	Insignificant
Technology Progression Rate	*0.10454*	Insignificant
Personnel Focus	*0.03100*	Insignificant
Team Size	*0.14789*	Insignificant
Executive Pressure	*0.02347*	Insignificant
Project Structure	*-0.00257*	Insignificant
Resource Doubling Impact	*0.13289*	Insignificant
Progress Monitoring Frequency	*-0.04368*	Insignificant
Defect Index at Definition	*0.16682*	Insignificant
Defect Index during Build	*0.10385*	Insignificant
Defect Index in Production	*-0.03787*	Insignificant

Table 34 Variable Correlation on Time Estimate Variance

The researcher has found time variances correlating with Experience of the Team members, Changes in Personnel, Requirements, Activity inter-dependence, Business Complexity, Business Geography as well as Solution Alignment defects.

In contrast to departing impressions, the researcher found that the bulk of the factors influencing IT cost estimation discrepancies were related to project execution. Executive interference on time and cost estimations had a strong correlation to defect index, which in turn had a strong correlation to time and cost variances. This is caused by lack of autonomy for projects.

The Explosion Effect

The researcher would like to introduce the term “Explosion Effect” on projects to describe phenomena analogous to system destruction due to excessive pressure. Effect of destruction on IT projects could be seen in terms of poor quality, extension of timelines and budgets as well as exodus of people from organizations. Movement of people did also show an inverse correlation to cost and time variances.

5.2.2 Improving Current Time Cost Estimation methods

The researcher observed a trend where time/cost estimations are impacted by project factors. Excluding such projects which were severely impacted by quality and unforeseen environmental factors such as executive pressure, resource continuity etc., following sample was extracted for building a generic model.

By observation, the researcher eliminated some results and managed to find a relationship between cost variance and factors considered. By using multipliers the researcher created a scoring mechanism which was used to predict cost and time estimates.

Variable Analysis Table																			
Cost Variance	Score	Product Complexity	Product Significance	Product Budget	Technology Maturity	Technology Spread	Technology Progression	Resource Experience	Resource Focus	Resource Count	Business Complexity	Business Geography	Team Structure	Activity Interdependence	Resource Doubling Impact	Monitoring Frequency	Technological Risk	Resource Risk	Business Risk
		PC	PS	PB				RX		RC	BC						TR		
0.00	12.00	3	5	5	2	3	5	3	4	2	2	3	2	3	2	4	2	3	1
5.00	7.00	2	3	4	3	3	5	5	3	3	2	1	3	3	3	4	2	2	1
11.28	12.00	3	3	4	4	5	4	4	4	3	4	2	3	2	4	4	1	2	1
16.00	8.00	3	3	2	4	4	4	4	1	2	3	1	3	3	3	4	1	2	1
16.67	17.00	4	4	5	4	5	5	3	5	4	4	4	5	3	2	5	1	4	5
16.67	14.00	4	4	4	2	3	5	3	5	2	5	1	5	2	2	4	2	2	3
20.00	3.00	1	3	1	3	4	1	3	1	2	1	2	1	2	5	4	2	3	1
22.22	9.00	2	3	2	2	4	5	2	2	3	4	3	3	4	3	4	3	3	4
28.00	20.00	5	5	5	4	5	4	3	5	5	4	2	5	3	3	5	1	2	1
30.00	10.00	2	5	2	4	5	4	3	2	3	2	2	2	3	3	4	1	2	1
60.71	9.00	2	3	4	4	4	5	4	2	2	4	5	2	3	3	4	2	2	1
Multiplier		1	1	1	0	0	0	-1	0	1	1	0	0	0	0	0	-1	0	0

