Decision Support for Operational ERP systems implementation in Small and Medium Enterprises

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DECLARATION

I certify that this work has not been accepted in substance for any degree, and is not concurrently being submitted for any degree other than that of Doctor of Philosophy being studied at the University of Greenwich. I also declare that this work is the result of my own investigations except where otherwise identified by references and that I have not plagiarised the work of others.

Signed:

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ABSTRACT

Today organisations, due to increased competition, globalisation and cost saving, are seeking ways to improve their operational effectiveness and sustain their competitive advantage through effective deployment of available resources and strategically implementing business processes. It is observed that incorporating new developments in information technology with core business processes results in enhanced functioning and improved services to customers. To benefit from the available IT support, organisations are adopting application software, such as ERP systems, to improve operation efficiency and productivity.

ERP system is primarily implemented to integrate business processes and enhance productivity. However, ERP system comes with a high price tag, implementation complexities, and prerequisite changes in how organisation and its staff functions. Implementing ERP is a challenging task for SMEs since it consumes a major portion of limited resources and carries a high risk of causing adverse consequences. To overcome the implementation challenges and assist SMEs in ERP implementation, an integrated decision support system for ERP implementation (DSS_ERP) is developed in this research. This decision support system consists of analytical regression models, a simulation model and nonlinear programming models, and it enables SMEs to identify the resources requirements for achieving the predetermined goals prior to ERP implementation.

The key contribution from this research are: i) the DSS_ERP offers an analytical models to monitor the implementation progress and cost consumed by each critical success factor (CSF) during the implementation against time; ii) it assists in determining the priorities of CSFs, based on which it facilitates decision makings on resource allocations to achieve the predetermined target; iii) and it can be applied to evaluate the impacts of changes to the resources allocations.

Contents

CHAPTER 1: INTRODUCTION 1
1.1 Background 1
1.2 Objectives of the research 4
1.3 Research contribution 5
1.4 Outline of the thesis 5

CHAPTER 2: LITERATURE REVIEW 7
2.1 Introduction 7
Part I – ERP System 7
2.2 History and definition of ERP 7
2.2.1 Definition of ERP system 7
2.2.2 History of ERP development 8
2.3 ERP system 11
2.3.1 ERP Selection 14
2.3.2 Role of ERP in SCM 16
2.3.3 Role of ERP in SMEs 17
2.4 Benefits of ERP system 18
2.5 Challenges of ERP implementation 20
2.5.1 ERP implementation success attributes 22
2.5.2 ERP implementation failure attributes 22
2.6 ERP implementation Strategies 26
2.6.1 ERP system implementation model 26
2.6.2 ERP system implementation strategies 28
2.7 Post-ERP implementation 32
Phase II – Critical Success Factors 34
2.8 History and Definition of CSFs Approach 34
2.8.1 Benefits and difficulties of using the CSF approach 35
2.8.2 CSFs in ERP Implementation 36
Part III – SMEs 38

2.9 SMEs – Definition 38
2.9.1 Particular operational difficulties of SMEs........ 39
2.10 Implementing ERP System for SMEs........ 40
2.10.1 Growth in availability of ERP system 40
2.10.2 Benefits of ERP implementation for SMEs 43
2.10.3 Particular difficulties in ERP implementation for SMEs........ 43
2.10.4 CSFs for SMEs 45
2.11 CSFs for ERP implementation........ 47
2.11.1 Top Management Support........ 47
2.11.2 Users 49
2.11.3 IT........ 50
2.11.4 Project Management........ 51
2.11.5 Vendor's Support 52
Part IV Simulation modelling and DSS 53
2.12 Definition of modelling and simulation........ 53
2.13. Definition of DSS 54
2.14 Practical use of Simulation and DSS 55
2.15 Applying DSS to ERP System........ 58
2.16 Summary........ 59

CHAPTER 3: METHODOLOGY 61
3.1 Introduction........ 61
3.2 Justification of Methodology 61
3.3 Research Framework 63
3.4 Pilot Study........ 66
3.5 The Main Quantitative Survey........ 67
3.5.1 Research Sample........ 67
3.5.2 Data Collection 69
3.6 The proposed decision support system 70
3.6.1 Analytical regression model 70
3.6.2 Monte Carlo simulation model 73
3.6.3 Nonlinear programming model........ 74

3.7 The Key Informants Interview Method 75
3.8 Reliability and validity... 77
3.9 Verification of Models.. 79
3.10 Summary... 81

CHAPTER 4... 82
Regression based decision support system for ERP implementation in SMEs 82
4.1 The proposed decision support system 82
4.1.1 ERP Analytical Regression Models.. 86
4.1.2 ERP Simulation Model 90
4.1.3 ERP Nonlinear Programming Model.. 92
4.2 Measuring ERP level of performance... 93
4.3 Illustrative examples 94
4.3.1 Development of Analytical Regression Models 94
4.3.1.1 Development of Linear curve... 106
4.3.1.2 Development of Exponential curve 109
4.3.2 Development of Simulation Model to verify analytical models............................ 115
4.3.3 Nonlinear programming Model 119
4.4 Summary.. 122

CHAPTER 5... 123
Application of DSS_ERP to forecast project duration, project cost and performance level... 123
5.1 Results from the survey 123
5.2 Application of DSS_ERP to predict project duration, project cost and performance level... 128
5.2.1 Goal Seeking Analysis.. 128
Goal 1:... 129
Goal 2:... 131
Goal 3:... 133
Goal 4:... 134
Goal 5:... 136
Goal 6:... 137

Goal 7: 139
5.2.2 What-If Analysis 140
5.3 Comparison of results between DSS_ERP and SMEs' results 145
5.4 Summary 152

CHAPTER 6: KEY INFORMANTS INTERVIEWS 153
6.1 Introduction 153
6.2 Organisations' background 153
6.3 Key Informants 154
Key Informant 1 – "MIS-Manager" 154
Key Informant 2 – "SQA-Analyst" 155
Key Informant 3 – "Net-Developer" 155
Key Informant 4 - "BI-Administrator" 155
6.4 Key Themes 156
6.4.1 Scope of a generic prediction model for ERP implementation 157
6.4.2 CSFs for ERP implementation 159
CSF 1- Top Management Support (TM) 160
CSF 2 - Users 161
CSF 3 – Project Management (PM) 163
CSF 4 – Information Technology Systems (IT) 164
CSF 5 - Vendor Support (VS) 165
6.4.3 Analysis of performance measures 168
6.4.4 Functionalities of the DSS_ERP and potential improvements 171
6.4.5 CSF attributes 172
CSF 1-Top Management (TM) attributes 173
CSF 2 - Users attributes 173
CSF 3 – Project Management (PM) attributes 174
CSF 4 – Information Technology (IT) attributes 174
CSF 5 – Vendor's Support (VS) attributes 175
6.5 Discussion 176

CHAPTER 7: RESEARCH SYNTHESIS 179

CHAPTER 8 ... 183
Conclusions, limitations and suggestions for future work ... 183
8.1 Conclusions ... 183
8.2 Recommendations to SMEs ... 186
8.3 Limitations of research ... 187
8.4 Recommendations for future research ... 187

References ... 190

Appendices ... 220
Appendix A Covering Letter and Questionnaire ... 220
Appendix B ... 222
Appendix C key Informant's Interviews ... 227
Part A – Warm-up questionnaire ... 227
Part b- Interview Schedule ... 227
Appendix D: Probability distribution of ti ... 231
Appendix E: Confidence interval ... 232
Appendix F: Publications generated during the PhD study ... 232

List of Figures

Figure 2.1 The evolution of ERP system..10

Figure 2.2 Integration by ERP system...12

Figure 2.3 Failure rates mentioned in literature ……………………………………………..14

Figure 2.4 ERP vendors' market share in 2010...15

Figure 3.1 Development and structure of DSS_ERP...67

Figure 3.2 Key informants' interview process 76

Figure 3.3 Verification of the DSS_ERP Model..80

Figure 4.1 A typical S-Curve...84

Figure 4.2 an exponential curve for ERP implementation project...........................85

Figure 4.3 a linear curve for ERP implementation project..85

Figure 4.4 parameters of an exponential curve..89

Figure 4.5 Linear and exponential curves for CSF-TM...97

Figure 4.6 Linear and exponential curves for CSF-Users..99

Figure 4.7 Linear and exponential curves for CSF-PM..101

Figure 4.8 Linear and exponential curves for CSF- IT...103

Figure 4.9 Linear and exponential curves for CSF-VS...105

Figure 4.10 ERP simulation model..116

Figure 5.1 Percentage of ERP functionalities used by SMEs..................................127

Figure 5.2 Comparison of output variables..146

Figure 5.3 Comparison of results for SME1...147

Figure 5.4 Comparison of output variables..148

Figure 5.5 Comparison of results for SME 2..149

Figure 5.6 Comparison of output variables..149

Figure 5.7 Comparison of results for SME 3..150

Figure 5.8 Comparison of output variables..151

Figure 5.9 Comparison of results for SME 4...151

List of Tables

Table 2.1 Benefits of ERP system...19

Table 2.2 Success and failure attributes for ERP implementation...25

Table 2.3 Critical success factors investigated...49

Table 3.1 Categories of the organisations participating in the quantitative survey.................68

Table 4.1 Time series data for CSF-TM..96

Table 4.2 Time series data for CSF-Users...98

Table 4.3 Time series data for CSF- PM..100

Table 4.4 Time series data for CSF- IT..102

Table 4.5 Time series data for CSF- VS...104

Table 4.6 Data for determination of coefficients of CSF-TM...107

Table 4.7 Data for coefficient of determination, R_i^2for CSF-TM....................................108

Table 4.8 Linear equations with coefficients and R^2 values..109

Table 4.9 Estimated performances for CSFI-TM..110

Table 4.10 Performance threshold (p_i) and progression coefficient (k_i) values
for CSFs..111

Table 4.11 Data for coefficient of determination, R_i^2 for exponential curve of
CSF1-TM..112

Table 4.12 Values of coefficient of determination, R^2..113

Table 4.13 Values of d_i, k_i and p_i for CSFi...113

Table 4.14 Frequency table for days spent on CSF1...117

Table 4.15 Probability distribution for days spent on CSF1...118

Table 4.16 Summary of results for model verification...119

Table 4.17 Solution for goal-seeking analysis..121

Table 5.1 Mean values of time, cost and performance contributed by each CSF................124

Table 5.2 Mean values of time, cost and performance achieved by the surveyed SMEs......124

Table 5.3 CSFs' contribution towards overall performance...125

Table 5.4 Constraints defined for Goals 1-7 129

Table 5.5 Solutions for Goal 1 130

Table 5.6 Solution of Goal-seeking analysis 132

Table 5.7 Solution of Goal-seeking analysis 133

Table 5.8 Goal-seek analysis result 135

Table 5.9 Goal seek analysis result 137

Table 5.10 Goal seek analysis result 138

Table 5.11 Goal seek analysis result 140

Table 5.12 Results of What-if analysis 143

Table 5.13 Comparison of results for SME 1 146

Table 5.14 Comparison of results for SME 2 147

Table 5.15 Comparison of results for SME 3 149

Table 5.16 Comparison of results for SME 4 150

Table 6.1 Key Organisational Features of the Participating Organisations 150

Table 6.2 Proposed additional CSFs 168

Table 6.3 Variables important to each participant 169

Table 6.4 CSFs attributes proposed by Key Informants 175

List of Abbreviations

B2B – Business to business

B2C – Business to customer

BI – Business intelligence

BPR – Business process re-engineering

CAGR – Compound annual growth rate

CSF – Critical success factors

DSS – Decision support systems

ERP – Enterprise resources planning

GRG – Generalised reduced gradient

IS – Information system

IT – Information technology

LE – Large enterprise

MIS – Management information system

MRP – Material requirement planning

PM – Project management

PIR – Post implementation review

ROA – Return on assets

ROI – Return on investment

SaaS –Software as a service

SAP – Systems, Applications, and Products in Data Processing

SCM – Supply chain management

SME – Small and medium enterprises

SQA –Software quality analyst

TM – Top management

VAR – Value added reseller

VS – Vendors support

CHAPTER 1

INTRODUCTION

1.1 Background

The last decade has seen the use of Enterprise Resources Planning (ERP) systems increasing many folds. These systems are an information system that assists in management all aspects of business including production planning, purchasing, manufacturing, sales, distribution, accounting and customer service (Scalle and Cotteleer, 1999). They achieve this through integration, which in turns allows seamless integration of information flows and business processes across functional areas within a company (Davenport, 1998; Mabert et al., 2003). The growth may be due to increased competition, globalisation and need for greater visibility into business functioning. Nevertheless, whatever the cause of the growth, several researchers and practitioners have argued that ERP systems have actually been the most popular new business software of the last fifteen years (Ehie and Madsen, 2005; Behehsti, 2006; Wagner et al., 2006; Kamhawi, 2008; Baiyere, 2012).

ERP system is a set of packaged application software modules with an integrated architecture, which can be used by organisations as their primary engine for integrating data, process and information technology, in real time, across internal and external value chains. Some of the substantial outcomes that emerge when companies implement and operate ERP systems are increases in productivity and added value (Davenport, 1998), improved operational performance (McAfee, 2002), integration and process optimisation (Davenport et al., 2004), increased firm's market value (Meng and Lee, 2007) and noticeable financial performance (Hendricks et al., 2007). In addition, ERP system has arguably become imperative for companies in order to gain competitive advantages, such as cost reduction, integration of operations and departments, business process improvement, increasing their effectiveness and competitiveness (Vlachos, 2006).

ERP system support information sharing along organisation's main process flow and thus help organisation to achieve better productivity and results (Van Hillegersberg et al., 2000).

ERP packages offer a 'workflow engine' which allow the generation of automated workflows according to business strategy and approval matrices so that information and documents can be routed to operational users for transactional handling, and information can be provided to managers and directors for review and strategic oversight (James et al., 2002).

The development of ERP system has changed the way many organisations function. The most significant change is the integrated operation, information sharing and improved performance brought in by new ERP system. This may usually give an organisation a competitive advantage over its competition where the competition has not adopted ERP system (Yusuf et al., 2004).

Yet, despite these benefits, organisations are sometimes reluctant to adopt ERP system because of amount of time, money and efforts required to implement the new system and more importantly, their perceived high risk of failure (Malhotra and Temponi, 2009). Davenport (1999) reported that ERP implementation could be challenging, time consuming and expensive, and could places tremendous stress on corporate time and resources. Due to these impediments and the implementation complexities, the literature identifies that approximately 66 to 70 percent of ERP implementation projects were reported to have failed to achieve their implementation objectives in some way (Lewis, 2001; Carlo, 2002; Shores, 2005; Ward et al., 2005; Zabjek, 2009). In addition, some surveys show that failure is a common experience part of ERP implementation projects and success cannot be guaranteed even in the most favourable situations (Liao et al., 2007).

Similarly, a study by Harvard Business School found that "65 percent of the executives believe ERP system have a moderate chance of hurting their business because of potential implementation problems" (Hill, 1999, p.2) and according to Cliffe (1999), it is the single business initiative most likely to go wrong. In the most recent research published on this phenomenon, Panorama Consulting company surveyed 246 organisations from 64 countries during 2011, and found that in 50 percent of cases, at least 50 percent of expected benefits from an ERP implementation were not actually realised.

In addition to these concerns, the literature acknowledges that small and medium enterprises (SMEs) might face added constraints in ERP implementation. Beyond, the ordinary concerns that SMEs have lesser resources, there might be the added complication that SMEs are more likely to be lacking modern information technology infrastructure and experienced IT staff, and might have less openness in their attitudes to the perceived usefulness of new technology. These constraints might cause the ‘average’ SMEs to refrain from adopting an ERP system or, even if they did adopt, the constraints might increase the probability of implementation failure. For SMEs, it is noted that a failed implementation might generally have more catastrophic consequences than for a larger organisation, even perhaps leading up to bankruptcy (Beheshti, 2006).

Given the potentially high cost and potentially low-success rate, it is necessary for the causes of these problems or failures in ERP implementation to be better understood, and through this understanding, solutions leading to greater implementation success may be found (Calisir and Calisir, 2004). As a consequence, ERP implementation has been a focal point of much academic research. Multiple streams of research exists on the ERP implementation and critical factors required for its successful implementation as well as impact of ERP on organisational performance (Al-Mashari, 2003; Hitt et al., 2002; Holland and Light, 1999). For example, several studies have identified the critical success factors (CSF) needed to enable project managers and higher management to improve ERP implementation projects. Some of the CSFs are in common with other types of IT projects, such as top management support, the role of users, and business process reengineering. Although the identified CSFs enable SMEs to better understand their impact on implementation process, however the extent of these impacts are not clear, therefore SMEs are not able to make effective intervention in ERP implementation. In order to gain the understanding of the ERP implementation, different models have been proposed (Parr and Shanks, 2000; Akkermans and van Helden, 2002; King and Burgress, 2005). However, most of these models are either theoretical or developed for large enterprises.

To assist SMEs in their ERP implementations by providing a method to predict ERP project implementation outcomes and facilitate allocation of resources during implementation accordingly, an integrated Decision Support System (DSS) for ERP implementation (called DSS_ERP) is developed in this research. The DSS_ERP links CSFs to project outcomes measured by implementation cost, project duration and performance level, and particularly explores the impact of changes to budget limit and focus on individual CSFs. Within the

DSS_ERP, each CSF is analysed in the context of time, cost and performance level. Since the cost and the performance level depends upon the amount of time spend and effort placed on CSFs, therefore the implementation cost and performance level can be forecasted by strategically implementing CSFs.

1.2 Objectives of the research

The aim of this research is to develop a decision support models for ERP implementation in SMEs to enhance operational decision making, optimise resources allocation and developing a strategy to achieve predetermined implementation goals.

The key objectives of the research are:

1. To study the ERP implementation in SMEs, analyse and identify the resources that SMEs can afford for the ERP implementations. The resources may include management support, knowledge about ERP, prior training, balanced teams etc.
2. To identify CSFs which are essential during the implementation process and analyse their interrelationship using empirical observations. To evaluate CSF effect on ERP implementation performance and to identify the CSF that make greater contribution to the ERP project, therefore addressed with greater focus
3. To analyse the potential of using analytical modeling to describe, explain and build relationship between the variables.
4. To develop a Decision Support System (DSS) for operational decision making and forecasting the decision variables of project duration, project cost and performance level. The DSS_ERP will combine three types of models: (1) ERP analytical regression model, (2) ERP simulation model and (3) ERP non-linear programming model, which provide the dynamic view of ERP implementation and forecast the decision variables.
5. To evaluate and compare different implementation strategies using the DSS_ERP developed in 4.

1.3 Research contribution

This research contributes towards ERP implementation in SMEs by developing a decision support system to monitor ERP implementation progress and the cost during the implementation process. It also assists in determining the priorities of CSFs during implementation, which can applied in resources allocation to achieve successful implementation. DSS_ERP offers guidance in resource acquisition and allocation that achieves predetermined ERP implementation performance level, within budget and time limits. Further, it can also be used to analyse the impacts on overall ERP performance of changes to resource allocations. It offers a risk analysis tool to analyse potential risks and opportunities caused by the changes to ERP project, therefore helps SMEs to be better prepared and reduce failures.

1.4 Outline of the thesis

This thesis is organised as follows:

A literature review of ERP systems is given in **Chapter 2**. The background and evolution of ERP systems, their implementation in large enterprises and introduction in SMEs, success and failure attributes, CSFs and different implementation models and strategies are reported in this chapter. In addition, by reviewing the wide range of literature, this chapter identify gaps in current knowledge.

Research methodology is discussed in **Chapter 3** taking into consideration the nature of the research topic and, aims and objectives of the research. It discusses the mixed method approach, selection of sample, quantitative and qualitative data collection process and describes the model development.

In order to assist SMEs in ERP implementation, a regression based decision support system DSS_ERP is developed and introduced in **Chapter 4**. The DSS_ERP combines types of model namely; analytical regression model, ERP simulation model and ERP non-linear programming model.

In **Chapter 5**, the developed DSS_ERP system is applied to forecast the decision variables of time, cost and performance by applying different scenarios using dummy data. Further, the data collected from four SMEs is compared against the result generated by DSS_ERP to analyse the performance of the model.

To confirm the veracity of the model and to improve the understanding of the implementation process, key informants interview process in described in **Chapter 6**. The chapter presents the background of the interview participants and SMEs, and the qualitative data collected from interview process.

Chapter 7 discusses in detail the research findings and they are compared against the extant literature in ERP area to demonstrate the contribution of research.

Chapter 8 provides a conclusion for this research and the limitation of the study. This chapter also identifies opportunities for future research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter provides a critical review of relevant literature with a focus on ERP adoption and implementation in SMEs, with the aim of identifying key issues of ERP implementation and establishing the need of this research. The chapter also reviews different methodologies and implementation models proposed in the literature to enhance the understanding and knowledge of the ERP system implementation process.

In the next section, a detailed literature is reviewed in the following aspects: ERP evolution and introduction, ERP implementation process, ERP implementation in SMEs, critical success factors and, ERP post implementation evaluation and benefits.

Part I – ERP System

2.2 History and definition of ERP

In sub-sections 2.2.1 various definitions of ERP available in literature are discussed. The sub-section 2.2.2 describes evolution and development of ERP system.

2.2.1 Definition of ERP system

ERP system is a business management system that comprises integrated set of comprehensive software that can be used to manage and integrate all business processes and function within an organisation. They usually include a set of mature business applications and tools for accounting and finance, sales and distribution, management of material, human resources, production planning and computer integrated manufacturing, supply chain, and customer information (Stemberger and Kovacic, 2008).

Nah et al. (2001, p. 285) defined ERP system as a “packaged business software system that enables company to manage the efficient and effective use of resources (material, human resources, finance etc.) by providing a total integrated solution for the organisation's information-processing needs". While at an operational level, Gable (1998, p. 3) defined ERP as a "comprehensive packaged software solution that seeks to integrate the complete range of business processes and functions in order to present a holistic view of the business, from single information and IT architecture".

According to Davenport (1998), ERP system is generally comprise of different software modules which allow organisations to automate and integrate the majority of business functions by sharing common data and practices across the enterprise to produce and access information at real-time. Further, he explained the anatomy of ERP system: "at the heart of [an ERP] system is a central database that draws data from and feed data into a series of application supporting diverse company function. Using a single database dramatically streamlines the "flow of information throughout a business" (Davenport, 1998, p.124). He further highlighted that a definition feature of ERP system is the integration of different functions of the organisation so the information is entered only once and available across the organisation with real-time update (Davenport, 1998).

In summary then, ERP system facilitates the integration and automation of firm's business processes by using single database for business functions across the organisation. This gives the comprehensive view of the business and ensures the availability of up-to-date information across the organisation.

2.2.2 History of ERP development

The history of the ERP system can be traced back to Material Requirement Planning (MRP) system from 1960s. The MRP system focus on the inventory control including material managing and ordering (Davenport, 1998). Early version of MRP system was useful applications for planning and scheduling materials for complex manufacturing processes. MRP improves planning processes by systematically planning and efficiently scheduling all parts of the manufacturing process and in gaining productivity and quality (Davenport, 1998; Chung and Snyder, 2000).

During the 1980s, further advancement of information and manufacturing technology resulted in a growing need for more advanced planning system which led to the development of a class of software system broadly called Manufacturing Resources Planning (MRP II)

(Davenport, 1998). The emergence of MRP II is attributed to the fact that MRP system was generally incapable of responding to rapidly changing business requirements (Barker, 2001). MRP II system was considered as a step forward since they utilised more advanced software algorithms for coordinating all the manufacturing processes, right from product planning through to stocking of finished parts and purchasing, inventory control through to product distribution (Davenport, 1998; Abdinnour-Helm et al., 2003).

However, MRP II programmes were more complex and expensive than their predecessors, requiring dedicated technical staff and IT hardware resources such as mainframe computers to support their application (Chung and Snyder, 2000; Beheshti, 2006). In addition, MRP II often ran on different operating system for each unit, and failed to become a real enterprise-wide system (Chung and Snyder, 2000).

Developing from the perceived failures of the MRP II generation of software programmes, and to actively streamline business processes and enhance the integration inside organisations, a new generation of applications called Enterprise Resource Planning (ERP) system evolved in early 1990s (Markus et al., 2000). ERP system, viewed as a newer paradigm, has several differentiating factors which make it unique from its predecessors. According to Skok and Legge (2002) factors such as number and variety of stakeholders, high cost of implementation and consultancy, integration of business functions, configuration of software representing core processes, management of change and political issues associated with BPR[1] project and enhanced training and familiarisation requirement, are unique feature of ERP system. Figure 2.1 illustrate the evolution of ERP system.

[1] Business Process Reengineering (BPR) is the process of analysing and redesigning the workflows and processes within and between enterprises.

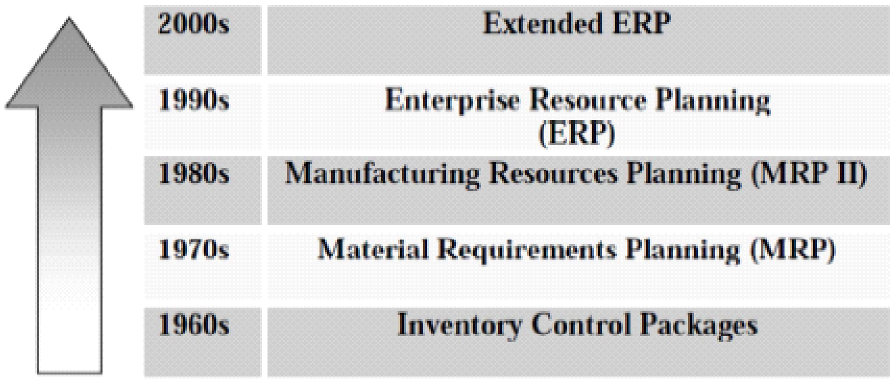

Figure 2.1 The evolution of ERP system (Source: Rashid et al., 2002)

Gartner Inc. of Stamford was the first one to use the term ERP in early 1990s to describe the business software system that were then, the latest enhancement of MRP II system (Chen, 2001). Many software system vendors are also emerged during this time offering 'ERP' system; such as SAP, Oracle, MS Dynamics, Oracle\PeopleSoft, Sage, Lawson, Infor, IFS, Baan, Epicor and Netsuite. Like MRP II system these newly developed ERP system was touted as designed to integrate business processes and activities across multi-functional departments, i.e. from product planning, parts purchasing, inventory control, product distribution and fulfilment to order tracking (Beheshti, 2006). In contrast, ERP system implementation is not limited to manufacturing companies, but implemented across a range of industries to integrate its business and information system across the functional areas (Abidinnour-Helm et al., 2003).

Guffond and Leconte (2004) performed an in-depth analysis of ERP system and concluded that ERP system is a tool assembling and integrating all data and management skills which represents the firm's activity, in a unique database: from finance to human resources, going through the elements of supply chain that permanently link the production to purchasing and sales. In addition, ERP system conceptually has two layers. The "generic layer" attends to respond to the needs of firm according to better practices and standard rules of management. While, the "specific layer" is a multiuser layer and therefore personalised taking into account the particular characteristics of the organisation. Lastly, ERP system is composed of different modules which are interlinked to process data and information sharing.

To summarise, according to Violino (2008), from the first software solution, in the 1960s (which had the form of material requirements planning); until recently, when on-demand delivery of ERP software is the vendors' last innovation, the ERP market has experienced an overall 'flourishing' despite some disruption. ERP system has been successful in catering the needs of complex and fast-paced businesses while continuously improving to fulfil the diverse demands of the organisations.

2.3 ERP system

Commentators highlight that many organisations today feel the pressure to cut costs and improve productivity and profitability because of increasing competition and globalisation (Nah et al., 2001). For example, manufacturing firms are under pressure to cut costs and improve quality (Goshal, 1987; Lengnick-Hall et al., 2004), services firms are increasingly expected to improve responsiveness and customer service (Schneider and Bowen, 1995) and public enterprises like city governments are increasingly required to save costs and provide good services to their constituents (Davenport, 2000).

A key strategic underpinning assumed to increase the level of productivity, profitability and performance relates to improvement of operational effectiveness (Porter, 1996). Porter (1996) defined operational effectiveness as performing similar activities well, and preferably better than rivals. ERP system fit into this agenda because it is assumed, that if correctly implemented they can enhance the operational effectiveness of organisations by employing best business practices.

ERP system allows seamless flow and availability of information (Davenport, 1998) across functional areas within an organisation. They offer a workflow[2] 'engine' that organise processes according to business rules and decision, and approval matrices. This underlying organising schema has the potential benefit of allowing information and documents to be routed to operational users for transactional handling, and to mangers for review and approval and thus forms the basis for managers having structured data and information flows and potentially gaining a more holistic view of the business functioning (James et al., 2002). It is achieved by utilising single database and applications with the same interface across all processes of the entire business, as shown in Figure 2.2 (Bingi and Sharma, 1999).

[2] Workflow is the automation of business process, in whole or part, during which the information or task are passed from one participants or departments to another for action, according to set of rules.

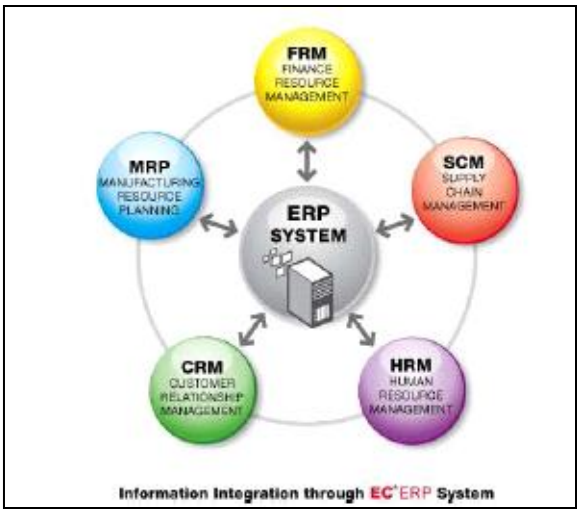

Figure 2.2 Integration by ERP system (Source: Secured Enterprise Application, 2009)

The ERP system is designed to facilitate the flow of information in an organisation by integrating the data processing and information management activities in the main areas of business. It is observed that ERP usage has had a great impact on the transformation of many organisations (Holland et al., 1999) and especially through enhancing control, permitting a centralized view from top corporate on each entity, or allowing controlling matrix structure through real time information (Qauttrone et al., 2004). Studies confirm that the introduction of new business and organisational practices are highly correlated with labour productivity (Falk, 2005). Similarly, ERP system is becoming a platform for electronic business, business to business and business to customer applications, allowing organisation to reduce their inventory cost, to better manage their supply chain and customer relationship (Beheshti, 2006). Manufacturers, suppliers, and retailers can also coordinate their activities and track items, which are most commonly used benefit of ERP system.

ERP system is often implemented to address the issues of organisational failures in information coordination due to the application of legacy system (Nah et al., 2003). These legacy systems are usually aging solutions which are difficult to maintain and no longer meet the business needs of the organisation (Bradley, 2008). The literature suggests that the new ERP system enhance the information coordination by integrating data flows across different departments previously working in ‘silos’ caused by the lack of system integration. According to Kogetsidis et al. (2008), the benefits offered by properly selected and implemented ERP system include time and cost reduction in processes, faster transaction processing, and improvement of operational performance, financial management and customer service, web-based interfaces and more effective communication. ERP benefits will be further discussed in section 2.4.

In order to realise these business benefits, ERP software is installed by 1600 organisations in last four years (from 2006 to 2010) and all major Fortune 500 companies have adopted ERP system (Panorama consulting group[3], 2010). These organisations vary in sizes and locations, with a majority based in North America and Asia Pacific (31 percent each) and, 14 percent each in Europe and South America. According to Lucintel[4] research report (2012), the global ERP software industry has reached an estimated $47.5 billion in 2011 with 7.9 percent compound annual growth rate (CAGR) and is forecast to attain an estimated $67.7 billion by 2017 with 6.1 percent CAGR over 2012-2017.

However, despite the literature stressing the manifest benefits of ERP system, ERP implementation is also acknowledged as a challenging process that requires great deal of hard work and attention to technical detail (Momoh et al., 2010). Literature indicates, ERP projects are highly risky with relatively low success rate, for example, Umble and Umble (2002) – 50-75 percent, Zhang et al. (2003) – 67-90 percent, Sarkis and Sundarraj (2003) – 33 percent. Figure 2.3 presents the percent failure rate suggested in the literature. This high failure rate is a cause of concern for researcher and practitioners alike.

[3] Panorama Consulting Solution is an independent organisation which study ERP implementation across the globe. It helps firms evaluate and select ERP software and manages the implementation of the software.

[4] Lucintel is a premier global market research and management consulting firm. It provides actionable results that deliver significant value and long-term growth to clients from various industries. Lucintel has created measurable value for more than 12 years and for thousands of clients in more than 70 countries worldwide.

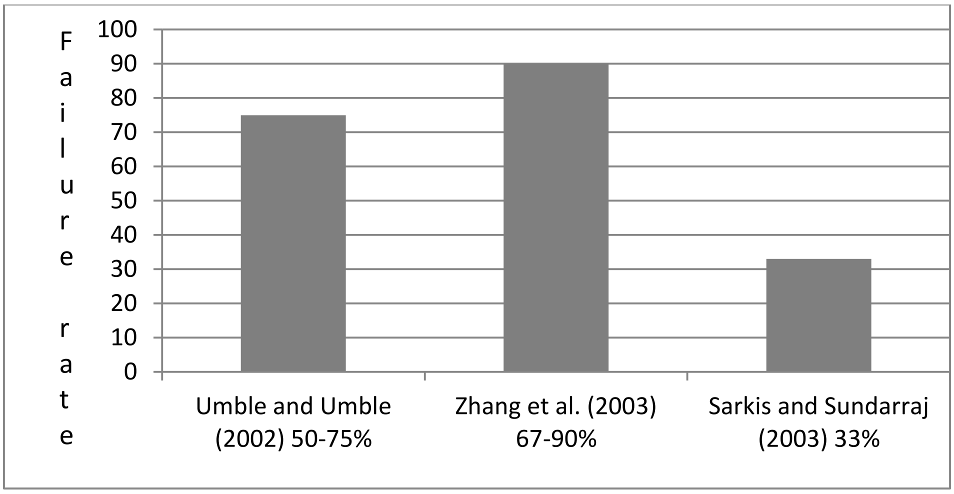

Figure 2.3 Failure rates identified in literature

In addition, literature reports that 66 to 70 percent of ERP implementation projects fail to achieve all of the set goals (Lewis, 2001; Carlo, 2002; Ehie and Madsen, 2005; Shores, 2005; Ward et al., 2005; Zabjek, 2009). Illustrative cases of 'failure' in the literature include organisations such as Fox-Meyer Drug, Dell, Unisource Worldwide, Inc., Dow Chemical and Hershey in which ERP implementation resulted in 'complete failure' (Cotteleer, 2002). Similarly, Avis Europe Ltd abandoned its ERP implementation project in 2004 (at the estimated cost of US$54.5 million) and of Ford Motors' ERP implementation was called off after US$200 million had already been spent (Markus et al., 2000). Markus et al.'s (2000) most spectacular example was the collapse of pharmaceutical giant FoxMeyer Drugs that was partially attributed to their failed ERP implementation. Kim et al. (2005) provide other examples of failed implementation including; Allied Waste Industries, Inc. which stopped its ERP implementation after spending US$310 million and Waste Management, Inc. which called off ERP installation after spending US$45 million. According to a study conducted, 51 percent of the respondents viewed their ERP implementation as unsuccessful while 46 percent of the respondents felt that their organisations lacked the understanding of how to use the system to improve their business operations (IT Cortex, 2009).

2.3.1 ERP Selection

It is estimated that there are approximately 200 ERP system vendors in the market at the present time (ERP software 360, 2012). However, the 53 percent of the market (by value of sales) is dominated by three major vendors: SAP, Oracle/PeopleSoft and MS Dynamics. As illustrated in Figure 2.4, SAP[5] has the highest market share (24 percent), while Oracle has 18 percent of the ERP market and MS Dynamics has an 11 percent share of the ERP market. SAP and other vendors provide assistance in analysing the need of the organisation, checking organisation's readiness, on-site implementation assistance, regular system upgrade and after sale or post implementation assistance.

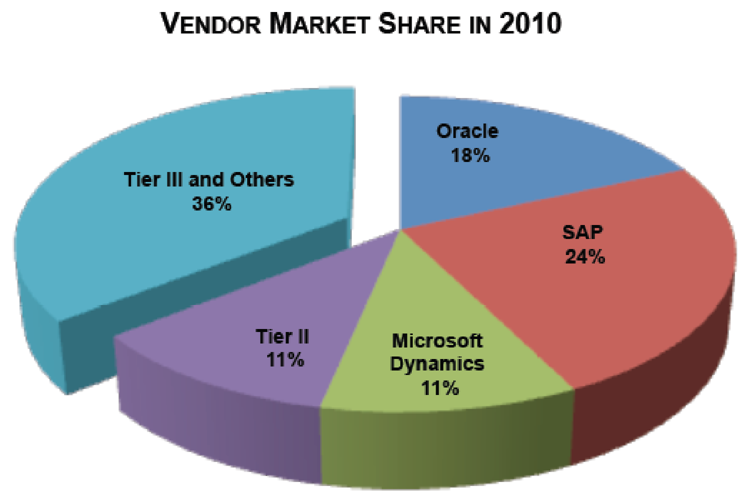

Figure 2.4 ERP vendors' market share in 2010 (Source: Panorama Consulting Group, 2011)

Among the wide choice of available ERP software in the market, selecting the right one which satisfies individual needs of organisation can be a difficult decision. Tsai et al. (2012) carried out a comprehensive study of the relationship between ERP selection criteria and ERP success. They identified four selection criteria which are critical to making right choices: consultant's suggestion, a certified high-stability system, compatibility between the system and the business process, and the provision of best practices. They also identified three ERP supplier selection criteria; international market position, training support by the supplier and supplier technical support and experience, and two consultant selection criteria; consultant's

[5] SAP AG is a German corporation that makes enterprise software to manage business operations and customer relations. Headquartered in Walldorf, Baden-Württemberg, SAP is the market leader in enterprise application software. The company's best-known software products are its enterprise resource planning application (SAP ERP). SAP is one of the largest software companies in the world.

ERP implementation experience in a similar industry and consultant support after going live for successful implementation (Tsai et al., 2012).

2.3.2 Role of ERP in SCM

ERP systems are being implemented in industry representing diverse sectors such as human resources management, manufacturing, finances, IT, sales etc. Among all the sectors where ERP system is being implemented, SCM represents the most diverse field encompassing the wide range of activities. ERP implementation aims to improve the internal efficiency, SCM focuses on the external relationship with trading partner in supply chain. The implementation of ERP requires companies to have effective communication and share information flow between extended supply chain agents, as well as make extensive use of functionalities offered by ERP system. According to Tarn et al. (2002) integration of ERP and SCM is natural and necessary process in strategic and managerial consideration.

A key feature of ERP system is it makes enterprise more flexible and improves the responsiveness essential for successful supply chain (Chan et al., 2009) by speeding up the integration of incoming data from supplier with outgoing data to customers. According to Tarn et al. (2002), ERPs aim to improve internal efficiency by integrating different parts in the organisation, while SCM focus on external relationship with trading partners in a (integrated) supply chain. Therefore, the combination of ERP and SCM is often a self-evident development, and perhaps a 'necessary' process in strategic and managerial considerations (Tarn et al., 2002). This is because, by doing so, organisations are able to reduce cycle time, enable faster transactions, have better financial control, lay the groundwork for e-commerce, and make tacit knowledge more explicit (Su and Yang, 2010). These features all, themselves, leading to efficient supply chain (Gimenez et al., 2004) which is likely to be more effective and responsive to the needs of internal and external customers. This not only increases the organisation's efficiency but also reduces paperwork, and provides for better inventory management, improved order tracking and production, hence reducing the overall costs of the organisation's processes (Gimenez et al., 2004). Further, during implementation process innovation is expected (Fleck, 1994) which can result in further enhancing the supply chain.

Chang et al. (2008) proposed that while the external environment and alliance partnerships facing an enterprise are becoming more complex, with implementing ERP system, managers can enhance efficiency and performance of supply chain management (SCM) and gain potential competitive advantage. Since ERP gives access to real time information sharing among supply chain partners resulting in streamline business processes, enhanced communication and cooperation among functional department (Kelle and Akbulut, 2005) between the organisation and its upstream and downstream trading partners.

Su and Yang (2010) studied adoption of ERP system and its impact on firm competence in supply chain in Taiwanese firms. They found that ERP system has such a positive impact on supply chain that leads to better overall SCM competence. The proved benefits include operational benefits, business process and management benefits, as well as strategic IT planning benefits. These benefits in turn enhance firm competences of SCM in operational process integration, customer and relationship integration, and planning and control process integration (Su and Yang, 2010). Koh et al. (2006) investigated the integration of SCM and ERP system and found that a single and integrated plan leads to cost reduction, lead-time reduction, improved visibility, reduced time to market, and increased efficiency in the company.

However, Akkerman et al. (2003) predicted only a modest role for ERP in improving supply chain effectiveness in the future, while Su and Yang (2010) warns about the risk of ERP actually limiting progress in SCM. These assessments are because the initial ERP system were designed to only integrate functions of individual organisation while developments in SCM are more complex and require a greater understanding on the working relationship between the internal departments and external customers (Su and Yang, 2010).

2.3.3 Role of ERP in SMEs

As the ERP system market has begun to saturate, ERP developers (including SAP, Oracle, Sage, Lawson, Infor and JD Edwards) are shifting their focus from the customers that are ‘large’ organisations to SMEs (Gable and Stewart, 1999; Everdingen et al., 2000). The vendors are increasingly developing software that serves the requirements of SMEs; such as comparatively less complexity, minimal customisation and most importantly, a lower price tag for the system. Meanwhile, in response to increasing competition, SMEs need to improve efficiency and pressure from partners in their supply chain, are themselves beginning to realise the significance of ERP system (Gable and Stewart, 1999). There is an increasing awareness and positive perception by SMEs on the potential benefits accruable from adopting ERP implementation (Baiyere, 2012). However, due to their relatively limited resources and lack of IT infrastructures or experience, SMEs faces a significant challenge in implementing new ERP system successfully (Laukkanen et al., 2007). Further, it seems likely that SMEs, due to their more limited resources and more tenuous market share, cannot afford to absorb a failed ERP implementation in the same way in which a larger organisation might (since SMEs 'cushions for failure are fairly thin). On the whole, they do not have the finances to recover from a failed implementation (Mabert et al., 2000; Baiyere, 2012). A failed implementation can have catastrophic implications including loss of market share and could even lead to bankruptcy (Markus and Tanis, 2000). Nevertheless, despite the higher stakes involved, there is limited research on how to assists SMEs implementing ERP system and in overcoming the complexities. ERP system in SMEs will be discussed in detail in section 2.9-10.