Table 35 Variable Analysis

Using the above table, the researcher built the scoring formula,

Score = PC + PS + PB – RX + RC + BC - TR

Parameter	Values
Product (Project) Complexity	1- total of less than 5 interfaces (reports, screens, files)
	2 – total of less than 10 interfaces (reports, screens, files)
	3- total of less than 25 interfaces (reports, screens, files)
	4- total of less than 50 interfaces (reports, screens, files)
	5- total of more than 50 interfaces (reports, screens, files)
Product Significance	1- Undecided
	2- Nice to have
	3- Operational necessity
	4- Driven by a strategic decision
	5- Industry Compliance
Product Budget	1- Less than R 250K
	2- Less than R 750K
	3- Less than R 1.2M
	4- Less than R 10M
	5- Over R10M
Resource Experience	1- Majority of the members new for Technology; New for Environment
	2- Majority of the members new for Technology; Experienced in the environment
	3- Majority of the members experienced in the Technology; New for Environment
	4- Majority of the members experienced in the environment; experienced in technology.
	5- Majority of the members experienced in Technology; Experienced in the Environment; Has worked with most team members before.
Resource Count	1- less than 5 members
	2 – less than 10 members
	3 – less than 25 members
	4 – less than 50 members
	5- more than 50 members
Business Complexity	1- Less than 5 business rules; Well documented.
	2- Less than 20 business rules well documented.
	3- less than 20 business rules partly documented.
	4- more than 20 business rules partly documented
	5- No clear business rules. Project team has to find out.
Technological Risk	1- Established technology in the organization.
	2- Established technology but new in organization.
	3- Used first time in the country.
	4- Among the first 10 projects in the world.
	5- Evidence of unsuccessful implementations in many other organizations.

Table 36 Parameter Values for Project Scoring

The researcher applied the above formulae in to the whole sample and obtained approximate cost forecasts as follows

Cost Prediction Accuracy	Sample Count	Observed Issues
Below 1%	2	
Between 1% to 5%	3	
Between 5% to 10%	8	Low Technological Continuity, High level of defects at each stage
Between 10% to 20%	4	Low Technological Continuity, High level of defects at each stage
Between 20% to 30%	6	High degree of Requirements Changes, Low Technological Continuity, High level of defects at each stage
Over 30%	7	High degree of Requirements Changes, Low Technological Continuity, High level of defects at each stage
Total	30	

Table 37 Prediction Accuracy of Developed Formula

5.3 Risk Approximation ($\delta r \xrightarrow{\lim} 0$)

	Risk Profile	Degree of Correlation
Project Complexity	*0.10920*	*Insignificant*
Project Significance	*0.14489*	*Insignificant*
Project Budget	*0.08943*	*Insignificant*
Technology Risk	*0.06028*	*Insignificant*
Resource Risk	*0.07450*	*Insignificant*
Business Risk	*0.03492*	*Insignificant*

Table 38 Risk Profile Correlations

The researcher found a lack of correlation between risk consideration and various risk elements in the NPV calculation. Most projects only use cost of capital in the process. The researcher would like to emphasize the existence of the difference to the success of projects bearing different levels of technological, resource and business risks. Investment appraisal of which is incomplete without due focus on appropriate risk assignment, as proven by this study.

5.4 Recommendations

1. The author sees the need for addition steps as per figure 11 below, in the current software Development Life Cycle (SDLC) model. Cost allocation needs to be redistributed accordingly as per the diagram.

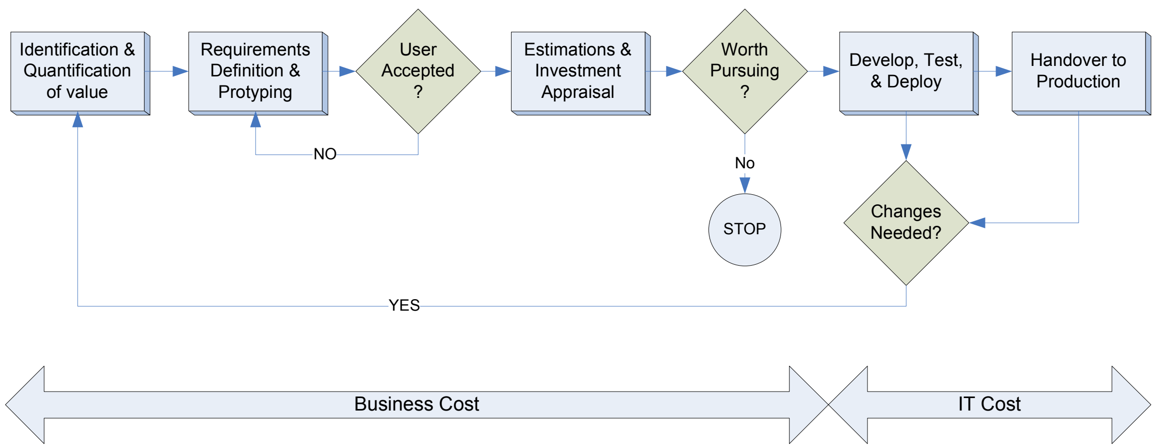

Figure 11 A Modified SDLC Model

2. Elaborating further on previous point, the researcher believes the need for an initial time and cost allocation is for requirements definition and prototyping. This cost should not be assigned to IT as this effort is spent in the match making process between business requirements and the IT solution. Enablers of this process include prototyping tools and concepts such as Service Oriented Architecture (SOA). This would help to reduce number of defects.