2.4 Benefits of ERP system

Despite the fact that benefits resulting from ERP implementation vary from one organisation to another, there are certain common benefits that the literature agrees all organisations can achieve by implementing ERP system. Ragowski and Somers (2002) found that by adopting ERP system, inventory cost can be reduced by average of 25-30 percent and raw material costs can be reduced by about 15 percent. Similarly production time, lead time for customers, and production cost are decreased while the efficiency of internal and external supply chain is improved by implementing ERP system (Bergstrom et al., 2005). Hawking et al. (2004) suggested that the benefits attained included financial close cycle reduction, order management improvements, cash management improvements, inventory reductions, transport/logistics reductions, and revenue/profits increase.

Studying ERP implementation impact on financial position of organisation, Hendrick et al. (2007) observed improvement in profitability, which is stronger in case of early adopters of ERP system. The findings are important because, despite high implementation cost, Hendrick et al. (2007) did not find persistent evidence of negative performance associated with ERP investments. Similarly studying the financial impact of ERP, Hunton et al. (2003) found that return on assets, return on investment, and asset turnover are significantly better over 3-years periods for ERP adopters as compared to non-adopters. While Hayes et al. (2001) observed a significantly higher stock return upon the announcement of ERP implementation.

In the Hasan et al. (2011) study of ERP implementation in Australia, it was found that the most observed performance outcomes included improved information response time, increased interaction across company, improved order management/order cycle, decreased financial cost, improved interaction with customers, improved on-time deliveries, improved interaction with suppliers and lower inventory level. Similarly, Kelle and Akblut (2005) also found that ERP system play an essential role in maintaining the optimum level of inventory thus saving organisations financial resources.

	Operational Benefits	Managerial Benefits	IT Infrastructure Benefits	Organisational Benefits
Ragowski and Somers (2002) Bergstrom et al. (2005) Hawking et al. (2004)	i) Reduction in inventory ii) Reduction in lead time iii) Decrease in production cost			
Hendrick et al. (2007) Hunton et al. (2003)				i) Increased profits ii) Increases ROI and ROA
Hasan et al. (2011)	i) On-time deliveries ii) Lower inventory level	i) Improved information response time		i) Increased interaction ii) Decreases financial cost
Beheshti (2006)			i) IT system standardisation	i) Centralised information
Shang and Seddon (2002)	i) Improvement in business processes	i) Enhanced reporting function	i)Technology upgrade ii)Attain, expand and extend enterprise systems	i) Business and system change ii) Organisation learning
Spathis and Constantinides (2003)		i) Improved financial reporting	i) Integration of application ii) Easier maintenance of database	i) Information generation

Table 2.1 Benefits of ERP system

Beheshti (2006) looked at how ERP can benefit organisations in improving their practices and operations. He found out that ERP system generally come with standard applications centralising the information of separate department into a common database (Beheshti, 2006). The use of a common database and standardisation of business applications provide companies with a similar appearance and use of software programs and this process of standardisation can create greater ease of use and improve efficiency. Most ERP system has a customised browser that allows managers and employee to configure their own view of the program to carry out their day to day activities (Beheshti, 2006).

Shang and Seddon (2002) undertook a meta study and proposed an ERP benefits framework from analytical analysis of 233 ERP system adopting firms. They listed benefits in five dimensions: operational benefits (including business process change), managerial benefits (including enhanced reporting functions), strategic benefits (including technology upgrading), IT infrastructure benefits (including attain, expand and extending enterprise system) and organisational benefits (including business and system change and organisational learning).

Similar to nature of ERP, benefits resulting from ERP implementation are observed across the organisation. As shown in Table 2.1 benefits of the implementation are not just to limited to increase in profits, rather as according to Shang and Seddon (2002) they cover wider dimension. Benefits such as flexibility in information generation, improved reporting, integration of different functions and application, standardisation of IT systems and process are most commonly observed in an organisation and are the key reasons for growth of ERP system.

2.5 Challenges of ERP implementation

Implementation is the process through which technical, organisational and financial resources are configured together to provide an efficiently operating system (Fleck, 1994). ERP system is complex, and implementing a system can be difficult, time consuming and expensive project for an organisation (Shehab et al., 2004). There are several reasons for complexities of the ERP system which makes it implementation more challenging. One of the reasons is the functionalities offered by ERP system which usually covers thousands of business activities (Daneva and Wieringa, 2008). They found that complexities and associated challenges in implementation are due to the nature of ERP which treat the cross-organisational business processes in a value web as the fundamental building block of the system, deliver a shared system which lets the business activities of one company becomes an integral part of the business of its parameters. This creates system capabilities far beyond the sum of the ERP components' individual capabilities and each functionality offered matches the need of the unique stakeholders group. In addition, ERP system requires regular adjustment to the business needs to mirror rapidly-changing business requirements (Daneva and Wieringa, 2008).

Since ERP system are developed on 'best practice' intra-organisational functional models and so implementing ERP often requires organisations to restructure their business processes around those practices. Not surprisingly then, Maguire et al. (2010) found that the introduction of ERP system result in key organisational changes which, if not managed carefully, can actually result in conflict within organisation. This conflict is especially evident in relation to the questions of how to integrate the ERP system, what should happen to the legacy system, and how the business processes of the organisation should be revised. This necessary realignment, is often cited as the source of many of the implementation failures (Soh et al., 2000). According to Hirt and Swanson (2001) organisations that plan to adopt ERP but lack a 'realignment strategy' suffer technical and administrative problems and usually experience, at the least delays in project implementation, or on occasion, may suffer a complete implementation failure.

It is due to aforementioned reasons that a study by Nelson (2007) found that only 34 percent of IT projects initiated by Fortune 500 companies are successfully completed, and Muscatello and Parente (2006) found that ERP implementation failure rates were around 50 percent including numerous examples of failed implementation cited in literature, such as Dell, Waste Management, Mobile Europe and Hershey (Davenport, 1998).

ERP system is known for their implementation challenges and high rate of failure. This has been a cause of concern for researcher and practitioners alike, who also recognise the challenges that accompany ERP system. Although each organisation is unique and is effected in a different way, literature identifies few similar causes of implementation challenges. The commonly identified causes include integrating departments across the organisation, creating central database for information, aligning business activities around the new ERP system and need to constantly update the system. In order to overcome these challenges, researchers have proposed implementation strategies which will be discussed in section 2.6 and the attributes for successful and failed implementation, which will be discussed in next sections.

2.5.1 ERP implementation success attributes

'Success' has often been defined as a favourable or satisfactory results or outcome (Saarinen, 1996). According to Wei et al. (2006), success for an ERP system is achieved when the organisation is able to better perform all its business functions and the adopted ERP system achieves the implementation objectives.

Umble et al. (2003) measured success of implementation in more concrete terms, i.e. of benefits achieved such as personnel reduction, better inventory management, reduction in IT cost, and improvement in ordering and cash management. Some other factors that are used to measure the success of ERP implementation include overall reduction in planning and scheduling cycles, reduction in delivery times, reduction in production times, reduction in inventory stocks, reduced late deliveries and increased productivity (KMPG, 1997). Similarly, end users' satisfaction and their constructive perception about the new ERP system is also most commonly used measure of system success (Delone and McLean, 1992). While Sun et al. (2005) found that users' involvement determine the success of implementation and this further corroborated by Chang et al. (2008) who suggested that 'users' are the significant determinant effecting the ERP usage and eventually success of the system. Likewise Calisir and Calisir (2004) found that users' perception and perceived usefulness is a significant determinant of end-user satisfaction that assist in maximum utilisation of the system.

Bhatti (2006) also measured ERP success in terms of project's completion time, compliance within budget, users' satisfaction and overall system utilisation. Bradford, (2003) suggested another measure of success in organisational context is the rate of return on investment (ROI). Bradford (2003) observed that organisations generally set their ROI targets for ERP implementation at 5 percent or higher, while actual ROI results in certain cases are reported as high as 33 percent (Fryer, 1999).

2.5.2 ERP implementation failure attributes

Literature identifies several studies which have studied ERP system implementations to identify failed implementation and to find strategies for successful implementations (i.e.

Sumner, 1999; Slooten et al., 1999; Bukhout et al., 1999; Mabert et al., 2001; Amid et al., 2012). From within this stream of the literature it is found that most common cause of the failure is due to the combination of poor planning and high customisation of the ERP software (Scheer and Habermann, 2000). And by converse, one of the key factors associated with implementations going well is implementing with minimal customisation, as this eases the burden on implementation team, avoid technical pitch falls and generally saves resources (Sumner, 1999; Shehab et al., 2004).

Among several other studies, Markus et al. (2000) found several attributes that are associated with the failures including approaching ERP implementation from an excessively functional perspective, inappropriately cutting the project scope, eliminating users' training, inadequate testing, not improving business processes initially, underestimating data quality problems, fragile human capital and data migration problems. In comparison Kumar et al. (2003) suggested that only one attribute, organisational change, as the most important impediments to successful implementation.

ERP system appears to present unique on-going risk due to its uniqueness, argued Huang et al. (2004). They identified several factors and constructed a framework to analyse and prioritise these factors. The factors in the order of importance include; lack of top management's commitment, ineffective communication, inefficient training, lack of users' support, poor project management, relying on legacy systems, inter-departmental conflicts, composition of project team, failure in redesigning business processes and lack of clarity about required changes. The results of this study can assist practitioner on assessing the risks associated with ERP implementation.

Adopting a different approach, Xue et al. (2005) studied failure due to ERP vendors practices in China and found out that vendors failure to adapt to local culture, business process reengineering, managing local human resources, lack of information sharing, failure to understand cultural characteristics, lack of adaptability of ERP vendors towards changing business and economic environment, lack of cost control function (i.e. adapting to changing cost) and failure to understand technical issues specifically in the context of language barrier are the main cause of failure. While Amid et al. (2012) studied critical failure factors in Iranian companies and classified failure attributes in seven groups named as vendors and consultants, human resources, managerial, project management, processes, organisational and technical.

Further, Sammon and Adam (2004) found another key cause for failure; they suggested that inadequate organisational analysis at the beginning of the project, resulting in downstream complexities during the implementation phase can also be a major cause of failure. Since many organisations implementing ERP run into difficulty because they are not ready for integration and various departments within it have their own agenda and objectives that conflict with each other (Langenwalter, 2000). In addition, an important part of organisational analysis is to identify the organisation's requirement and functionalities offered by ERP since according to Soh et al. (2000) mismatch between these two factors, very frequently, are cause of failure.

Momohet et al. (2010) performed in depth analysis of literature review (from 1997 thru 2009) and identified the causes of ERP implementation failure as: excessive customisation, dilemma of internal integration, poor understanding of business implication and requirements, lack of change management, poor data quality, misalignment of IT with business, hidden cost, limited training and lack of top management support.

Some other factors mentioned in literature as reasons for implementation failure include excessive business process change (Motwani et al., 2002), poor data accuracy, and limited user involvement (Sun et al., 1997), lack of focus on users' education and training (Markus et al., 2000), change in personnel, lack of discipline, organisational resistance and lack of organisational commitment (Wilson et al., 1994) and cost, long project duration, technical challenges and change management (Kamhawi, 2008).

Table 2.2 shows the list of attributes for success and failure for ERP implementation found in literature. As observed, the attributes for success are mostly related to users, financial aspects and productivity. In contrast, there are numerous attributes of failure identified in literature. The amount of research in this area depicts high level of concern of researchers and practitioners. Among the attributes of failure identified, the most commonly observed include lack of top management support, software customisation, business process reengineering and lack of user's involvement which often lead to failed implementation. In the next section different implementation strategies will be discussed for implementing ERP system successfully.

Success Attributes	Failure Attributes
Increased users involvement (Sun et al. 2005; Chang et al., 2008)	Poor planning (Scheer and Habermann, 2000)
Increased return on investment (ROI) (Bradford, 2003)	High customisation (Scheer and Habermann, 2000)
Reduction in planning , scheduling and production time (Umble et al., 2003)	Inadequate training and testing (Markus et al., 2000)
Compliance with allocated budget (Bhatti, 2006)	Underestimating data quality (Markus et al., 2000)
User's satisfaction (Chang et al., 2008)	Data migration problem (Markus et al., 2000)
System utilisation (Wei et al., 2006)	Organisational changes (Soh et al., 2000)
Reduction in inventory (Umble et al., 2003)	Lack of top management commitments (Huang et al., 2004)
Improved communication	Ineffective communication (Huang et al., 2004)
	Lack of users' support (Huang et al., 2004)
	Poor project management (Huang et al., 2004)
	Poor composition of team (Mohomet et al., 2010)
	Inter-departmental conflicts (Huang et al., 2004)

Table 2.2 Success and failure attributes for ERP implementation

2.6 ERP implementation Strategies

Literature identifies several implementation strategies and models to overcome the intricacies of ERP implementation. The sub-section 2.6.1 discusses the ERP system implementation model and different implementation strategies found in existing literature are discussed in sub-section 2.6.2. The post implementation phase and strategies to evaluate the performance of ERP system are presented in sub-section 2.6.3.

2.6.1 ERP system implementation model

The literature identifies a myriad of different ERP implementation models proposed to comprehend the implementation process. Shtub (1999) defined model as a simplified presentation of reality and since real problems can be complex because of sheer size and the number of different factors, therefore by making simplifying assumptions it is possible to develop a model of the problem which is simple enough to understand and analyse, and yet provides a good presentation of the real problem. In an effort to overcome implementation challenges, as discussed in section 2.5, Bancroft et al. (1998) proposed a five phase model for implementation strategy that consists of following:

1) *'focus'* phase; a planning phase,

2) *'as is'* phase; analysis of current business,

3) *'to be'* phase – creating a detailed design subject to user's acceptance,

4) *construction and testing* phase and

5) *implementation* phase.

Similarly, Markus and Tanis (2000) proposed a four-stage model for ERP implementation which is consist of chartering, project phase, shakedown phase, onward and upward phase stages. Parr and Shanks (2000) utilised largely the same approach, however their model does not include shakedown phase. Whereas including post implementation as part of a model, Rajagopal (2002) proposed a six stages model including initiation, adoption, adaption, acceptance, routinisation, and infusion. The first four stages of this model represent pre-going live phase while last two represents post-implementation stages.

With a main focus on technical aspects of implementation, Umble et al. (2003) proposed an eleven steps model including: 1) a review of pre-implementation to date, 2) install and test new hardware, 3) install the software and perform the computer room pilot, 4) attend system training, 5) train on the conference room pilot, 6) establish security and necessary permission, 7) ensure that all data bridges are sufficiently robust and the data are sufficiently accurate, 8) document policy and procedures, 9) bring entire organisation on-line, either in big bang or in a phased approach, 10) celebrate, and 11) improve continually. This implementation strategy is mainly technically focused and although it aims to cover both pre- and post-implementation aspects, it lacks both a pre-implementation system alignment and a post-implementation system evaluation process.

Adopting reverse engineering process, Soffer et al. (2003) developed a model that captures available alternatives at different level of ERP implementation therefore aligning ERP system with the need of enterprise. The model explores the ERP system's functionality and their findings particularly stress the importance that the ERP system should be aligned with the needs of the organisation and not *vice versa*. While Santos et al. (2004) took a differing approach to CSF and they developed a model to study the relationship between key factors experienced during implementation. Factors such as 'best fit' with the current process, resistance to change, training and workforce allocation, are all key factors which affect implementation results (Santos et al., 2004). With a focus on role of CSFs and the interrelationship between them, King and Burges (2005) presented a model for ERP CSFs drawing upon existing and applying simulation in order to better understand interrelation between CSFs and to encourage further exploration of more appropriate implementation strategies arising from these interactions.

Drawing upon the 4P[6] business model, Marnewick and Labuschagne (2005) proposed a model for ERP implementation which is divided in four main sections; software, customer mind-set, change management and the flow of processes within it. This model simplifies and reduces ERP systems to manageable and understandable components which in turn enable managers to focus their attention on all four components covering essential aspects of implementation.

Taking an evaluative approach, El Sawah et al. (2008) proposed a model to predict implementation success rate as a function of interrelated CSFs and organisational culture. Lea

[6] 4P model is a business marketing model and stands for people, price, promotion and product.

et al.’s (2005) model used a prototype of a multi-agent system to collect information and interact with users in order to facilitate ERP implementation. Also in an attempt to minimise the implementation risks and improve decision making, Hakim and Hakim (2010) proposed a practical model for measuring and controlling the ERP implementation risks. This model analyses the decision making process from three different perspectives; strategic, tactical and executive, and overall it suggests that ERP implementation team should plan the process with a view of these perspectives.

As can be observed from the preceding discussion, many different models have been proposed for ERP implementation over the years – it is a rich source of literature. However it is also notable that the majority of these models are either entirely theoretical or implicitly developed to cater to the requirements of large enterprises. Literature review suggests that there is a lack of research in the area of implementation models for SMEs, therefore in many instances SMEs struggle in implementing ERP due to lack of guidance.

2.6.2 ERP system implementation strategies

Beyond the archetypes for different ERP implementation models that have been identified in the various literatures, researchers have also studied ERP implementation strategies in detail. Although ERP solutions come with pre-built software and in-built business process functions, there is nevertheless, no industry standard ERP implementation strategy; instead, each organisation approaches implementation process according to its own business strategy and requirements. Therefore, Yusuf et al. (2004) suggested that before embarking on ERP implementation, organisation must not only plan for resources availability but also assess itself for readiness for ERP implementation. Further, it should determine if it is ready for the changes brought in by new ERP system in a way it will perform business and also the users attitude towards new technology.

Studying commonly applied strategies, Mabert et al. (2003) suggested following as essential factors to be considered during implementation, to enhance the understanding of procedures required: upfront planning; keeping the modification of the source code to the minimum; managing implementation processes; and communication. Similar to their work, Verville et al. (2007) identified six ‘good practice’ found across the organisations. They include project team formation, requirement definition, establishment evaluation and selection criteria, marketplace analysis, choice of acquisition strategy, and anticipated acquisition issues, that should be considered before starting implementation process. In comparison to Mabert et al. (2003), they stressed more on the technical aspects of the implementation such ERP selection and acquisition.

Velcu’s (2010) research took a more analytical approach, as it found that when ERP system implementation strategy are aligned with business strategy, it is more likely that ERP implementation will be completed on budget and on time. Velcu’s (2010) research also highlighted that over the long run, changes in business strategy must be coordinated with functionalities in the ERP system.

By contrast to the literature that takes a modelling, tactical or strategic approach, several authors have taken contingent approaches and highlighted that different styles might be more effectively used in certain situations. For example, Sankar and Rau (2006) proposed three alternative strategies for the final phase of implementation depending upon organisational needs. They include:

- Step-by-step implementation – this strategy involves implementing one module at a given time. Focussing and implementing one module reduces the complexity of implementation process. Meanwhile, implementation team gain knowledge and understanding of the system that can be used further along the implementation.
- Big-bang implementation – this strategy involves implementing the complete ERP system in a single step. This involves a great deal of complexity, attention to detail, intensive system testing and a backup plan. An experienced and capable project team is essential for this strategy.
- The rollout implementation – this is a phased implementation process in which implementation is carried out in a certain area of the company at first and then it is spread out to the other functioning departments. Basically, it creates an implementation model initially, which is then tested, bugs fixed and problems solved. It is then implemented in other parts of the organisation. This type of strategy is well suited for large organisation.

Similarly, Zhang and Li (2006) suggested certain contingent strategies for implementation including:

1) complete conversion; i.e. all modules are implemented at once,

2) progressive conversion; i.e. modules are implemented one, at a time,

3) special type progressive conversion; i.e. a transitory link between new system and old legacy system, and

4) parallel conversion; i.e. a new and existing system is operated at the same time for certain amount of time.

Beheshti (2006) also proposed several strategies for implementation. One approach is the one time complete conversion from old legacy system to new ERP system. In this implementation strategy, the organisation removes the legacy program and immediately installs and begin the use of the new ERP system throughout its functional units. Another implementation method is the gradual replacement of legacy program with ERP system. This approach is best suited for those organisations in which different ERP modules are being implemented across the organisation, and also for the organisations who seeks for control over the implementation process by implementing one module at a time. By adopting this strategy, ERP system can be implemented within the individual units of the organisation in a piecemeal fashion, one at a time, and then individual implementation within each unit can be integrated with each other. This strategy is more beneficial to smaller and medium sized (SMEs) organisations since they can choose to implement ERP system one module at a time with more control over the implementation, and later they can add more modules over time (Beheshti, 2006).

However, this literature is notable for its repetition, with little distinction between the lessons implied in the modelling, tactical or strategies approaches indeed, it should be noted that strategies suggested are almost similar to the one mentioned earlier and author has given a different name to the strategies.

Botta-Genoulaz et al. (2005) proposed mapping out an implementation strategy which they called a ‘phased optimisation’ process. This includes three stages: operational (using information system as production tool), tactical (control of operational process for better integration of between function) and strategic (contributing to company strategy). They argued that this would assist in internal procedural simplification, easier information retrieval, improved performance management and increase in production efficiency (Botta-Genoulaz et al., 2005).

Analysing the ERP implementation from the vendor's perspective, Helo et al. (2008) suggested starting ERP implementation process at slow pace to allow employees to get familiarised with ERP system and the implementation process. He also advised that the implementation process be started by implementing simpler modules, such as finance and human resources, to allow ERP consultants and staff time to learn more about company problems and preferences before tackling the more complex modules (Helo et al., 2008).

Noting complexities resulting from customisation of ERP, Daneva (2003) proposed a method of 'composition and reconciliation' to achieve working realignment strategy suitable for ERP implementation. This method proposes organisations exploring the standard ERP functionalities to first, find out how closely they match to existing business process and data needs, and then second, selecting the most suitable combination of functionalities present. Another common approach to avoid the complexities of realignment and customisation involves organisations selecting the 'best' modules within an ERP system (such as human resources, accounting, product life cycle management and inventory management) and implement these instead of implementing the complete ERP system (Alshawi et al., 2004). Still, Federici (2009) advised, that an initial part of planning should involve preparing strategies for organisational change and then determining criteria for the selection of the 'right' ERP vendor to assist in implementation.

Aladwani (2001) argued that ERP implementation requires matching appropriate strategies with the suitable stage to overcome resistance sources (habits and perceived risks) effectively. One of such appropriate strategy, proposed by Kremmergaard and Rose (2004) is changing project managers during each implementation phase since each phase requires a specific set of competencies and skills.

Since implementation process involves various associated risks, therefore Dey et al. (2010) proposed a risk management framework for ERP implementation by categorising risk factors into planning, implementation and operation phases. They found that implementation phase is most vulnerable to failure. In addition, the effect of other on-going projects, including the management of overall IT architecture and non-availability of resources for organisational transformation, are the most critical risk factors for implementation.

As observed in literature, there exists vast research work in the area of ERP implementation strategies. Researchers have attempted to identify the best strategy which can lead successful implementation. However, since each organisation has unique culture and implementation objectives, selecting the right strategy can be challenging. Analysis of organisational needs and status of current infrastructure and users skills can be a good starting point for organisation including SMEs planning to implement ERP system. Further research in implementation strategies specifically according to size of organisation and trade sector are also recommended.

2.7 Post-ERP implementation

An important phase in the implementation process is the post implementation, as according to Nah et al. (2001) implementation concerns related to ERP do not end once the system becomes operational. Rather as William and William-Brown (2002) argued, once ERP system is successfully set up it has a 'go-live' date but that point of the implementation of the system is not the end of the ERP journey, rather the post-implementation or exploitation stage is where the real challenges begins. It is due to the reason that Davenport (1998) argued against the prevailing assumption of treating ERP as a project that has termination date.

Post implementation stage involves critical processes such as testing the system for effectiveness (i.e. it's actual, versus projected, compatibility with business processes), checking the reliability, data integrity, system utilisation and most importantly, assessing and evaluating the benefits of implementation of the system (Holland and Light, 1999; Nah et al., 2001). In addition, during this phase organisations often encounter a wide range of risks (including technical pitfalls, emergent business needs, inadequate users behaviour and deficient system design) when using, maintaining and enhancing ERP system (Peng and Nunes, 2009). Pal et al. (2010) also investigated the risk factors that affect the long term viability of ERP project. He found that risk factors such as loss of qualified IT experts after implementation, inaccurate master production schedules, users' resistance, loss of ERP-related know how, lack of vendor support, failure to produce appropriate material requirement plan and inefficient integration between modules are primary risk factors that can affect the viability of ERP projects.

Caldwell (1998b) indicated that benefits of fully functional ERP system are realised in next one to three years after implementation. He also observed that many firms suffer an initial 3 to 9 months productivity dip after the ERP system "goes live" (Caldwell, 1998b). It can be avoided by establishing new procedures and job roles according to new ERP system. The next stage, which lasts from 6 to 18 months, often involves structural changes, process integration, and implementing extensions to the ERP system (Caldwell, 1998b). The resulting streamlining of operations and effective system usage helps firms achieve return on investment as well as reap efficiency benefits. The third stage, of 1 to 2 years duration, involves organisational transformation, where the synergies of people, process, and technology usually results in increased customer satisfaction and competitive advantage to firms (Caldwell, 1998b).

Observing a similar phenomenon to Caldwell (1998b) but with a differing research motivation, Nah et al. (2011) identified five maintenance activities pertaining to ERP implementation in the post go-live phase. The activities include corrective maintenance (troubleshooting, importing new data objects and updates from vendor), adaptive maintenance (transfer, testing, modification and enhancement, authorisation etc.), perfective maintenance (version upgrades), preventative maintenance (routine administration, monitoring workflow), user support (continuing the training of the users and helpdesk-type support services) and external parties (coordination and administration with vendors, consultants and external users organisation).

The literature is unified in observing that it is important that after any ERP implementation (including those by SMEs), time is taken to evaluate the system's performance to find out if the system satisfies their organisational requirements; particularly given the investment of the resources and time, (Francoise et al., 2009). To facilitate such evaluation, Wei (2008) proposed a framework to assess the performance of a new ERP system based on the ERP implementation's project objectives. Appropriate performance indicators are identified and a consistent evaluation standard is set up for ERP evaluation process (Wei, 2008). The proposed framework also establishes a feedback mechanism between the desired objectives of the ERP adoption and the effects of ERP implementation (Wei, 2008).

Approaching the question of feedback and post implementation more holistically, Mandal and Gunasekaran (2003) propose a feedback system to help organisations constantly monitor the ERP system's implementation performance and post-implementation strategies to measure the effectiveness of the ERP system including measurement of objectives achieved, cost estimates and improvement in IT infrastructure. While concentrating on post-implementation, Nicolaou (2004) examined the post implementation stage in ERP implementation and identified the factors which contribute towards high-quality post implementation review (PIR). These factors include: review of overall project scope and planning, review of driving principles for project development, evaluation of misfit resolution strategies, evaluation of attained benefits and evaluation of user and organizational learning. These five PIR can be examined to measure the quality of implementation and success level. Taking different approach, Chou and Chang (2008) examined the ERP performance at the post-implementation stage from the perspective of managerial intervention. They found that both customisation and organisational mechanisms affect intermediate organisational benefits in post implementation (including particularly coordination improvement and task efficiency), and they concluded that this in turn, influences the overall benefits achieved by the organisation following ERP implementation.

This section illustrated the research in the area of different strategies for ERP implementation. Davenport (1998, p.121) stated that 'an enterprise system is not a project; it's a way of life'. Once implemented, it is important for an organisation to evaluate and analyse the outcome of implementation. Due to high cost and technical challenges involved in implementation, post implementation phase analysis is critical. Researchers have suggested performance evaluation framework and strategies specifically for this phase. Besides performance evaluation, post implementation phase covers some other important aspects, such as maintenance, users training and support and hands-on training. As mentioned previously, it is the phase where real challenge begins, therefore it demands a comprehensive strategy to exploit the potentials of ERP and to evaluate the resulting benefits.

Phase II – Critical Success Factors

2.8 History and Definition of CSFs Approach

The notion of success factors is rooted in management literature (Bradley, 2008). It was first introduced by D. Ronald Daniel in 1961. It was refined to critical success factor and adopted in IT literature by John F. Rockhart in 1979. According to Rockhart (1979) the process of identifying the CSFs helps to ensure that those factors receive necessary attention. In his view, CSFs are those key areas in which favourable results are absolutely necessary for the business to successfully compete.

Critical success factors are those few things that must go well to ensure success for a manager or an organization, and, therefore, they represent those managerial or enterprise area, that must be given special and continual attention to bring about high performance. CSFs include issues vital to an organization's current operating activities and to its future success. In terms of ERP implementation, CSFs are those conditions that must be met in order for the implementation process to occur successful (Bradley, 2008).

2.8.1 Benefits and difficulties of using the CSF approach

Literature generally agrees with Rockhart (1979) over the important role CSF play during implementation. Pinto and Selvin (1987) suggested that addressing CSFs can significantly improve the chances of successful implementation. Brown and He (2007) suggested that CSF approach is not only attractive to researcher but resonates with the managers, since it is researchable and vigorous, and it facilitates the identification and prioritisation of the factors that could influence the implementation success. Therefore understanding and managing these key points can lead to successful implementation (Zhang and Li, 2006).

Bonyton and Zamud (1984) highlighted two main strength of CSF method. First, it generates users' acceptance at the senior managerial level. They proposed that senior managers seem to intuitively understand the thrust of the CSF method, and consequently, they strongly endorse its application as a mean of identifying important areas that need attention. Second, the CSF methods facilitate a structured, top-down analysis or planning process by focussing on core set of essential issues, and then proceeds to refine these issues which allows an evolving desirable role of CSFs (Bonyton and Zamud, 1984).

However it should be noted that there has been some criticism of the CSF approach. It is suggested that it relies excessively on the opinion of the managers without involving any other parties participating in the implementation processes. Davis (1980) argued that this approach stresses on the importance of certain factors only while ignoring many other important aspects that can play as crucial role during implementation. Munro and Wheeler (1980) examined the weakness and developed a new approach accordingly to overcome this issue by incorporating manager's subjective opinion into the decision making for establishing CSFs, thus broadening the scope of information input in establishing the CSFs. While Boynton and Zamud (1984) suggested that CSF approach can be strengthened by involving management across section and acquiring their feedback to improve the implementation process experience.

2.8.2 CSFs in ERP Implementation

Literature review identifies several CSFs which influences and guide ERP implementations and which have a direct impact on implementation outcomes. In one of the earliest studies of ERP implementation, Bancroft et al. (1998) identified CSFs for successful implementation as top management support, the presence of champion, good communication with stakeholder, effective project planning, re-engineering business processes and using a business analyst on the project team. Similar to work of Bancroft et al. (1998), Bingi et al. (1999) identified CSFs which they considered must be understood for implementation success. They include top management commitment, reengineering, integration, ERP consultant, implementation time and cost, ERP vendors, selecting right employees, and employee morale.

In an important study, Somers and Nelson (2001) presented a comprehensive taxonomy of CSFs for ERP implementation after an extensive literature review and practitioners recommendation. They also rated CSFs by the degree of importance during ERP implementation as follows:

1. Top management support
2. Project team competence
3. Interdepartmental cooperation
4. Clear goals and objectives
5. Project management
6. Interdepartmental communication
7. Management of expectation
8. Project champion
9. Vendors support
10. Careful package selection
11. Data analysis and conversion
12. Dedicated resources
13. Use of steering committee
14. User training on software
15. Education on new business processes
16. BPR
17. Minimal customisation
18. Architecture choices
19. Change management
20. Partnership with vendors
21 Use of vendors' tool
22. Use of consultant

Literature review suggests that very often researchers have focussed on specific phase of implementation, specific CSFs or comparing relative importance of CSFs. Drawing from a comprehensive literature review, Nah et al. (2001) classified CSFs and then apply CSFs into Markus and Tanis (2000) process-oriented ERP life cycle model to present which CSF is important at a particular phase. CSFs identified are: ERP team work and composition, top management support, business plan and vision, effective communication, project management, project champion, appropriate business and legacy system, change management program and culture, business process reengineering (BPR) and minimum customisation, software development, testing and trouble shooting, monitoring and evaluation of performance.

Akkermans and Helden (2002) adopted and then applied the CSFs proposed by Somers and Nelson (2001) in ERP implementation in aviation industry, which initially led to serious project crisis however the situation was then turned into a success. The list of CSFs explained both the initial failure and later success. The result showed that CSFs were interrelated and interdepartmental communication played essential role in success. Whilst top management support, project team, project champion and software vendor played essential role in achieving success.

Adopting a holistic approach, Umble et al. (2003) not only identified CSFs but also implementation procedure critical to successful implementation. CSFs identified are clear understanding of strategic goals, commitment by top management, excellent management, organisational change management, a great implementation team, data accuracy, extensive education and training, focused performance measures and multi-site issues as essential for successful implementation. Umble et al. (2003) also analysed a successful implementation in terms of these CSFs. In addition, Nah and Delgado (2006) conducted a study examining the temporal importance of CSFs across different stages of implementation. They found that top management support was the most important during early phase of the implementation. These findings are identical to earlier work by Parr and Shanks (2000) which also found that top management was important during early stages of implementation. Besides top management, other CSFs considered important include business plan and vision, change management, communication, ERP team composition, skills and compensation, project management, system analysis, selection and technical implementation.

Conducting a case study comparison of four firms grounded in business process change theory, Motwani et al. (2005) proposed factors observed as essential for success. They suggested that a cautious, evolutionary, bureaucratic process backed with careful change management, network relationship, and cultural readiness have a positive impact on ERP implementation. However, their research sample only involved four firms, suggesting a cautious approach when implementing the findings.

Several other CSFs identified in more general literature include: process re-engineering, IT infrastructure (Ehie and Madsen, 2005), committed leadership, open and honest communication, balanced and empowered implementation team (Sarkar and Lee, 2003), software selection process, selection of appropriate implementation process (Umble et al., 2003), functional coordination between different departments (Kim et al. 2005), top management support, users, vendors' selection, project management, training, risk management, system re-engineering and customisation (Maguire et al., 2010).

Literature on CSFs for ERP implementation is exhaustive. Due to broad nature of ERP, researchers have focussed on different aspect of implementation. Despite the variation in focus of researcher there are certain CSFs which are common and are as critical irrelevant of the implementation or implementation strategies. After reviewing the literature, the CSFs which were most commonly cited include; management support, effective project planning, BPR, project team, vendors, IT related CSFs (such as data accuracy, internal structure and software development) and communications.

Part III – SMEs

2.9 SMEs – Definition

Small and medium enterprises (SMEs) are often considered to be the backbone of major economies around the world (Love et al., 2005; IDC, 2006). However there is no single generalised definition of what constitutes a 'SME', some of the most widely used defining criteria of SMEs focus on characteristics of size, including the number of employees, turnover or sales volume, asset size and capital requirement (Ibrahim and Goodwin, 1986). According to the UK Department of Trade and Industry (DTI), SMEs include the organisation that that have less than 250 employees while the USA's Small Business Administration agency describes a small business as "one which is independently owned and operated and which is not dominant in its field of operation" (Small Business Administration, 2006, p. 323).

Ayyagari et al. (2007) suggested that SMEs employ between 6 to 80 percent of world's workforce and on average SMEs constitute 54 percent of the economy across the globe. In a recent study, Hsu et al. (2012) argued that SMEs account for approximately 90 percent of the companies throughout the world and moreover, SMEs employee constitutes 50-60 percent of the entire world's workforce. In 2009, the USA Small Business Administration, estimated that there were 27.5 million functioning SMEs in the USA and that employed approximately 50 percent of the private sector workforce (Small Business Administration, 2009). Similarly, in 2010 Canadian SMEs employed an estimated 48 percent of the private sector workforce (Industry Canada, 2011) and in European Union 85 percent of the net new jobs were created by SMEs between 2002 and 2010 (Eurostat, 2012).

The literature identifies significant differences between SMEs and large enterprises (LEs) with the most distinguishing features of SMEs being their generally more limited resources and comparatively small organisational and simple organisational/functional structures. Accordingly, top management in SMEs is usually involved in day-to-day activities and decision making (McCarton-Quinn and Carson, 2003) which might give SME a comparative strategic advantage. Jutla et al. (2002) suggested that SMEs most commonly have limited resources in terms of personnel, finance, and knowledge pertaining to management, marketing and IT. SMEs generally have relatively informal structures and cultures (Mintzberg et al., 2003), and this is often identified as resulting in increased capacity for cross-functional exchanges and smaller, more efficient teams that are conducive for more efficient decision making (McAdam, 2000). Further, Caskey et al. (2001) suggested that SMEs are generally more entrepreneurial, innovative and ready to experiment with new strategies. Some commentators also highlight that in the time of globalisation and increasing competition, SMEs have shown to have some advantage by being more agile (Bill and Raymond, 1993).

2.9.1 Particular operational difficulties of SMEs

SMEs, due to their limited resources in term of personal, finance and knowledge, face unique operational difficulties which are not observed in large enterprises. Due to their limited set up and market share, SMEs face inexistence of scale economy, deficiency of cash (SMEs are not in position to raise enough cash in short terms, if opportunity arise for business extending their current possibilities) and deficiency of expert personal (because of lack of financial resource, growth and development of the company usually is not adequately accompanied with employing of necessary personal from different fields, whose expertise is usually necessary). Regarding expertise, SMEs typically have lower technical expertise and poorer management and marketing skills than those found within larger organisations. While externally, the SME has little or no control over its macro-environment, rendering it vulnerable to change and competition which leaves SME at the mercy of both suppliers and distributors (Harrigan et al., 2011).

Similarly, SMEs generally face disadvantage in benefitting from developing new IT technologies (Raymond et al., 1998) because of lack of relevant knowledge, technical and IT skills. Further SMEs have limited resources such as inability to afford a dedicated IT staff or necessary infrastructure (Adam and O'Doherty, 2000) while larger enterprises generally have a greater capability to make use of new information system technologies such as ERP system (Raymond et al., 1998). This lack of essential resources generally poses greater challenges to SMEs in adopting new technology (Raymond et al., 1998). Similarly the cost of implementation is a major factor that influences the decision to implement new system or continue working with legacy system (Mabert et al., 2000).

2.10 Implementing ERP System for SMEs

This section discusses the introduction of ERP system in SMEs in sub-section 2.10.1. In the following sub-sections benefits and difficulties in implementing ERP system in SMEs are described.

2.10.1 Growth in availability of ERP system

As discussed in section 2.3, owing to technological and economical restrictions, ERP system is mainly implemented in large enterprises, however the SMEs start realising the benefits brought by ERPs and ERP vendors specially develop new ERP system or revise existing version to accommodate the need of SMEs (Chen, 2001; Bell and Orzen 2007; Deep et al., 2008).

The potential benefits and economically attractive initial price of the ERP system has developed an increasing interest by SMEs. In response to growing competition and operational challenges, SMEs appreciate the functionality of ERP system (Koh and Simpson, 2005) and increasing number of SMEs are upgrading their legacy system to ERP system (Esteves, 2009). There has been a significant growth in the use of ERP system by SMEs. The reasons for this are fourfold (Gable and Stewart, 1999): firstly, saturation in the large enterprise market for ERP system; secondly, significant benefits can be achieved with the advancement of technology and internet, as well as integration of large enterprises and SMEs; thirdly, the number of SMEs is far greater than the number of large enterprises (see section 2.9). Lastly, the package initially designed for SMEs are now becoming upward scalable in line with the growth of an organisation (Gable and Stewart, 1999).

Raymond et al. (2007) studied the profile of 356 Canadian firms and suggested that 'internally predisposed[7]' SMEs and the 'externally predisposed' manufacturers are more likely to adopt and implement ERP system. Whilst Bernroider (2008) suggested that the companies with strong IT governance domains are more likely to adopt ERP system and these organisations also have higher chances of implementation success. Buonanno et al. (2005) studied the factors affecting ERP system adoption in SMEs and large companies, and their findings reveal that company size is a good predictor of ERP adoption. Surprisingly, they found that for SMEs structural and organisational reasons are main deterrent for not adopting ERP system, i.e. instead of financial reasons (which are more often assumed in the literature). For SMEs, ERP implementation is more affected by exogenous reasons or 'opportunity of the moment' than business related factors, and this is different from the findings for larger enterprise, that were found to be more interested in managing process integration and data inconsistency.

Bernroider and Koch (2001) found that SMEs have a generally different strategy for selecting ERP system compared to larger enterprises as SMEs mostly follow an adoption strategy which is based on their operating requirements, logistic fulfilment and most important their financial capabilities (Huin, 2004). It must also be noted that SMEs have more choices of ERP system to implement in comparison with larger enterprises. SMEs can buy their system directly from software vendor or indirectly through a value added reseller (VAR). Large vendors offer more variety of modules and have considerable resources for on-going support and upgrades with a high cost and higher degree of standardisation. While system offered by VARs are more flexible and offer modules geared towards the need of specific industries and require less organisational change, thus reducing the overall costs (Beheshti, 2006). Liang and Xue (2004) studied ERP implementation from vendors' perspectives of the SME market segment and suggested three strategies that could be applied when SMEs implementing ERP system. The first strategy is to localise ERP system to reflect local management issues; the second one is to customise ERP system at a variety of levels and the third one is to carry out

[7] Internally predisposed SMEs can be those enterprises who are more inclined towards implementing ERP systems to improve their internal efficiency.

BPR in an incremental manner, taking the dialectic of organisational learning and ERP requirements into account.

To overcome the implementation challenges in SMEs, Zafeiropoulos et al. (2005) developed a management application for modelling, optimal adaption and implementation of ERP system in SMEs. The application covers wide range of risks such as project definition and size, users, sponsorship and commitment, software package selection, technology and project management structure. The application evaluates different types of risks and, provides a structured procedure to manage risk and knowledge repository on managing risk. Similarly, Metaxiotis (2009) insisted that since ERP system integrate different business functions and establish central database for information sharing, it is therefore essential that SMEs should incorporate information sharing mechanisms into their organisational culture.

However, Olsen and Saetre (2007) warn that ERP system are not always the best solution for small niche companies because the inherent nature of ERP system 're-writing' business processes to fit particular models do not always conform with the specific needs of these organisations. Tagliavini et al. (2002) had similar observations in certain situations, where SMEs make use of ERP system mostly for contingency, exogenous reasons (such as pressure for integration by suppliers or customers), rather than undertake an analysis of their own needs and making the most of the opportunities ERP system provide.

Esteves (2009) proposed a benefit road map for ERP implementation in SMEs and suggested that a long-term vision is required in order to obtain a successful realisation of the potential benefits of ERP system. He also found that ERP benefits realisation dimensions are interconnected, and that managers should perceive ERP benefits realisation as a continuum cycle along the ERP post-implementation (Esteves, 2009).