3. Impact of quality on maintenance cost needs more focus as this impacts net value during operation, C_t as well as Initial Cost C_0.

4. The researcher found a lack of correlation between risk consideration and various risk elements impacting projects. Most projects only use cost of capital in the process. Proper risk considerations should be performed to incorporate all risks into discount rate to get a realistic NPV.

5. Development of understanding on project management principles by all senior management and develop an appreciation for project autonomy, thus improving project management maturity in the organization.

6. Realistic time and cost estimation approach rather than target driven or bonus linked approach to project delivery creates unrealistic expectations, with long term consequences in terms of quality.

7. Appreciation of software development as a creative process is required. A production line approach should not be employed for software projects. However, this situation could be improved by establishing an overall architecture for the organization, providing a framework. This again needs constant improvements to provide innovative solutions in novel situations.

8. Importance of retaining key IT resources as they hold key to efficient systems against unrealistic expectation of transparency in knowledge management and handover. As IT knowledge of a business is a multi dimensional equation, it is easy to miss few important variables.

9. Creation of a culture of metrics to IT value. If the benefit is unquantifiable, it cannot be managed.

5.5 Future Research

The researcher observes the need for more studies in IT value quantification, as the knowledge base is narrow in this field. The researcher could only find one practical methodology which is AIE and very few frameworks for analysis including BSC.

5.6 Conclusion

Investment appraisal of projects involving Information Technology (IT) is a leadership challenge in organizations. The intention of this research was to fill the gap on investment appraisal for business projects involving IT, providing a solution for the above problem by better application net present value (NPV) method.

Lack of understanding and appreciation for software development is a creative process is also seen to impact cost and time estimate variance. Production line approach for software development using pressure to get more output from resources is seen to impact quality, causing an explosion effect. This is evident from the insignificant correlation between resource doubling impact and time cost variances. Although the production line approach might work for routine efficiency improvement projects, it does not suit projects where innovation is needed. Majority of modern IT projects are of the latter category hence the impact is significant.

The researcher also found inadequate risk profile consideration for IT projects where only the cost of capital is used in most cases. This distorts NPV output giving a false sense of security.

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Appendix A: Research Questions

Appendix A.1 – Questionnaire for Value Quantification

<u>IT Value Quantification - Interview questions</u>

An appointment was made with each interviewee, with a minimum of 45 minutes being allocated to each interview. Following is a list of the interview questions, which were used in an unstructured interview format. These questions were used as a guide only and the discussions progressed into free-form conversations about the topic.

IT Value Quantification

Qualitative interview with business users (sponsors) will be conducted to get these information and metrics. Metrics where there are no financial measures will be evaluated using AIE.

How do you measure IT value added from these dimensions
Financial Perspective

Are we meeting the expectations of our share holders?

1. Which of these measures you think relevant for measuring financial perspective?
   a. earnings,
   b. Cost Savings
   c. Increase in revenue,
   d. Increased throughput(more with less)
   e. sales volume,
   f. level of debt,
   g. inventory turnover
   h. returns on equity.
   i. Other (specify)
2. How do you think we can measure these?
3. How can we link the measurement to financial terms?

4. How confident are you with these claims? (Best case, Worst Case estimates)

Customer Perspective

Are we delighting(or at least satisfying) our customers?

5. Which of these measures you think relevant for measuring customer perspective?
    a. Increased market share
    b. customer satisfaction based on prices, value and quality of products.
    c. Sales volume.
    d. Growth in customer base.
    e. Other (Specify)
6. How do you think we can measure these?
7. How can we link the measurement to financial terms?
8. How confident are you with these claims? (Best case, Worst Case estimates)

Internal process perspective

Are we doing the right things and doing things right?

9. Which of these measures you think relevant for measuring Internal process perspective?
    a. Increase in market share for new products;
    b. Decrease in cycle times;
    c. Decrease in inventory levels; and
    d. Increase in customer satisfaction based on customer satisfaction with quality of product, time of delivery and after-sale service.
    e. Other(specify)

10. How do you think we can measure these?
11. How can we link the measurement to financial terms?

12. How confident are you with these claims? (Best case, Worst Case estimates)

Learning and Growth Perspective

Are we prepared for the future?