A more recent development in the area of ERP system is its availability as Software as a Service (SaaS). According to Torbacki (2008), SaaS provides services of remote access to software currently experience dynamic development and is supported by major ERP developers.

Besides software itself, a key part of ERP system is the design and integration of the business processes. ERP system implementations challenge organisations to rethink their business processes and system, which need to be more streamlined and integrated (Laukkanen et al., 2007). These underpinnings require organisation to adapt to the challenges and make continuous changes to suit business environment (Malhotra and Temponi, 2010).

2.10.2 Benefits of ERP implementation for SMEs

ERP system implementation in SMEs deliver same benefits as discussed in section 2.4 and has a positive impact on overall SME operational activities. ERP implementation can help SME's to respond quickly to changes in local market demand, improve business processes and benefit from economies of scale. In addition, ERP system enables SMEs to connect with the suppliers and buyers in supply chain.

In a study of benefits of ERP implementation in SMEs, Baharti and Rakesh (2012) found a reduction of up to 30 percent of inventory level, 80-90 percent of inventory accuracy, 80-90 percent of on-time delivery, on average 80 percent reduction in raw material waste, 30 percent reduction in operational cost and up to 30 percent increase in operating profits are commonly observed in SMEs.

2.10.3 Particular difficulties in ERP implementation for SMEs

As discussed in the previous section, there exist significant differences between SMEs and larger enterprises and SMEs have their own set of strategies, policies and priorities in comparison with larger enterprises. Therefore strategies and theories applied in larger enterprises (which generally form the majority of 'received wisdom' in literature and practice) cannot be assumed to be suitable for SMEs (Schubert et al., 2007; Thong et al., 1996). In addition, the factors affecting the implementation of ERP system in large organisations do not necessarily apply to small businesses (Tarn et al., 2002) due to their specific characteristics. Federici (2009) argued that lessons learned from ERP implementation in larger enterprises cannot be simply replicated in SMEs since ERP adoption in SMEs is mainly driven by competitive pressure and need of integration with partner organisation in supply chain (Elbertsen and Van Rennekum, 2008). Huin (2004) insisted that unless differences between small and large enterprises are understood, managing ERP project in SMEs "will continue to be slow, painful and at times even unfruitful" (Huin 2004, p. 516).

SMEs face many issues when implementing ERP system, due to limited IT infrastructure and staff, and generally less specialist business process (Nah and Lau, 2001). In addition, SMEs are more likely to have informal structures and less formalisation of procedure, which run counter to the core of efficiency for ERP system (Achanga et al., 2006). This often leads to a situation where the concept of process owner or key user is often ambiguous (Koh and Simpson, 2005), the features of the software do not correctly fit the business requirements and SMEs thus either need to change to match the software and minimise customisation or to modify the software to fit the process (Buonanno et al., 2005).

Literature suggest that the particular difficulties in ERP implementation are due to the fact that SMEs operates in a highly competitive environment with limited resources - financial, technical personnel, technology and so forth (Yap et al., 1992), business problem resulting from lack of alignment of implementation practices with firm competitive strategy (Yen and Sheu, 2004) and cost and risk in undertaking the technology and the system (Sun et al., 2005). In addition, lack of human and financial resources are major impendent in ERP implementation (Achanga et al., 2006; Gunaeskaran et al., 1996; McAdam, 2000). This often leads to problems during implementation wherein resource allocation and utilisation may be subject to changing priorities during implementation (Achanga et al., 2006). Also, due to resource limitation in certain cases, SMEs are not able to afford appropriate users training (Raymond et al., 1998), hindering project success and decreasing system utilisation (Sun et al., 2005).

To overcome these issues, Malhotra and Temponi (2010) recommended six best practices for ERP implementation in SMEs based on 'critical decisions'. They include project team structure, implementation strategy, selection of transition technique, database conversion strategy, risk management strategy and change management strategy. To implement these critical decisions, positive support by the CEO and perceived benefits of ERP system can play important role (Shiau et al., 2009). Whilst the high involvement of top management in day-to-day operation in SMEs means that explicit limitation of scope of implementation appears not to be such an issue in SMEs. Nevertheless SMEs should develop a culture which is ready to accept the changes due to evolving information technology and business environment (Doom et al., 2010).

Similar to large enterprises, ERP implementation in SMEs is fraught with challenges and difficulties. Due to their unique characteristics, SMEs are mostly like to suffer due to complication arising from ill-planned implementation.

2.10.4 CSFs for SMEs

In the quest to explain as why some firms succeed in their implementation while other struggle, it is essential to understand the role CSFs play during an implementation. As discussed in section 2.8, CSFs are those few things that must go well to ensure success for a manager or an organisation. CSFs for SMEs usually differ from large enterprises, as according to Doom et al. (2010), who argued that CSFs for ERP implementation in SMEs environment differ substantially from ERP implementation in larger enterprise. CSFs in large enterprises focus on environmental factors as compared to CSFs in SMEs (Ramdani et al., 2009). Among the articles identifying CSF for ERP implementation in SMEs, Cantu (1999) proposed a framework for ERP implementation in SMEs based on five CSFs. They include: management/ organisation, process, technology, data and people. He analysed these CSFs in the framework of their attributes and found that the degree to which the framework CSFs are addressed during implementation has direct impact on the implementation success.

Among the identified CSFs for SMEs in literature, Wee (2000) suggested effective project management, a clear business plan and vision, top management support, effective communication, strong ERP teamwork and composition, effective BPR and minimum customisation, efficient change management program and culture, efficient software development, testing and troubleshooting are required for efficient implementation. Rosario (2000) agreed with previously proposed CSFs but surprisingly he did not consider top management support critical for implementation success.

Loh and Koh (2004) identified and classified the CSFs corresponding to implementation phases proposed by Markus and Tanis (2000). Through a comprehensive literature review and interviews, they identified ten CSFs. They found that the CSFs: project champion, project planning, business plan, top management support, effective communication, ERP team work, BPR and customisation, change management program, software development, testing and troubleshooting, and performance monitoring and evaluation are essential for successful implementation.

Lee and Molla (2006), applied Loh and Koh’s (2004) model to study critical element in SMEs during ERP implementation. They identified that the particular uncertainties faced by SMEs are funding, project leadership, project partner, resistance to change, software selection and evaluation. The CSFs that are important are identified as: top management support, project planning, effective communication, business process change, customisation, system testing and change management.

Taking a different approach, Plant and Willcocks (2007) studied project managers’ perception of CSFs at different implementation stages. They found that during initial stages of implementation CSFs top management support, clear goals and objectives, and dedicated resources are most important factors. In the middle of implementation process, three leading CSFs were top management support, project team competence and dedicated resources. While top management support, dedicated resources and management of expectations were considered essential in the final stages of the projects. They further proposed CSFs that were considered essential during and after the implementation, including careful package selection, vendors support, vendor partnership, access to physical resources, software functionality and vendor-client proximity (Plant and Willcocks, 2007).

In addition to above mentioned CSFs, additional CSFs identified in literature include; good project champion and strong ERP teamwork and composition (Stefanou, 1999), efficient software development, testing and troubleshooting (Scheer and Habermann, 2000) and effective executive management, reengineering of business processes and need assessment (Muscatello et al., 2003) which play critical role in implementation.

In comparison with research on CSFs for large enterprises, research in the area of CSFs in SMEs is in evolving phase. Literature points out the growing interest of the researchers in this area. The most commonly cited CSFs include top management, users (including users’ training and learning), IT (including infrastructure, database), project management (including team composition and teamwork) and vendors (including their support and selection).

2.11 CSFs for ERP implementation

In this section, five most commonly observed CSFs for all type of organisations are discussed. The CSFs are listed in Table 2.3.

2.11.1 Top Management Support

Top management support is the overall support provided by the higher management to the implementation project, and studies suggest that it reinforces the degree of commitment of all employees to the implementation. Proactive top management support is critical in information system (IS) implementation and is identified as one of the most important CSF for ERP implementation (Akkerman et al., 2002; Bingi et al., 1999; Davenport, 1998; Holland et al., 1999; Umble et al., 2002; Weston, 2001; Willcocks et al., 2000; Zhang et al., 2005; Soja, 2006; Finney et al., 2007; Remus, 2007; Nah et al., 2003).

According to Laughlin (1999) top management support is the first order of business for ERP, while Brown and Vassey (2003, p. 67) insisted that to achieve higher level of success it is important that "top management must be engaged in the project, not just involved". Snider et al. (2009) argued that management support appeared particularly relevant due to their high level of involvement in SMEs, besides their direct influence on resources allocation and informal communication.

Top management support is identified in the literature as essential from the planning phase through to the system going live, assisting in overcoming obstacles such a political resistance, establishing a strategy, availability of resources, creating vision and encouraging participation throughout the organisation and information sharing (Thong et al., 1996; Zabjek et al., 2009).

Top management support is also argued to be instrumental during the entire ERP implementation process as it continuously monitor the progress, provide direction, support and own ERP implementation, and allocate required resources (Stratman and Roth, 2002; Bingi et al., 1999). This is because taking 'ownership' of the implementation by the top management is imperative for success (Umble et al., 2003), as observed in organisation like GTE (Caldwell, 1998) and Fujitsu Microelectronics (Zerega, 1997) where companies completed their implementation on time and within budget.

Nah et al. (2001) suggests that top management support for the implementation can be acquired by appropriate corporate remuneration policy. This creates interest on the part of top management to be actively involved in implementation by providing direction and support, ensuring that staff is satisfied and comfortable with the new system and changes brought with them (Davenport, 1998; Somers and Nelson, 2004; Nandhakumar et al., 2005). Also, according to Bradford and Florin (2003) top management support increases efficiency related to perceived organisational performance and users' satisfaction. Surprisingly, Soja (2006) found this factor might be significant only in larger organisations.

From the preceding discussion, it can be summarised that a successful ERP implementation is contingent upon strong and persistent top management support and involvement. It is due to the essential role they play during implementation process that CSF top management support is incorporated in the simulation model developed for this study.

Critical Success Factors	Literature identified
Top Management Support (TMS)	Al-Mashari et al. (2003), Al-Sehali(2000), Akkerman and Van Helden (2002), Bingi et al. (1999), Esteves-Souza and Pastor-Collado (2000), Gattiker (2002),Gupta(2000),Holland and Light (1999), Loh and Koh(2004), Mabert et al. (2003), Nah et al. (2003), Paar and Shanks(2000), Sommers and Nelson (2001), Sternad et al. (2007), Umble et al. (2003),Yen et al. (2002), Zhang et al. (2003)
Users	Aladwani(2001), Al-Sehali (2000), Akkerman and Van Helden (2002), Bingi et al. (1999), Bradley(2008),Earnest and Young(2006),Esteves-Souza and Pastor-Collado (2000), Gattiker (2002),Gupta(2000), Mabert et al. (2003), Shanks et al. (2000), Sommers and Nelson (2001), Sternad et al. (2007),Sumner (2005), Umble et al. (2003),Yen et al. (2002), Zhang et al. (2003)
Project Management (PM)	Al-Mashari et al. (2003),Al-Sehali (2000), Akkerman and Van Helden (2002), Earnest and Young (2006), Esteves-Souza and Pastor-Collado (2000), Holland and Light (1999), Nah et al. (2001),Reif (2001),Shanks et al. (2000), Sommers and Nelson (2001), Sternad et al. (2007), Sumner (2005), Umble et al. (2003),Yen et al. (2002), Zhang et al. (2003)

IT	Al-Sehali (2000), Akkerman and Van Helden (2002), Earnest and Young (2006), Esteves-Souza and Pastor-Collado (2000), Gattiker (2002), Holland and Light(1999), Nah et al. (2003), Ross et al. (2006), Sommers and Nelson (2001), Sternad et al. (2007), Umble et al. (2003), Yen et al. (2002), Zhang et al. (2003)
Vendors Support (VS)	Al-Mashari et al. (2003), Al-Sehali (2000), Akkerman and Van Helden (2002), Bingi et al. (1999), Esteves-Souza and Pastor-Collado (2000), Holland and Light (1999), Sommers and Nelson (2001), Sternad et al. (2007), Umble et al. (2003), Yen et al. (2002), Zhang et al. (2003)

Table 2.3 Critical success factors investigated

2.11.2 Users

CSF 'users' refers to the people involved in implementation process. Users' perceptions, interest and feedback play a very important role during implementation (Stewart et al., 2000). During the implementation process it is important that users commit themselves to the definition stage of the company's ERP system requirement analysis and to the ERP implementation (Zhang et al., 2005; Nah et al., 2003). Involving users in the planning stage can be beneficial in getting them acquainted with the new system and potentially minimises their resistance in the implementation process and in communicating with consultants (McLachlin, 1999). Additionally improving users' perceptions of perceived usefulness, ease of use of technology, users' level of intrinsic involvement can enhance the use of ERP system (Amoako-Gyampah, 2007).

Fleck (1999) argued that substantial involvement of the users during implementation is necessary to make the most out of implementation. According to him, the value of local knowledge held by users should be recognised as crucial for successful implementation.

Koh et al. (2006b) studied six manufacturing organisations of all sizes and reported that 'human factors' constitute a major problem, particularly for small and medium enterprises. Their findings highlighted the fact many employees were not trained to use the system and many were unfamiliar with computers. Subsequently, this created several issues such as erroneous data input, poor use of the system, increasing costs of training services offered by the vendors, employee resistance to integration of the ERP system into business processes and the need to hire personnel versed in information technology.

User training on the new system is argued to be essential in improving their perception of the new ERP system and increasing utilisation (Bingi et al., 1999; Kumar et al., 2002; Trimmer et al., 2002; Robert et al., 2002; Somers and Nelson, 2001). Umble et al. (2003) found users' education/ training as the most widely recognised CSF. It is suggested that in terms of characteristics, essential users' training should encompass the development of IT skills where these are required (Stratman and Roth, 2002; Tarafdar and Roy, 2003), it should involve 'hands-on' training (Aladwani, 2001) and there should be practice facilities where users can enhance their IT skills (Siriginidi, 2000a, b). The Gartner Group study suggests that up to 25 percent of the ERP budget should be dedicated to training users (Coetzer, 2000). Snider et al. (2009) suggested that SMEs might particularly benefit from end user training conducted by external consultant, due to lack of expertise or time of internal team members.

However, assuming that they will save upfront costs, many organisations do not implement the necessary training programmes. Wah (2000, p.20) suggested that while shortening planned training may be the "fastest and least expensive way" of saving upfront costs, it may be "counterproductive in long run". Nelson and Cheney (1987) also found a positive relationship between training and computer-related ability, and computer-related ability and acceptance of IS product and technologies. Meanwhile Longinidis and Gotzamani (2009) suggested that interaction with IT department, pre-implementation processes and ERP product and adaptability are three main components that affect the level of satisfaction of ERP users.

2.11.3 IT

CSF IT covers a wide spectrum including all aspects related to information technology (IT) such as infrastructure, IT related resources, database, methods of data migration, IT skilled staff, software and hardware.

For ERP implementation in SMEs the presence of reliable IT infrastructure and an adequate quality database are essential pre-requisites for success (Holland and Light 1999; Ross et al., 2006; Doom et al., 2010). Further, it is also important that IT acceptance, including the IT architecture and skills (Sommers and Nelson, 2001; Bajwa at el., 2004; Tarafdar and Roy,

2003) be assessed in the preliminary planning phase and based upon that decision should be made to either upgrade existing infrastructure or revamped it (Kumar et al., 2002; Palaniswamy and Frank 2002).

Somers and Nelson (2001) similarly highlighted the availability and timeliness of accurate data as essential for effective ERP system. Often this will also involve migrating data from legacy system to the new ERP system and it is important that this is done without compromising the integrity of the data (Umble et al., 2003; Bajwa et al., 2004; Somers and Nelson, 2001; Zhang et al., 2003; Xu et al., 2002; Shanks et al., 2001).

Stressing upon the quality of data, Park and Kusiak (2005) argued that any problem with the underlying quality of the data being fed into the ERP system can have significant impact on the eventual quality of organisation's information system. In the most obvious interpretation of this, poor data quality at the operational level will increase operational costs because of the time and other resources spent on detecting and correcting the errors. Moreover, if the data entered is incorrect the whole system becomes suspect in the eyes of users and commitment and adoption will invariably suffer (Alshawi et al., 2004). Which usually have negative impact on the organisation as estimated by Redman (1998), who found out that the total cost of poor data quality ranges from 8-12 percent of revenue and in some instances, 40-60 percent of the service organisation's expense is wasted as a result of poor data quality.

2.11.4 Project Management

Project management refers to the establishment and management of on-going implementation process to achieve successful completion of project (Zhang et al., 2005). Project management involves planning, allocation of responsibilities, setting up milestones and critical paths, users training, human resources planning, and developing measures of success (Nah et al., 2001). The literature highlights that IT implementation project management teams should be balanced i.e. they should comprise of comprising of team members from both business and technical departments (Nah et al., 2001; Parr and Shanks, 2000), additionally, they should be empowered[8] (Parr and Shanks, 2000a and b; Umble et al., 2003) and perhaps most importantly, they should possess sufficient required competence (Somers and Nelson, 2001). If required, training may be provided to enhance project team members' skills (Soh et al.,

[8] Empowered to make critical decisions.

2000; Bajwa et al., 2004) and this might also be useful to foster and develop a high level of employee morale and motivation during the project (Willcocks and Stykes, 2000; Bingi et al., 1999).

The project manager's previous experience in implementation can also be key to success (Sumner, 2005) since project manager can use experience to create a conducive and productive work environment (Mandal and Gunasekaran, 2003) by recognising and appreciating the work of team members (Barker and Frolick, 2003). According to Bradley (2007), the project manager should be in a relatively high hierarchy position within the organisation to ensure she or he has sufficient authority to make strategic and timely decisions (Zafiropoulos et al., 2005).

The aforementioned literature highlights that a key contributor to the implementation project's success or failure derives from the nature and skills of project management and the project team themselves. It is due to the essential role played by project management that, the CSF 'project management' is included for further study and in developing the simulation model.

2.11.5 Vendor's Support

'Vendor's support' is the characteristics of external expertise, including the provision of technical knowledge, maintenance, back up support, technical assistance, emergency management, updates, service responsiveness and reliability, and users training during and after implementation; all of which are generally supplied by the purveyors of the ERP system software (Somers and Nelson, 2001; Zhang et al., 2005; Ramayah et al., 2007; Remus, 2007). Vendor's support is assumed to be particularly necessary for SMEs since they may often lack the experience and skills necessary to grasp all the complexities of implementing ERP system (Markus and Tanis, 2000; Davenport, 2000).

ERP software is offered by different vendors who specialises in particular function organisation performs such accounting, human resources, inventory, supply chain and customer service. Currently, the major ERP vendors are SAP, Oracle and Microsoft Dynamics (Panorama, 2010). These vendors usually provide assistance in analysing the needs of organisation, examining organisation's readiness, on-site implementation assistance, regular system upgrade, after sale and post implementation assistance (Nashmi and Eissa, 2003). Liang et al. (2005) suggested that ERP vendors should focus on individual and localised requirements and ease in software customisation during implementation. In addition they highlighted that vendors should focus on improving internal efficiency of their system through support and should help manage purchasers' expectations while implementing ERP system (Liang et al. 2005).

Davenport writing in 1998 reported that organisations spend US$10 billion a year on services of IT vendors and implementation consultants. This high cost of external implementation services sometimes puts management in dilemma in choosing between reducing the external implementation costs or reducing the development of internal skills and knowledge through training and development (Haines and Goodhue, 2000).

Part IV Simulation modelling and DSS

Modelling and simulation are the most important tools for developing a DSS (Power, 2009). Modelling and simulation are discussed as an independent process in section 2.12, followed by an introduction on how DSS is developed using modelling and simulation in section 2.13.

2.12 Definition of modelling and simulation

A stream of literature discusses the practical approach adopted by researchers which involve simulation modelling and building decision support system. 'Simulation' is the imitation of the operation of the real-world process or system, played out over time. It is the process of creating model replica or copying the behaviour of the system or phenomenon under study. Naylor et al. (1966, p.2) defined simulation as, "numerical technique for conducting experiments on a digital computer, which involves certain types of mathematical and logical models over extended period of real time". In other words, a simulation is a technique of solving problems by observing the performance dynamic model over time.

Levy et al. (1988) suggested that the simulation is essential to understand the relationships within a complex system, to experiment with the model to assess the impact of actions, options, and environmental factors, to test the impact of various assumptions, scenarios, and environmental factors and to predict the consequence of action on a process.

Balakrishnan et al. (2007) are also proponents of simulation, they suggested following advantages of simulation modelling:

- A simulation model can be made flexible enough to easily accommodate several changes to the problem scenario;
- It can be used to analyse large and complex real-world simulations that cannot be solved by using conventional decision model;
- Simulation allows ‘what-if’[9] types of questions;
- Simulation modelling does not interfere with the real-world system;
- Simulation allows researchers to study the interactive effects of individual components or variables to determine which ones are important; and
- “Time compression” is possible with simulation.

Application areas of simulation are numerous and diverse. In section 2.13 practical use of simulation will be further discussed.

2.13. Definition of DSS

A DSS is a computer based information system that affects or is intended to affect how people make decision (Silver, 1991). Whereas according to Power (2009), DSS is usually interactive computer based system or subsystem intended to help decision maker use communication technologies, data, documents, knowledge and/or identify and solve problems, complete decisions process task, and make decision. DSS, first introduced in 1970s, differ from other information system in respect of their structure, development, use and research have been applied to variety of disciplines, including finance, marketing and production (Kivijarvi, 1997).

The basic objectives of DSS include; a) facilitation in decision making activities, b) interaction, by decision makers or staff users who control the sequence of interaction and the operations performed, c) task oriented, providing capabilities that support tasks related to decision making such as intelligence and data analysis, and d) decision impact, they are

[9] What-if analysis studies the resulting impact in model output with changes in input and will be further discussed in Chapter 3 and 5.

intended to improve the accuracy, timeliness, quality and overall effectiveness of a specific decision or set of related decision.

Literature suggests following advantages of computerised DSS (Silver, 1991; Pearson and Shim, 1995; Khivijarvi, 1997). Decision Support System:

- have been observed to reduce decision cycle time, increase cycle productivity and to facilitate the availability of more timely information for decision making process.
- assist in enhanced decision making effectiveness.
- have the capacity to improve the quality of information by providing the medium to amalgamate high quality data with more commonly available data.
- have played role in cost savings associated with reduced labour cost in making decisions and lowering infrastructure and technology cost.
- may reduce frustration of decision makers by reducing felt uncertainty and create a perception that better information is being utilised and applied.

Application of DSS greatly enhance and simplify the decision making process across the organisation. The use of DSS is not limited to any particularly industry or department, as it will be discussed in Section 2.14, they are effectively applied in any organisation.

2.14 Practical use of Simulation and DSS

Simulation has long been a significant tool for facilitating decision making and improving processes (Gupta, 2004). O'Kane (2002) suggested the greatest strength of simulation modelling lies in its ability to help users to analyse complex system such as production facilities, where volume of variables and complex decision making logic makes other types of analysis difficult to apply and prone to error. Simulation can be applied at the planning stages to help evaluate different layout configuration, test alternate strategies and scenarios that may eventually lead to a smooth transition from conventional operation to truly flexible automated environment. Indeed, Robinson (1994) found that simulation modelling is useful because of its ability to provide the "whole" picture of the process and demonstrate the frailty of local solutions.

Literature review suggests that many simulation models have been proposed and developed. By converting CSFs into quantitative information, Sun et al. (2005) developed a simulation model for SMEs to assist in identifying the key requirements (time spent on each CSF) and measurements (cost, schedule and goal achievement) that determine the achievement of ERP implementation. Daneva (2010) developed simulation model for balancing uncertainty in the context of ERP project estimation. The simulation model allows practitioners to address the challenging question of how to adjust project context factors (such as cost) so that chances of project success are increased. Dunham et al. (2000) developed simulation game designed to quantify the benefits of ERP system. Evaluating three scenarios with balanced scorecard framework, the results from the model can be useful in analysing the impact of ERP data on strategic decision making. Further simulation game can be used in consulting to assess the benefits of ERP prior to implementation.

Moon and Phatak (2005) applied discrete event simulation to enhance ERP functionality. Based on assumptions of ERP inability to handle uncertainties since ERP inherits MRP logic and shortcoming, they developed discrete event simulation model using probability and statistics to explicitly consider the effects of uncertainties which expand the functionality of the ERP system. Applying the simulation methods, Lee and Miller (2004), developed a method (called critical chain project management) which integrate the system dynamic model with a multi-project network constructing methods. The model not only constructs the network but also recognise the interdependencies of the multiple project in software engineering.

In order to illustrate the power of modelling manufacturing performance measure and to gain better understanding of how simulation modelling can be approached across different manufacturing enterprises and help organisations achieved organisational excellence, O'Kane (2003) studied three companies with distinctive characteristics and attributes. From the cross-case analysis of the use of discrete-event simulation, he developed a policy implication to provide understanding of applying simulation and highlight critical factors that should be taken into account for successful application of simulation. These factors include; data accuracy, complete understanding of the business processes, developing baseline model, realistic and relevant simulation runs and engaging company personal in model building and experimentation tasks.

To overcome the risk associated with ERP implementation, Lopez and Salmeron (2012) developed a simulation model for risk management. Using concept of Fuzzy logics, it models uncertainty and related events, and simulation modelling is applied in developing forecasting exercises. This informs the users about which problems will arise if risks are not treated and its impact on the project outcome.

Simulation-based decision making is one of the prospective applications of computational sciences which is central to advance in manufacturing, material and microelectronics. The main advantage of this approach is a possibility to solve extremely complex problems, where analytical approaches are not available (Karmani, 2011). Simulation-based DSS facilitate the decision making process by compiling raw data collected from the field into useful information that decision makers can effectively use and apply to organisational and business decisions.

Holsapple and Whinston (1996) suggested the potential benefits of DSS which include; enhancing decision maker’s ability to process knowledge and complex problems, shorten time associated with making a decision, improve reliability of decision making process or outcomes, encourage exploration or discovery by decision maker, reveal or stimulate new approaches to thinking a problem space or decision context, furnish evidence in support of a decision or confirmation of existing assumptions, and create a strategic or competitive advantage over competing organisation.

Marquez and Blanchar (2006) proposed a DSS for evaluating operations investment in business. The DSS connect customer value (i.e. based on which customer make purchase decision) to business targets and show scenarios to customers responses and business results that will enable future funding and it also provides optimisation techniques to compare alternatives. Applying same methodology, Swanepoel (2004) developed a DSS for real-time control of manufacturing processes. The DSS comprises the capability of supporting both the process operator and managers in the decision-making process by providing optimised process control variables resulting in optimised output factors. Also studying the manufacturing, Heilala and Maantila (2010) proposed a simulation-based DSS to assist planner and schedulers organise production more efficiently in manufacturing While Ivanov et al. (2012) developed a simulation based decision support for flood control management to enhance decision making.

2.15 Applying DSS to ERP System

Research in the area of application of DSS in ERP system is very limited. An extensive search found only few studies investigating DSS application in SMEs. Stanek et al. (2004) proposed a decision support system for ERP system by integrating the different information technologies such as an analyser, a simulator and a communicator hence forming a model that cover the entire process and communicate the results in the end thus assisting in decision making process.

Liang and Zhang (2006) developed a knowledge warehouse system for ERP systems. It manages data and information, and knowledge assets of organisation. Working as a support mechanism for DSS, knowledge warehouse analyse, integrate knowledge and convert it into a new knowledge through the coordinated interaction within knowledge warehouse.

In order to make decision when different perspectives are involved, Cil et al. (2005) developed a DSS for multiple perspective decision making in an organisation. Applying the built in group decision making process and multi-criteria decision-making methods, it provides solution to online queries and online analysis function to users. Cil et al. (2005) applied their DSS towards decision making process during ERP implementation in ERP system adoption and evaluation stages. The results provide practical guidelines for the selection of ERP systems.

In any supply chain, since all the organisations are critically dependent upon the action of others. This necessitates the need of collaborative decision making. Shafiei et al. (2012) proposed and developed a multi-enterprise collaborative DSS for SCM which enables decision makers across organisational boundaries to generate accurate, effective and timely decisions. Applying DSS, decision makers from all across supply networks can access, and flexibly use decision making components, explore a range of what-if scenarios and make the most suitable decision.

As mentioned previously, there is a limited research work in the area of DSS and ERP system. One reason could be due to that fact that most organisation implementing ERP system are dependent upon the consultants' or vendors' recommendations for decision making. This potentially makes decision making quicker and less risky, however, by doing so, organisation are totally dependent on the vendors, who in most cases do not have complete knowledge of the business functions and culture of the organisation. In the long run it can have negative consequences to organisation. An ideal solution to this problem is that organisations are provided with complete information and they make decision keeping in perspective their implementation objectives, resources and information provided. This is the real purpose of DSS in an organisation. Keeping in view the lack of research in this area and SMEs struggle for successful implementation, a need exists for the study to understand and effectively contributes towards ERP implementation and decision making in SMEs.

2.16 Summary

This chapter provides a literature review of the ERP system and the subjects associated with ERP implementation in SMEs, and identify the research gap in ERP implementation knowledge. A theme in the literature highlights that ERP system are prone to deployment and operational challenges, therefore making the implementation of ERP system a potentially major challenge for an organisation. In a related theme in the literature, a great deal of research work has been undertaken on the factors that aid ERP implementations; and particularly highlighted in this chapter, how CSFs can influence outcomes, and the role of users during implementation. As highlighted in the literature reviewed, the potential for ERP implementation success is enhanced if important tactical factors are in place, such as: top management support, appropriate vendor selection and support, availability of an appropriate IT infrastructure (and reliable databases), an overarching implementation strategy and a method of acquiring user support. Taken as a whole, these factors also highlight that very often ERP implementation requires a complete business process transformation.

As the literature highlights that ERP system implementation are loaded with difficulties, a subset of the literature also points to particular challenged for SMEs. While acknowledging the benefits of ERP system, organisations often struggle in implementing ERP system. Several examples of failed ERP implementations are found in literature, some occasionally leading the organisation into bankruptcy. As a result of these challenges, a major theme in the literature consists of different models of ERP implementation. However, the majority of these models focus on the implementation process and impact of CSFs on implementation in a manner that makes their observations relevant only to large enterprises.

A smaller body of literature highlights that the challenges of ERP implementation are particularly difficult in the case of SMEs, particularly because of their (usually) comparative lack of IT infrastructure and skills. Very few best practice ERP implementation models are presented for SMEs, and the small amount of literature that does touch this area are either entirely theoretical or based on very limited study. And yet, it is evident that SMEs, perhaps more than larger organisations, must identify and understand the implementation strategies and the factors which can be critical to success.

This research is intended to fill the gap in the literature on ERP implementation in SMEs by studying the ERP implementation in SMEs, and then; to overcome implementation barriers and to save SMEs time and resources; this research develops DSS_ERP to simulate ERP implementation. It is intended that this decision support system will aid SMEs in considering the contributions of CSFs and target their resource allocation to achieve their predetermined implementation goals. The DSS_ERP can also act as a forecasting tool for SMEs to predict project outcomes, facilitate resources allocation and exploring different implementation strategies.

CHAPTER 3

METHODOLOGY

3.1 Introduction

As the philosophical objective of this research is functional and practical, this research uses a mixed method approach. In mixed method research, researcher first collects and analyses the quantitative data, then builds on those findings in a qualitative follow up, which seeks to provide a better understanding of the quantitative results. Building can involve either using the quantitative data to select cases or to identify questions that need further explorations in the qualitative phase (Creswell et al., 2003). By adopting mixed method approach in this study, the quantitative primary data is collected and analysed, followed by Key Informant interviews to further elaborate and understand the relationship between variables and to confirm the veracity of the model.

This chapter explains the methodological questions relevant to the research, it is structured as follows: Section 3.2 presents the justification for adopting mixed method approach, research framework is introduced in Section 3.3, pilot study and primary data collection processes are discussed in Section 3.4 and 3.5. The proposed decision support system in presented and discussed in Section 3.6, while in Section 3.7 key informant interview process in discussed. Reliability and validity are discussed in Section 3.8 and Section 3.9 presents process of verification of model.

3.2 Justification of Methodology

Mixed method approach, according to Johnson et al. (2007, p. 123) "is a type of research which combines elements of qualitative and quantitative research approaches (e.g. use of qualitative and quantitative viewpoints, data collection, analysis, inference techniques) for the broad purpose of breadth and depth of understanding and corroboration". A mixed method research is a growing methodological approach in several disciplines (Creswell and Clark,

2011) and many researcher have promoted the use of mixed methods to more effectively answer research questions (Tashakkori and Teddlie, 2003; Johnson and Onwuegbuzie, 2004).

Mixed method is useful when qualitative data are needed to help explain or build an initial quantitative data. Two variants of explanatory mixed design include follow up design and participant selection models (Creswell et al., 2003). In follow-up explanation models, specific results are used to explain and expand on quantitative results.

It is generally observed that when researchers quantitatively examine the data associated with many individual people, the voice of the individual is diminished, and when researchers qualitatively examine few individuals, the ability to generalise the results to many is lost (Creswell and Clark, 2011). Combining quantitative and qualitative data in a single study can overcome this problem and be beneficial in a variety of ways. For example, the researcher can 'triangulate'; which involves combining quantitative and qualitative methods to produce a set of data that has complementary strengths and non-overlapping weaknesses (Johnson and Onwuegbuzie, 2004; Johnson and Turner, 2003; Tashakkori and Teddlie, 1998). However, this approach is not the answer to every research problem, nor does it diminish the value of research conducted entirely quantitatively or qualitatively.

According to Onwuegbuzie and Johnson (2006), the fundamental principle is that quantitative and qualitative data can be mixed and adapted for multiple purposes. The purposes are initiation (discovering contradictions), expansion (attaining a deeper and broader understanding) and complementary analysis (examining overlapping parts of a phenomenon). Complementing mathematical modelling with an empirical survey and in depth interviews, this research uses a mixture of quantitative research and qualitative research to achieve research objectives. The quantitative research approach utilised involved developing mathematical models using data collected from survey, and the qualitative research is applied in verifying and testing the developed models through key informant interviews where expert opinions on these models are collected. Adopting this technique assist in developing model first, and then by adopting key informant interviews process, veracity of the model can confirmed and further information can be gained to improve the model.

Quantitative research is treated as central in this research because it is more apt for answering questions about relationship between specific variables, and questions of 'who', 'where', 'how many', and 'how much' (Creswell and Clark, 2011). Adopting quantitative research approach in this research facilitates in identifying SMEs for the data collection and analysis, and developing analytical regression models. While qualitative research is more apt for answering 'why' and 'how' questions. Therefore, adopting qualitative research enables us to explain interrelation between CSFs, and also between CSFs and successful implementation.

3.3 Research Framework

As shown in Figure. 3.1, the mixed quantitative and qualitative research methods are applied in this research, to develop a decision support system for ERP (DSS_ERP) implementation in SMEs. The motivation for this approach arises from the need to have two sets of data; a primary quantitative data set, and a qualitative data that plays both a supportive role and a complementary role. Adopting mixed methods provides better opportunities to answer research questions and also allows evaluating the extent to which research finding can be trusted and inference made from them (Saunders et al., 2005). The concept of combining approaches for complementary strengths and non-overlapping weaknesses has been called the fundamental principle of mixed research (Johnson and Turner, 2003).

The research framework for developing and verifying DSS_ERP is shown in Figure 3.1, which shows how quantitative and qualitative are integrated:

Step 1. Using data collected from the survey as an input construct analytical regression models (a) which express the relationship between ERP project outcomes and resource allocations, such as time, budget and staff commitment.

Step 2. Develop a Monte Carlo simulation model to verify the validity of models (a).

Step 3. If models (a) are not validated, Step 1 is repeated to develop new models (a). If models (a) are validated, they are applied to construct a nonlinear programming model (c). The nonlinear programming model is used to facilitate resource allocations to achieve predetermined goals.

Step 4. Key informant interviews are conducted with ERP experts to obtain their views and judgement on DSS_ERP, in terms of its applicability, effectiveness and efficiency in SMEs.

Sections 3.4-3.7 provide detailed introductions to the survey conducted, the analytical regression models, the simulation model, the nonlinear programming model and the key informant interviews.

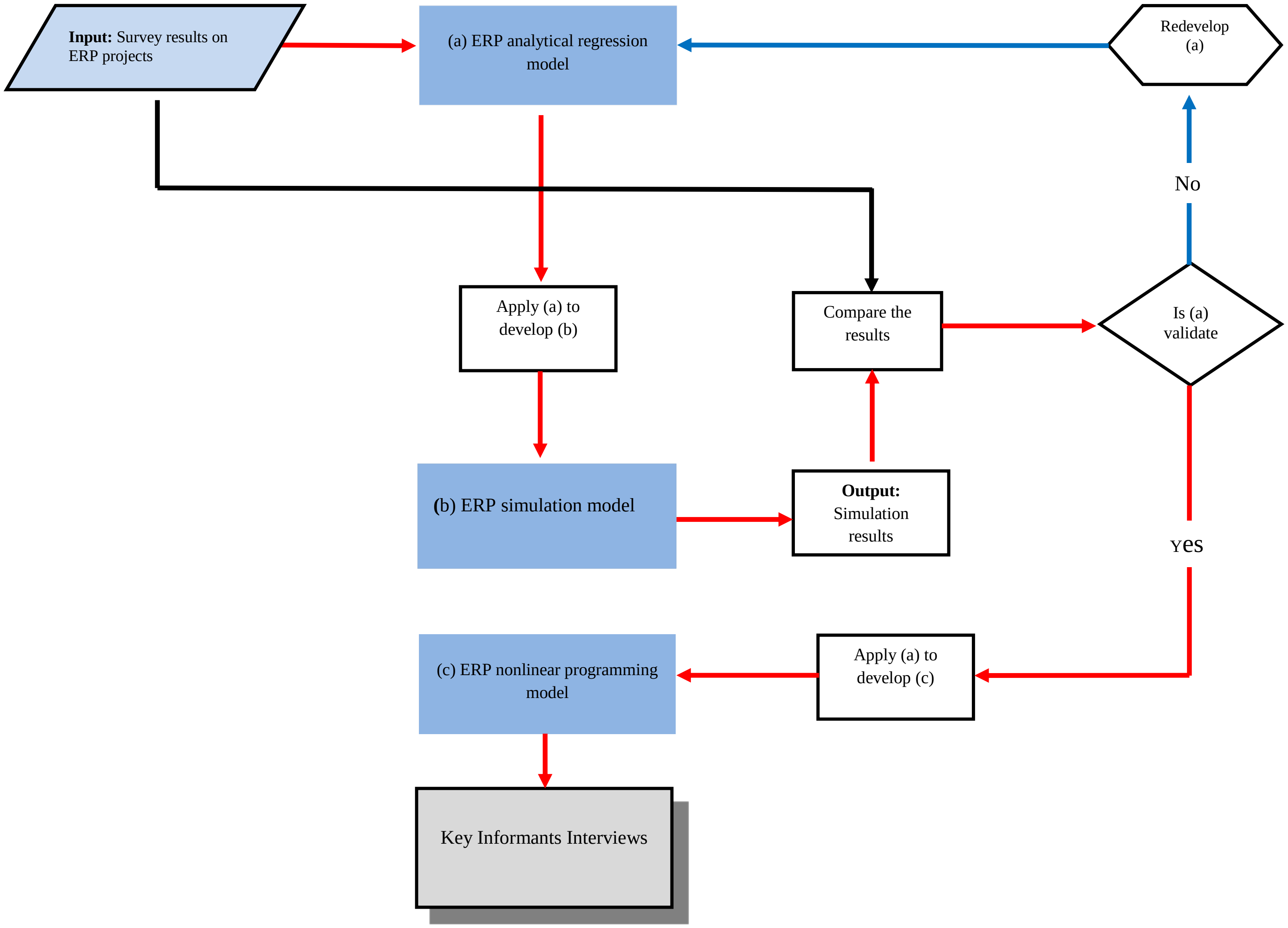

Figure 3.1 Development and structure of DSS_ERP

3.4 Pilot Study

In November 2010, a pilot study was conducted with ten participating SMEs. The SMEs for the pilot study are selected using convenience sampling. Convenience sampling is a non-probability sampling procedure in which cases are selected randomly from that part of the population which are easiest to obtain (Saunders et al., 2005). A convenience sample is generally viewed as an acceptable approach, particularly in recent operational management studies, because of the benefits of increased internal validity and control from such selection (Hoyle et al., 2002). Convenience sampling is often used in research on IT (Dagada, 2005; Ahmed et al., 2006; Ramayah and Lo, 2007), therefore, it is adopted in this research for the following reasons: 1) there are limited numbers of SMEs that have completely implemented ERP systems; 2) such SMEs are relatively difficult to locate in the broader population of SMEs due to their limited number; and 3) when organisations are reluctant to share or release information, convenience sampling is effective since it randomly select organisations willing to share information.

Although it is acknowledged that convenience sampling can make research prone to bias and influence, Saunders et al. (2005) argued that these problems are less important where there is little variation in the population. In our pilot study, SMEs were selected from ERP vendors' websites, Thomson database, ERP magazines and ERP users groups. Access to the key people who are involved in decision making for ERP implementation is one of selection criteria, as this group of employees are most knowledgeable about the ERP implementation in organisations (Sedera et al., 2004).

Prior to the pilot study, the questionnaire was cross-checked by an expert professional with fifteen years of working experience on ERP systems implementations prior to distribution. The questionnaire was emailed to the participating organisations with a brief explanation of the purpose of the study. The email survey is faster and cheaper to develop, and has higher response rate than other survey methods. In addition, email survey can be sent directly to the key respondents in SMEs, which increases the reliability and validity of the survey results. To increase the response rate, respondents were assured of complete confidentiality and promised a copy of research findings.

The feedback received from the pilot study was utilised to improve and update the survey questionnaire for the main study. The changes made to the survey instrument following the pilot include: adding a section at the start of survey discussing the purpose of conducting the study and explanation of terminologies used; and adding contact information and improving some structure aspects of the questionnaire.

3.5 The Main Quantitative Survey

The main survey collects primary data on ERP implementation using the refined questionnaire, beginning with specific observations and measures drawn from SMEs who have completed at least one ERP implementation, empirically evaluating implementation cost, performance level and project duration broken down by CSFs.

3.5.1 Research Sample

The European Commission defines SMEs using three broad parameters: micro enterprises are companies with up to 10 employees, small enterprises employ up to 50 workers, and medium-sized enterprises have more than 50 but less than 250 employees.

In order to reflect a realistic implementation, a representative sample needs to be chosen to collect information and construct the analytical regression models. A sample of SMEs is defined with the following criteria:

Criterion 1: The SMEs are of similar size in term of number of staff, and SMEs with 50-250 staff are chosen in this research

Criterion 2: The SME had completed at least one ERP project

Criterion 3: The SME is able to consider the CSFs during their implementation.

It is essential that only SMEs satisfying these criteria are included in sample since this will allow collecting the correct data for this research required to develop a DSS. The criterion define the basic characteristic of sample of SMEs, which are the central focus of this research due to their higher rate of ERP adoption than micro-enterprises (less than 50 staff) (Fonatinha, 2010). In addition, SMEs must have been through one complete implementation and lastly, it is required that SMEs must be able to consider five CSFs during their implementation. These CSFs include top management support, users, project management, IT and vendors support, and are considered as essential for successful ERP implementation in the literature (see Chapter 2).

This research focuses on studying ERP implementation in SMEs in UK and North America, since according to Panorama[10] report of 2010, this region has highest concentration of SMEs which have implemented ERP systems. Due to higher concentration of SMEs, this region was suitable choice for gaining from SMEs experience, data collection and experimentation of model. The research sample was selected through ERP vendors websites (such as Oracle.com, SAP.com), Thomson Data and SAP users group. The ERP vendors' websites and ERP users groups provide substantial information about the firms that have adopted ERP system. A sample of 400 SMEs was selected from the population for the survey using convenience sampling (discussed in section 3.4).

The types of the organisations that participated in the survey and provided valid responses are presented in Table 3.1. The majority of the respondents are from IT companies (23%) or classified themselves as 'other'.

Organisation Type	Number of Organisations	Percentage
IT	14	23
Manufacturing	8	13
Banking and Finance	6	10
Education	2	3
Telecommunication	9	15
Utility	7	11
Others	14	23
Total	60	100%

Table 3.1 Categories of the organisations participating in the quantitative survey

[10] Panorama Consulting Solution is an independent organisation which study ERP implementation across the globe. It helps firms evaluate and select ERP software and manages the implementation of the software.

In total, 23 percent of respondents identified their sector as ‘others’. While 15 percent of the respondents are from telecommunication industry and 13% belong to manufacturing sector. Appendix B presents the primary data collected for each organisation.

3.5.2 Data Collection

The updated version of the survey questionnaire (refined following the pilot study), was sent out via email to 400 SMEs. The questionnaire itself was also made available in the email as a link to *surveymonkey.com*[11]. SMEs were recommended to quit the survey if they did not meet all the Criteria 1-3 in section 3.5.1. The main survey was carried out from January to April 2011. (The questionnaire and cover letter are provided in Appendix A).

According to Saunders et al. (2005), the reliability of data collection process is increased when the ‘right persons’ are approached in SMEs. Therefore, key people involved in ERP implementations, such as IT professional, managers or decision makers with knowledge of ERP implementation were asked to complete the survey in order to improve the validity of responses. After two weeks, follow up reminders were sent out to encourage respondents to complete the survey.

By the end of the survey, 95 responses were received, and were scrutinised to exclude invalid responses. The following accounted invalid responses:

- incomplete response;
- the organisation is not a SME (rather a large enterprise);
- respondent was not involved in implementation;
- SMEs abandoned the implementation half way through, maybe due to technical or financial issues;
- responses were not consistent, such as a respondent indicating a failed implementation, but with 80% performance level;

After excluding invalid responses, only 60 were valid responses with a response rate of 26 percent[12]. The absolute number of responses is small, however, the response rate is considered relatively reasonable in comparison with the response rates received in other ERP

[11] Surveymonkey.com is an independent online survey service provider.
[12] Response rate = total number of responses /total number in sample - ineligible, (95/400-32) = 26%

related research: Infinedo and Nahar's study (2009) has a sample size of 62 (13 percent response rate), Hasan et. al (2011) studied the ERP implementation in Australia with 79 responses and 23 percent response rate, Lin's (2010) study in this area reported response rate of 13 percent and Hung et al. (2004) research had response rate of 17 percent. Given that the email survey is carried out on a very specific area in specific regions (UK and North America) the response rate of 26 percent is also acceptable.

3.6 The proposed decision support system

The primary purpose of DSS is to support and improve managerial decision making. It is a coordinated collection of data, systems, tool and technology, with supporting software and hardware by which an organisation gathers and interprets information from business and environment and turns it into basis decision making (Silver, 1991; Power, 2009). The DSS_ERP developed for this research combines three types of models:

i) ERP analytical regression models: to calculate the ERP project cost and performance according to the resource allocations;

ii) Monte Carlo based ERP simulation model; ERP simulation model providing techniques to validate the analytical models developed in (a) and help develop a more rigorous theory of ERP implementation verify and validate the analytical regression models; and

iii) ERP non-linear programming model; to study and evaluate implementation strategies to obtain solution for predetermined goals.

3.6.1 Analytical regression model

Analytical regression modelling is a set of equations describing the performance of a system (Fox, 2008). The approach is useful in studying the relationship between variables. The analytical models for DSS_ERP are based on the relationships between the independent variable of *time*, and the dependent variables of *cost* and *performance*.

These variables were firstly analysed at CSF level by plotting them in time-series format. Time series is an ordered sequence of values of a variable at equally spaced intervals and it analyses accounts for the fact that data points taken over set periods of time may have an internal structure (such as autocorrelation, trend or seasonal variation) that should be accounted for (Chatfield, 2004).

The usage of time series is twofold, 1) To obtain an understanding of the underlying forces and structure that produced the observed data, 2) To fit a model and proceed to forecasting, monitoring or even feedback and feed-forward control.

Next, the data was analysed using a regression analysis method. Through a non-empirical evaluation, Stensrud (2001) shortlisted regression analysis as the only parametric effort prediction system suitable for ERP projects. The regression analysis is able to express the relationship between dependent variable (for example, budget and performance level) and the associated independent variable (for example, ERP project duration) in mathematical form. However, due to the non-empirical nature of his research, there is no limitation on the context where this finding is applicable. Therefore, analytical regression models are developed to model: 1) the relationship between the cost and time spent on each CSF, and 2) the relationship between performance achieved by each CSF and time spent on it.

There are two types of regression models: linear and nonlinear regression. Linear regression models represent the linear relationship between the variables. Such as during ERP implementation, project cost is positively related to the time spent on a particular CSF, i.e. the more the time is spent, the higher cost is incurred. Therefore the relationship between cost and time is represented by Cost vs Time linear curve. The linear curve is generated using least square method for a straight line, applying equation (3.1):

$$Y_i = \beta_o + \beta_1 X_1 \quad (3.1)$$

Where β_o is constant and β_1 is regression coefficient and its value determined by using formula:

$$\beta_1 = \frac{n(\sum xy) - (\sum x)(\sum y)}{n(\sum x^2) - (\sum x)^2} \quad (3.2)$$

Where,

n = total number of observations

$x =$ number of days

$y =$ cost of implementing CSF

While nonlinear regression model represents the nonlinear relationship between the variables. Such as during implementation the relationship between the progress of implementation team and the time follows a nonlinear exponential curve, i.e, overall performance increases up to a certain level and then remains unchanged and/or levels out as was demonstrated in Plaza and Rohlf (2008) research for a project management team. This nonlinear relationship is represented by formula:

$$PF_i(t_i) = p_i \,.\, (1 - e^{-k_i t_i}) \quad (3.3)$$

Where;

p_i = the performance threshold,

k_i = the progressing coefficient directly relates to the rate of the progress made

t_i = time period

In order to determine the goodness of fit of a model, i.e. to measure how well the linear and nonlinear regression line approximates the real data points, R^2, coefficient of determination is calculated. The coefficient of determination is calculated using formula (3.4):

$$R^2 = 1 - \frac{SSerr}{SS_{Total}} \quad (3.4)$$

Where,

$SS_{err} =$ difference between sum of squared difference between observed values and predicted values

$SS_{Total} =$ total sum of squares, i.e. sum of squared difference between observed values and mean observed values

If the average value of R_i^2 is lower than 0.5, i.e., $\frac{\sum_{i=1}^{M} R_i^2}{M} < 0.5$, other regression curves need to be experimented with and compared to the observed data until the average value of R_i^2 is higher than 0.5.

3.6.2 Monte Carlo simulation model

A Monte Carlo simulation approach was adopted to verify the validity and effectiveness of the analytical regression models. The term 'Monte Carlo' refers to the field of applied and computational mathematics and denotes a broad family of techniques used to approximate such quantities as integrals and the sum of random variables, for which analytic, closed form formulas are not available because of the form or complexity of the situation (Aren et al. 2006). It is a scheme of employing random numbers, which is used for solving certain stochastic[13] or deterministic problems where the passage of the time plays a role (Law & Kelton, 2000).

Monte Carlo simulations have been applied to a diverse range of problems, specifically when a forecast or estimate is required in a significantly uncertain environment. In the area of cost estimation, Monte Carlo simulation is used to identify variation in the results as a function of the uncertainty inputs. It is applied in evaluating the expected probability value of certain outcomes by running multiple simulation trial-runs, using random input values. The motivation of choosing a Monte Carlo simulation technique as a component of DSS_ERP included the following:

- it is already successfully used for project estimation analysis at major organisations including RAND, Northrop and Jet Propulsion Lab (Daneva, 2010);
- it has the reputation of being a well-studied, and well-understood numerical technique with an accumulated body of supporting literature of its own (Savage, 2003);
- it can provide a final *cost-probability* distribution directly, without the necessity of first doing a deterministic cost estimate (i.e. a cost point estimate can be derived from any desired function of the probability distribution, such as mean, median, or mode) (Jones, 2008).

The Monte Carlo simulation model was deployed in MS Excel, which is commonly available, user-friendly software to store data, perform numerical calculations, data exploration, analysing descriptive statistics, errors checking and data validation.

[13] Stochastic techniques are based on the use of random numbers and probability statistics to investigate the problems.

3.6.3 Nonlinear programming model

The third component of the DSS_ERP is a nonlinear programming model developed to optimise ERP implementation by establishing objective function under constraints. Nonlinear programming is adopted when relationship between variables is nonlinear. It can be used to facilitate resource allocations in ERP implementation to achieve predetermined goals, and to evaluate impacts caused by changes to resources.

In nonlinear programming model, if the goal of implementation team is to maximise the overall performance level of ERP implementation, with the constraints of project duration and implementation cost, the objective function can be formulated as:

$$\text{Max } PF\ (t_1, t_2, \ldots., t_M) = \sum_{i=1}^{M} PF_i(t_i) \tag{3.5}$$

$$\sum_{i=1}^{M} t_i \leq T \tag{3.6}$$

$$\sum_{i=1}^{M} Cost_i(t_i) \leq C$$

$$t_i \geq 0 \tag{3.7}$$

$$t_i \leq T_i$$

Where:

T = total time spent on the project

C = total cost of the project

T_i = time spent to address CSF_i

M = total number of CSF considered

The nonlinear programming model is solved using Excel's "Solver", which uses the *generalised reduced gradient (GRG)* procedure. Using nonlinear programming model, Goal-Seeking and What-If analysis are conducted to analyse the performance of the CSFs. Goal seeking analysis is the process of determining the decision variables (such as project duration) to achieve certain goals. While, What-if analysis studies the impact of changes to constraints (such as time, budget) on the project outcome (such as output, project duration, budget). Applying Goal-Seeking and What-if analysis can help decision makers to focus their effort and resources on the CSFs that have greater impact on achieving predetermined goals, and it allow them to develop corresponding implementation strategies accordingly.

3.7 The Key Informants Interview Method

Once the DSS_ERP is developed by quantitative approaches, qualitative key informant interviews were conducted in the next phase of the research. The interview approach augments the quantitative approach by collecting qualitative information on the perceived validity and performance of the DSS_ERP. This approach provides an understanding on the key informants' opinions on the viability of the model and gathers their suggestions to make further improvements to the model. Hence, adopting this qualitative approach, which places a greater emphasis on the subjective experiences of the participants, was a suitable choice for the required information.

Further, Yin (2003) suggests that such an approach is an ideal method when a 'how' and 'why' question is being asked about a set of events over which the investigator has little or no control. 'How' questions are usually associated with describing relationships (previously identified by answering what questions such as how CSFs influence implementation outcome and how to optimise the performance), while 'why' questions tend to explain the reasons why those relationships exist (such as understanding why top management is essential for implementation success or why vendors support is critical for SMEs) (Yin, 2003). The qualitative researchers often use different research methodology simultaneously. These methods may include participant observation, in-depth interview, focus group discussions, document analysis and archival records (Iorio, 2004).

Benbasat et al. (1987, p.368) explained that a method such as this allows examination of 'a phenomenon in its natural setting, employing multiple methods of data collection to gather information from one or few entities (people, groups or organisation)'. The key purpose of this method is to obtain in-depth understanding of the complex phenomenon, both in and of itself and in relation to its broader context (Patton, 2002). Similarly, Stake (1994) argued that the aim of this method is not to generalise to a large population of cases but to obtain an in-depth understanding of the particular case or cases.

In this research, the key informant participants were selected from the SMEs that had already participated in the quantitative survey, and again they were selected from that sub-set using

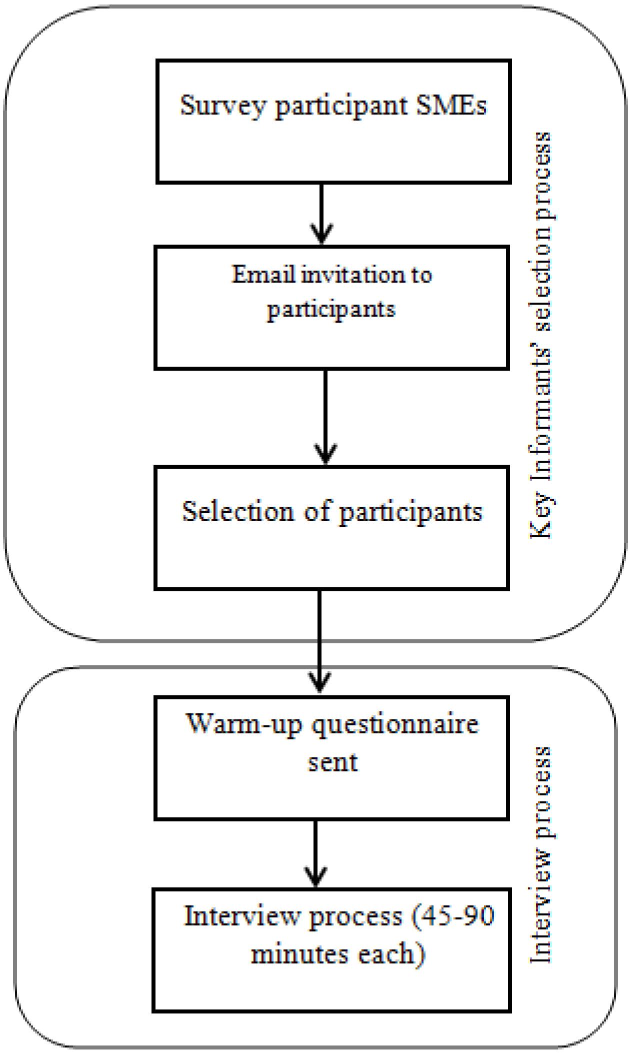

Figure 3.2 Key informants interview process

convenience sampling, as show in Figure 3.2. During the SMEs selection process, several SMEs were contacted to take part in the interview process and finally four SMEs were recruited based on the key informants' willingness to participate. Although a small subset sample, the use of four SMEs is in line with Eisenhardt's (1989) guideline a number between 4 and 10 usually works well.

For the interview process, two sets of questions were designed. First set, called the 'warm-up', was structured and designed to collect basic information about the participants, SMEs and ERP implementation. The warm-up questions were sent to the participants in advance before the main interviews.

For the main interview, the second set of questions was designed in a semi-structured interview format. In semi-structured interviews, the researcher had a list of themes and questions to be covered. The interviewee was given an opportunity to talk freely about events and behaviour. This is also called as an informant interview since it is the interviewee's perception that guides the conduct of the interview. This semi-structured format is suitable for this research since the interview process was performed to elicit participant's views on the performance of the model, the roles of CSF and decision variables, and the CSF's attributes. In addition, information about participants' experiences, their views on viability of generic DSS and suggestion for model improvement were also obtained.

The key informants were selected based on their experiences and their roles during ERP implementation. Literature on ERP implementation in SMEs, primary data collected and SMEs information available on their web page, was used as a backdrop to data collection. This approach enhanced the construct validity of the study. The interviews were audio recorded with participant's consent and they were assured of complete confidentiality. Each interview process lasted for 45-90 minutes. The interviews were transcribed and analysed using a narrative method in NVivo 9 software[14]. A narrative method of qualitative data analysis is based on data being coded and analysed to identify and explore themes, patterns and relationship.

3.8 Reliability and validity

Patton (2002) suggests that validity is focussed on the meaning and meaningfulness of the data while reliability focuses on the consistency of the results. Reliability is concerned with the accuracy of the data. In quantitative terms, this concept of accuracy is usually associated with the exactness of the measurement process gained through the research instrument, whereas in qualitative term it is concerned with proper execution of the procedures, so that another researcher can obtain similar results if a replication study is carried out.

In this research, the reliability for the instruments for quantitative survey and the qualitative interviews are achieved in a number of ways. Firstly, questionnaires were designed with the

[14] NVivo is a qualitative data analysis (QDA) computer software package produced by QSR International. It has been designed for qualitative researchers working with very rich text-based and/or multimedia information, where deep levels of analysis on small or large volumes of data are required.

advice of a professional with many years of industry experience and particularly experience with ERP implementation. Secondly, the feedback received from the pilot study was also incorporated in the final version of the questionnaire to improve the overall reliability. In addition, to ensure the reliability of the survey questionnaire, steps were taken to avoid duplicate responses and the responses were examined for any internal inconsistencies and variations. The responses were also examined to find out if the respondents have approached and understood the questions correctly. Finally, respondents were encouraged to seek clarification if they don't feel confident as how to answer a question (i.e. an email address was provided for this purpose) (per advice from Buonanno et al., 2005; Soja, 2008).

In the qualitative interviews, the steps taken to increase the reliability include the following: a semi-structured interview questionnaire was developed on standard format, interviews were recorded and transcribed, field notes and supporting information was also kept as a record and all the collected information and the process of data collection is stored and available for any future references.

Another important part of research is the validity, which is concerned with the integrity of the conclusions that are generated from the research and defining appropriate operational measures of research instrument. According to Yin (2003), construct validity can be improved by triangulation of data, such as using multiple sources of information and evidences including websites, in depth interviews, informal discussions, quantitative data, documentary evidence and observations, to gain in depth understanding of the phenomenon.
In the qualitative data collection phase, external validity is concerned with achieving generalisation of finding through case study research. In Yin's (2003) opinion in-depth qualitative research provides analytical generalisation and researcher attempt to generalise a particular set of the results to some broader theory. In this research, the use of key informant interviews has particularly enabled the testing of the theory through replication of the findings in similar cases.

Finally, this research adopts convergent validity as part of validation of the developed simulation model. While for the qualitative phase, external validity is a more central consideration, since it is concerned with achieving generalisation of findings through case study.

3.9 Verification of Models

Model verification is defined as "ensuring that the computer program [in this instance simulation model] and its implementation are correct" (Sargent, 1996, p.1). Model verification is essential part of any model development since it ensures and validates the basic construct and performance of the model. According to Sargent (2011), the developers and users of these models, the decision makers using this information obtained from the results of these models, and the individuals affected by decisions based on such models are rightly concerned with whether a model and its results are 'correct'. Therefore the model verification process is intended to ensure that the model does what it is intended to do. Usually, for model verification purposes, there are set of acceptable ranges and model is considered 'valid' if the results it produces are within these ranges. In this research it is conducted during the development of simulation model, with an ultimate goal of producing a more accurate and credible model.

There are several different techniques and test uses for model verification (Kleindorfer and Ganeshan, 1993; Balci, 2003; Sargent, 2011). Some commonly used include:

(i) Comparison to other model: Various results (e.g. outputs) of the simulation model being validated are compared to result of other models. For example, (i) simple cases of a simulation model are compared to the known results from an analytic model, and (ii) the new simulation model is compared to other simulation models that have already been validated.

(ii) Event Validity: The 'events' of occurrences of the simulation model are compared to those of the real system to determine if they are similar. For example, compare the number of fires in a fire department simulation to the actual number of fires experienced in reality.

(iii) Face validity: key individuals' knowledge about a situation or system are utilised when they are asked whether the model and/or its behaviour are reasonable.

(iv) Historical data validation: If the historical data exist (e.g. data collected on a system specifically for building and testing a model), part of the data is used to build the model and the remaining data are used to determine (test) whether the model behaves as the system.

(v) Internal validity: Several replications (runs) of the stochastic model are made to determine the amount of (internal) stochastic variability in the model. A large amount of variability (lack of consistency) may cause the model's result to be questionable.

(vi) Multi-stage validation: Naylor and Finger (1967) proposed combining three validation steps; developing the model-based on observation and general knowledge, validating the model by empirically testing them and then comparing the input-output relationships of the model to the real systems.

(vii) Predictive validation: The model is used to predict (forecast) the system's behaviour, then comparison are made between the system's behaviour and the model's forecast to determine if they are same.

In this research the DSS_ERP verification strategy adapts several methods to ensure the model is working correctly and the results are satisfactory (See Figure 3.2 below).

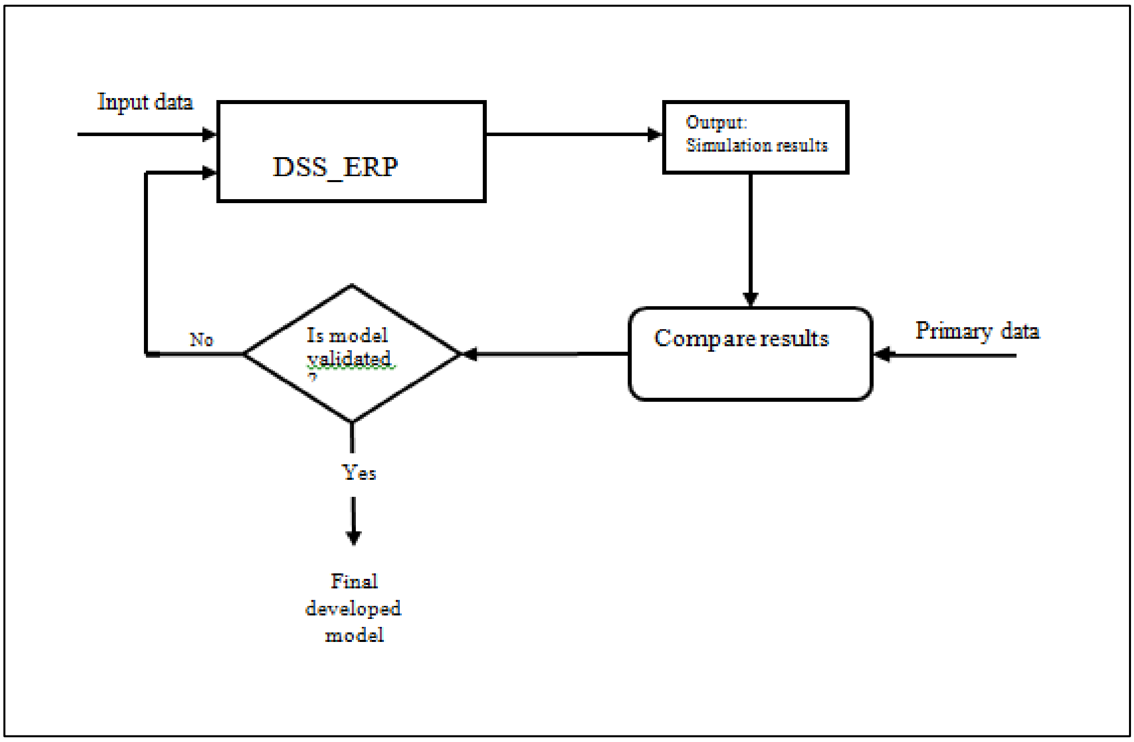

Figure 3.3 Verification of the DSS_ERP Model

As illustrated in Fig. 3.3, different approaches adopted for verification of model include:

- comparison to other model; it is performed by developing a model based on probability distribution and comparing it against the developed model,
- events validity; it is performed by comparing the model's outcome or result with the primary data collected as show in Figure 3.3,
- face validity; during this process model is demonstrated to Key Informants and they evaluated the performance of the model,
- historical data validation; this process involved comparing the output of the model with the primary data,
- internal validity; this process involved generating random numbers based on probability distribution of primary data and applying these random numbers to replicate the simulation model,
- multi-stage validity; this process encompass the previously described methods,

By adopting variety of approaches, the verification of model process is strengthened which confirm the veracity of the model. The different techniques used for the model verification all augments the research, and all confirm the veracity of the model.

3.10 Summary

This chapter reported on the research design for this thesis. A mixed approach was applied since the philosophical objective of this research is both functional and practical. Quantitative research approaches were used in initial primary data collection and the process of developing the DSS_ERP model. Then, to confirm the veracity of the developed model, qualitative methods were also adopted. In depth, key informant interviews were carried out to test and verify the validity, effectiveness and efficiency of the DSS_ERP.

CHAPTER 4

Regression based decision support system for ERP implementation in SMEs

As noted in Chapter 2, SMEs often particularly struggle with ERP implementation because of their relatively lesser IT infrastructure (compared to larger enterprises). Therefore SMEs are usually less able to incorporate best business practices in their operations and thereby potentially benefit from the resulting increased operational efficiency, which are the distinctive characteristics of ERP systems. Whilst some researchers and practitioners have attempted to understand ERP implementation by proposing implementation models. However, most of these models are designed for large enterprises, and the few models that can be related to SMEs, are either theoretical or are based on limited research. In order to overcome the limitations of previously proposed models, this research develops the DSS_ERP, which is based on the real data collected from the SMEs which have implemented ERP systems. It consists of three models for more complete understanding and analysis of implementation. The DSS_ERP is developed using Microsoft Excel which does not require additional software installation or extra training but most importantly provides a tool to decision makers to evaluate and implement strategies to achieve predetermined ERP implementation goal.

This chapter is organised in three sections: Section 4.1 introduces the structure of DSS_ERP, which is consist of three models and Section 4.2 discuss the performance metrics developed. In Section 4.3 development of the DSS_ERP is illustrated by examples followed by verification of model.

4.1 The proposed decision support system

Simulation-based DSS facilitate the decision making process by compiling raw data collected from the field into useful information that decision makers can effectively use and apply to organisational and business decisions. In this research, the DSS_ERP is developed to assist

SMEs to determine the project cost, performance level and project duration for implementation, and further to assist allocating required resources to achieve predetermined implementation objectives. In this model, the implementation cost is the cumulative cost of the overall ERP implementation, excluding the cost of ERP software, while the performance level (explained in section 4.2) is the percentage of the SME's functional requirement met by ERP implementation. The project duration is total amount of time spend, from start of implementation till going live and it includes training, configuration and testing (Plaza and Rohlf, 2008; Sanchez et al., 2010).

In DSS_ERP, the relationships between cost and project duration, and cost and performance level are depicted by curves. A curve could be used as a quantitative measure of the changes during the lifetime of the project (Plaza and Rohlf, 2008). The learning curves have been used in a variety of contexts, such as in observing, measuring or forecasting the cost, production rates and the progress.

Cioffi (2005) advances the application of the learning curve into the project management field. He proposed a 'S-curve' approach to develop a technique of observing and tracking the progress of the project. The S-curve approach was first used by Butler (1988) to assess technological innovation, while Rogers (1995) applied this approach to study the diffusion innovation. The S-curve, as show in Figure 4.1, is a "display of cumulative cost, labour hours or other quantities plotted against time" (PMBOK, 2000, p.178). In S-curve, time is chosen as an independent variable and its influence over the cost and progress are considered.

The S-curve approach, which is one of the two functional forms of more widely applied 'progress curve', and has been commonly applied in information technology project. An exponential curve is a simplified version of S-curve when start-up effect is usually not considered. It is most commonly used to track performances in technology related projects (Butler 1998; Dardan et al., 2006; Plaza et al., 2010).

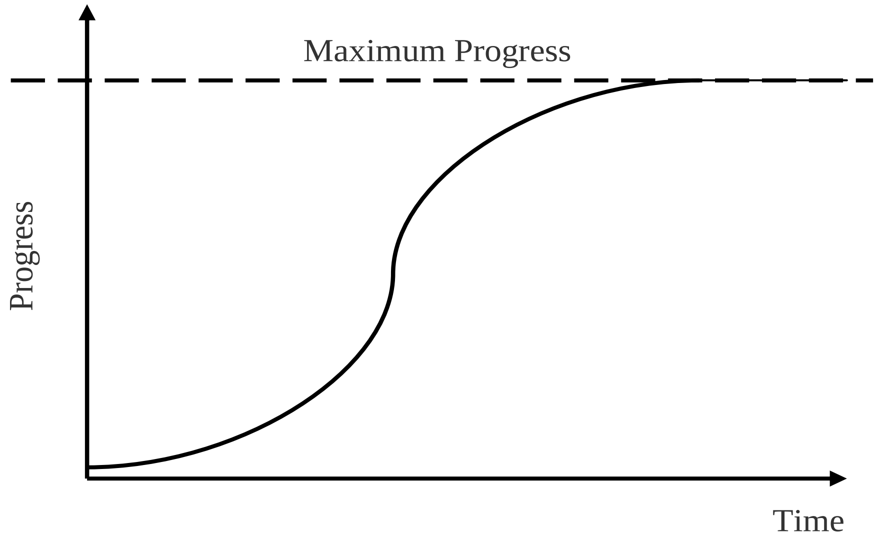

Figure 4.1 a typical S-curve

An exponential curve is a robust modelling approach and has wide range of applicability, and is considered standard form for modelling the performance under given conditions (Plaza and Rohlf, 2008). One reason for adopting the exponential curve, is that initial integration period of ERP project is dedicated to structure learning rather than project implementation, therefore the start-up effect can be ignored in exponential curve.

Figure 4.2 (below) shows an example of exponential curve for a typical ERP implementation process. Note the implementation progresses slowly in the initial phase, which involves training and familiarisation with the new system; then it advances at a steady pace during implementation phase, involving integration, configuration and testing phase, and then it reaches a asymptotic state as project goes live (Cioffi, 2005).

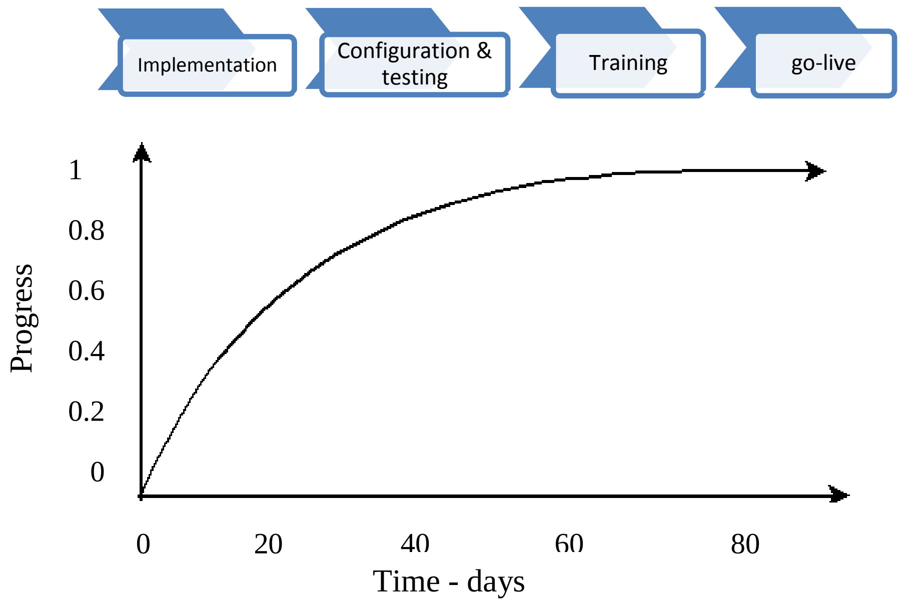

Figure 4.2 an exponential curve for ERP implementation project

Whereas the relationship between cost and time can be assumed to be linear, when the initial planning phase and final phasing off stage are not considered. This concept of linear relationship has been widely adopted in project management (Babu and Suresh, 1996; Khang and Myint, 1999; Plaza and Turetkan, 2009). Therefore the ‘cost and time’ relationship is assumed as linear for DSS_ERP development purposes as shown in Figure 4.3.

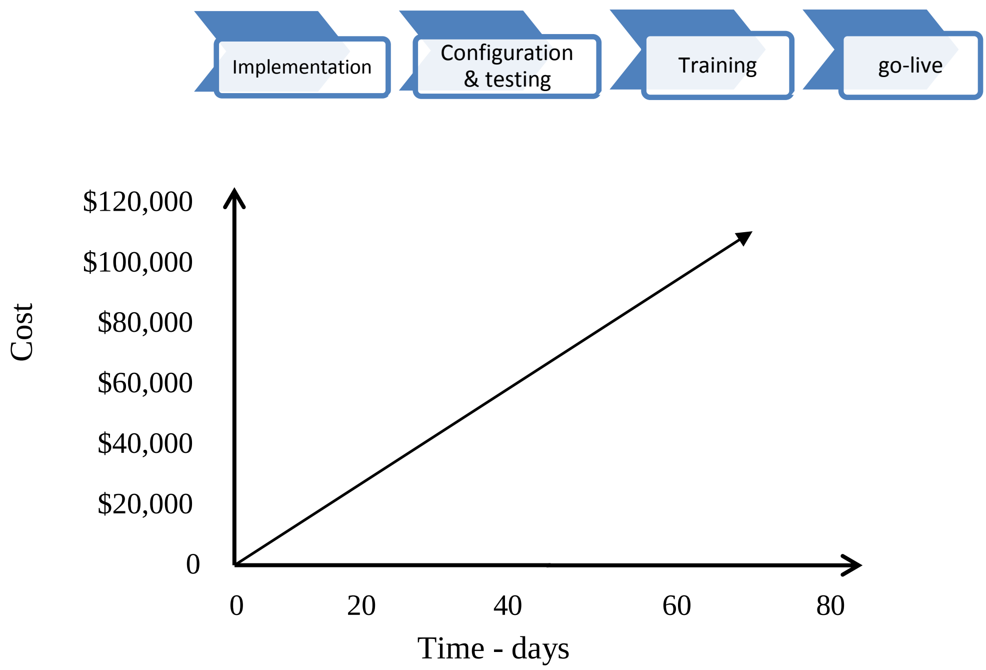

Figure 4.3 a linear curve for ERP implementation project

Beginning with specific observations and measures drawn from SMEs who have completed at least one ERP implementation, empirically evaluating implementation cost, performance level and project duration broken down by CSFs, this research adopts aforementioned two curves at CSF level: 1) Cost vs Time as a linear curve showing cost distributed over time spent on a CSF, and 2) Progress vs Time as an exponential curve representing the percent of performance level contributed by a CSF over the project duration. Analytical regression models are developed to represent these curves. The models can be applied to predict the implementation cost, performance level based on the amount of resources allocated to CSFs (for example, time spent on each CSF). This method of developing curves to predict results is in line with well-established approaches in the literature (Parente, 1994; Dardan et al., 2006; Plaza and Rohlf, 2008).

As presented in Figure 3.1, the DSS_ERP combines three types of model:

(a) ERP analytical regression models to determine the ERP project cost and performance level over time spent, according to initial resources allocation on the CSFs.

(b) ERP simulation model to confirm the validity of analytical models developed in (a) and to help develop a more rigorous theory of ERP implementation. The output from the simulation model is compared against the data generated using probability distribution based on the observations.

(c) ERP nonlinear programming model to conduct Goal-Seeking analysis and What-If analysis to determine the input values for the predetermine goals, optimum allocation of resources and to analyse the impacts of varying focus on ERP performance.

These three models are discussed in detail in next sections.

4.1.1 ERP Analytical Regression Models

As part of development of DSS_ERP, the first phase involves developing an analytic regression model. An analytical model is mathematical model in which the relationship between the variables is expressed in the form of mathematical equations (Sanderson and Greun, 2006). They are commonly applied in analysing the relationships and the influence of the variables. The analytical model are regression method based, since according to Stensrud

(2001), a model developed on regression analysis makes ‘good sense’ for use as a prediction system for ERP projects.

According to Fox (2008), the regression based analytical model use mathematical formulae to derive an optimal solution, or to predict a certain result, and is mainly applied in solving structured problems, or to determine the associations between a dependent variables (i.e. project cost and performance) and one or more independent variables (i.e. project duration or time).

The analytic regression model depicts the real life relationship between the variables. For example, as observed in ERP literature, the relationship between the variables is as such that during the implementation, the total cost of implementation increases with the time spent on the project, while overall performance increases up to a certain level and then remains unchanged and/or levels out (Sun et al., 2005, Plaza and Rohlf, 2008, Plaza et al., 2010). These relationships can therefore be presented in the form of linear curve for cost and time, and exponential curve for progress and time, thus representing the accumulated cost and performance level over time period.

During the ERP implementation, project cost is positively related to the time spent on a particular CSF, i.e. the more the time is spent, the higher cost is incurred. However, relationship between the progress of implementation team and the time follows an exponential curve, as was demonstrated in Plaza and Rohlf (2008) research for a project management team. This is because at the start of the project, implementation team are generally less familiar with the system they are about to implement and often they lack the experience in IT and advanced systems. At the same time, at the outset, the team of consultants or vendors hired to assist in implementation is still getting themselves acquainted with the internal IT set up of their client organisation. Therefore at this initial phase of implementation the initial contribution made by various CSFs is low, but gradually increases with time as implementation team gain experience and collaboration increases.

At the CSF level, the relationship between cost and time is represented by Cost vs Time linear curve. A linear curve is a line of best fit[15] for the given data, which is determined by applying least square method and it gives linear regression formula (4.1):

$$Cost_i(t_i) = d_i . t_i \tag{4.1}$$

Where d_i is the coefficient of the cost function representing the cost of implementation a CSF, and t_i represents time spent on CSF_i, which is one of the CSFs addressed during the ERP implementation. The constant β_o in (3.1) is omitted in formula (4.1) as, although some costs may be incurred when no time is spent, those costs are so low relative to the costs incurred in spending time that they can effectively be regarded as zero, i.e., $cost_i(t_i) = 0$ when $t_i = 0$.

The total implementation cost of ERP is obtained as:

$$Cost(t_1, t_2, \ldots., t_M) = \sum_{i=1}^{M} cost_i(t_i) \tag{4.2}$$

Where M denotes the total number of CSFs considered.

Similarly, the relationship between progress and time is represented by Progress vs Time exponential curve. The generated curve depicts the implementation progress, PF_i, over the period of time and is formulated as the exponential regression model (4.3). In this model the progress is measured as the percentage of the performance level contributed by CSF_i:

$$PF_i(t_i) = p_i \, . \, (1 - e^{-k_i t_i}) \tag{4.3}$$

Where p_i denotes the performance threshold of CSF_i and is a constant progress function that depicts the peak performance level of the particular CSF and directly impact the duration of the ERP project. Figure 4.4 shows a typical exponential curve parameters.

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[15] A straight line drawn through the canter of a group of data points plotted on a scatter plot which depict the results of gathering data on two variables; the line of best fit shows whether these two variables appear to be correlated. A method for determining the line of best fit is called the least squares method.

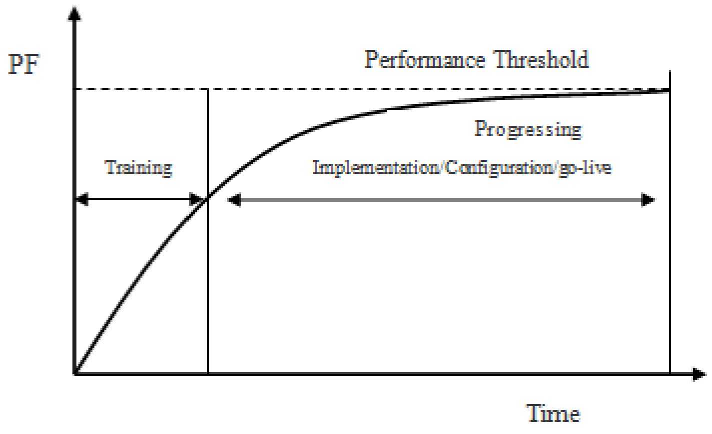


Figure 4.4 parameters of an exponential curve (adopted from Plaza and Rohlf, 2008)

For formula 4.3, the progressing coefficient k_i directly relates to the rate of the progress made by a team and its impact on CSF. However, since the ERP project team is diverse by nature and each CSF performs differently, therefore k_i vary considerably with the context within which ERP is implemented (Nah et al., 2001; Umble et al., 2003; Sumner, 2005; Yoon, 2009) and is difficult to calculate accurately. To obtain single value of k_i that represents the changes in performance of the team and CSFs, and to enhance the accuracy of k_i, the SMEs chosen for the survey are required to meet Criteria 1 -3 in section 3.5.1.

Formula 4.3 represents the performance level of a single CSF. The collective performance of CSFs is calculated as:

$$PF\ (t_1, t_2, t_3, \dots, t_M) = \sum_{i=1}^{M} PF_i(t_i) \qquad (4.4)$$

Having the surveyed results as inputs, the parameters d_i, p_i and k_i are the outputs to the analytical regression models, and are calculated using the least square method which finds the best fit Cost vs Time linear curves and Progress vs Time exponential curves for the observed data.

Next, the coefficient of determination of the regression curve for CSF_i, denoted R_i^2, is calculated to describe how well the regression curve fits the original set of data. If the average value of R_i^2 is lower than 0.5, i.e., $\frac{\sum_{i=1}^{M} R_i^2}{M} < 0.5$, other regression curves need to be experimented with and compared to the observed data until the average value of R_i^2 is higher than 0.5.

4.1.2 ERP Simulation Model

As mentioned in Chapter 2, a computer simulation involves the construction of an artificial environment within which relevant information and data can be generated. Simulation is defined as “using computer to imitate the operations of a real world process or facility according to appropriately developed assumption taking the form of logical, statistical, or mathematical relationship which are developed or shaped into a model” (McHaney, 2009, p. 10).

In this research Monte Carlo simulation model (Aren et al. 2006; Law & Kelton, 2000) is developed to imitate ERP implementation in SMEs and to verify the validity and effectiveness of the analytical regression models developed in previous section of this chapter. The verification process is performed by comparing the outputs from the simulation model with the observation from survey, enabling a verification check as to whether the regression models work as expected.