13. Which of these measures you think relevant for measuring Internal process perspective?
    a. Employee satisfaction based on a survey of leadership opportunities and level of motivation;
    b. Employee turnover;
    c. Revenue,
    d. Sales volume,
    e. Decrease in cost to income ratio,
    f. Other (specify)
14. How do you think we can measure these?
15. How can we link the measurement to financial terms?
16. How confident are you with these claims? (Best case, Worst Case estimates)

Any other Perspective you can think of

17. What tools do you currently use for IT investment appraisal?
18. Are you happy with the outcome?
19. Do you periodically monitor benefits after project implementation?
20. Any other comments?

Appendix A.2 – Questionnaire for Estimation Variances

An appointment was made with each interviewee, with a minimum of 45 minutes being allocated to each interview. Following is a list of the interview questions, which were used in an unstructured interview format. These questions were used as a guide only and the discussions progressed into free-form conversations about the topic.

1	Project Name(Code)		
2	Estimated Cost		
3	Actual Cost at Completion		
4	Time Estimate		
5	Actual time spent for completion		
6	Time and Cost estimates at following stages of the project		
6.1	Conception		
6.2	Specification		
6.3	Construction (i.e. development)		
7	**Quality Dimension**		
7.1	Defect Index at Product Definition	1- No time/cost impact	
		2- Time cost impact < 1 day	

		3- Time cost impact < 1 week
		4- Time cost impact > week
		5- Caused business/project to stop
7.2	Defect Index at Component Integration	1- No time/cost impact
		2- Time cost impact < 1 day
		3- Time cost impact < 1 week
		4- Time cost impact > week
		5- Caused business/project to stop
7.3	Defect Index at User Acceptance Testing	1- No time/cost impact
		2- Time cost impact < 1 day
		3- Time cost impact < 1 week
		4- Time cost impact > week
		5- Caused business/project to stop

7.3	Defect Index during 1st month in Production	1- No time/cost impact
		2- Time cost impact < 1 day
		3- Time cost impact < 1 week
		4- Time cost impact > week
		5- Caused business/project to stop
8	**Product Dimension**	
8.1	Complexity	1- total of less than 5 interfaces (reports, screens, files)
		2 - total of less than 10 interfaces (reports, screens, files)
		3- total of less than 25 interfaces (reports, screens, files)
		4- total of less than 50 interfaces (reports, screens, files)
		5- total of more than 50 interfaces (reports, screens, files)

8.2	Significance	1- Undecided
		2- Nice to have
		3- Operational necessity
		4- Driven by a strategic decision
		5- Industry Compliance
8.3	Budget	1- Less than R 250K
		2- Less than R 750K
		3- Less than R 1.2 million
		4- Less than R 10 million
		5- Over R10 million
8.4	Requirements change during project	1- No change during project duration
		2- 10% change during project duration
		3- 25% change during project duration

		4- 50% change during project duration
		5- 100% Change during project duration
9	**Resource Dimension**	
9.1	Experience of Team Members	1- Majority of the team new for Technology; New for Environment
		2- Majority of the team new for Technology; Experienced in the environment
		3- Majority of the team experienced in the Technology; New for Environment
		4- Majority of the team experienced in the environment; experienced in technology.
		5- Majority of the team experienced in Technology; Experienced in the Environment; Has worked with most team members before.
9.2	Personnel Continuity	1- 100% team moved/changed during project

		2- 50% of the members changed/moved during project.
		3- 25% of the team members changed/moved
		4- 10% of team members moved
		5- none of the members moved/changed
9.3	Resource Allocation (%)	1- More than 50% of members Allocated to more than 2 other projects
		2- More than 25% of members Allocated to more than 2 other projects
		3- More than 50% members allocated to 1 more project
		3- More than 25% members allocated to 1 more project
		5- All members allocated 100% to project.
9.4	Team size	1- less than 5 members