The simulation model is constructed as a time dependent model with time spent on each CSF as an independent input and implementation cost, project duration and performance level as dependent output. By employing simulation model the relationship between the independent variables and dependent variables can be effectively studied. In the simulation model, a sequential implementation approach is implemented which involves implementing one CSF at a time (instead of all CSFs simultaneously).

This approach to the analysis is not only influenced by the necessities of the modelling, but is also in concert with the general model of ERP developments according to Sun et al.’s (2005) observations. They highlight that the sequential approach to ERP implementation is also generally more likely to be preferred by SMEs, due to relatively more limited manpower and resources, and since hiring service of extra staff or vendors could create a burden on the resources (Sun et al., 2005). In addition, sequential implementation allows SMEs to focus on one CSF at any time during the project, which in turn gives SMEs’ more control over the implementation process.

Therefore in this simulation model CSFs are implemented sequentially in the order of CSF-*Users*, *PM*, *IT*, *VS* and *TM*. The process starts with time spend on the CSF as an input value and the cost and progress level are obtained through the regression models developed for each CSF. When the last CSF is processed, final result is displayed as project duration, implementation cost, and performance level achieved for the implementation.

The DSS_ERP is spreadsheet based model. A spreadsheet is enabling technology for the decision support. Spreadsheets in MS Excel have sophisticated data handling and graphic capabilities and they can be used for "what-if" analysis which makes them suitable for decision support systems (Power, 2009).

For model verification purposes, the input data in the simulation model are 1) time spent on each CSF, and 2) the number of replications[16]. During the implementation process time spend on each CSF is given as random independent variable. This random variable is generated by establishing a probability distribution by examining the historical outcomes from the survey and dividing the frequency of each observation by the total number of the observation using formula (4.5).

$$prob(t_i') = \frac{n_{t_i'}}{\sum_{i=1}^{N} n_{t_i'}} \tag{4.5}$$

Where;
t_i' = possible value that t_i or time takes
N = total number of possible values of t_i,
$n_{t_i'}$ = frequency of t_i' or the number of times t_i' occurs

In each replication, random numbers are used to simulate values for time t_i' (Appendix D) presents probability distribution of (t_i) generated from the probability distribution in (4.5). The random numbers are substituted in analytic regression equations (4.1) and (4.3) to obtain cost and progress for each CSF, and after replications, the total cost and total achievement of the overall ERP implementation.

[16] Replication of model is important since instead of accepting results based on one replication, average results are obtained by replicating model several times, which gives more credibility and validity to the results.

After a number of replications, the following outputs are generated: i) average cost and performance level of each CSF and ii) average project outcome measures, i.e., project duration, implementation cost and performance level of the overall ERP implementation.

The next step is to verify the model to ensure that the results are valid and can be applied towards real-life implementation. The outputs from the simulation model are compared against the observed ERP implementation data (i.e. primary data) in terms of average project duration, average implementation cost and average performance level. If the observed results are within 99% confidence interval of the simulation model, the regression models are verified and the results resemble the real life ERP implementation.

In a situation where the results are not within the required confidence interval, model needs to be re-evaluated and modified accordingly, which means that either parameters need to be calculated or some other types of regression models should be selected.

In practice, during the course of developing the DSS_ERP, after experimentation with different types of models, linear and exponential regression models were found to be the most suitable to resemble the relationship between the variables and hence were adopted for model development.

4.1.3 ERP Nonlinear Programming Model

The nonlinear programming model is used in optimisation process which involves nonlinear functions. In this type of model, there is a nonlinear objective function, or at least one non-linear constraint, or both. In DSS_ERP, a non-linear programming model is developed to optimise ERP implementation to achieve specific predetermined implementation goals which are expressed in mathematical manner, and are subject to a number of constraints on budget, project duration, vendor support level, current IT infrastructure and project management.

In nonlinear programming model, if the goal of implementation team is to maximise the overall performance level of ERP implementation, the objective function can be formulated as:

$$\text{Max } PF\ (t_1, t_2, \dots, t_M) = \sum_{i=1}^{M} PF_i(t_i) \tag{4.6}$$

s.t. $\sum_{i=1}^{M} t_i \leq T$ (4.7)

$$\sum_{i=1}^{M} Cost_i(t_i) \leq C$$

$$t_i \geq 0 \quad (4.8)$$

$$t_i \leq T_i$$

Where:

T = total time spent on the project

C = total cost of the project

T_i = time spent to address CSF_i

M = total number of CSF considered

If a new goal is setup with different constraints, the formulae (4.6-8) can be modified accordingly. This will be further discussed through application in Chapter 5.

4.2 Measuring ERP level of performance

Performance measurement is an essential part of implementation strategy since it assists in understanding, managing and improving the implementation process. In the ERP implementation context, it is essential since ERP implementation entails the application of relatively large amounts of financial and human resources. Consequently, organisations usually put in place a mechanism to measure changes in performance levels due to new ERP system implementations. Yet the definition of 'performance' may vary between organisations according to their strategic goals and/or which aspect of operations they want to evaluate, such as; measuring performance in terms of productivity, finances, market share or inventory. Teltumbde (1999) suggested that the most important element of the success is neither cost nor schedule, but whether or not the system meets the users' needs or objectives. This thesis adopts a view similar to Teltumbde's (1999): focusing on measuring the performance based on achievement of users implementation objectives, and upon what percentage of SMEs functional requirements are met by implementing the new ERP system. The performance metric for this approach is adopted from Sun et al. (2005), who defined performance as a percentage average of ERP utilisation and functional requirements met:

$$Performance = \frac{utilisation + functionality}{2} \qquad (4.9)$$

where utilisation is the estimated percentage of the ERP functionalities utilised by SMEs. The functionalities are such as integrating/streamlining business processes, information sharing, order tracking, central data ware housing etc. While 'functionality' itself, represents an estimated percent of the targets achieved or functional requirements (such creating central database, integrating business function, improved productivity etc.) that are met by implementing ERP systems. The composite achievement score presents a single metric capable of representing both target achieved and functionalities utilised.

Further to elaborate by an example, suppose in *Company X*, the ERP professional estimates that 60 percent of acquired system's capabilities are being utilised and 80 percent of the functional requirements of SMEs that are met by implementing ERP systems. Therefore the combined achievement from the implementation is calculated as;

$$Company\ X\ Performance = \frac{80 + 60}{2} = 70\%$$

Therefore according to the developed performance metric, this implementation achieves 70% performance level. Similarly, given an overall 70% performance level, ERP professional's judgement can determine how much each CSF contributed to the outcome. For example, in this case CSF_1- TM contributed 10%, CSF_2- Users 15%, CSF_3- PM 20%, CSF_4- IT 10% and CSF_5- VS contributed 15% towards the overall performance level. [Note for information: Appendix A presents the total calculated performance for each SME rather than just their individual values].

4.3 Illustrative examples

In this section the development of DSS_ERP is illustrated through an example.

4.3.1 Development of Analytical Regression Models

The analytic regression model is developed in three steps.

Step1:

The primary data was firstly analysed at CSF level by presenting relevant data in time series format representing time, cost and performance.

Time series, as explained in chapter 3, is the collection of data over a period of time and suitable to make current decision and plan based on long term forecasting. In the time series format, if there is more than one occurrence, the mean value is calculated for that time period. For example, if multiple SMEs have spend the same number of days to implement a CSF but the performance level and cost incurred varies, the *average value* of cost and performance is calculated for given number of days. The primary data is presented in time series format in Tables 4.1-5 for each CSF.

Step 2:

Next, time series data is applied to develop regression model which is a forecasting technique to establish relationship between quantifiable variables. For each CSF, the independent variable (i.e. time) is plotted on the horizontal x-axis, and the dependent variables (i.e. cost and progress) are plotted on the vertical y-axis (see Figures 4.5-9). The graphs show the accumulated cost and progress level as a function of time. The curve that best fits with original data (or the line of best fit) is obtained using least square method, and modelled in regression equation (explained in Section 4.3.1.1-2). The relationships between Cost and Time, and Progress and Time are best represented by linear curves and exponential curves respectively.

CSF_1 –TM

Number of Occurrences

Time Series Data	7	1	1	2	4	8	3	1	8	2	8	2	5	1	5	1	1
Time- days	0	1	2	4	5	7	8	9	10	12	14	18	21	28	30	45	84
Mean Cost-$	0	0	0	910	2,115	2,220	4,273	7,000	7,047	5,595	11,406	3,750	7,885	20,000	28,010	40,000	50,000
Mean Performance	0	0	1	13	4	7	5	5	9	7.75	8	8.5	14	15	17.6	10	21

Table 4.1 Time series data for CSF-TM

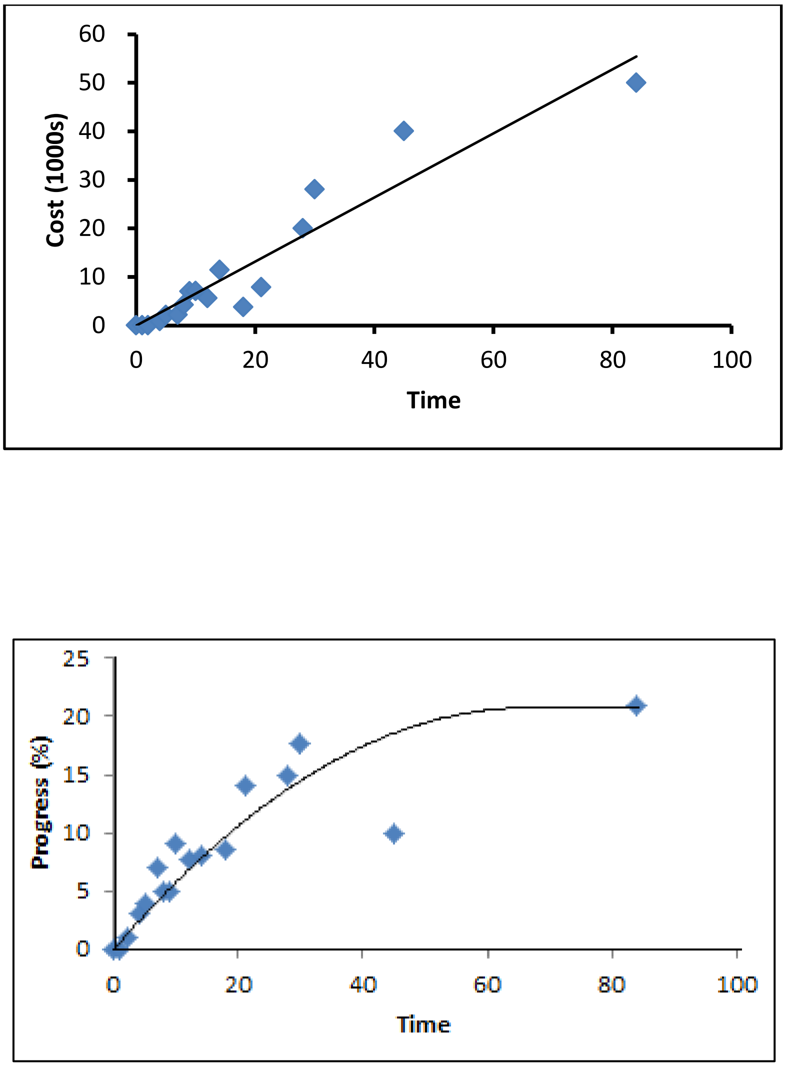


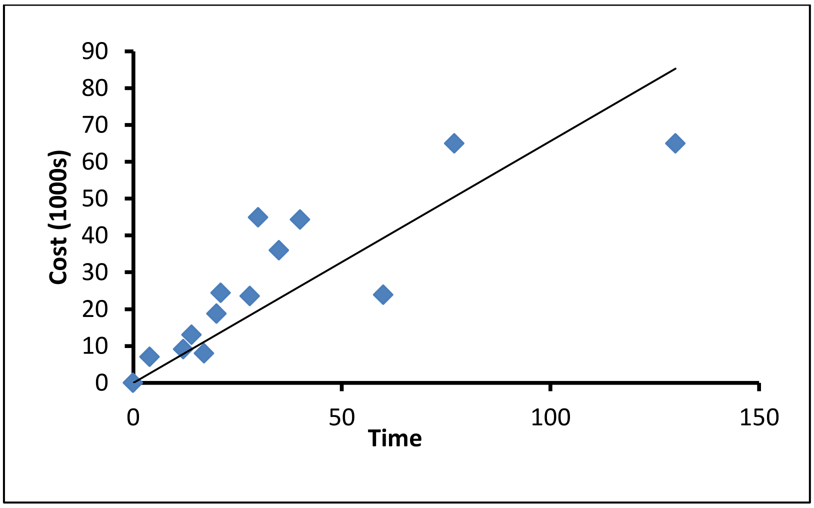
Figure 4.5 Linear and exponential curves for CSF-TM

CSF_2 - User

Number of occurrences

Time Series Data	5	4	5	3	4	9	9	4	5	3	8	2	1
Time- days	4	12	14	17	20	21	28	30	35	40	60	77	130
Mean Cost-$	7,080	9,125	13,076	8,040	18,800	24,434	23,548	44,980	36,000	44,350	23,916	65,000	65,000
Mean Performance	13	5.88	17.6	15	15.75	18	18.56	19	18	20.67	12	16.5	16.5

Table 4.2 Time series data for CSF-Users



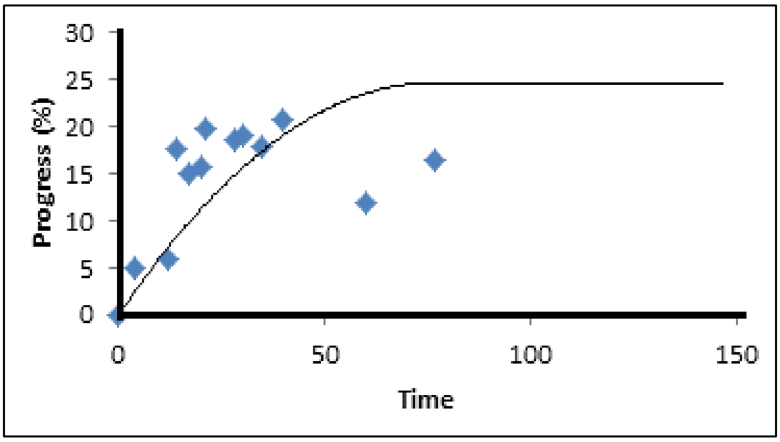


Figure 4.6 Linear and exponential curves for CSF-Users

$CSF_3 - PM$

Number of occurrences

Time Series Data	1	1	3	5	4	7	7	3	5	8	7	3	1	2	2	1
Time- days	3	7	10	14	18	20	21	25	28	30	35	40	49	60	84	180
Mean Cost-$	3,000	10,250	10,983	11,878	18,230	15,811	21,427	24,700	27,042	30,062	28,268	27,916	84,000	57,700	72,500	100,000
Mean Performance	0	5	3	14.6	12	14	15	19	17	19	17	16	15	26.5	23	25

Table 4.3 Time series data for CSF-PM

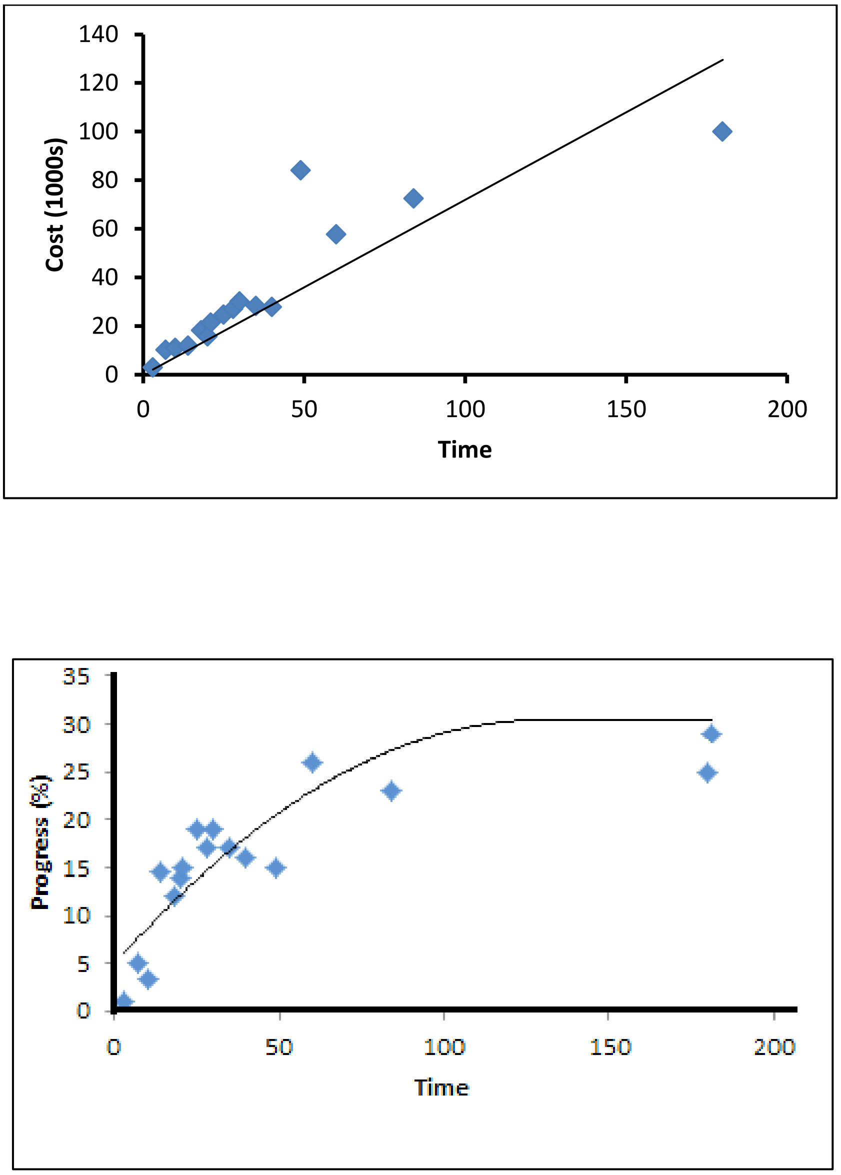


Figure 4.7 Linear and exponential curves for CSF-PM

CSF_4 -IT

	Number of Occurrences												
Time Series Data	1	1	1	4	3	5	3	2	7	2	3	4	5
Time- days	3	4	7	10	12	14	18	20	21	24	28	30	35
Mean Cost-$	3,750	5,200	14,350	23,575	24,893	21,628	15,576	16,250	48,850	39,900	68,600	49,787	35,890
Mean Performance	0	3	5	8.5	11.67	14	11.66	19	15	24.5	12.66	19.5	17

Cont'd

Time Series Data	3	4	2	2	2	2	2	1
Time- days	37	42	60	63	70	84	100	180
Mean Cost-$	55,483	33,550	64,833	66,350	137,900	100,625	40,000	80,000
Mean Performance	20	21	13	13	18	16	25	20

Table 4.4 Time series data for CSF-IT

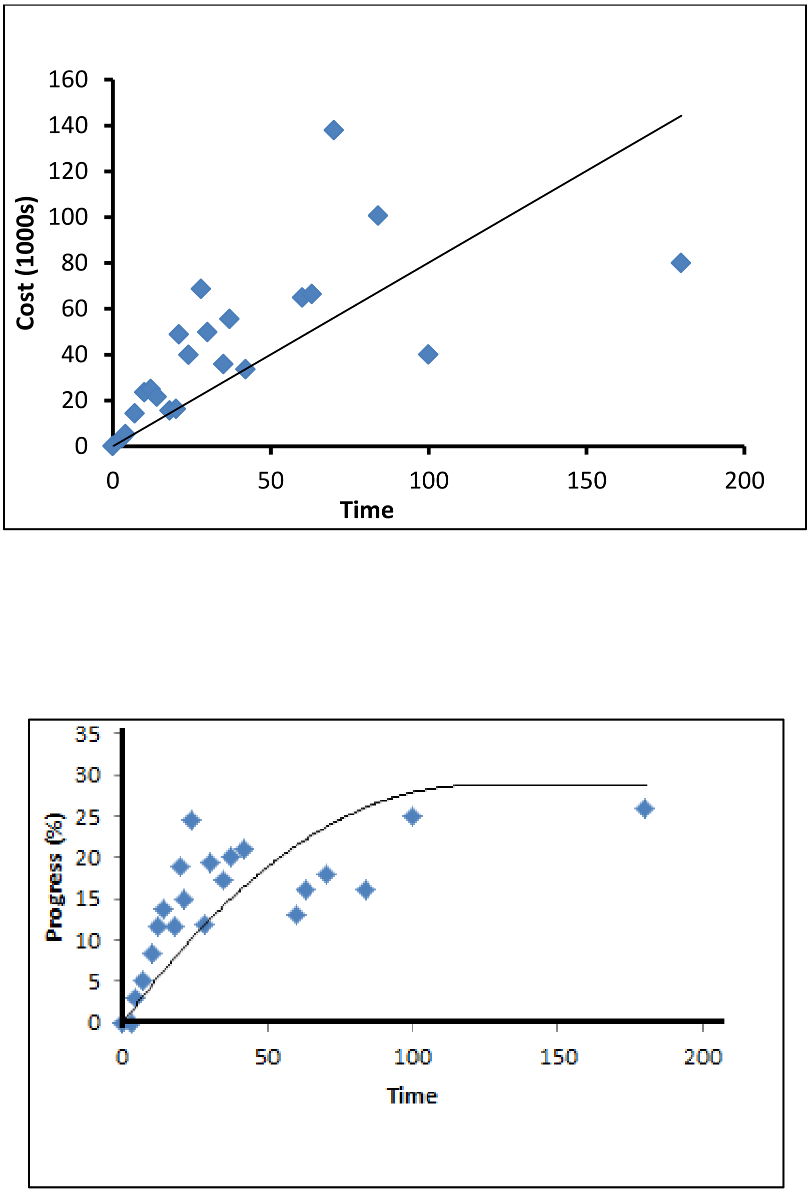


Figure 4.8 Linear and exponential curves for CSF-IT

CSF_4 -VS

Number of Occurrences

Time Series Data	1	4	5	2	3	3	3	9	2	3	5
Time- days	3	5	6	7	9	10	11	13	15	18	20
Mean Cost-$	3,750	11,231	11,135	12,820	11,270	15,966	19,966	17,945	41,280	9,900	22,240
Mean Performance	0	6	7.6	9.5	7	9	14.6	11.6	14.5	13	12

Cont'd

Time Series Data	3	3	3	5	4	1	1
Time- days	21	24	26	30	33	44	15
Mean Cost-$	46,723	16,943	23,275	26,950	54,575	36,000	200,000
Mean Performance	11	12	14	7	8	15	17

Table 4.5 Time series data for CSF-VS

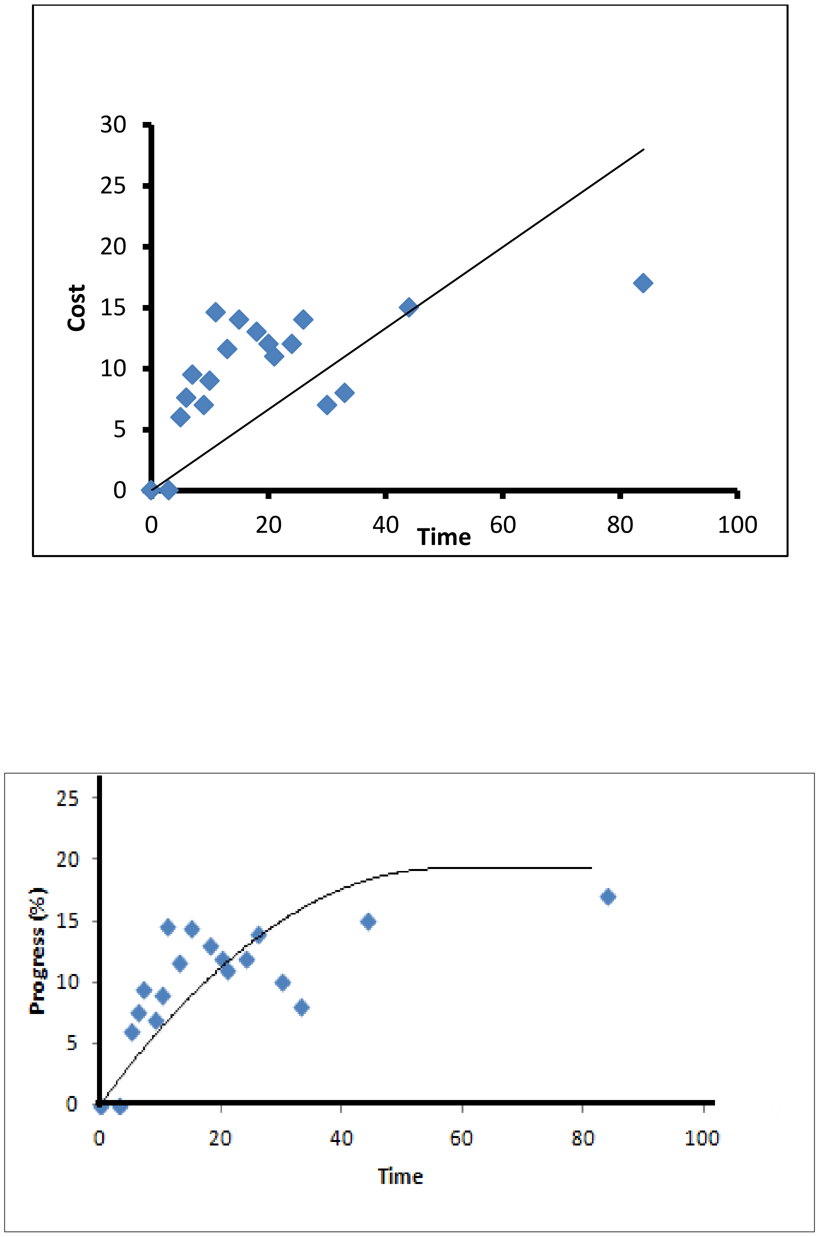


Figure 4.9 Linear and exponential curves for CSF-VS

Figure 4.5-9 presents the linear and exponential curve for each CSF derived from the primary data show in Table 4.1-5. As discussed in section 4.1, the Cost vs Time represent the linear relationship, while exponential curves represent the Progress vs Time relationship.

Step 3

Next, the linear curve and exponential curves are generated and the values of coefficients are determined using least square methods.

4.3.1.1 Development of Linear curve

As mentioned in previous section, the linear curves ideally represent the relationship between time and cost. The liner curve is generated using least square method, and the coefficient d_i are determined using formula (3.2).
Using $CSF_I -$ TM as an example, the time series data for time and cost from Table 4.1 is applied towards calculating the coefficient of determination d_i in formula (3.2), and are listed in Table 4.13.

Observations (n)	**Time (x)**	**Cost (y)**	xy	x^2
1	0	0	0	0
2	1	0	0	1
3	2	0	0	4
4	4	910	3640	16
5	5	2115	10575	25
6	7	2220	15540	49
7	8	4273	34184	64
8	9	7000	63000	81
9	10	7047	70470	100
10	12	5595	67140	144
11	14	11406	159684	196
12	18	3750	67500	324

13	21	7885	165585	441
14	28	20000	560000	784
15	30	28010	840300	900
16	45	40000	1800000	2025
17	84	50000	4200000	7056

Table 4.6 Data for determination of coefficients of $\boldsymbol{CSF_I}$**-TM**

From the above table, $\sum xy$ =8057618, $\sum x$ = 298, $\sum y$ =190211, $\sum x^2$ = 12210 and n = 17.

Substituting these values in formula:

$$d_1 = \frac{n(\sum xy) - (\sum x)(\sum y)}{n(\sum x^2) - (\sum x)^2}$$

$$= \frac{17(8057618) - (298)(190211)}{17(12210) - (88804)}$$

= 659.92

Next, substituting the value of d_1 to formula (4.1), the linear equation for CSF_I-TM is obtained:

$$Cost_1(t_1) = 659.92\ t_1 \tag{4.10}$$

This process is repeated to determine coefficients d_i $(i = 2,3,4,5)$ for the other CSFs.

Next, to determine the goodness of fit of a model, i.e. to measure how well the linear regression line approximates the real data points, R_1^2 for $CSF_I - TM$, the data from the Table 4.1 is applied in determining the values of SS_{err} and SS_{Total}, as shown Table 4.7.

Time (x)	Cost (y)	Predicted value	SS_{err}	SS_{Total}
0	0	0	0	125191088.3
1	0	659	434821	125191088.3
2	0	1318	1737124	125191088.3
4	910	2636	2979076	105655422.4
5	2115	3295	1392400	82335340.96
7	2220	4613	5726449	80440850.66
8	4273	5272	998001	47829428.72
9	7000	5931	1142761	17546735.37
10	7047	6590	208849	17155189.43
12	5595	7908	5349969	31291519.78
14	11406	9226	4752400	47140.07266
18	3750	11862	65804544	55336970.66
21	7885	13839	35450116	10915638.6
28	20000	18452	2396304	77635794.19
30	28010	19770	67897600	282949998.9
45	40000	29655	107019025	830080500.1
84	50000	55356	28686736	1506302853

Table 4.7 Data for coefficient of determination, $\boldsymbol{R_i^2}$ for $\boldsymbol{CSF_I - TM}$

From the above table, Mean y = 11188, $\sum SSerr$ = 331975635 and $\sum SS_{Total}$ = 3521096648.

Substituting the values from Table 4.7 to formula (3.4):

$$R_1^2 = 1 - \frac{331975635}{3521096648}$$

$$R_1^2 = 0.9$$

The value for R_1^2 for $CSF_I - TM$ is 0.9, suggesting that regression line fits well with the observed data, i.e. it closely resembles the observed data.

This process is repeated to determine the values of coefficient, R^2 for remaining CSFs. The values of R^2 are presented in Table 4.8.

CSF_1 –TM	$Cost_1(t_1) = 659.92. t_1$	$R_1^2 = 0.9$
CSF_2 − Users	$Cost_2(t_2) = 656.28. t_2$	$R_2^2 = 0.61$
CSF_3 – PM	$Cost_3(t_3) = 719.66 . t_3$	$R_3^2 = 0.68$
CSF_4 –IT	$Cost_4(t_4) = 1361. t_4$	$R_4^2 = 0.76$
CSF_5 –VS	$Cost_5(t_5) = 1770.7 . t_5$	$R_5^2 = 0.78$

Table 4.8 Linear equations with coefficients and $\boldsymbol{R^2}$ values

R_i^2 given in Table 4.8 describes how well the linear regression curves fits the original set of data. The average value of R_i^2 for Cost vs Time curve is 0.75, indicating that the selected regression curves are an acceptable fit for the observed data.

4.3.1.2 Development of Exponential curve

As discussed in previous section, the relationship between the performance and time follows an exponential curve. The curve is developed based on the fact that at the start of implementation the performance is zero and it increases with time spend on implementation up to certain level and then it levels out. The progress, denoted PF_i, is measured as the percentage of the performance level contributed by CSF_i , and reaches the maximal performance threshold level p_i when unlimited time (associated with unlimited cost) is spent on it, i.e., $PF_i(t_i) = p_i$ when $t_i = \infty$. Therefore, the equation for the exponential curve is expressed as:

$$PF_i(t_i) = p_i . (1 - e^{-k_i t_i}) \quad (4.11)$$

In the given curve equation, the value of p_i and k_i presents the coefficient values of performance threshold and progression of CSF. These values vary for each CSF, therefore required to be calculated in order to determine the unique exponential curve for each CSF.

Using CSF_I as an example, the time series data for time and progress level from Table 4.1 is applied towards calculating the estimated performance using exponential curve formula. The initial values of $p_1$and k_1 are set to be 2 and 0.2, respectively. Based on these values, the estimated values of progress level are calculated for different input (number of days spent on CSF_i) using formula 4.11, and are listed in Table 4.13.

Days	Performance	Estimated Performance	Difference
0	0	0	0
1	0	0.84	0.71
2	1	1.65	0.43
4	3	3.16	0.027
5	4	3.87	0.0006
7	7	5.2	3.27
8	5	5.8	0.65
9	5	6.4	1.94
10	9	6.9	4.17
12	7.75	8	0.06
14	8	9	1.05
18	8.5	10	4.57
21	14	11.7	4.36
28	15	13.7	1.67
30	17.6	14	11.76
45	10	16.57	43.21
84	21	18.61	5.69
Total			83.6

Table 4.9 Estimated performances for $\boldsymbol{CSF_I - TM}$

The differences between the estimated values and the observed values are calculated, and the coefficient p_1 and k_1 are determined in such a way that the sum of the differences is minimised. The parameters $p_1$and k_1 are solved using Excel Solver, and the minimal value of the sum of the differences is 83.6. The resulting value for coefficient $p_1$and k_1 for $CSF_I - TM$ are 19.03 and .045 respectively.

Substituting the values of coefficient $p_1$and $k_1$to formula (4.11), the exponential curve for $CSF_I - TM$ is obtained as:

$$PF_1(t_1) = 19.03\ .\ (1 - e^{-0.045\ .\ t_1}) \qquad (4.12)$$

This process is repeated to determine the coefficients of remaining CSFs and the results are shown in Table 4.10.

	p_i	k_i
CSF_1 –TM	19.03	0.045
CSF_2- Users	17.13	0.163
CSF_3 – PM	24.26	0.04
CSF_4 –IT	19.28	0.076
CSF_5 –VS	12.94	0.143

Table 4.10 Performance threshold ($\boldsymbol{p_i}$) and progression coefficient ($\boldsymbol{k_i}$) values for CSFs

Substituting the values of coefficient $p_1$and k_1 from Table 4.10 to formula (4.11), Progress vs Time exponential curve are formulated as follows:

CSF_1-- TM $\quad PF_1(t_1) = 19.03\ .\ (1 - e^{-0.045\ .\ t_1})$ (4.13)

CSF_2 -- Users $\quad PF_2(t_2) = 17.13\ .\ (1 - e^{-0.163\ .\ t_2})$ (4.14)

CSF_3 – PM $\quad PF_3(t_3) = 24.26\ .\ (1 - e^{-0.04\ .\ t_3})$ (4.15)

CSF_4 – IT $\quad PF_4(t_4) = 19.28\ .\ (1 - e^{-0.076\ .\ t_4})$ (4.16)

CSF_5 –VS $\quad PF_5(t_5) = 12.94\ .\ (1 - e^{-0.143\ .\ t_5})$ (4.17)

Similar to linear model, next step is to determine the how well the exponential regression curve approximates the real data points. The coefficient of determination, R^2 is calculated applying formula (3.4).

The value for R_1^2 for $CSF_I - TM$ is determined by applying time series data from Table 4.1 and calculating the sum of squared errors and total sum of squares as shown in Table 4.11.

Time (x)	**Performance (y)**	**Predicted value**	$SSerr$	SS_{Total}
0	0	0	0	63.5
1	0	0.83	0.70	0
2	1	1.63	0.40	1
4	3	3.13	0.01	9
5	4	3.83	0.002	15.05
7	7	5.14	3.45	49
8	5	5.75	0.56	25
9	5	6.33	1.78	25
10	9	6.89	4.42	81
12	8	7.94	0.036	60.06
14	8	8.89	0.91	63.04
18	8.5	10.56	4.26	72.25
21	14	11.63	4.69	190.44
28	15	13.63	1.87	225
30	17.6	14.09	12.27	309.76
45	10	16.51	42.48	100
84	21	18.59	5.78	441
Total			83.67	1730.11

Table 4.11 Data for coefficient of determination, R_i^2 for exponential curve of $\boldsymbol{CSF_I - TM}$

From the above table, Mean y = 7.96, $\sum SSerr$ = 83.67 and $\sum SS_{Total}$ = 1730.11. Substituting these values in formula (4.11):

$$R_1^2 = 1 - \frac{83.67}{1730.11}$$

$$R_1^2 = 0.95$$

The value for R_1^2 for $CSF_I - TM$ is equals 0.95, suggesting that the regression line is a best fit with the observed data, i.e. it closely resembles the real data.

This process is repeated to calculate the values of coefficient of determination, R^2, for remaining four CSFs. The values of R^2 are presented in Table 4.12.

CSF_1 –TM	$R_1^2 = 0.95$
CSF_2 − Users	$R_2^2 = 0.89$
CSF_3 – PM	$R_3^2 = 0.93$
CSF_4 –IT	$R_4^2 = 0.92$
CSF_5 –VS	$R_5^2 = 0.66$

Table 4.12 Values of coefficient of determination, $\boldsymbol{R^2}$

The values of R_i^2 given in Table 4.12 describe how well the exponential regression curves fit the original set of data. The average value of R_i^2 for Progress vs Time curve is 0.87, indicating that the selected exponential regression curves are fit well with the observed data.

Table 4.13 presents the values of cost coefficient d_i, progression coefficient k_i and performance threshold p_i for each CSF determined in previous sections.

Parameters	$\boldsymbol{CSF_1 - TM}$	$\boldsymbol{CSF_2 - Users}$	$\boldsymbol{CSF_3 - PM}$	$\boldsymbol{CSF_4 - IT}$	$\boldsymbol{CSF_5 - VS}$
$\boldsymbol{d_i}$	659	656	719	1361	1770

$\boldsymbol{k_i}$	0.045	0.16	0.04	0.076	0.143
$\boldsymbol{p_i}$	19.03	17.13	24.26	19.28	12.94

Table 4.13 Values of $\boldsymbol{d_i}$, $\boldsymbol{k_i}$ and $\boldsymbol{p_i}$ for $\boldsymbol{CSF_i}$

Comparing the values, performance and contribution of CSFs towards implementation can be observed and can be applied to make informed decision making. The values reveal the following features:

i. The values of cost function d_i shows that in comparison with other CSFs, *VS* and *IT* are much more costly than other CSFs during the course of implementation. This perhaps indicate that hiring the services of external consultant, purchase of software, upgrading existing infrastructure, IT training are major expense and can consumes major portion of implementation budget. This feature is consistent with the findings in Sun et al. (2005) and Plaza and Rohlf (2008).

ii. Analysis of progressing coefficient k_i values indicates that *Users* and *VS* have higher progressing speed than other CSFs. The performance of these two CSFs is a result of extensive users training and their involvement, and the experience and knowledge of *VS* and their contribution in smooth implementation in SMEs. The surveyed SMEs provided different levels of education and training to the end users at different phases of implementation. Users' training and development are useful in understanding the intricacies of ERP implementation, minimising users' resistance and yielding full benefits of ERP systems. In comparison with other CSFs, users' interaction with the system and involvement in the implementation process expedite the implementation with minimal chances of system error. Similarly, VS is offered by a third party in the form of technical and implementation support while recommending an implementation strategy and essential technical know-how. Since vendors (or consultants) have a greater knowledge of the ERP systems, it have positive impact in comparison with other CSFs, although the initial progress is slow since it takes time for vendors to understand the organisational requirements and functioning, and to figure out how the ERP systems will meet the customer's functional requirements. This means that *Users* and *VS* progress at quicker pace in making contribution towards implementation process.

iii. Examining the values of performance threshold p_i to find out which CSF make more contribution towards implementation, it is observed that *PM, TM* and *IT* show stronger performance contribution as compared to other CSFs. This suggests that a well-planned project management with the availability of IT infrastructure in the presence of top management support should form the basis of the implementation process in order to attain success. This includes defining clear objectives, having a competitive and experienced project team, development of clear work plan and resource plan, setting up hardware and software systems and applications, and gaining top management support for ERP implementation.

Further, as illustrated in Figures 4.5-9, the relationships between time and cost, and time and performance from the observed data, indicate that there is a significant cost increment when time increases, while performance tends to level off at some point, beyond which there is little or no improvement. These relationships are the same as the ones verified in Sun et al. (2005), which suggest that the longer duration or too much effort does not necessarily will result in higher performance rather it can be unproductive. Therefore it is worth identifying the optimal solution from which the highest possible achievement is acquired while time and cost are maintained low.

4.3.2 Development of Simulation Model to verify analytical models

Model verification is defined as "ensuring that the computer program (in this instance simulation model) and its implementation are correct" (Sargent, 2011, p. 183). The process of model verification is critical in the development of analytical models. A developed model must go through the verification process so as to make sure that the information obtained from the results of the model is correct. A model is considered valid if the model accuracy is within the acceptable range and it is essential that the model output variables and their acceptable range of accuracy is defined at early stage (Sargent, 2011). There are several techniques for model verification described in literature and discussed in section 3.11, simulation modelling approach is adopted to verify analytical models developed in section 4.2.1.

In this research Monte Carlo simulation model (shown in Figure 4.10) is developed to verify the analytical models. The model is based on an assumption that sequential implementation strategy is used in SMEs implementing ERP systems, rather than a 'big bang' implementation strategy (which the literature indicates is more suitable for large enterprises). This sequential implementation strategy allows SMEs to focus and implement one CSF at given time which usually leads to better results (see section 4.1.2). The simulation model is developed in Microsoft Excel and has five process 'locations' with associated regression logic, one for each CSF.

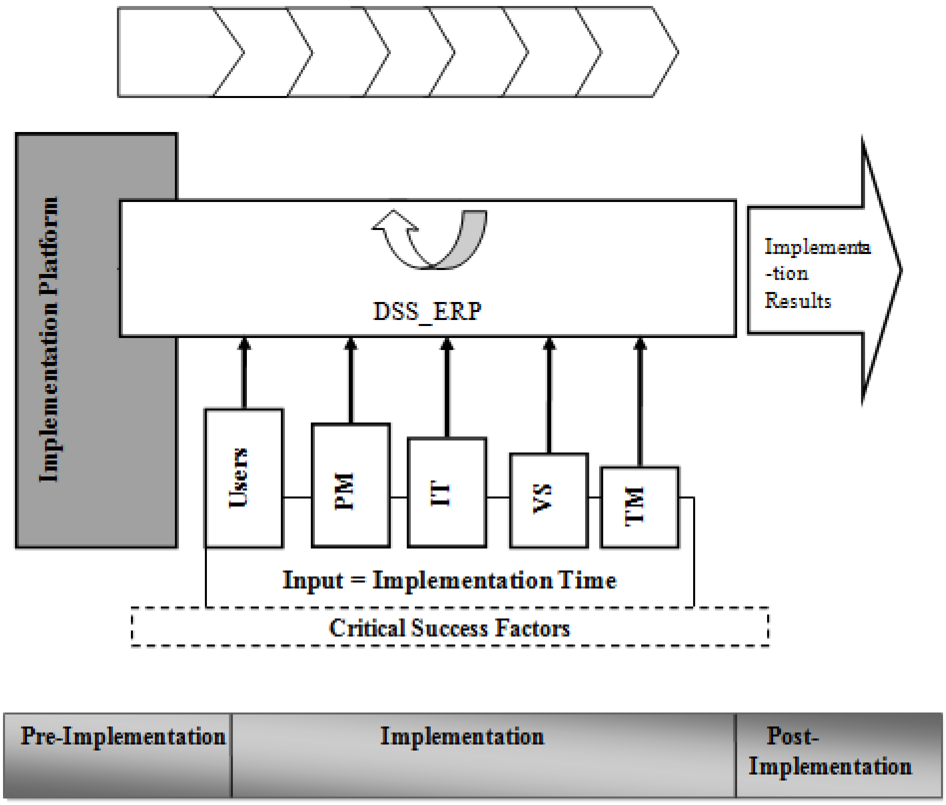


Figure 4.10 ERP simulation model

The input data for the simulation model are: 1) time spent on each CSF, and 2) number of replications. The numbers of days are randomly generated using probability distribution of observed time spent on each CSF by applying probability formula (see Appendix D). For example, to calculate the probability distributions of time spend on CSF1, the frequency of same number of days is calculated, as shown in Table 4.14.