		2 - less than 10 members
		3 - less than 25 members
		4 - less than 50 members
		5- more than 50 members
10	**Technology Dimension**	
10.1	Maturity	1- new technologies involved which was used for the first time in the country
		2- new technologies involved which was used for the first time in the organization but been used in the country for over 1 year
		3- all technologies involved which was used for more than a year in the organization
		4- all technologies involved which was used for more than 5 years in the organization
		5- all technologies involved which was used for more than 10 years in the

		organization
10.2	Continuity	1- Technology was changed due to limitations/ upgrades to original choice
		2- Upgrades in technologies caused hardware upgrades
		3- New releases caused changes to the product (code changes)
		4- New releases caused re-testing of the product
		5- None of the technologies changed during the project conception to deployment
10.3	Technology Spread(Popularity)	1- Only user in the world (could be due to freshness or age)
		2- Only user in the country and less than 10 worldwide
		3- Less than 10 installations in the country
		4- Widespread technology but the only installation in the country in the

		industry
		5- Widespread use in the country and in the industry
10.4	Progression Rate (Rate of Adaptability by others)	1- Among the surviving few users due to legacy dependencies
		2- Phasing out technology with a known end date
		3- Phasing out in the organization, but still popular outside
		4- No real growth but established technology(stable)
		5- Popular and growing technology
11	**Environment Dimension**	
11.1	Executive pressure on Time/cost estimates	1- No pressure
		2- Negotiable with facts
		3- Negotiable with facts after more than 2 deliberations
		4- Negotiable only when difficulties

		experienced
		5- No negotiations
11.2	Business (product) Complexity	1- Less than 5 business rules; Well documented.
		2- Less than 20 business rules well documented.
		3- less than 20 business rules partly documented.
		4- more than 20 business rules partly documented
		5- No clear/documented business rules. Project team has to find out.
11.3	Business (geographical) complexity	1- All users and interfaces in one business unit and in the same location as the project team.
		2- All users and interfaces not in the same business unit but all units located in one building and are from the same organization.
		3- Users are spread over different

		business units and organizations, but located in the same building.
		4- Users are spread over different business units and organizations, and not located in the same building.
		5- Users are spread over different business units and organizations, and not located in the same building but spread over countries with different time zones.
11.4	Project Friendliness of team Structure	1- Matrix Organization with priority to functional work.
		2- Functional Organization with project as another task
		3- Matrix organization with priority to project work.
		4- Organic structure to suit the project
		5- Dedicated project team
12	**Time Dimension**	
12.1	Task Interdependence	1- 100% independent tasks capable of

		parallel execution
		2- 75% independent tasks capable of parallel execution
		3- 50% independent tasks capable of parallel execution
		4- 10% independent tasks capable of parallel execution
		5 - All tasks interdependent only sequential execution possible
12.2	Time advantage of doubling resources could have had on the project	1- Increase delivery time.
		2- No change to delivery time.
		3- Reduce delivery time by less than 25%.
		4- Reduce delivery time by less than 50%
		5- Reduce delivery time by more than 50%.
12.3	Progress monitoring frequency	1- Never.

		2- Only during a crisis.
		3- Only during a change.
		4- Weekly and regularly.
		5- Daily and regularly.
12.4	Increase of priority for project during execution	1- High to low during execution.
		2- High to medium during execution.
		3- High priority from beginning to end.
		4- Medium to high during execution.
		5- Low to high during execution.
13	**Risk Dimension**	
13.1	Risks considered in discount rate	1- Only cost of capital
		2- Cost of capital and business risk
		3- Cost of capital business risk and technological risk
		4- Cost of capital, business risk, technological risk and resource risk

		5- Special risk analysis was done to include all possible risks negotiations
13.2	Technological Risk	1- Established technology in the organization.
		2- Established technology but new in organization.
		3- Used first time in the country.
		4- Among the first 100 projects in the world.
		5- Evidence of unsuccessful implementations in many other organizations.
13.3	Resource Risk	1- Many resources with the skill in the organization.
		2- Few resources in the organization with the skill and no real demand for the skill in the market.
		3- Many resources in the organization, but the skill is in high demand
		4- Only one resource in the whole

		organization. No training available.
		5- No resources in the organization, only person in the country was sourced for the project.
13.4	Business Risk	1- Established Product offering.
		2- New product offered only by two other competitors.
		3- Successful product in other countries, tried for the first time locally.
		4- New product supported by market research
		5- New product. No market research available

Appendix B : Schedule

Task to complete	**Estimated amount of time needed**	**Target date for completion**	**Task completed (indicated with a √)**
Interviewing Industry experts	1 week	27 Oct	
Sourcing of historical data for cost elements	1 week	27 Oct	
quantitative analysis of historical data	1 week	03 Nov	