No.	**Days**	**Frequency**
1	0	7
2	1	1
3	2	1
4	4	2
5	5	4
6	7	7
7	8	4
8	9	1
9	10	8
10	12	2
11	14	8
12	18	2
13	20	3
14	21	2
15	28	1
16	30	5
17	45	1
18	90	1

Table 4.14 Frequency table for days spent on $\boldsymbol{CSF_I - TM}$

Next by applying probability formula (4.5), the probability distribution for number of days is calculated and is presented in Table 4.15:

N	$n_{t'_i}$	$prob(t'_i)$
0	7	0.11
1	1	0.02
2	1	0.02
4	2	0.03
5	4	0.07
7	7	0.12
8	4	0.07
9	1	0.02
10	8	0.13
12	2	0.03
14	8	0.13
18	2	0.03
20	3	0.05
21	2	0.03
28	1	0.02
30	5	0.08
45	1	0.02
90	1	0.02

Table 4.15 Probability distribution for days spent on $\boldsymbol{CSF_I - TM}$

The probability distribution for remaining CSFs is given in Appendix D.

Once the input value is processed through all five locations (see Figure 4.10), an implementation result indicating total cost of implementation, project duration and performance level is generated. Since input data is randomly generated, the results obtained from simulation are also random and are based on one replication. The simulation is replicated 100 times to get an average result of total cost, project duration and performance level.

4.3.2.1 Verification of Model

The validity and the effectiveness of the analytical models are evaluated and verified before they are applied to develop DSS_ERP. As a part of model verification process, a hypothetical implementation model is developed by applying the analytic regression equations. The input values of time spent on CSF_i, presented as $t_{i,}$ is a random input to the simulation model. The value of $t_{i,}$ is generated using probability distribution and is calculated using formula (4.5).

The probability distributions of t_i are represented in Appendix D. The input value t_i is entered hypothetical model and is applied to the regression logic associated with each CSF. The model is developed to run 100 replications and gives average value of these replications as a final result. In Table 4.16 final results from the hypothetical model are compared against the observed.

	Project duration (days)	**Implementation cost ($)**	**Performance level (%)**
Observed results	128	131,806	66
99% confidence interval of simulation result	[127, 131]	[129, 991, 133,360]	[65.76, 66.27]
Simulation results	129	131, 676	66

Table 4.16 Summary of results for model verification

As shown in Table 4.16, the average project outcome from the observed data fall within the 99% confidence interval[17] values of the hypothetical simulation model, therefore verifying that the analytical models closely resemble the performance of the CSFs in reality, and work as expected. Hence the results generated from the model are robust and the developed DSS_ERP can be used during the ERP implementation.

3.3 Nonlinear programming Model

[17]See appendix E

Since the relationship between time and progress level is nonlinear, a nonlinear programming model (Taha, 2011) is constructed to optimise ERP implementation to achieve the predetermined goals which are expressed in mathematical manner, subject to a number of constraints. Goal Seeking analysis is conducted to make decisions on the decision variables. By setting up the goals, the nonlinear programming model calculates either or both t_i or k_i, which in turn can help decision makers to focus efforts and resources on CSFs that have a greater impact on achieving their desired goals, and to develop corresponding implementation strategies.

The three primary elements of a nonlinear programming model are:

i) objective function: maximise performance level or achieve a predetermined level of performance,

ii) decision variables: time needed t_i and/or progressing coefficient, k_i

iii) constraints; total budget, the maximal or minimal time to spent on each CSF and total project duration,

If the goal is to maximise the overall performance level of ERP implementation, the objective function can be formulated as:

$$\text{Max} \quad PF(t_1, t_2, \ldots, t_M) = \sum_{i=1}^{M} PF_i(t_i) \tag{4.18}$$

s.t.

$$\sum_{i=1}^{M} t_i \leq T$$

$$\sum_{i=1}^{M} cost_i\,(t_i) \leq C$$

$$t_i \geq 0 \tag{4.19}$$

$$t_i \leq T_i$$

The constrained nonlinear programming model in (4.18-19) cannot be solved explicitly for symbolic solutions, but a wide range of optimisation tools such as Excel's Solver and CPlex can be used to solve it numerically when the parameter values are given. The algorithms implemented by the optimisation tools vary with the solvers adopted, and Excel's Solver uses the Generalised Reduced Gradient (GRG) method, which is a generalisation of the Steepest Ascent (or Steepest Descent) method (Taha, 2011).

Further to elaborate, for example, if SME plans to implement ERP systems within a budget of \$120,000 and project duration of 110 days, to determine the suitable allocation of resources for each CSF in order to achieve maximum performance level, a nonlinear programming model constructed as follows:

$$Max\ \ PF(t_1, t_2, t_3, t_4, t_5) \tag{4.20}$$

subject to the constraints of limited budget and project duration:

$$\sum_{i=1}^{M} t_i \leq 110$$

$$\sum_{i=1}^{M} cost_i\,(t_i) \leq 120{,}000$$

Time spent on CSFs must not be negative:

$$t_i \geq 0 \tag{4.21}$$

For this scenario, the objective function is,

$$Max\ PF(t_1, t_2, t_3, t_4, t_5) = PF_1\,(t_1) + PF_2(t_2) + \ PF_3(t_3) + PF_4(t_4) + PF_5(t_5) \tag{4.22}$$

Substituting nonlinear equations (4.13-17) in formula (4.22), the non-linear objective function becomes:

$$\text{Max } PF(t_1, t_2, t_3, t_4, t_5)$$
$$= 19.03\ \ (1 - e^{-.045.t_1}) + 17.13\,(1 - e^{-.1638t_2}) + 24.26\,(1 - e^{-.04*t_3}) +$$
$$19.28\,(1 - e^{-.076*t_4}) + 12.94\,(1 - e^{-.143*t_5}) \tag{4.23}$$

The above equation is solved using Excel's Solver. The solution of t_i and project outcomes are listed in Table 4.17.

$Cost$ (\$)	$Time$ $(Days)$	$Performance$ $level - \%$	CSF_1 $- TM$	CSF_2 $-Users$	CSF_3 $-PM$	CSF_4 $-IT$	CSF_5 $-VS$
\$120,000	110	73.4	26	14	33	23	14

Table 4.17 Solution for goal-seeking analysis

The results presented in Table 4.17 show that under given constraints the maximum performance level which can achieved is 73.4%, while the project duration of 110 days.

4.4 Summary

This chapter presents an integrated decision making system for ERP implementation, DSS_ERP, employing analytical regression models, a simulation model and a nonlinear programming model. The DSS_ERP uses the observed data obtained from empirical surveys to develop analytical regression models, which are verified by the simulation model before they are applied to construct the nonlinear programming model. The nonlinear programming models are employed to determine the resource allocations for the predetermined goals. The detailed steps involved in developing DSS_ERP are demonstrated through an illustrative example. The application of DSS_ERP will be discussed in the next chapter.

CHAPTER 5

Application of DSS_ERP to forecast project duration, project cost and performance level

This chapter analyses data collected from the survey, with the aim to study ERP implementations in SMEs and the roles played by CSFs in implementations. Using the data collected from the survey conducted on 400 SMEs, the DSS_ERP developed in Chapter 4 is applied to demonstrate: (1) DSS_ERP can act as an analytical tool to monitor ERP implementation progresses, (2) DSS_ERP can facilitate decision making on resource allocations to achieve the predetermined targets and (3) DSS_ERP can be a risk analysis tool to analyse potential risk and opportunities caused by the changes.

This chapter is organised as follows: Section 5.1 report findings from the survey. Section 5.2 demonstrates how DSS_ERP can monitor ERP implementation progresses and facilitate resource allocations through Goal-Seeking analysis using hypothetical data. What-if analysis is conducted to analyse the impacts of changes and potential risks caused by the changes. The primary findings from four SMEs are compared against the results from DSS_ERP. Finally, the summary is given in Section 5.3.

5.1 Results from the survey

The empirical findings suggest that 47 percent respondents' have 'strongly agreed' that CSF_1 - TM plays a critical role in successful implementation. This CSF appears most frequently in literature and is considered particularly crucial for success (Holland & Light, 1999; Umble et al., 2003; Ernst & Young, 2006; Chang et al., 2008). Top Management support encompasses the overall support and direction provided by the senior management to the project and this in turn reinforces the degree of commitment of all employees to the implementation. It is essential because ERP implementation involves technological, organisational and operational related segments and simply introducing new ERP system software does not guarantee successful management of ERP projects. Therefore TM can play facilitating role by ensuring that leadership and direction during the implementation.

The primary responsibility of TM can include providing sufficient financial support and adequate resources (including people and equipment), to build a successful system Apart from this primary resource oriented support, political and psychological or behavioural support is also important in making sure the development runs more smoothly, this is especially the case if there is significant resistance from the staff involved (Ngai et al., 2008). The support of the management also generally ensures that ERP project will have a high priority within the organisation, and that it will receive required resources and attention.

Table 5.1 presents the observed mean values at CSF level, in terms of time spent, cost incurred and progress level achieved. These values present an individual contribution towards overall implementation. While Table 5.2 presents the combined mean values of primary data for project duration, total cost and performance level.

	$CSF_1 - TM$	$CSF_2 - Users$	$CSF_3 - PM$	$CSF_4 - IT$	$CSF_5 - VS$	$Total$
Time (Days)	13	29	31	36	19	128
Percent	10	23	24	28	15	100%
Cost ($)	9,119	26,186	27,030	44,178	25,293	$131,806
Percent	8	20	20	33	19	100%
Performance level - %	8	17	16	15	10	66
Percent	12	26	24	23	15	100%

Table 5.1 Mean values of time, cost and performance contributed by each CSF

	Project duration (days)	**Implementation cost**	**Performance level**
Mean values	128	$131,806	66%

Table 5.2 Mean values of time, cost and performance achieved by the surveyed SMEs

Table 5.3 (below) shows the weight each CSF carry from the observed implementations, according to its contribution towards the overall ERP implementation performance level. For example based on the observed ERP project outcomes, the resources are allocated in such a way that Users' contribution is higher than other CSFs. On the basis of the level of

	$CSF_1 - TM$	$CSF_2 - Users$	$CSF_3 - PM$	$CSF_4 - IT$	$CSF_5 - VS$	$Total$
Performance level	12%	26%	24%	23%	15%	100%

Table 5.3 CSFs' contribution towards overall performance

contribution each CSF makes towards ERP implementations, CSFs can be prioritised according the weight they carry and their contribution in the order of Users, PM, IT, VS and TM. The relationship between cost and performance is influenced by Users involvement and contribution they make towards implementation. Comparison between Users' performance and money spent, suggests that Users make highest contribution contribute (26 percent) towards overall performance at the expense of 20 percent of total implementation budget. As shown in Table 5.1, whereas CSF-PM contributes comparatively less (24 percent) towards the overall achievement while spending same similar amount of budget (20 percent) resources. The higher level of performance gained at lower cost might guide the implementation team to increase focus on Users, therefore saving resources and achieving higher performance level. Further, implementing Users and PM in close collaboration can make significant contribution towards implementation, since they both make substantial contributions towards performance level. In SMEs, due to lack of resources and experience, PM can provide a complete strategy to plan, coordinate, and monitor various activities in different stages of implementation involving hardware, software and organisational issues. In addition, PM tools such as Gantt chart, critical path method, or program evaluation review techniques can be utilised in estimating duration of project, performance evaluation and progress.

Furthermore, data analysis suggests that CSFs IT and VS consume a major portion of implementation budget (i.e. 53 percent of the budget). The relatively high cost can be due to lack of IT infrastructure and generally less skilled IT staff in SMEs. The supposition is consistent with the literature where IT is identified as the major expense in SMEs (Sedara et al., 2003). Due to lack of internal expertise, the selection of a vendor is a critical step in pre-planning implementation stages (Ponis et al., 2007). In practice, criteria of evaluating vendor's include experiences in the industry, vendor's reputation, financial stability, technical capabilities and mission and longevity/ experience in the field. Selected vendor can provide support ranging from technical issues arising during implementation, to training and post implementation support.

The cost of implementing the CSFs IT and VS can be controlled by acquiring the services of a single vendor, minimal customisation and clearly identifying the implementation requirements. By acquiring single vendor instead of retaining the services of several vendors for each modules or implementation phases; SMEs can save substantial amounts. In addition, research shows that SMEs can also develop a cost-minimisation strategy by creating a positive adoption attitude towards ERP adoption among employees. For example, if the worker is shown that the ERP system is an opportunity for enhancing his or her job performance and skills, then he or she is more likely to develop an interest in the ERP system and making the best use of the system.

The above summary are made based on observed data from project outcomes achieved in the surveyed SMEs, and the outcomes might not be optimal or reach SMEs' predetermined goals. Therefore, the prioritised order of CSFs and the focus needed on each CSF are not absolute.

After going through the complex implementation process and investing resources, it is observed that only 27 percent of the SMEs achieve their total implementation objectives. While remaining SMEs (73 percent) achieve different levels of implementation objectives. This is a significant finding since it suggests that after spending considerable resources and time, three out of four SMEs do not achieve their implementation objectives with their ERP system. The types of objectives not being met usually include integrating and streamlining business process, information sharing, improving productivity and creating a central database. However it is noted that the better defined the objectives of the ERP implementation (and the parameters coming into play), the more effective and timely the end results will tend to be. Extant literature provides evidence that many ERP implementation failed because they did not achieve predetermined corporate goals (Al-Mashari et al., 2003).

To avoid failure and increase probability of achieving goals, it is essential that project manager develop comprehensive implementation strategy with objectives that are achievable in the allocated budget and time.

Further, it is observed from the data collected from SMEs that when it comes to benefitting from the functionalities of ERP systems, only 15 percent SMEs exploit complete functionalities offered by ERP systems (Figure 5.1). The ERP system functionalities usually include real time data processing, system integration, analytical tools and forecasting, and inventory control. Similarly, it observed that 29 percent of the SMEs make use of 80 percent of ERP functionalities, while 24 percent of the SMEs utilise only 60 percent of the available functionalities. This shows that a large number of SMEs are not benefitting from the full potential of ERP system. Given the high cost of ERP implementation, the disparity in available functionalities and their usage by SMEs is unusual and demands further investigation.

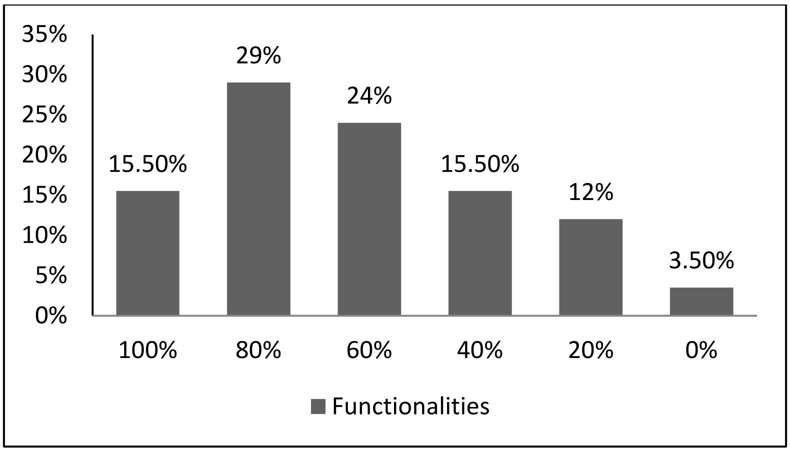


Figure 5.1 Percentage of ERP functionalities used by SMEs

These findings reveals a need to develop a robust quantitative tool to assist ERP implementation in SMEs by identifying emphasis placed on CSFs, and resources allocated to each CSF. The tool is the DSS_ERP developed in Chapter 4, which demonstrates both the analytical and practical aspects of an ERP implementation, and offers a dynamic view of implementation process.

5.2 Application of DSS_ERP to predict project duration, project cost and performance level

In this section, the application of the DSS_ERP, (introduced in chapter 4), is described. The DSS_ERP was tested against data for the time input for CSFs, cost of implementation, performance level and constraints. The main characteristics of the data used are:

a) time input is in number of days, and
b) forecasting process is performed on daily basis for each CSF

The prediction data generated provides an estimate of the project duration, required resources and expected performance level. This can ultimately improve the implementation process in terms of a greater focus on the CSFs which carry more weight towards successful implementation, and better resource allocation by; first keeping track of resources utilised, and second in tracking achievement of predetermined performance levels. In addition, the application of DSS_ERP presented in this chapter also verifies the flexibility of DSS_ERP when working with various input values and constraints. This finding is necessary and advantageous for SMEs, since it allows a platform to examine different implementation strategies and resulting performance of the process.

5.2.1 Goal Seeking Analysis

As discussed in section 3.6.3, Goal seeking analysis is the process of determining the decision variables (such as project duration) to achieve certain goals. Goal Seeking analysis allows users to specify a goal or target for a specific cell and automatically manipulate other cell to achieve that target (Balakrishnan et al., 2007). Goal seeking analysis is conducted to make decision on the following variables:

- t_i, time needed to address CSF_i
- k_i, progress coefficient of CSF_i

DSS_ERP calculates either or both t_i or $k_{i,}$ to achieve the pre-determined goal. This is turn can help decision makers to concentrate efforts and resources on CSFs that have a greater impact on achieving pre-determined goals, and to develop implementation strategies accordingly. In order to demonstrate the functionality of DSS_ERP, seven different goals are setup under a variety of constraints, and resources allocations are determined through the Goal Seeking analysis. Seven goals established with their constraints given in Table 5.4:

Goals	Constraint 1: Project duration-days	Constraint 2: Budget	Other Constraints
1	110	\$120,000	
2	110	\$120,000	
3	110	\$120,000	$t_5 = 30$
4	110	\$120,000	$k_2 \geq 0.163$ $k_3 \geq 0.04$
5	110	\$120,000	$k_4 \geq 0.076$ $k_5 \geq 0.143$
6	110	\$120,000	$k_1 \geq 0.045$ $k_2 \geq .0163$
7	110	\$120,000	$k_2 \geq 0.163$ $k_5 \geq 0.143$

Table 5.4 Constraints defined for Goals 1-7

Goal 1:

With project duration of 110 days and budget of \$120,000, determine the time spent on each CSF to achieve maximum performance level.

The nonlinear programming formulation for Goal 1 would be written as:

$$Max\ PF(t_1, t_2, t_3, t_4, t_5)$$

s.t.

$$\sum_{i=1}^{M} t_i \leq 110 \tag{5.1}$$

$$\sum_{i=1}^{M} Cost_i(t_i) \leq 120{,}000 \tag{5.2}$$

$$t_i \geq 0 \tag{5.3}$$

Applying the formula to calculate performance level objective function is:

$$\text{Max } PF(t_1, t_2, t_3, t_4, t_5) = PF_1(t_1) + PF_2(t_2) + PF_3(t_3) + PF_4(t_4) + PF_5(t_5) \tag{5.4}$$

Substituting (4.13-17) to formula (5.4), the objective function becomes:

$$\text{Max } PF\ (t_1, t_2, t_3, t_4, t_5) = 19.03\ (1 - e^{-.045.t_1}) + 17.13\ (1 - e^{-.1638t_2}) + 24.26\ (1 - e^{-.04t_3}) + 19.28\ (1 - e^{-.076t_4}) + 12.94\ (1 - e^{-.143t_5}) \tag{5.5}$$

The solution of t_i and resulted project outcomes are listed in Table 5.5.

$\boldsymbol{Cost}$ (\$)	$\boldsymbol{Time}$ ($\boldsymbol{Days}$)	$\boldsymbol{Performance}$ $\boldsymbol{level}$ – %	$\boldsymbol{CSF_1} - \boldsymbol{TM}$	$\boldsymbol{CSF_2} - \boldsymbol{Users}$	$\boldsymbol{CSF_3} - \boldsymbol{PM}$	$\boldsymbol{CSF_4} - \boldsymbol{IT}$	$\boldsymbol{CSF_5} - \boldsymbol{VS}$
$106,000	110	73.40	26	15	33	23	9

Table 5.5 Solutions for Goal 1

Without additional external consulting and users training and development, the progressing coefficient k_i, is kept same and the maximum value of 73.40 percent is achieved with the project duration of 110 days, and more time is allocated to TM and PM. It is due to the fact that these CSFs have higher performance thresholds, hence they are prioritised and given more focus. Due to lower performance threshold, less time is spent on CSF VS and also because it is costly to acquire full VS and services. However, it is observed that SMEs are mostly dependent on VS due to their lack of IT experience. In a situation when VS is acquired, a strategy can be adopted where CSF VS and PM work to benefit from the VS services. This may include establishing learning, testing and hands-on training program for users to improve their skills. Further, decision makers can play an important role in creating teams for specific tasks. These teams should consist of effective managers and employees from representing various business functions to ensure that implementation team has a basic understanding of the needs of all sections of SME (Nah et al., 2001).

Another strategy to improve performance is to focus on the CSFs with higher progression speed, without incurring additional cost and time. Decision makers can select such CSFs and focus on them according to the available resources. Since the majority of the SMEs cannot afford extra staff for implementation or investment in advanced IT systems, it can be compensated by TM and PM collaboration and increased commitment towards project (Wang et al., 2005) and providing more hands-on training to users.

During the course of implementation, if decision makers come across a situation when a certain level of performance must be reached in order to classify implementation as successful, while remaining inside the budget and time, goal 2 will be set up as follows:

Goal 2:

With the budget limit of $120,000 and project duration of 110 days, determine the time which should be spend on each CSF so that performance level is at least 70% at the end of the project.

Goal 2 is formulated as previous goal, with the same constraints but new objectives:

$$PF(t_1, t_2, t_3, t_4, t_5) \geq 70\% \tag{5.6}$$

$$\sum_{i=1}^{M} t_i \leq 110 \tag{5.7}$$

$$\sum_{i=1}^{M} Cost_i(t_i) \leq 120,000 \tag{5.8}$$

$$t_i \geq 0 \tag{5.9}$$

As shown in Table 5.6, a targeted higher performance level can be achieved by strategically focussing and implementing CSFs which yield higher performance. Such as, according model prediction, allocating resources specifically towards CSF TM, PM and VS can produce a significant contribution towards overall performance. These three factors, especially PM and TM have higher performance threshold p_i, making more contribution towards

$Cost$ (\$)	$Time$ ($Days$)	$Performance$ $level$	CSF_1 $-TM$	CSF_2 $-Users$	CSF_3 $-PM$	CSF_4 $-IT$	CSF_5 $-VS$
\$98,000	100	70%	26	15	22	23	14

Table 5.6 Solution of Goal-seeking analysis

implementation. Hence an experienced project management team with a TM support can be decisive in successful implementation since any change requires a strategic vision to ensure long term success (Aladwani, 1999) and in a survey by Zairi and Sinclair (1995) leadership was ranked the number one facilitator of large transformation effort (such as changes brought in by ERP). Commitment by management should be incorporated into the business culture and users through the use of training program, team building efforts and recognition of each success. In addition, it is essential to change the attitude of the potentials users through communication. One effective communication strategy involves informing potential users about the benefits of ERP and how it can assist in their daily job functions and eventually improving job performance. Further, the higher level of performance can be achieved by availability full time balanced team project team who is cross functional and comprises of people with business and technical knowledge. Project team's prior experience in large IT project can be added advantage, while extended VS can bring in much needed expertise during implementing ERP. Doom et al (2009) found that vendors or consultants' expertise in cross functional business processes, system configuration and specific module customisation can be a game changer. Project manager can work with vendors in laying out the best strategy starting from the initial planning stage through the go-live phase.

To overcome the lack of internal expertise, in many instances SME's decision makers can allocate fixed budget for support and services of vendors. Since vendor support contributes towards ERP implementation process, increase users' learning by knowledge transfer and training, the allocating resources specifically for VS can beneficial. Using the parameters developed in Goal 1, Goal 3 is defined where decision makers allocate fixed number of days for VS:

Goal 3:

With a budget of $120,000 and project duration on 110 days, find out the maximum attainable performance when SME must invest at least 30 days on Vendors Support due to limited knowledge in the implementation area;

Goal 3 is formulated as follows:

$$\text{Max } PF(t_1, t_2, t_3, t_4, t_5)$$

s.t.

$$\sum_{i=1}^{M} t_i \leq 110 \quad (5.10)$$

$$\sum_{i=1}^{M} Cost_i(t_i) \leq 120{,}000 \quad (5.11)$$

$$t_i \geq 0 \quad (5.12)$$

$$t_5 \geq 30 \quad (5.13)$$

In Goal 3, a scenario is presented when extra focus is given due to the fact that SMEs lack advanced IT system implementation experience such as new ERP system, as a result they rely on VS which provide much needed technical and transformational skills to SMEs.

$\boldsymbol{Cost}$ (\$)	$\boldsymbol{Time}$ ($\boldsymbol{Days}$)	$\boldsymbol{Performance\ level}$	$\boldsymbol{CSF_1 - TM}$	$\boldsymbol{CSF_2 - Users}$	$\boldsymbol{CSF_3 - PM}$	$\boldsymbol{CSF_4 - IT}$	$\boldsymbol{CSF_5 - VS}$
$120,000	110	70 %	22	13	27	18	30

Table 5.7 Solution of Goal-seeking analysis

Table 5.7 shows 1/3 time is spent on acquiring and maintaining VS. This strategy can be effective when SME lacks IT infrastructure and experienced staff, however, too much focus and allocation of extra resources on one CSF can impede the performance of other CSFs.

Such as it is observed that, as shown in Table 5.7, the overall performance level achieved in Goal 3 is decreased approximately 5 percent (70 – 73.4 / 73.4 = 0.46) in comparison with Goal 1 when 1/3 of the project duration is spent on VS, while the constraint of project duration and implementation budget remains the same.

As results in Table 5.7 suggest, a special focus on VS, should accompany with PM's strategy to utilise benefits of the available VS. Such strategy can encompass knowledge transfer from vendors to users, ensuring availability of vendors and hands-on training under vendor's guidance. This is also corroborated by Thong et al. (1994) and Willcocks & Sykes (2000), who suggested that the project success can be positively associated with fit and compatibility with the IT vendors employed. Therefore selection of a suitable vendor with previous implementation experience is extremely important.

If the decision makers decides to provide more user training with experienced project management to achieve 75 percent performance level at the end of the project duration, a new goal is set up to observe results:

Goal 4:

With budget of $120,000 and 110 days determine the time spent of CSFs, progressing coefficient of Users and PM, so that performance level of 75% is obtained.

Goal 4 is formulated with following equation while keeping in perspective the decision variable and constraints;

$$PF(t_1, t_2, t_3, t_4, t_5) \geq 75\% \quad (5.14)$$

$$\sum_{i=1}^{M} t_i \leq 110 \quad (5.15)$$

$$\sum_{i=1}^{M} Cost_i(t_i) \leq 120,00 \quad (5.16)$$

$$t_i \geq 0 \quad (5.17)$$

$$k_2 \geq 0.163 \quad (5.18)$$

$$k_3 \geq 0.04 \tag{5.19}$$

Results in Table 5.8 indicate that with a limited budget, a higher performance can be achieved with increase in progressing speed of the CSFs.

$\boldsymbol{Cost}$ (\$)	$\boldsymbol{Time}$ $(\boldsymbol{Days})$	$\boldsymbol{Performance}$ $\boldsymbol{level}$
\$104,000	110	75%

$\boldsymbol{CSF_1 - TM}$	$\boldsymbol{CSF_2 - Users}$	$\boldsymbol{CSF_3 - PM}$	$\boldsymbol{CSF_4 - IT}$	$\boldsymbol{CSF_5 - VS}$	$\boldsymbol{k_1}$	$\boldsymbol{k_2}$	$\boldsymbol{k_3}$	$\boldsymbol{k_4}$	$\boldsymbol{k_5}$
27	16	32	25	12	0 .045	**0.177**	**0.048**	0.076	0.143

Table 5.8 Goal-seek analysis result

Table 5.8 presents the time (t_i) needed to spend on each CSF to attain the performance level of 75 percent. The progressing speeds of Users and PM are increased to 0.177 and 0.048 respectively. Compared with the goal 1, the increments in progressing speed are; 8.59 percent for Users and 20 percent for PM, and thought to be achievable. The higher performance threshold of PM play essential role is achieving target performance level. Therefore, with limited budget, an experienced project management team working alongside with users can make significant contribution to the implementation process. It is required that PM must have clear and defined project plan including goals, objectives, strategy, scope and schedule. Since it will allow SMEs to plan, coordinate, and monitor various activities in different phases of implementation.

Therefore when a SME aims to maximise performance level within budget limitation, increased focus should be given to CSFs that make greater contributions to the performance level, such as PM and Users. In addition, presence of project champion is critical since they not only play critical role in ERP implementation but also in handling organisational changes. In addition project champion can be a source of motivation for the project team.

During the implementation, when certain performance level is targeted with a focus on IT and VS while staying inside budget limits, the progression speed of IT and VS can be increased, a new goal is set up to observe the results:

Goal 5:

> *With budget of $120,000 and 110 days for implementation, determine the time spent on CSF, and progressing coefficient of IT and Vendors Support so that performance level is at least 75% at the end of the project.*

Goal 5 is formulated in following way presenting a new objective function and constraints of time, cost and progressing coefficient:

$$PF(t_1, t_2, t_3, t_4, t_5) \geq 75\% \quad (5.20)$$

$$\sum_{i=1}^{M} t_i \leq 110 \quad (5.21)$$

$$\sum_{i=1}^{M} Cost_i(t_i) \leq 120,000 \quad (5.22)$$

$$t_i \geq 0 \quad (5.23)$$

$$k_4 \geq 0.076 \quad (5.24)$$

$$k_5 \geq 0.143 \quad (5.25)$$

Table 5.9 presents the time required to spend on each CSF when minimum performance level of 75 percent is desired. In this scenario, CSF IT and VS are given more focus and the resulting increment in the progressing speeds of IT and VS is calculated as: (0.09-0.076)/0.076 = 18 percent for IT and (0.17-0.143)/0.143 = 19 percent for VS and are thought to be achievable. This increased progressing speed enables achieving higher performance level with less time and money spent on CSFs. It is due to the fact that performance threshold of the VS is smaller than other CSFs, and when less time is being spent of these CSFs, the increment in progressing speed of VS is smaller increment in contribution to the performance level of the ERP implementation.

$Cost$ (\$)	$Time$ $(Days)$	$Performance$ $level$
\$105,000	110	75%

CSF_1 $-TM$	CSF_2 $Users$	CSF_3 $-PM$	CSF_4 $-IT$	CSF_5 $-VS$	k_1	k_2	k_3	k_4	k_5
27	17	32	25	12	0.045	0.16[illegible]	0.04	**0.095**	**0.170**

Table 5.9 Goal seek analysis result

The higher progressing speed enables the implementation team to achieve the predetermined target quicker. To achieve higher performance level, TM can play important role by providing resources for IT and selecting the experienced VS, however, these will cost more Factors such as adequate technological planning, users involvement, training, maintaining implementation schedule and availability of adequate IT skills should be given special focus. This in turn gives SMEs a strong IT foundation and infrastructure to compete and progress. This is in accordance with Infinedo's (2006) argument that IT in SMEs has morphed from its traditional role of supporting back-office operations to offering competitive advantage. Results in Table 5.10 show less time is allocated to IT since IT progresses more quickly towards the predetermined performance level but is still expensive to address.

During implementation if TM decides to provide extra resources for user training and TM proactively involve in the implementation process to achieve 75 percent performance level at the end of project, goal 6 would be setup.

Goal 6:

> *With a very limited budget of \$120,000 and 110 days allocated to implementation, SMEs aims to achieve 75% performance level. Determine the time spent on each CSF with special focus on TM and Users so that performance level of 75% is achieved.*

In Goal 6, new objectives function and constraints are formulated in following way:

$$PF(t_1, t_2, t_3, t_4, t_5) \geq 75\% \quad (5.26)$$

$$\sum_{i=1}^{M} t_i \leq 110 \quad (5.27)$$

$$\sum_{i=1}^{M} Cost_i(t_i) \leq 120{,}000 \quad (5.28)$$

$$t_i \geq 0 \quad (5.29)$$

$$k_1 \geq 0.045 \quad (5.30)$$

$$k_2 \geq 0.163 \quad (5.31)$$

As shown in Table 5.10, the constraints of implementation cost and project duration is identical to Goal 1, but the progressing speeds of TM and Users are increased to 0.055 and 0.18 respectively. Compared with the progressing values in Goal 1, the increments of progressing speeds are 22 percent for TM and 12 percent for Users, and are thought to be achievable.

$Cost$ (\$)	$Time$ ($Days$)	$Performance$ $level$
\$104,000	110	75%

$CSF_1 - TM$	$CSF_2 - Users$	$CSF_3 - PM$	$CSF_4 - IT$	$CSF_5 - VS$	k_1	k_2	k_3	k_4	k_5
27	16	32	25	12	**0.055**	**0.183**	0.40	0.076	0.143

Table 5.10 Goal seek analysis result

As shown in Table 5.10, higher performance level is obtained in comparison with Goal 1 with comparatively less cost when extra focus is given on TM and Users. Presence of TM, during implementation, ensures that essential resources will be available and strategic guidance will be provided to the implementation team. While users working under guidance of TM and benefitting from the training and learning provided will significantly contribute towards higher performance level.

Implementing any information technology related software (such as ERP) requires a close working relationship between vendors and users, therefore understanding how they complement each other can be productive. Such as with constraints of limited budget and project duration, if more focus is given to Users and VS, the observe effect on the performance of the CSF, goal 7 is set up as follows:

Goal 7:

With a budget limit of $120,000 and maximum time allowed to finish project is 110 days, determine the time spend of each CSF and the regressing coefficient of CSF Users and VS, so that the performance level is at least 75% at the end of the project.

Goal 7 is formulated with objective functions and constraints in the following way,

$$PF(t_1, t_2, t_3, t_4, t_5) \geq 75\% \quad (5.32)$$

$$\sum_{i=1}^{M} t_i \leq 110 \quad (5.33)$$

$$\sum_{i=1}^{M} Cost_i(t_i) \leq 120{,}000 \quad (5.34)$$

$$t_i \geq 0 \quad (5.35)$$

$$k_2 \geq 0.163 \quad (5.36)$$

$$k_5 \geq 0.143 \quad (5.37)$$

In this Goal-Seeking analysis, target performance level is achieved by strategically focussing on CSF with higher progression speed, thus enabling SME to achieve targeted performance level within implementation budget.

$\boldsymbol{Cost}$ (\$)	$\boldsymbol{Time}$ ($\boldsymbol{Days}$)	$\boldsymbol{Performance\ level}$

\$104,000	110	75%

$CSF_1 - TM$	$CSF_2 - Users$	$CSF_3 - PM$	$CSF_4 - IT$	$CSF_5 - VS$	k_1	k_2	k_3	k_4	k_5
27	15	32	12	14	0.045	**0.208**	0.040	0.076	**0.187**

Table 5.11 Goal seek analysis result

The progressing speed of the Users and VS are increased to 0.208 and 0.187 respectively. Compared to goal 1 the increments of progressing speed are: 27 percent for Users and 30 percent for VS, which are more difficult to achieve. Since the performance threshold of the Users and VS is smaller than the performance threshold of PM, TM and IT. Therefore time spent on Users and VS is shorter, which results in smaller increment in contribution towards performance level.

Since VS contributes more towards the implementation due to higher progression speed, a selection of suitable vendor by SME is critical. An experienced vendor can provide wide ranging support from technical assistance to users training, therefore accelerating implementation process. A proactive team of users working with vendors can produce a conducive atmosphere for progress and learning (Somers et al., 2000), which is the necessary premise for ERP implementation success.

Decision makers can implement different techniques to improve progression speed of CSFs, this can include availability of additional resources, increased TM involvement, ensuring the staff is involved in every phase and providing a learning and training environment, IT infrastructure and diversified project team. Basically, project team should have a common vision of the implementation's goal and they should also have an extensive understanding of ERP concepts and detail understanding of the specific software tool. The project team should involve people who are core of the business and have good understanding of how business functions. A good PM team can be essential for reaching implementation objectives.

5.2.2 What-If Analysis

The *goal seeking analysis* discussed in previous section is an effective decision-making tool for developing implementation strategies, resources allocation, and for observing the performance of different variables in planning and implementation phases of ERP implementation. However, within *goal seeking analysis,* the constraints in each goal are constant and perform under certain pre-defined limits. Although the effectiveness of *goal seeking analysis* is undeniable, constraints in certain scenarios limit their usefulness as in 'real life', implementation can be very dynamic in nature. Along with ERP implementation, factors such as time, cost, manpower and availability of other resources can vary, for example, more staff can participate in implementation; extra funds are obtained; investment is reduced due to economic downturn; vendors or consultants perform under expectation, and the resignation of project manager, etc. The unforeseen circumstances can hamper the project progress, therefore, it is essential that decision-makers plan in advance and develop contingency plans accordingly (Nah et al., 2001). *What-if analysis* analyse the effects of the possible changes on the theoretical solutions. Therefore, to further enhance the understanding of ERP implementation in SMEs, *What-If analysis* is conducted in eight different scenarios generated to explore the effects of changes on resource allocations and ERP implementation performances.

Using goal 1 as Scenario 0, What-If analysis is conducted on eight new scenarios.

Scenario 1:

With budget limit increased by 5% to $126,000., and no limits on project duration, determine the time to be spent on each CSF to maximise the performance level achieved at the end of the project.

Scenario 2:

With the budget increase of 20% to $144,000, and other constraints remain same as in Scenario 1.

Scenario 3*:*

With the budget increase of 100% to $240,000, other constraints remain the same as in Scenario 1.

Scenario 4:

With the budget increase of 200% to $360,000, other constraints remain the same with no constraint of time.

Scenario 5:

With budget increase of 300% to $480,000, other constraints remain the same.

Scenario 6:

With $120,000 in budget and maximum implementation time allowed of 160 days while no VS is available (note more focus on IT in the presence of VS).

Scenario 7:

With a budget of $120,000 and project duration of only 160 days, due to limited IT setup SME must spend minimum of 25 days on IT and VS to achieve satisfactory success level.

Scenario 8:

With additional 10% on the PM budget, with project duration less than or equal to 160 days, and total budget of $120,000, determine the time spent on each CSF so that the performance level is maximised.

The objective functions in these scenarios are identical to formula (5.4), but with different constraints for each scenarios. The results for these scenarios are generated using Excel's solver and presented in Table 5.12. The ΔC is the change in C – the implementation cost factor, calculated as the percentage of difference between C given for each scenario and the base scenario 0. Project duration is the actual amount of time spend on the project and ΔPD represent the change in project duration while ΔPL is the change in the performance level.

$\boldsymbol{Scenario}$	$\boldsymbol{Cost}$ $(\boldsymbol{in\ 1000s})$	$\Delta\boldsymbol{C}$ (%)	$\boldsymbol{Project\ duration}(\boldsymbol{Days})$	$\Delta\boldsymbol{PD}$ (%)	$\boldsymbol{Performance\ Level}$ (%)	$\Delta\boldsymbol{PL}$ (%)	$\boldsymbol{CSF_{TM} - t_1}$	$\boldsymbol{CSF_{User} - t_2}$	$\boldsymbol{CSF_{PM} - t_3}$	$\boldsymbol{CSF_{IT} - t_4}$	$\boldsymbol{CSF_{VS} - t_5}$
0	120	0	110	0	73.40	0	26	14	33	23	14
1	126	5	143	30	79	7.6	42	19	48	22	12
2	144	20	162	47	82	11.7	48	20	55	26	13
3	240	100	268	143	90	22.6	80	29	91	45	24
4	360	200	400	263	92.2	25.61	119	40	135	68	36
5	480	300	531	382	92.5	26	159	51	180	92	48
6	120	0	113	3	65.5	-10.76	36	17	41	19	0
7	120	0	111	1	71.66	-2.37	22	13	26	25	25
8	132	10	145	32	80.6	10	44	19	50	23	12

Table 5.12 Results of What-if analysis

In scenarios 1-5, increment in the budget results in longer project duration and improved performance level. Beheshti (2006) found that it is not uncommon that many organisations allocate significant resources during implementation phase of the project. Extra budget allows longer project duration and more time spent on users training, upgrading infrastructure and more staff allocated towards implementation. Umble et al. (2003) propose that 10-15 percent of the total budget be reserved for users' training in order to obtain an overall implementation success rate of 80 percent. Training also offers a good opportunity to users to adapt to the changes that are presented by the ERP systems, and can help in building a positive attitude towards the new system (Yu, 2006; Maguire and Redman, 2007). This in turn can lead to improved performance levels and increased chances of successful implementation. However, it is important to know that performance level increases up to certain level and then remains unchanged. This is attributed to the features of the Cost vs. Time linear curve and Progress vs. Time exponential curve constructed for each CSFs and is also reflected in realistic ERP implementation.

The results in the scenario 1-5 can provide sources of guidance to the implementation team and top management, since, according to literature review, ERP implementation fails when top management delegates a project's progress monitoring and decision making to lower management (Motwani et al., 2002). Therefore, top management's supervision and backing is required to maintain a constant performance level. Furthermore, ERP implementations usually cause radical changes in organisational work habits and procedures which need great organisational alignment. This is only achievable when top managers are fully involved in every step of implementation.

Comparing scenarios 1-5, as the implementation budget is increased, more time is allocated to the CSFs in the order of: PM (highest), TM, IT, Users, and VS (lowest). The CSF are prioritised and ranked by the DSS_ERP taking in account their performance threshold, progressing coefficient and cost of CSFs. Therefore, if the project manager's objective is to achieve higher or certain specific level of performance, the CSF with higher performance thresholds, lower progressing speeds and lower costs are given priority. These CSFs should be given more focus by spending more time on them therefore enabling them to make their anticipated contribution to toward ERP implementation.

Scenarios 3-5 present more rapid increments in the implementation budget. Initially, more resources (budget) lead to increment, however, it is observed that the increment in the performance level out as the implementation progresses with time. This can be observed in scenarios 3-5 in Table 5.12 (above), where the increment in performance level is less than 3 percent (92.5-90/90 = 2.77%), indicating that implementation progress has reached the effective maximum performance threshold (i.e. an optimal performance point), and there will be no further increase in the performance beyond this point.

Scenarios 6-8 analyse the impact of varying focus on CSFs. In scenario 6, there is no vendor's support available to the SME and this results in 10.76 percent drop in the performance, i.e., $\Delta \boldsymbol{PL}$ = -10.76 percent. This further strengthens the necessity of having VS in ERP implementation as SMEs are lack of knowledge on complex IT systems and specifically about ERP systems. To ensure set up of the infrastructure successfully, a fixed number days (25 days) are allocated for CSF-IT in scenario 7. Ross et al. (2006) and Ernst and Young (2006) consider standardisation in IT infrastructure to be an important factor for all IT implementation. However, allocating resources to IT incurs cost, therefore, less resources are available to other CSFs, which can lead to drop in overall performance, and a 2.37 percent drop in performance (i.e., $\Delta \boldsymbol{PL}$ =-2.37%), is observed in this scenario.

Scenario 8 presents a situation when additional 10% of resources become available to the ERP implementation project. The additional resources are directed towards the project management which in turn contributes towards increasing performance level. This also suggests that effective project management with formal implementation plan and with a realistic timeframe can pave way towards successful implementation. This is also corroborated by Umble et al., (2003), Ernst and Young (2006), Sumner (2005) and Nah et al., (2005).

5.3 Comparison of results between DSS_ERP and SMEs' results

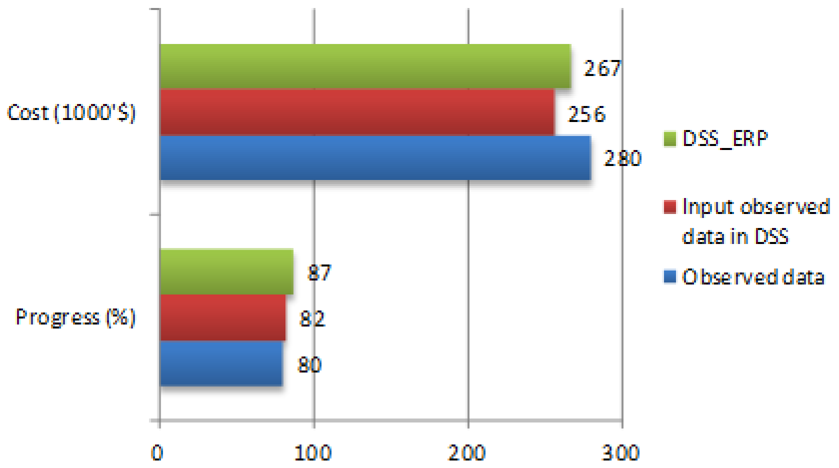
In previous section, the performance of DSS_ERP is examined by applying dummy data in variety of scenarios and then performing *Goal Seeking analysis* and *What-if analysis* to observe the performance of the model and its predictability. In this section data collected from survey are input to the DSS_ERP and results are compared with observed data. For this purpose four SMEs are selected from the survey sample.

SME 1[18]

The primary data collected during survey is input to DSS_ERP and the optimal solutions of t_i are obtained with the object to maximise the performance level. There are two sets of results generated, as shown in Table 5.13.

	$CSF_1 - TM$	$CSF_2 - Users$	$CSF_3 - PM$	$CSF_4 - IT$	$CSF_5 - VS$	*Project Duration*	*Project Cost*	*Performance Level*
Observed data	14	68	103	59	27	270	$280,000	80%
Input observed data to DSS_ERP	14	68	103	59	27	270	$256,098	82%
DSS_ERP results	30	33	109	62	35	270	$267,000	87%

Table 5.13 Comparison of results for SME1



Progress (%) - Cost (1000 $)

Figure 5.2 Comparison of output variables

Comparison between the observed data and DSS_ERP results suggest that the improved performance level can be achieved with less cost and same project duration, as shown in

[18] The four SMEs selected are further discussed in chapter 6.

Figure 5.2. DSS_ERP suggest, as shown in Figure 5.3, more focus on CSFs TM, PM and VS, due to their higher performance threshold. This assists in achieving higher performance level while remaining under budget.

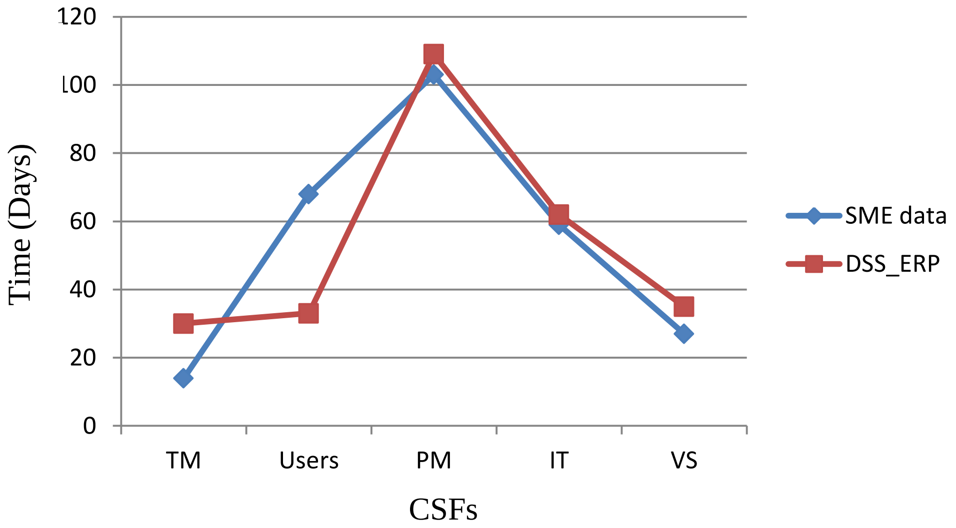


Figure 5.3 Comparison of results for SME1

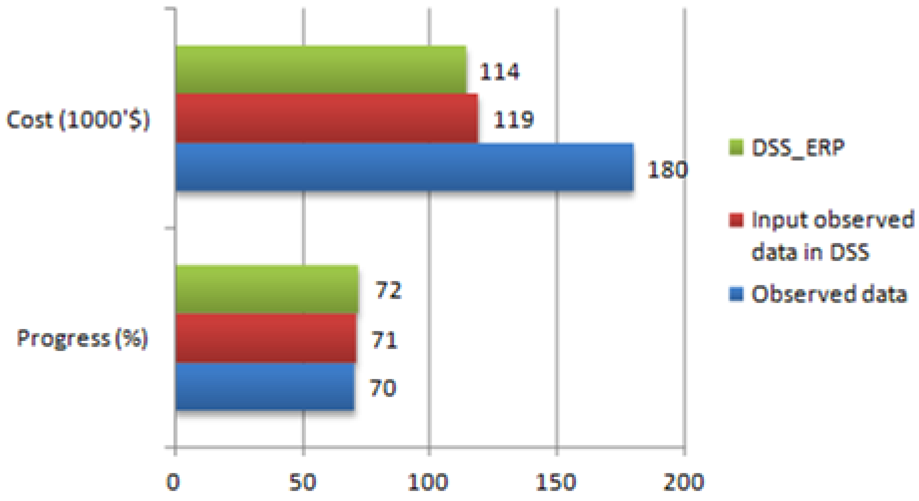
SME 2

SME 2 implemented ERP project with a budget of $180, 000 and project duration of 114 days, and achieved the performance level of 70 percent. Table 5.14 presents the observed data, results of application of observed data in DSS and results obtained from DSS_ERP.

	$CSF_1 - TM$	$CSF_2 - Users$	$CSF_3 - PM$	$CSF_4 - IT$	$CSF_5 - VS$	*Project Duration*	*Project Cost*	*Performance Level*
Observed data	10	21	34	29	20	114	$180,000	70%
Input observed data to DSS_ERP	10	21	34	29	20	114	$119,000	71%
DSS_ERP results	12	17	42	27	16	114	$114,000	72%

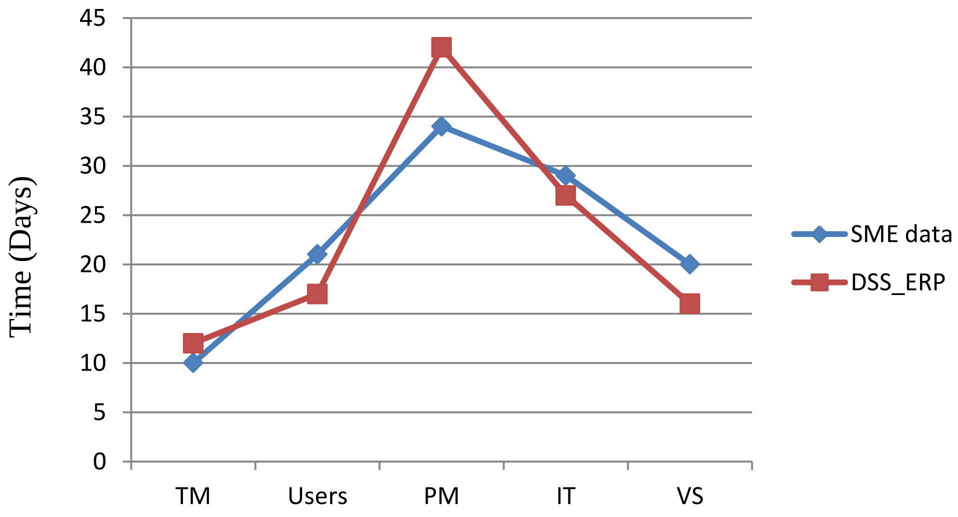
Table 5.14 Comparison of results for SME 2

When same time is allocated in DSS_ERP, the results suggest 71 percent progress level but at significant less implementation cost, as shown in Figure 5.4. Under the same constraints of time and budget, DSS_ERP forecast that by giving extra focus to PM, due to its highest performance threshold among all CSFs, better results can be obtained. Whereas the project duration remains the same and implementation cost is inside the budget. Figure 5.5 shows the comparisons of the numbers of days spend on CSFs by SME2 and DSS_ERP.



Progress (%) – Cost (1000 $)

Figure 5.4 Comparison of output variables



CSFs

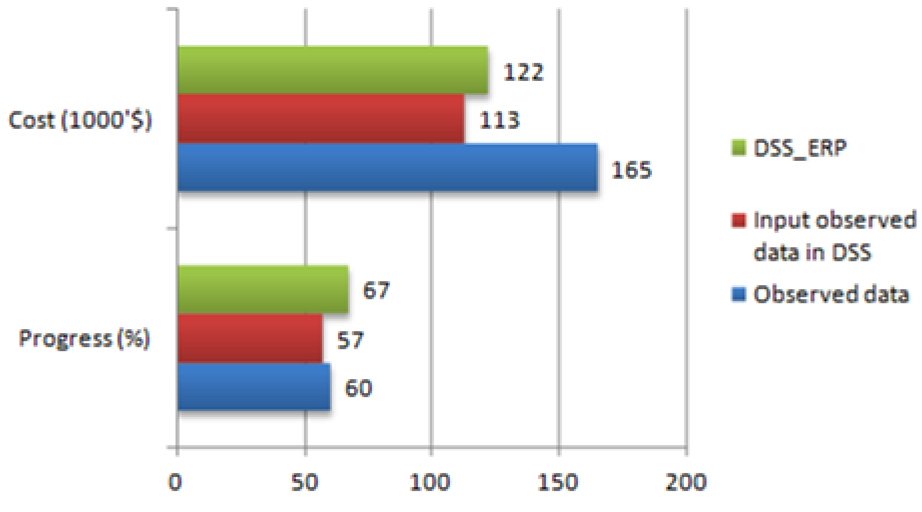
Figure 5.5 Comparison of results for SME 2

SME 3

Table 5.15 shows the comparative results from primary data for SME 3 and results from DSS_ERP. The results generated by DSS_ERP forecast increased performance level and improved allocation of resources which results in decreased the implementation cost, as show in Figure 5.6.

	$CSF_1 - TM$	$CSF_2 - Users$	$CSF_3 - PM$	$CSF_4 - IT$	$CSF_5 - VS$	*Project Duration*	*Project Cost*	*Performance Level*
Observed data	6	34	17	51	3	115	$165,000	60%
Input observed data to DSS_ERP	6	34	17	51	3	115	113,230	57%
DSS_ERP results	10	25	23	45	11	115	$122,000	67%

Table 5.15 Comparison of results for SME 3



Progress (%) – Cost (1000 $)

Figure 5.6 Comparison of output variables

According to DSS_ERP forecast, more focus on TM and PM, due to their higher performance threshold, and on VS, due to higher progression coefficient can be effectively contribute towards the performance (as shown in Figure 5.7).

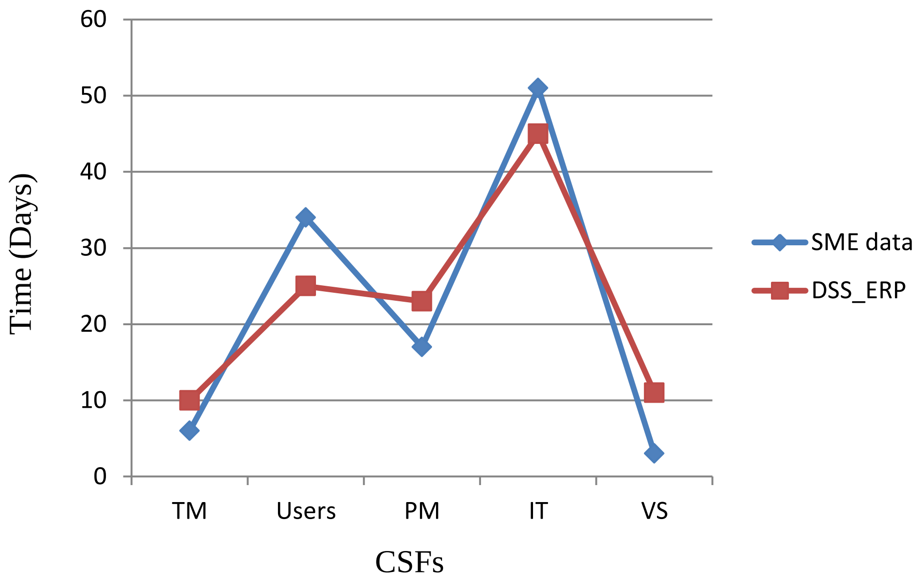


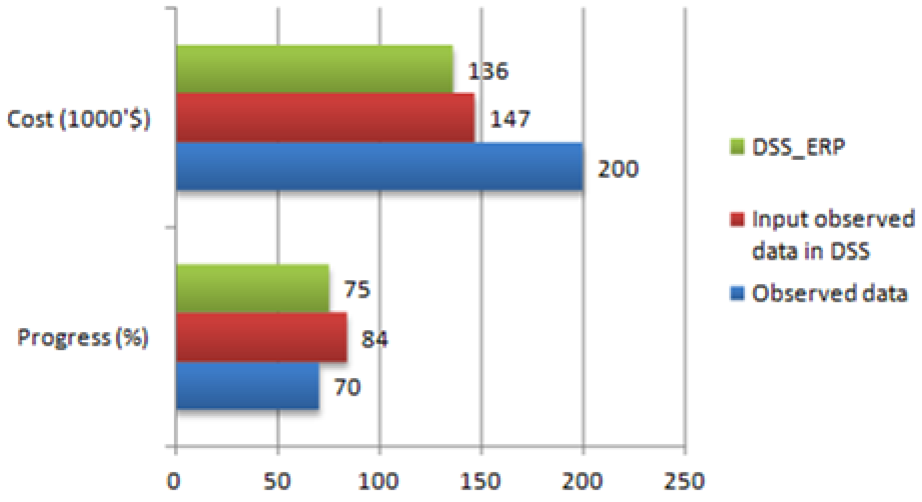
Figure 5.7 Comparison of results for SME 3

SME 4

Table 5.16 presents the results for the survey and DSS_ERP. SME's observed data shows more focus is given to IT and hence major portion of resources are allocated to IT. In comparison, DSS_ERP places more focus on PM and TM due to their higher performance threshold. In addition, DSS_ERP forecast that, when time spends on CSFs is same as in observed data, significantly higher performance at lower implantation cost can be achieved.

	$CSF_1 - TM$	$CSF_2 - Users$	$CSF_3 - PM$	$CSF_4 - IT$	$CSF_5 - VS$	*Project Duration*	*Project Cost*	*Performance Level*
Observed data	7	26	26	53	20	132	$200,000	70%
Input observed data to DSS_ERP	7	26	26	53	20	132	$147,000	84%
DSS_ERP results	15	17	43	40	16	132	$136,000	75%

Table 5.16 Comparison of results for SME 4



Progress (%) – Cost (1000 $)

Figure 5.8 Comparison of output variables

As shown in Figure 5.8, the less time spend on IT in DSS_ERP which is compensated by allocating more resources towards TM and PM. The reduced allocated days for IT can be compensated by developing strategy by TM and PM toward training and learning, and knowledge transfer from VS. This enables to achieve higher performance level while staying within allocated budget.

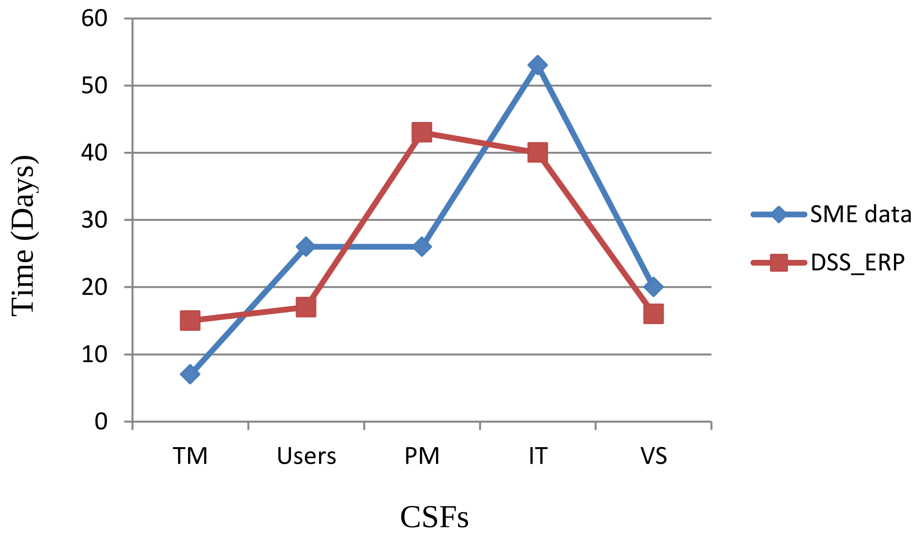


Figure 5.9 Comparison of results for SME 4

5.4 Summary

In this chapter, the application of DSS_ERP is demonstrated with the hypothetical data and then tested with the observed data provided collected from the survey. The effectiveness and efficiency of DSS_ERP is evaluated by the observed data, showing that DSS_ERP is applicable to real-life ERP implementation and facilitate SMEs in allocating resources more effectively.

It is evident that the DSS_ERP simulation model provides quite a number of advantages as it incorporates a range of the considerations described in previous chapters. In addition, its flexibility and ease of use in dealing with real life forecasting problems is another property that was of importance. The DSS_ERP is designed to handle various types of information, including time period, predetermined performance level and project cost. Based on the forecasts obtained, a practical implementation strategy can be developed by an SME interested in developing an ERP system, which will include the optimum time inputs for the key CSF, and will permit the prioritisation of these CSFs according to their contribution towards the implementation and resources allocation. Further to evaluate the validity and effectiveness of the DSS_ERP, a key informant interview process is conducted with four participating SMEs which will be discussed in next chapter.

CHAPTER 6

Key Informants Interviews

6.1 Introduction

This chapter presents the data collected through semi-structured interviews with key informants in four SMEs (Studies 1-4) conducted in North America and UK. The Key Informant interview process was carried out with interviewees by demonstrating functionalities of DSS_ERP and collecting their views on the CSF selection and variable definition in the model (see section 3.7). The SMEs who participated in the primary survey were invited to participate in key interview process. After reviewing the responses, four participants were selected for the interview process. The main criteria for selection of participants includes; ensuring that the participants represents UK and North America, are from diverse industries and have diverse work experience and roles. During the interview process, participants evaluate the performance of the DSS_ERP by sharing their opinions on its validity, suitability, effectiveness and efficiency. Before the interviews are conducted, SMEs' background information (such as how long SME has been in the field, product or services offered, etc.) is collected. The chapter starts with the background introductions to the SMEs then continues with the interviews with the key informants.

6.2 Organisations' background

The first SME, denoted CS1, is an IT company that designs and manufactures computer-networking equipment, such as routers and switches, for corporate, educational, and governmental clients. The company was setup in 2002 and is based in San Jose, USA. The company literature describes CS1 as "a global technology leader that data centre, service provider and enterprise customers rely on when the network is their business. The company's high-performance solutions are designed to deliver new economics by virtualizing and automating Ethernet networks".

The second SME, CS2, is based in UK and provides software solutions and services to the leisure industry. The company supplies membership management and booking systems to health and fitness groups, leisure centres, trusts, universities, and various private and single site clubs. For multi-site operators, it offers central database solutions that facilitate central and cross-site online bookings, membership management, central administration, CRM, marketing, and reporting. CS2 also provides a range of systems and software based solutions, such as e-registration, cashless catering payments, and biometric recognition for schools.

The third SME, CS3, is located in the UK, and its main business is providing software application management to educational institutions. In addition, CS3 carries out research, consultancy, and advisory work related to organisation's IT needs for schools, colleges, careers services, professional bodies, and employers. CS3 also offers continuing professional development that can be customised to meet the needs of individual customers.

The last SME, CS4, is located in Canada and provides a range of financial services to its clients such as financial planning, insurance services and portfolio management.

6.3 Key Informants

The key informants that represent the four SMEs, which participated in the survey, played major role during implementation in different capacities such as ERP project manager, MIS manager, ERP implementation team leader etc. The survey was conducted to collect primary data in January –April 2011. A brief introduction of the key informants is provided in this section and in Table 6.1

Key Informant 1 – "MIS-Manager"

The Key Informant 1, works in CS1 as Management Information System (MIS) manager, and has rich experiences in programming, networking, and information services, accumulated through 13 years working in the IT field. As the MIS manager, Key Informant 1 is responsible for implementing IT infrastructure in CS1. He also manages new technology introductions and plans how it meets CS1's business needs. MIS-Manager liaison with business manager and IT team in CS1.

Key Informant 2 – "SQA-Analyst"

The Key Informant 2, works a SQA[19]-Analyst in the CS2, with 16 years of experience in software development and IT management. SQA-Analyst's main role includes software quality assurance, process formulation, IT strategy formulation and IT planning and budgeting. SQA-Analyst has participated different stages of IT projects, for example, B2B transactional services, conceptualisation prior to implementation and post-implementation SQA-Analyst is the implementation team leader for the ERP implementation in CS2.

Key Informant 3 – "Net-Developer"

The Key Informant 3 works as a Net Developer in CS3. He has accumulated good experiences by working 11 years in IT field taking different roles and participating in a variety of projects. His main area focuses on education sector. He has a leading role in CS3's ERP implementation, starting from initial evaluation of business needs, to ERP software selection, then to work with ERP vendors for ERP implementation.

Key Informant 4 - "BI-Administrator"

The Key Informant 4 works as a BI-Administrator in CS4. Before joining CS4, he has worked 18 years on different software applications including Clarity, Business Objects XI and SAP Business Objects FMS applications. BI-Administrator is the key participant in the acquisition and implementation of CS4's new ERP system. During the implementation, he is the team leader responsible for configuring the software, and supporting business processes and resource allocation.

[19] Software quality analyst

	Case Company 1	Case Company 2	Case Company 3	Case Company 4
Participant's Job Title	MIS-Manager	SQA-Analyst	Net-Developer	BI-Administrator
Industry	IT	Leisure Industry	Education	Financial
Location	USA	UK	UK	Canada
No. of employees	118	220	240	150
Total sales/Turnover	Confidential	-	-	-
No. of internal resources+ external consultants	2+5	8+4	10+6	10+5
Implementation result	Successful	Successful	Successful	Successful
Implementation completed on time?	No	No	Yes	Yes
Completed within budget?	No	No	Yes	Yes
Project duration – Days	270	114	132	115
Cost of implementation	$280,000	$180,000	$200000	$165000

Table 6.1 Key Organisational Features of the Participating Organisations

6.4 Key Themes

This section discusses the key themes generated from the key informant interview process. Empirical data collected from interviews provides the basis for generating the key themes. These themes are presented in narrative extract form in section 6.4.1- 6.4.5 as they appeared in the interviews.

6.4.1 Scope of a generic prediction model for ERP implementation

As is discussed in previous sections, ERP implementation is a challenging process due to complexities involved during implementation. SMEs tend to be either reluctant to implement ERP systems or overly rely on external support to avoid failure. The external support is sought from ERP vendors, ERP forums, and online support forums. According to the Key Informant 1 who is the MIS-Manager, '*the prediction model can be really useful*' during the implementing process of a ERP project. Key Informant 1 further elaborated on how these types of model can be effectively used:

> *'In fact if I had such a model, I would have been more successful in getting my project completed in time. In short, with such a model, I can convince my management in a very short time about the use of resources, and results of implementation. At the same time, if I had the model and I can know in advance that in this type of implementation, how much time should be allocated and what will be the predicted results, then we could be confident of our efforts'.*

While Key Informant 3, the Net-Developer, agreed with the practical application of the model, but suggested that such a model's potential is limited when it is applied in the IT industry:

> *'...they are quite useful especially in the IT field. They can be helpful in finding out how [a] system works and [can be] implemented. They are quite useful and can be a good tool to convince the top management about the prospect of [the] project'.*

Key Informant 2, the SQA-Analyst, proposed that there are certain basic characteristics that a prediction model must possess in order to be successful,

> *'Any simulation model has to be expert at particular project or industry. So, if the simulation model embodies some qualities of that particular industry then they can be useful. However making such kind of simulation model is [a] time-consuming process, since it has to grow with time and it should be based on some artificial intelligence, kind of principles. So, I think simulation model must be good and can be useful, but I have little idea as how powerful they can*

[be] when actually we are dealing with implementation in different industries. For examples, like simulation model in engineering, they are widely used, [and] therefore their role cannot be denied'.

Key Informant 4, the BI-Administrator, expressed his views on the scope of a prediction model and the role it could play:

'Whenever there is an IT related project to improve the functionality of the company, if we are using a working simulation model then achieving implementation success is always easier. Such as, in our case, we had [a] limited number of people in our department and we did not follow any particular implementation model but if we had a simulation model, our implementation might have been quicker, cost effective [and] with better user success factors, so it all depends but definitely if we had a model things would be better'.

Further Key Informants agreed that a prediction model could be valuable for ERP implementation. Key Informant 1, the MIS-Manager, while recognising the operational value of prediction models, suggested that:

'Definitely, I think the model can be very useful and if you give me this model today and I have a project coming up tomorrow, I will be glad to use it, rather sell the project based on the outcome prediction from the model and convince my upper management. So, yes, I think they can be useful for SMEs'.

Key Informant 1, the MIS Manager further explained as how the prediction model can effective:

'Just to give you an idea that in SMEs upper management usually do not have implemented ERP projects and at the same time project managers have many other duties to perform. For bigger organisations ERPs are [a] fact of life regardless of [whether] they like it or not. For SMEs, it is a choice, and to implement ERP, you have to convince your manager and the users. When it comes to implementation, you need to make sure that what you are doing is actually inside the budget. You could be spending millions of dollars in small

projects but in case of SMEs, you could be doing this in couple of hundred-thousand dollars. So, yes, the model can be useful for SMEs'.

However, Key Informant 2, the SQA-Analyst argued that a prediction model can only bring operational value if it is industry specific and respects the nature of the industry where it is:

> *'if it is relevant to my industry and if embodies the industry requirement and it guides me in simulation process and step to take, than I am sure that they can be [of] good use, and if they don't, then I am afraid that it will not [be] of much help to me'.*

Since a decision support model simulates or copies the behaviour of the system under study, Key Informant 3, the Net-Developer suggests that 'th*ey can give you an idea as how the system will perform in the real life. So I think they have a quite useful value'.*

Key Informant 4, the BI-Analyst considers a prediction model a value adding model that can enhance implementation experience:

> *'Definitely, they have practical value, before the implementation goes live. If we have a model then we can implement in due time. So the value is there, but only up to the go-live date of the project. After that its end users, IT, functional consultants, they will take it from there but up to that point, yes it is added value'.*

Key informants agree with the practical value of a prediction model during implementation. It can guide the implementation team during implementation, however according to a participant, they should be industry specific.

6.4.2 CSFs for ERP implementation

The DSS_ERP is developed in Chapter 4 considers five CSFs, i.e., Top Management, Users, IT infrastructure, Project Management and Vendor Support. These five CSFs are evaluated to be the most important ones for successful implementation of ERP project. The four Key Informants were consulted upon their views on the roles of these CSFs and focus given to them during the implementation process. The Key Informants all acknowledged the importance of selected CSFs, i.e. '*you have included the most important CSFs that you need* *in an implementation'* (BI-Analyst). The following sub-sections further discuss the Key Informant's responses.

CSF 1- Top Management Support (TM)

Key Informants overwhelmingly agreed that Top Management plays the most important role in the ERP implementation. Top management support can be influential in initial planning and groundwork phase, mobilising resources and up to the system go-live phase. According to the Key Informant:

> *'Top management support is important - rather I will say it is the most important factor, because these are the guys who sign the cheques so in essence you first have to turn to them to get approval for the project and if they approve the budget then you can start the project'. (MIS-Manager)*

Key Informant 2, the SQA-Analyst further explained as why the top management support can be critical to project success:

> *'I would rate top management support extremely critical because if top management is not with your vision ... then [your] cause can be lost. In lots of cases, moral support and financial support comes from the top management. Top management gives the strategic directions, therefore when the project is not on right path, only top management can guide you. So [the] project has to aligned with the strategic direction of the company and if the top management support is not available than your project is not going anywhere even if you spend time and resources etc., (but if the top management support is not available than that good is gone). The project can go trash bin even after completion since it is not aligned with top management initiatives and strategies. I think top management is the key factor to carry out project and to implement it'.*

Key Informant 3, the Net-Developer also considers Top Management as a factor that is critical to the success of the ERP implementation:

'top management is quite critical to any project. Basically, the support of the top management can make the project successful. In my view, among these five factors, top management is the most important'.

In contrast, Key Informant 4, the BI-Administrator argues that Top Management is only required at the crucial phases during implementation:

'...it is usually not required all the time but it is needed at the most critical phase as whenever there is a roadblock in the project. Roadblock can be technical roadblock, resources unavailability, cost related etc. However, in a situation when the roadblock cannot be resolved by technical member of the team, the project manager, or the end user, it is where we need top management support and their availability at that critical moment is extremely important. So they are very important, but only, when they are needed at a certain critical time'.

As can be observed, Key Informants generally agreed that the top management is the most critical factor in implementation. Although, responses did vary as what Key Informants' expectations were from top management, and the particular role of top management in implementation. Some Key Informants perceived top management as an entity who would release funding for the project, and therefore convincing top management is essential. while in many instances top management gives a vision to act, which can be a guiding factor during the implementation. It was also suggested that if the project is not aligned with strategic vision and direction of top management, then even when a completed, a project can be a sometimes be considered failure. While in contrast, Key Informant 4, the BI-Administrator argued that top management support is not required most of the time; however, it might be needed at critical stages when there are *roadblocks* in implementation.

CSF 2 - Users

The four Key Informants confirmed the important role Users play during implementation and termed it an essential criterion for *things to go right* during implementation. Two Key Informants particularly acknowledged the effectiveness of the users during implementation:

'Users are also very important because what they will be doing is different from what they have been doing so far. Sometimes it depends on the organisation and its work culture, the reason I am saying this is that sometimes users are reluctant to change and they want to do things in a certain way in which they have been doing for a long time. In other cases, there are users who are very open to change and they easily adapt to the new project. So, in short, I would say user support is important but it depends on the organisation and its culture'. (Key Informant 1, the MIS-Manager)

Similarly,

'Users or the stakeholders, as I like to name them, are also extremely important because when they get involved in the project, they can provide essential support to the project. [The] project manager can get input from user and this lays the foundation of the good project. So involvement of stakeholders or users across the project ... comes after, top management and project management. Actually, they are next to top management in importance. Project management and users are extremely related. A good stakeholder team, with good project management, will deliver results'. (Key Informant 2, the SQA-Analyst)

Key Informant 3, the Net-Developer adds:

'Users are important in a sense that system implemented is for their use and therefor their feedback is essential'.

Similarly:

'Users are important because they are the ones who will be using whatever you are delivering or implementing. They are the ones who will provide you input during the project as what is required, and also will perform users' acceptance testing for the project to determine if they are satisfied with the implementation. Also, they are the ones who will be using the system after [the] implementation go-live date. So, 'yes' they are extremely important throughout the project and their input is the most valuable input that you can get on the project'. (Key Informant 4, the BI Analyst)

In general, Key Informants mostly viewed CSF Users from the point of view of their role in adapting to new technology and experimenting with new ERP system. In general, it is observed that users can be classified in two groups; one who are reluctant to change and others who are open to change and ready to adapt new technology. Further, during implementation, users can provide essential feedback that can guide the project manager, which, as according to a Key Informant, is the most valuable input that one can get during implementation. In many instances, users also work in close collaboration with top management during implementation. It is essential that users' needs and their IT skills be kept in perspective in pre-planning phase and during implementation to decrease user's resistance and utilise functionalities offered by ERP. Since if implementation team do not have a clear vision of the users' requirements and their aptitude and skills; then the implementation will not be successful.

CSF 3 – Project Management (PM)

According to Key Informant 4, the BI Analyst, *'project management is the backbone of the project'*. The BI Analyst further explains that project management covers a wide spectrum of issues during implementation, and if carried out in an efficient manner, it enhances the likelihood of success. Due to its wide reach and coverage, project management has developed into specialised 'science'. Key Informant 2, the SQA-Analyst elaborated on the nature and characteristics of project management:

> *'We have to understand the project management has become a highly specialised science, there many learning and educational studies around this field. Project management is not just an art rather there is a lot of science involved in it. Project management involves human skills, personal skills, so this CSF demands lot of consideration, if the project management is good, then [a] project will have certain vision aligned to companies' strategies and goals. A project manager [can] help you to keep the transparency of the project and make sure that project reaches the stage where it is completed inside budget constraints and you get value of the money'.*

Key Informant 4, the BI-Analyst commented the importance of having a project manager who is qualified and competent: *'[The] project manager is the key person who plays an important role in keeping all key people involved in the project, so that any information, critical aspects and critical deadlines are not missed. They are the 'make or break' people on the project and they have the most important role'.*

Key Informant 3, the Net-Developer evaluated project management to be *important,* while Key Informant 1, the MIS-Manager has *neutral* opinion role of project management in ERP implementation.

As can be observed, Key Informants stressed upon the importance of project management, terming as *a backbone* of the project. It generally agreed that for an efficient project management, a project manager is the key person, who keeps all people involved in implementation in a loop, so that any information, critical aspects, and deadlines are not missed. A project manager is a 'make or break' person of the project who can align the implementation with companies' strategies and vision.

CSF 4 – Information Technology Systems (IT)

According to Key Informant 2, the SQA-Analyst, the CSFs IT and Vendor Support need to work together during implementation. While, Key Informant 3 the Net-Developer ranked CSF IT 'as *the most important after top management'.*

Key Informant 4, the BI-Analyst suggested that the significance of the CSF IT is that it usually varies between organisations depending upon their existing infrastructure. According to this Key Informant:

> *'...it is very important but it varies from organisation to organisation ...the reason behind it is that the implementation in these types of project is always critical to your existing model i.e. what existing application and databases is utilised. Therefore what you need in this case is the database and infrastructure which will plug in [with the] existing model without any modification. If you can do that, this will decide that what database and infrastructure you should go with for this implementation. So, for me they are important'.*

Key Informants classified CSF IT as one of the two most critical factors for successful ERP implementation in SMEs. It is regarded as mandatory for the project survival, and to keep it on track since the presence of right infrastructure is basic requirement for project to progess and succeed. However, Key Informants agreed that IT requirements may vary between organisations. Key Informant 3, the Net-Developer, viewed IT as a second most important CSF after top management during implementation.

CSF 5 - Vendor Support (VS)

Due to their limited IT resources, SMEs usually heavily rely on ERP vendor’s support to setup IT infrastructure for ERP implementation. Most importantly, Vendor Support helps SMEs customise the ERP system to match the actual features of existing processes in the SMEs. All the Key Informants stated that Vendor Support is essential for project success. Key Informant 1, the MIS-Manager termed it ‘very essential’ during their implementation, due to their limited IT set up:

> *‘Vendor’s support in my case is extremely important and I think perhaps it is true for many SMEs as well since they do not have big internal team so generally SMEs rely on external teams of consultants to implement the project. So in that sense if you don’t have support of the vendors then your project may not be successful. In my case, vendor’s support was very important since I had very limited internal resources. [So] I have to hire external vendors from strategic point of view’.(Key Informant 1, MIS-Manager)*

While according to Key Informant 2, the SQA-Analyst, both right Vendor Support and right IT infrastructure are mandatory for a successful ERP implementation:

> *‘...according to the requirement of the project, you need right infrastructure and right kind of support from consultants or external vendors. It is something which is mandatory for the project survival; and to keep project on track. [A] project needs certain specific kind of infrastructure and if you are unable to provide resources, essential tools or techniques than the project will not go anywhere. A*

good project manager should ensure that he has right resources and right infrastructure, and he draw contract or legal document with vendors that will enable him to satisfy the demand of the project'.

Similarly, Key Informant 4, the BI-Administrator also agreed on the role of Vendor Support during implementation:

'vendor's support is critical because if you end up in a situation where you are getting an error. [If] your application is not running, or your database is popping out an error that your technical team cannot resolve, [then] in that case you need your vendor to jump in and resolve the situation….so [the] quicker you get those things resolved, the better it is for your project. So their support is very important when you get into these kinds of situations'

Vendor Supports' importance during implementation, as recognised by Key Informants, correspond with the literature and general observations in industry that SMEs mostly reply on vendors support. It is due to the fact that SMEs do not have big internal IT setup and SMEs seek support from vendors or external consultants, hence suggesting its importance from strategic point of view. In many instances if the vendor's support is not available, project may not be successful. While one Key Informant suggested that vendor's support is necessary at the critical phases of implementation and may not be required at the same level throughout the project.

During the interview process, the Key informants were also asked to identify other CSFs that are important to ERP implementation. These are summarised in table 6.2 below. According to Key Informant 1, the MIS-Manager:

'...there can be couple of other CSFs, for example organisational culture i.e. if an organisation is willing to change. Therefore, it can be a very important CSF for this model. Business process reengineering could be [another] important CSF. It is dependent on the organisational structure and implementation strategy but it can be very important CSF'.

Key Informant 2, the SQA-Analyst proposed 'quality factor' as another important CSF. He explained:

'It is because these days you have to finish the project in time with reasonable cost and within the parameters of quality. If you are able to deliver the project but you don't have requisite quality then obviously it will run into problems. This will result in extra monetary cost for your project because you will deliver and redeliver the project and run into vicious cycle due to non-quality product. This means you are actually wasting lot of resources which otherwise can be applied to other areas, project or avenues. These resources can use up extra profitability and revenues. So if the quality of implementation is not good then all these resources will go to waste. Therefore I think the quality is essential CSF for project implementation'.

Key Informant 3, Net-Developer recommended *effective communication* and *business planning* as additional important CSFs, while Key Informant 4, the BI-Analyst suggested functional consultant as an important CSF, and explained:

'*In an organisation you can have your technical team, which can be your database and infrastructure people but you don't have any functional consultants who act as bridge between end users and [the] IT [team]. The common problem is that the end users will use their own terminologies (maybe, let's say financial terms, if it the module implemented is finance related) but they will not be able to explain to [the] IT [team] in terms of the way [or] information [the] IT department is looking for. Similarly, when [the] IT staff asks a question usually it will be so technical that it will be beyond the understanding of users. So we need someone who is somewhat familiar with IT and more important is familiar with the product that you are delivering and its functionality, so they can translate that information for IT. Functional consultants are very important and play a key role in this kind of situation during implementation'.*

As can be observed, Key Informants views generally vary when asked to suggest any other CSFs that they thought critical for the success from their own ERP implementation experience. This question generated variety of responses from the participants, confirming the general observation that each organisation goes through different experience during

	MIS-Manager	SQL Analyst	Net-Developer	BI Analyst
Additional CSFs identified	i).Organisational Culture ii).BPR	i). Quality Control	i).Effective communication ii).BPR	i).Functional Consultants

Table 6.2 Proposed additional CSFs

implementation. Different CSFs proposed by Key Informants, as shown in Table 6.2, included, organisational culture; innovative, dynamic, teamwork or how much they are ready to change and adapt new technologies, Business Process Reengineering (BPR); restructuring organisation setup for new ERP system, quality; maintaining certain quality standards, effective communication; including vertical communication and horizontal communication and functional consultant; to act as bridge between IT/VS and users.

6.4.3 Analysis of performance measures

As has been previously explained, the DSS_ERP model predicts project outcomes of a ERP implementation, measured by *project duration, implementation cost* and *performance level*. The four Key Informants were asked to evaluate the efficiency, effectiveness and importance of the performance measures. As shown in Table 6.3, the four Key Informants rate the performance measures differently, influenced by the organisational and technological context where the ERP projects are implemented. However, all the Key Informants agree that the three performance measures are good indicators of project implementation outcomes. Key Informant 1, the MIS-Manager rated *performance level* to be the most important measure:

> *'Achievement was most important for me. Achievement in the sense that before starting the project we had some goals that we will attempt to achieve from the project and if those goals are not achieved then I will not consider the project as successful. Therefore, achievement was my top priority and I wanted to achieve 100% performance (if not above 100%) and that was my goal. Anything less 80% was considered as failure. Time and cost can be important but from our*

perspective, they were slightly less important. In some situations we might save few thousands dollar but in grand scheme of things saving of couple of thousands of dollar is not that important as compared to achievement'.

Project duration	**Project cost**	**Performance**
		MIS-Manager
Net-analyst		
BI-analyst		BI-Analyst
SQA-Analyst	SQA-Analyst	SQA-Analyst

Table 6.3 Participants preferred performance measurement variables

Key Informant 2, the Net-Developer evaluated *Time or Project Duration* to be the most important measure:

'…time is most important factor, since implementation project must deliver on time, therefore time is the most important factor, while cost and achievement may vary according to the demands of the implementation. Cost is important because we have to meet the deadline to deliver the results and more time we spend on the project, cost continue going up, therefore cost becomes second important factors after time. In our case, [not] delivering on time can also mean that project can cost more than our initial estimates. We have to spend whatever is required to finish implementation and deliver results'.

Key Informant 4, the BI-Analyst identified project duration and performance level the most important measure:

'I would say that time and achievement are more important than cost. The reason is: first of all these project are expensive. Let's say we have a million dollar project and you end up spend 1.2 million; I don't think [the] company would mind it if you end up delivering what they were looking for and the user acceptance is high. [It is] more important is that you deliver what was promised and you deliver in time. So, to me, time and achievement have higher level of importance than cost'.

In the views of Key Informant 2, the SQA-Analyst, the three performance measures are interrelated, and ERP implementation outcomes can only be properly measured when all the measures are utilised: *'…it is not about which factor is more important; in [a] corporate environment, time is [an] important factor, and so is the cost: they are interrelated. When you are utilising both time and cost in efficient manner, you are taking optimal amount of resources within that time unit and you are achieving more for your time invested. If time and cost are effectively managed, it means that you are minimising the losses since you are not wasting the resources. This, in turn, contributes towards the profitability of the company because you are lowering the cost and you are delivering more per unit time, so all these factors are interrelated. Achievement is always the results of efficient handling of the time and resources. I won't say that to me time is more important though in lot of conditions such as meeting deadlines, it can be important. We have to keep balance of time and resources to maintain a better achievement'.*

In terms of efficiency and effectiveness, both Key Informant 1 and 2, the MIS-Manager and the SQA-Analyst confirmed that the three measures are adequate to measure ERP implementation, but only when they function in interrelationship:

> *'These three variables are fine. They should be used in [a] balanced relationship, such [as], to achieve certain level of performance, it will cost certain amount of time and money. These variables should be applied in balance'. (Key Informant 1, the MIS-Manager)*

> *'...how you can separate interaction of time, cost and achievement. What is an achievement? You don't use time and cost effectively than you have no achievement; while if you use time and cost effectively you create sense of achievement. You [will] observe higher profitability, increase in revenues and so they are all interrelated and there is no other way. Your time is [the] most important variable, actually, you are managing your cost in certain way [so] that your time is utilised efficiently. Vice-versa we can say that cost is important variable than actually you are maintaining time well within time limit. We cannot separate these three variables such achievement is result of managing time and cost effectively' (Key Informant 2, the SQA-Analyst)*

It is observed that Key Informants identified performance measures influenced by the organisational and technological context of ERP implementing SME. It is interesting to observe that project cost was not the primary concern for any of the Key Informants, despite the fact that SMEs have limited resources and are sensitive with the budget. Nevertheless, one Key Informant argued that all three variables are interrelated and cannot be studied in an individual context.

6.4.4 Functionalities of the DSS_ERP and potential improvements

In the next stage of the interview, the functionalities of the DSS_ERP were demonstrated to Key Informants, and they share their views and comments on the effectiveness and applicability of the DSS_ERP. In general, Key Informants are satisfied with the functionalities of the DSS_ERP, and will consider adopting it prior to or even during ERP implementation.

According to Key Informant 1, the MIS-Manager:

> *'I think model works good and it can demonstrate to the organisation like ours the predicted end results.... From the model, I can tell my top management that these are the variables and if we put [in] this type of money and time, these are the results we will achieve. The other important thing in this model is keeping track of the progress'.*

Similarly, Net-Developer said:

> *'Yes, it is quite useful and it predicts total cost and performance level which can be effective in decision making'.*

BI-Analyst also added:

> *'Your model is good, definitely it's good. The importance of this is, I could relate it my project that If had used it our implementation, our project could have been more successful from the end users acceptance point of view'.*

Key Informants were further asked to recommend any improvement to enhance model's predictability. MIS-Manager suggested adding more CSFs:

'...maybe you can have couple of additional CSFs ...you can add couple of more dimensions to the model that can be helpful in improving the predictability. For example, I think, organisational changes (for example, how much users are adaptable to change), other can be BPR (Business Process Re-engineering). BPR studies if the organisational in general is open to change or if they have tools and strategy to change. So you can increase the number of CSFs and also if you add weightage to these CSFs, according to the industry and the size of the company'.

Key Informant BI-Analyst suggested following improvement to the model:

'For this model, I think, what would be helpful that you add end-users' feedback factor during the project and at the end of the project. During the project, it can guide you and the technical team as if you are moving in the right direction. Feedback at the end of project is mostly for record purpose. Therefore, feedback during the project gives a good idea that what is being delivered and if there are any changes and improvements needed. Adding this factor will give a solid understanding that implementation is moving in a correct direction'.

Key Informants acknowledge the operational value of the DSS during implementation and suggested different techniques in which the functionalities of the DSS can further exploited. However, it is important to understand that DSS requires upgrading in accordance with changing environments and business strategies overtime. Further, Key Informants also suggested different strategies such as by incorporating CSFs organisational change, BPR and end users feedback to enhance the decision making.

6.4.5 CSF attributes

In the final stage of the interview process, the Key Informants were asked to suggest attributes that define the CSFs, in their opinion. These are reported in the following section and summarised in Table 6.4.:

CSF 1-Top Management (TM) attributes

> According to Key Informant 1, the MIS-Manager: *'...their main attribute is ... how adept the management is with technology and advancement in the IT field including ERP. Another important attribute is if these people have gone through any ERP implementation in past'.*

While according to Key Informant 2 the SQA-Analyst, 'top management's v*ision and strategic direction, financial support, proactive, inquisitive and project alignment capabilities'* are important attributes.

For Key Informant 3 Net-Developer, 'top management *availability; as [and] when needed to make important decisions, their support and skills in managing project'* are essential attributes.

Key Informant 4 BI-Analyst suggested top management's support and availability were both jointly important attributes and added communication features of top management:

> *'top management their level of support is very important since they are decision maker. In addition, their availability is also essential when they are needed since they are busy people. Also their effectiveness and communication with the team, with the vendor or with end user is also important'.*

CSF 2 - Users attributes

Although all Key Informants reached an agreement on the importance of CSF Users, they identifies different attributes under it: *'Users attributes can be communication, open to learning, honest feedback, openness. (Key Informant 1, MIS-Manager)*

> *'…training, minimal resistance to change, learning' (Key Informant 2, SQA-*Analyst)

> *'...their availability, when need by IT team and communication skills are main attribute' (Key Informant 4, BI-*Analyst)

CSF 3 – Project Management (PM) attributes

Key Informant 4, the BI-Analyst, classified project management as '*the backbone of the project'*. Due to the significance and the nature of Project Management, a wide range of attributes were suggested:

> *'...the most important project management attribute is their experience in implementation.' (Key Informant 1, MIS-Manager)*
>
> *'...industry knowledge, experience and [being] well versed with project management methodologies, [plus] public dealings, ready [to] absorb lot of things, [being] organised, [having] excellent communication skills' (Key Informant 2, SQA-Analyst)*
>
> *'...good resources utilisation skills, experience, skills, time management'. (Key Informant 3, Net-Developer)*
>
> *'...effective communication and availability on time is essential ...the project manager is the most important person on the project which jives the entire key member[ship] together. Their important attributes include [being] clear in their thinking, and explaining the aspects of implementation from technical, functional point [of views] and vendor's support point of view. A good project management needs to have clear understanding of the project and they must understand project inside-out; functionality wise'.(Key Informant 4, BI Analyst)*

CSF 4 – Information Technology (IT) attributes

Attributes for CSF-IT are mostly related to the issue of reliability of the infrastructure. Key Informant 1 the MIS-Manager suggested for example, that *'IT related CSFs attribute include flexibility of the infrastructure and database. If the database is complete and/or being updated. Data measurement is also important attribute for the success of the project'.*

According to Key Informant 3, the Net-Developer, IT attributes are '*reliability, scalability, and ability to withstand stress*.'

Key Informant 4, the BI-Analyst suggested *'reliability, authentication of end users and a backup plan'* as essential attributes of the CSF IT.

CSF 5 – Vendor's Support (VS) attributes

Key Informants considered the following attributes significant for CSF-VS:

'...reliable, and fulfil requirement within organisation budget'.(Key Informant 1, MIS-Manager)

'...system support and on-time availability in case of problems'.(Key Informant 3, Net-Developer)

'...quick turn-around time and on-demand support...'.(Key Informant 4, BI-Analyst)

	CSF-TM	**CSF-Users**	**CSF-PM**	**CSF-IT**	**CSF-VS**
MIS-Manager	i). Tech savvy ii). Past implementation experience	i).Communication skills ii).Open to learning iii). Feedback	i). Experience	i). Flexibility of infrastructure and database	i). Reliable ii). Ability to fulfil requirement-s while staying inside budget
SQA Analyst	i).Vision ii). Financial support iii). Proactive Inquisitive	i). Training ii). Minimal resistance	i).Industry knowledge ii).Experience iii). Excellent communication skills		
Net Developer	i). Availability (when needed) ii). Support iii). Project management skills		i). Good resources utilisation skills ii) Time management skills	i).Reliability ii).Scalability iii).Ability to withstand stress	i).Systems support ii).On-time availability
BI Analyst	i). Availability (when needed) ii).Communication skills iii). Effectiveness in dealing with team and vendors	i).Communication skills ii).Availability (when needed by IT team)	i).Effective communication skills ii).Clear Understanding of the project	i).Reliability ii).Authentication of end users Back-up plan	i).Quick turn- around time ii).On-demand support

Table 6.4 CSFs attributes proposed by Key Informants

6.5 Discussion

The aim of conducting interviews with the Key Informants is evaluate the effectiveness, efficiency and applicability of the DSS_ERP in real ERP implementation projects. Whilst the studying ERP implementation process is not the focus of this process, the Key Informants are allowed to share their experiences accumulated from ERP implementation, raise issues and concerns encountered during implementation, as well as solutions to these issues.

The four Key Informants interviewed, with a total sixty years of experience in IT field, recognise the benefits that DSS_ERP can bring to ERP implementation. They agreed that DSS_ERP can be an useful tool prior to and during ERP implementation, and can be used to predict efforts and resources needed for an ERP implementation, which facilitate decision makers adopting a ERP system or not. According to Key Informant 1, the MIS-Manager, when SME utilise DSS-ERP, implementation can be accelerated, and cost effective with increased users' satisfaction. Further, Key Informant 4, the BI-Administrator suggested that presence of model could give implementation team a confidence to take initiatives. However, Key Informant 2, the SQA-Analyst was of the view that SMEs needs to be cautious before adopting the model since a model has to be expert at particular project and industry. In addition, he warned, too much reliance can be 'injurious' to the project and outcomes.

Furthermore, Key Informants all acknowledged that decision support models are valuable to SMEs. There are some models developed for large enterprises but there is no model specifically designed for the SMEs. Key Informant 1, the MIS-Manager suggested that since ERP implementation in SMEs is a critical decision and upper management usually do not have an experience in a major implementation project, therefore prediction results from the model can guide the implementation and keep it within budget. Moreover, according to Key Informant 4, the BI-Analyst, a prediction model provides an added value to the implementation process, therefore confirm the operational value of the model.

After discussing the role a prediction model could play in implementation, the next question in the interview was focussed on finding out participants' views on the five CSFs embedded in the model and level of importance they personally would give to these CSFs. It was observed that Key Informants generally agreed with the selection of CSFs for DSS while confirming the important role these CSFs play during implementation. It was generally agreed that top management support is essential for project success. However, according to one Key Informant top management support is not required most of the time; however, it might be needed at critical stages when there are *roadblocks* in implementation. As literature suggests that too much top management support can be dysfunctional and lead to failures (Collins and Bicknell, 1997; Keil, 1995). Whilst Young (2006) suggests that project can succeed without following general prescription for top management support. Similarly, Key Informants considered experienced project management as *a backbone* of the project. An efficient project management usually keep all persons involved in implementation in a loop, so that any information, critical aspects, and deadlines are not missed. CSF Vendor Support was also rated as an important CSF by Key Informants which corresponds with the literature and general observations in industry. Users were identified from the point of view of their role in adapting to new technology and experimenting with new ERP system. It was suggested that Users can be grouped in two groups; one who are reluctant to change and others who are open to change and ready to adapt new technology. Key Informants stressed upon the importance of feedback and input by users in improving the implementation process. While CSF-IT was termed as second most important CSFs after top management since it ensures the availability of right infrastructure before embarking on ERP implementation. According to a Key Informant it is mandatory for the project survival, and to keep it on track.

Key Informants were asked to suggest any other CSFs that they thought critical for the success from their own ERP implementation experience. This question generated different responses from the participants and different CSFs proposed by Key Informants included, organisational culture; innovative, dynamic, teamwork or how much they are ready to change and adapt new technologies, Business Process Reengineering (BPR); restructuring organisation setup for new ERP system, quality; maintaining certain quality standards, effective communication; including vertical communication and horizontal communication and functional consultant; to act as bridge between IT/VS and users.

The decision support model developed for this study was demonstrated to the Key Informants to seek their opinion on the performance of the model. After observing the working of the model, Key Informants affirmed its practical value and the generated result. Each Key Informant gave their personal views on how the model could be applied in the implementation and how its features could be exploited for additional benefits. According to

Key Informant 1, the MIS-Manager, the predicted end results can be used to convince Top Management to get funding for the project. While once the implementation process starts, the model can keep track of the project's progress. Further, the predicted total cost and overall performance can be applied in effective decision making. According to Key Informant 4, the BI-Administrator, if they had access to such a model during their implementation, their project would have been more successful. In addition, it was generally suggested that the results generated by the model can helpful to an extent, however it should be kept in perspective that all model grow overtime, therefore the model might need upgrading.

Key Informants were asked to suggest any improvements in the model to enhance its performance. It was suggested that addition of certain critical factors could give a new dimension to the model. CSFs such as organisational change capacity and BPR could provide more predicting power to the model. In addition, it was suggested that involving some kind of method to seek end users' feedback in the model can also be beneficial. This could assist in keeping project on track and advise management if the project is progressing as planned or if there any changes that need to be made.

Additionally, it was suggested that adding a weightage to the CSFs, according to their role and the industry the user belongs to, could also improve the applicability and accuracy of the model. For example, if the SME belongs to the IT industry, less weight could be given to CSF IT, alternatively, if a SME has a more traditional way of doing business and top management is less open to new ideas, then more weight could be given TM in the model.

The case study interview process confirms the functionalities, applicability and anticipated performance of DSS_ERP developed as a part of this research. In the next chapter research findings and the contribution of the research are discussed.

CHAPTER 7

Research synthesis

ERP systems have enhanced and revolutionised the way organisations function, ultimately helping them become more productive and competitive. However, ERP implementation is a challenging, time consuming and expensive process, and can have adverse consequences if not well managed; the failure rate of ERP implementation has been estimated at between 60% and 90% (Kwahk and Lee, 2008). Due to limited resources and a lack of perceived usefulness, ERP implementation becomes even more challenging to SME. ERP implementation and optimisation have been investigated thoroughly, including study of such topics as ERP software selection, CSFs, business process reengineering, post-implementation and achievement of competitive advantage through ERP (Schlichter and Kraemmergaard, 2010). SMEs are recommended to focus on CSFs in order to improve the chances of successful implementation (Akkermans & van Helden, 2002). However, the ERP implementation and optimisation literature lacks coverage of resource allocation to CSFs. Decision making tools that make it possible to predict required resources to address each CSF and to monitor the performance of each CSF and overall ERP project are not available in the literature. Without the ability to obtain more accurate estimates on required resources during the project planning phase, SMEs tend to underestimate based on inaccurate guesses and suffer project failures due to insufficient resources. This research addresses the issues above and contributes to the undeveloped area by developing DSS_ERP using simulation and modelling approaches:

- Compared with previous studies that focus on ERP implementation in large enterprises (i.e. Adam and Doherty, 2002; Akkerman et al., 2003; Berchet and Habchi, 2005; Bose et al., 2008; Hasan et al., 2001; Weider et al. 2006; Yusuf et al., 2004; Maguire et al., 2009), this research studies the roles played by CSFs in ERP implementation in SMEs.

- Rather than only broadly identifying the CSFs for ERP implementation (Nah et al., 2003; Zabjeck et al., 2009; Doom et al., 2010; Malhotra and Temponi, 2010), this research explored the specific practical contributions made by CSFs to overall ERP implementation performance, and how to prioritise them in implementation.

- This research further verifies the importance of CSFs in a quantitative way, by comparing the performance thresholds, progressing coefficient and cost for each CSF, and therefore allowing a level of priority to be determined in the achievement of the goals. The thesis reveals that the CSF with higher progressing coefficients generate more rapid improvement during the early implementation phase, while CSF with higher performance thresholds make greater contribution in the later phase of ERP implementation within SMEs. For example, '*PM*', with the highest performance threshold, contributes gradually towards the implementation phase, but makes most contribution to the overall ERP implementation performance level. While '*Users*' progresses faster than other CSFs, which means the users learn and progress at faster pace. These findings are consistent with the findings in Sun et al., (2005), Umble et al., (2003); Yen et al., (2002) and Zhang et al., (2003).

- The existing literature (i.e. Haines et al., 2000; Boyer, 2001; Sedara et al., 2003; and Plaza & Rohlf, 2008) reveals that '*VS*' costs a large portion of implementation project budgets, and suggests that '*VS*' involvement should therefore be carefully controlled. *VS* is also identified as the most expensive CSF. This research further confirms that CSFs '*VS*' and '*IT*' are much more costly than the other CSFs, which indicates that knowledge transfer from the external consultants and purchase of software and hardware systems are expensive components of the overall ERP implementation.

- Some researchers (i.e. Motawani et al., 2005; Umble et al., 2003: Mandal and Gunasekaran, 2003) have proposed that CSFs work as independent entities during the implementation, however this research has demonstrated that CSFs not only complement each other during the implementation, but also are more effective when they are interrelated; such as CSF '*PM*' can be more effective with '*TM*' support, and '*Users*' involvement. Likewise, '*VS*' is not only crucial in supporting the CSF '*IT*' but also works in collaboration with '*Users*' in learning and knowledge transfer.

- The DSS_ERP combines the collective subjective judgement of the experts with statistical analysis based on actual ERP implementations in SMEs to forecast the results. This is in line with the observations of Boehm and Sullivan (1999) and Stensrud (2005) who found that this is the most commonly used techniques for cost and schedule estimation. They suggested that main strength of these techniques is that they are generally based on real-life experience, and that the human judgement is often good at adjusting for special situations.

- The analytical regression models developed in the research are appropriate for analysing the relationship between the variables and effectively depict valid results. The approach is also corroborated by Stensurd (2001) who suggested that only regression analysis makes completely 'good sense' when used as a prediction system for ERP projects. The analytical regression models are developed to express relationships between the independent (i.e. time) and dependent variables (i.e. cost and performance). According to the general observations and analysis of primary data, two curves are identified as most suitable to represent the relationship between the variables. The analytical models represented by the curve for this study are, CSF level: 1) Cost vs Time linear model, i.e. cost increases with time spend on the project, and 2) Progress vs Time exponential model, i.e. performance increase up to certain point and then it levels out, which is line with the findings of Sun et al. (2005) and Plaza & Rohlf (2008).

- The exponential curve generated in the research to model the relationship between performance level and time, is in line with literature (i.e. Ngwenyama et al., 2007; Plaza et al. 2007; Plaza et al., 2010; Chamber 2004; Dardan et al., 2006) which suggest that performance continuously improves with most substantial improvement taking place at the beginning of the implementation, and eventually reaching asymptote.

- DSS_ERP is developed to forecast the project duration, implementation cost and performance level. The DSS_ERP can facilitate SMEs to concentrate effort and resources on CSFs that have a greater impact on achieving their desired goals while optimising utilisation of resources. DSS_ERP provides SMEs with a new instrument to develop implementation strategies, evaluate performance under various constraints, assist in resources allocation and forecasting implementation results. According to

Stensurd (2001), among the prediction models available at the time, there is none which is specifically designed for ERP systems and SMEs.

- A nonlinear programming model is developed to construct ERP implementation targets, and define limitations on budget and project duration as constraints. The model determines prioritisation of CSFs, and provides solutions on resource allocation, in such a way that predetermined targets are achieved.

- The validity of analytical regression models in the DSS_ERP is verified by comparing the results generated from Monte Carlo simulation model with the observed data. The validity and effectiveness of the DSS_ERP are verified by adopting methods suggested by Kleindorfer and Ganeshan (1993), Balci (2003) and Sargent (2011) (see section 3.9). Key informants from practice who have extensive IT experience are invited to share their opinions and judgements on the applicability, effectiveness and efficiency of the DSS_ERP. The key informants confirmed the general acceptability and anticipated performance of the model and its operational value, To ensure that the DSS_ERP is easy to use, all the models in DSS_ERP are developed in MS Excel. Excel is commonly available Microsoft Windows application, therefore DSS_ERP does not require installing a special software and arranging a training program for the users.

Since the validity and applicability of DSS_ERP are confirmed by both simulation and ERP practitioners, therefore the model can be a useful tool in decision making process during ERP implementation.

CHAPTER 8

Conclusions, limitations and suggestions for future work

8.1 Conclusions

Continuously changing business environment and increasing business competition have forced the organisations to constantly review/revise their business strategy and align the operations with their business strategy. In order to be competitive in the market, organisations need to develop and implement competitive strategies, including strategies for managing business processes, which can be automated by the adoption of new information technologies. For large enterprises, experimenting with new strategies and technologies is not as challenging as SMEs, since they have sufficient resources to be invested in experiments and they could afford switching to an alternative solution if one experimental strategy fails. In contrast, SMEs face more challenges in implementing new strategies and adopting new technologies, due to limited resources.

Enterprise resource planning (ERP) system automates core corporate activities and optimises the flow of information and resources throughout the entire supply chain. ERP systems seek to integrate different functions of the organisation previously working in silos. This enables most up to date information shared among all the entities within a supply chain, which in turn enhances the decision making, on time delivery, better inventory management and more profits. Initially, ERP systems were designed to cater the needs of large enterprises as they are the main customers who can afford higher price of implementing such a system and have the capabilities to deal with the complexities involved in implementing it. With saturation of large enterprises market, ERP vendors switched their attentions to SMEs. The ERP systems not only incorporate best business practices, but also require that implementing organisation reengineer business process around the ERP systems. SMEs have realised the usefulness and importance of this system, and prefer to adapt ERP systems to the business processes through customisation.

However, SMEs have been found to be constrained by limited resources that are needed to address these issues, and are forced to compromise implementation and subsequently putting the success of adopting new information system or technology at risk. ERP implementation becomes a real challenge for SMEs. In an ideal situation, SMEs would have implemented ERP successfully within limited budget and time duration. If there is a readily available and reliable tool to forecast efforts, schedules and costs required to achieve the desired success level in ERP implementation, SMEs will be able to plan ahead to acquire resources and increase the success rate of implementation. Since such a tool illuminates the relationships between the desired success level and the needed resources/resource allocation, it can provide proper justification for project planning.

The high probability of failure places a pressure on SMEs planning to implement ERP systems, since according to literature, there is a lack of research and guidance in the area of ERP implementation in SMEs. This lack of knowledge and guidance motivated the author to study the implementation in SMEs and explore the factors that are essential for successful implementation.

A quantitative tool DSS_ERP is developed in this research, combining analytical regression model, ERP simulation model and ERP nonlinear programming model. The analytical models are developed to represent the relationship between the variables of implementation cost, project duration and performance, which are broken down at CSF level and measured quantitatively using data collected from the survey conducted on 60 SMEs. The analytical models are verified by the simulation model before they are applied to construct the nonlinear programming model. The nonlinear programming models are employed to determine the resource allocations for the predetermined goals. The validity of DSS_ERP is further confirmed by implementing verification process including seeking opinion of key informants who have been involved in ERP implementation, confirming that the forecast results generated by DSS_ERP are valid therefore model can be useful during implementation decision making process.

DSS_ERP can help decision makers in measuring performance of CSFs and determining their priorities, and based on that it facilitate decision making on resources allocation to achieve the predetermined goals. The functionalities of DSS_ERP can be summarised as:

1. DSS_ERP serves as an analytical tool to monitor ERP implementation progresses and cost consumed along the time horizon;

2. it determines the priorities of CSFs for SMEs in their ERP implementations, based on which resources are allocated to achieve predetermine targets. In addition, it offers guidance in resource acquisition and allocation that achieves predetermined ERP implementation performance level, within budget and time limits;
3. it can also be used to analyse the impacts on overall ERP performance of changes to resource allocations. It offers a risk analysis tool to analyse potential risk and opportunities caused by the changes to an ERP project, therefore helps SMEs to be better prepared and reduce failures.
4. it can facilitate studying and developing ERP implementation strategies of SMEs under a variety of constraints ;
5. it offers a mechanism to track and monitor the resource utilisation during the ERP implementation processes on daily basis.

Despite the fact that DSS_ERP can be beneficial during implementation, it is necessary to acknowledge that careful considerations must be made when considering and implementing the forecasted results, since SMEs have different organisational structures and different goals in ERP implementation. During the course of the research few important developments have taken place in IT field in general and ERP systems in particular. The companies are investing more in their IT infrastructures, and in upgrading and implementing new software systems such as ERP, ever since dot-com bubble burst and recent recession. Further, there are many new entrants in the industry offering ERP system software to SMEs which are more functionally advanced and available at competitive prices. The newer version of ERP systems are also available in on-demand format, SaaS (software as a service) is becoming more common, application of web-based ERP has increased the price competition by lowering the cost of ERP and most recently, in-memory based ERP has increased the information processing to new higher limits. Still, even with new developments, the need to understand the logic behind the ERP and it implementation can be useful while working with ERP systems. Similarly, understanding the role of CSFs and their influence in organisation during the implementation can lead to development of theory for successful implementation and strategies to benefit from the ERP systems.

8.2 Recommendations to SMEs

Based on the conclusion, application of model and findings , the following recommendations are suggested to the SMEs planning to implement ERP systems:

1) It is recommended that during pre-implementation phase, implementation team consider all CSFs for implementation, and then select CSFs which can be closely related to their functional needs and positively contribute towards implementation. In addition, implementation team should analyse which CSF makes greater contribution towards implementation based on cost and time spent on it and adjust the focus on CSF accordingly. Further, it is advised that SMEs implement CSFs sequentially since it will give more control over the implementation process, monitoring performance and utilisation of resources.
2) It is recommended that top management must be involved during the entire implementation process. Top management's commitment towards implementation process in ensuring availability of essential resources, developing an implementation strategy, minimising users' resistance and creating contingency plans for possible impacts of ERP implementation in organisation is essentially required.
3) It is recommended that to keep the implementation cost in control, SMEs pay special attention to the factors which consume major portion of the budget, such as implementing IT related CSF (such as VS and IT). Developing strategies to evaluate the IT needs and required vendors support and planning to benefit and improve organisational and users skills through learning and knowledge transfer should be the focus of implementation team.
4) It is recommended that, as with any application of forecasting model or software, results should be applied carefully. It is due to the fact that each SME has unique business strategy, internal structure and culture. Therefore the results from the model should be applied while bearing in mind the uniqueness and general implementation environment of an SME
5) It is recommended that implementation team have clear understanding of how CSF functions including their performance threshold and progression coefficient. The CSF with higher progression coefficient contribute towards the implementation at faster pace at early stages, while CSF with higher performance threshold contribution increase with time till it reaches threshold.

8.3 Limitations of research

Although the development of the model and its contribution provides a valuable insight on how SMEs can effectively plan a successful implementation, limitations of this study need to be acknowledged.

The first limitation deals with the selection of CSFs for the study. In this study five CSFs, which are most often cited in the literature, are selected for analysis and model development purposes. Although these CSFs are recommended as most critical for implementation in literature, however it does limits the scope of the research. Therefore limiting number of CSFs selected to five for the study is a limitation itself.

The second limitation deals with the sample size which is due to the limited number of SMEs which have implemented ERP systems and the nature of information required (such as cost of implementation and results). This resulted in small sample size and low response rate. Although it is expected that the findings from the study and the developed model can be applied to the ERP implementation in similar context, however, generalisation should always be done cautiously. The results of this research are valid for the SMEs with 50-150 employees and have addressed the five CSFs in their ERP implementations: Project Management, Top Management, IT infrastructure, Users and Vendor Support

The third limitation deals with the focus on the implementation phase, that is, after the decision to implement ERP systems has been made. Therefore this study does not focus on the pre-implementation phase, which usually include studying SMEs' need to implement ERP systems, implementation pre-requisites, budget planning and selection of appropriate implementation strategy.

The fourth limitation deals with the generalisation drawn from the DSS_ERP. Since the research sample is representative of population in UK and North America, therefore the results from the model are representative and relates to the ERP implantation in this region and any SME located outside this region should apply the results with caution.

8.4 Recommendations for future research

While this study provides substantial research about ERP implementation in general and planning an effective strategy for successful implementation in particular, it raises additional questions for further research. Recommendations for the further research include the following:

1) This research focus on five CSFs for analysis and model development purposes. A further search can be extended to include additional CSFs, either cited in the literature or recommend by case study participants. The addition of more CSFs will further expand the understanding of the implementation process and contribution CSF make towards it.
2) Conducting a study in which sample population is drawn from a wide geographical area for data collection. The DSS_ERP developed using the data collected from the sample can be more generalisable and representative.
3) Conducting a qualitative study of SMEs to gain the in depth knowledge of the complete ERP implementation process starting from the pre-implementation planning through post-implementation phase, therefore obtaining an overview for the whole implementation process which can be beneficial for implementing SMEs.
4) Conducting a study to develop a DSS_ERP which is industry specific (such as focussing on companies in IT, manufacturing, finance field individually), since during the course of research it was observed that level of importance of a CSF can vary according to the industry SMEs belong to. For example, if the SME is in IT field, with their IT experience and infrastructure, CSFs IT and VS may not be as important for them as compared to other SMEs.
5) Conducting a study to enhance the understanding of CSFs by studying their attributes which contributes towards the overall performance of CSFs. By selecting attributes which define CSF and collecting quantifiable data which reflect their impact on the CSF, the overall impact of CSF on the implementation can be predicted and manipulated.

The DSS_ERP represented in this paper operates with the results of a survey of 60 SMEs, which results in the DSS_ERP being both generalisable and applicable. However, the methodology of developing DSS_ERP can work with results from any empirical study, and the analytical regression models, simulation model and nonlinear programming model can be revised accordingly. These features imply that the research is not restricted to ERP implementation, and future research will focus on real-world applications of the proposed decision support system for project management.

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Appendices

Appendix A Covering Letter and Questionnaire

Dear Sir/Madam

I am a doctoral student at University of Greenwich, London. My dissertation topic is on, "Designing a Decision Support System for ERP Implementation in SMEs." The focus will be on studying the ERP implementation in small and medium enterprises and the role played by certain critical success factors (CSFs) during implementation.

Below is a link to a confidential survey. The information from this survey will be used for tabulating results only. The survey takes, on average, approximately 5-10 minutes to complete. Also the information provided will not be revealed and will only be kept for the period necessary to analyse the responses. I will also send you the summary of the results.

The link to the survey is: http://www.surveymonkey.com

I would like to explain some of the terminologies being used in the questionnaire, such as 'Management support' which includes over all support provided by the senior management towards the implementation, 'users' include end users, their perception and issues related to adopting new systems, 'Infrastructure/database' covers the hardware/software, data migration and IT related factors, and 'vendors support' involves the overall experience while dealing with vendors, system providers and the services provided by them. The questionnaire is designed to cover a complete ERP implementation.

Finally, I realise that you may have reached the point of thinking *"not another survey"* but please be generous – since the results of the study will greatly enhance the implementation experience for SMEs and will add knowledge in the field of ERP implementation.

Please return you completed questionnaire in the freepost envelope provided. If you have any questions, please do not hesitate to contact me at m.ali813@gre.ac.uk.

Yours sincerely,

Mahmood Ali

PhD Researcher

University of Greenwich

London, UK

Questionnaire

Survey Guidance Notes:

- In questionnaire, number of days spent on critical success factors (CSFs) may include planning, implementation and/or training. CSF Top Management Support may involves providing overall support to the implementation, setting goals, developing strategy and communicating the corporate IT Strategy to all employees.
- In response to the questions enquiring for number of days or portion of budget spent; if the exact figures are not available please give the best approximate values.

____

Your Name (optional): __________________

Type of Organisation: ___________________

1. Top management's vision and support helped you to achieve the implementation goal.
   [ ] Strongly Agree [ ] Agree [ ] Undecided [ ] Disagree [ ] Strongly Disagree

- Was implementation successful? [ ] Yes [ ] No

3. How long did it take to complete ERP implementation? _______________ days

i. Please state how the total implementation time was divided among following critical success factors?

Top Management Support	Project Management	IT	Users	Vendors Support

4. How much was the overall cost of implementation? ________________

1) .

i. Please state how the total cost was spent on the following factors? (percentage or money value)?

ii.

iii.

Top Management Support	Project Management	IT	Users	Vendors Support

5. What was the success rate of the data migration?

[ ] 100%   [ ] 75%   [ ] less than 50%   [ ] less than 25%

6. What percentage of implementation targets were achieved? *(Target achieved such as Integrating/streamlining business processes, information sharing, improving productivity etc.)*
[ ] 100%   [ ] 80%   [ ] 60%   [ ] 40%   [ ] 20%   [ ] 0%   [ ] __________

7. On the basis of your response to above question, please state how each of the following factor contributed to overall targets achievement? (example: if you stated 80% targets were satisfied, your answer maybe CSF1 contributed 20%, CSF2= 35 % and so on adding up to 80%)

	Top Management Support	**Project Management**	**IT**	**Users**	**Vendors Support**
Targets Achieved					

8. How much functionality of ERP systems has been used?
(System functionalities such as streamline operations, integrating functions, managing resources, information exchange etc.)

[ ] 100%   [ ] 80%   [ ] 60%   [ ] 40%   [ ] 20 %   [ ] 0%   [ ] ___________

9. On the basis of your response to above question, please state how much each CSF contributed to your answer above (example: if you stated 80% ERP systems functionality is being used, your answer maybe CSF1 contributed 10%, CSF2= 35% and so on adding up to 80%)

	Top Management Support	**Project Management**	**IT**	**Users**	**Vendors Support**
Functionality					

Thank you for giving your valuable time in filling up the above questionnaire. If you have any comments or suggestions, please feel free to contact me at m.ali813@gre.ac.uk

Appendix B

Primary data

	Criteria		CSF1-M	CSF2-U	CSF3-PM	CSF4-D	CSF5-V	Total
1	Time	Days	30	60	30	30	30	180
	Cost (Dollars)		9,000	18,000	36,000	18,000	9,000	$90,000
	Achievement		7	15	10	11	7	50

2	Time	Days	1	4	3	3	3	14
	Cost (Dollars)		0	5,250	3,000	3,750	3,750	$15,750
	Achievement		0	20	0	0	0	20
3	Time	Days	18	9	36	108	9	180
	Cost (Dollars)		1,500	1,500	3,000	15,000	1,500	$22,500
	Achievement		3	10	8	25	5	50
4	Time	Days	20	5	40	30	5	100
	Cost (Dollars)		4,125	16,500	24,750	24,750	12,375	$82,500
	Achievement		10	25	25	25	15	100
5	Time	Days	10	50	20	20	20	120
	Cost (Dollars)		5,000	10,000	10,000	12,500	12,500	$50,000
	Achievement		13	20	20	18	10	80
6	Time	Days	8	20	16	30	16	90
	Cost (Dollars)		5,880	39,200	13,720	78,400	58,800	$196,000
	Achievement		7	18	24	22	11	80.5
7	Time	Days	30	30	30	60	30	180
	Cost (Dollars)		45,000	45,000	60,000	60,000	45,000	$255,000
	Achievement		28	5	23	8	8	70
8	Time	Days	30	60	90	90	30	300
	Cost (Dollars)		11,250	33,750	45,000	101,250	33,750	$225,000
	Achievement		25	8	25	15	8	80
9	Time	Days	30	130	60	100	40	360
	Cost (Dollars)		65,000	65,000	65,000	65,000	65,000	$325,000
	Achievement		10	10	30	25	5	80
10	Time	Days	18	18	18	18	18	90
	Cost (Dollars)		6,000	6,000	6,000	6,000	6,000	$30,000
	Achievement		14	14	14	14	14	70
11	Time	Days	20	20	30	40	10	120
	Cost (Dollars)		2,500	10,000	12,500	17,500	7,500	$50,000
	Achievement		10	15	19	18	12	73
12	Time	Days	20	30	35	45	20	150
	Cost (Dollars)		4,750	18,000	23,750	33,250	14,250	$94,000
	Achievement		10	20	20	15	15	80
13	Time	Days	30	60	70	70	40	270
	Cost (Dollars)		9,800	20,000	50,400	100,800	100,000	$281,000
	Achievement		18	13	23	23	5	80
14	Time	Days	2	20	10	50	18	100
	Cost (Dollars)		30,000	6,000	12,000	6,000	6,000	$60,000
	Achievement		0	10	5	35	10	60
15	Time	Days	10	25	30	35	20	120
	Cost (Dollars)		8,000	16,000	20,000	24,000	12,000	$80,000
	Achievement		14	13	23	13	17	80
16	Time	Days	45	30	180	180	30	465
	Cost (Dollars)		40,000	80,000	100,000	80,000	20,000	$320,000
	Achievement		10	20	25	20	5	80

17	Time	Days	14	56	21	70	21	182
	Cost (Dollars)		15,000	75,000	50,000	175,000	85,000	$400,000
	Achievement		7.5	10	10	13	10	50
18	Time	Days	28	28	21	15	15	107
	Cost (Dollars)		20,000	30,000	10,000	20,000	10,000	$90,000
	Achievement		15	10	25	20	10	80
19	Time	Days	14	28	21	21	30	114
	Cost (Dollars)		18,000	45,000	27,000	63,000	27,000	$180,000
	Achievement		15	20	10	18	8	70
20	Time	Days	10	45	35	28	14	132
	Cost (Dollars)		20,000	60,000	20,000	60,000	40,000	$200,000
	Achievement		15	25	10	13	8	70
21	Time	Days	90	90	90	90	90	450
	Cost (Dollars)		50,000	50,000	100,000	100,000	200,000	$500,000
	Achievement		21	15	21	17	17	90
22	Time	Days	14	76	28	21	21	160
	Cost (Dollars)		9,000	81,000	24,000	150,000	36,000	$300,000
	Achievement		21	18	19	17	17	90.75
23	Time	Days	21	52	28	28	28	157
	Cost (Dollars)		11,250	45,000	13,500	123,750	34,875	$228,375
	Achievement		21	21	21	20	17	100
24	Time	Days	7	35	14	14	14	84
	Cost (Dollars)		2,550	29,700	6,800	40,000	5,950	$85,000
	Achievement		19	18	20	18	15	90
25	Time	Days	4	4	10	4	6	28
	Cost (Dollars)		800	6,000	6,000	5,200	2,000	$20,000
	Achievement		0	3	3	3	3	10
26	Time	Days	7	21	18	20	14	80
	Cost (Dollars)		3,500	14,700	12,600	14,000	9,800	$54,600
	Achievement		10	28	23	15	15	90
27	Time	Days	0	30	35	30	25	120
	Cost (Dollars)		0	58,500	39,000	78,000	19,500	$195,000
	Achievement		0	33	25	20	13	90.5
28	Time	Days	8	23	17	35	20	103
	Cost (Dollars)		3,000	36,250	24,650	50,750	30,450	$145,100
	Achievement		4	17	14	11	5	50
29	Time	Days	21	35	25	39	20	140
	Cost (Dollars)		16,800	42,000	31,500	94,500	42,000	$226,800
	Achievement		3	21	14	29	14	80
30	Time	Days	5	42	33	65	25	170
	Cost (Dollars)		2,100	16,100	21,000	21,700	9,100	$70,000
	Achievement		7.5	32.5	19.5	22.5	8	90
31	Time	Days	7	28	21	14	14	84
	Cost (Dollars)		1,680	5,600	16,800	14,000	17,920	$56,000
	Achievement		3	15	13	13	13	55

32	Time	Days	10	20	30	20	20	100
	Cost (Dollars)		2,130	10,650	17,750	21,300	19,170	$71,000
	Achievement		3	9	11	6	7	35
33	Time	Days	10	21	28	15	6	80
	Cost (Dollars)		3,950	14,220	18,960	16,590	16,590	$71,000
	Achievement		7	27	23	16	9	80
34	Time	Days	14	25	35	50	26	150
	Cost (Dollars)		4,050	27,000	33,750	54,000	16,200	$135,000
	Achievement		5	20	10	15	10	60
35	Time	Days	10	20	25	20	5	80
	Cost (Dollars)		10,000	20,000	25,000	20,000	5,000	$80,000
	Achievement		10	20	25	20	5	80
36	Time	Days	5	12	18	10	5	50
	Cost (Dollars)		3,150	6,300	22,050	18,900	12,600	$63,000
	Achievement		1	6.5	5	5	2.5	20
37	Time	Days	14	28	30	24	14	110
	Cost (Dollars)		12,600	25,200	35,000	51,800	15,400	$140,000
	Achievement		3	23	23	21	12	80
38	Time	Days	0	14	20	10	6	50
	Cost (Dollars)		0	10,000	10,000	17,500	12,500	$50,000
	Achievement		0	0	0	0	0	0
39	Time	Days	10	17	25	27	11	90
	Cost (Dollars)		4,000	12,000	17,600	28,000	18,400	$80,000
	Achievement		5	30	18	28	10	90
40	Time	Days	14	35	42	56	33	180
	Cost (Dollars)		16,000	40,000	56,000	68,000	2,000	$182,000
	Achievement		3	13	10	10	5	40
41	Time	Days	0	28	30	35	27	120
	Cost (Dollars)		0	11,250	15,000	30,000	18,750	$75,000
	Achievement		0	25	25	25	15	90
42	Time	Days	14	40	49	63	44	210
	Cost (Dollars)		9,000	60,000	84,000	111,000	36,000	$300,000
	Achievement		4	16	15	11	15	60
43	Time	Days	5	12	15	18	10	60
	Cost (Dollars)		2,400	6,000	10,800	14,000	6,800	$40,000
	Achievement		2	8	8	7	7	30
44	Time	Days	9	21	19	11	10	70
	Cost (Dollars)		7,000	29,400	28,000	42,000	33,600	$140,000
	Achievement		5	8	9	10	9	40
45	Time	Days	7	21	21	21	14	84
	Cost (Dollars)		2,920	11,680	14,600	25,550	18,250	$73,000
	Achievement		10	36	20	22	12	100
46	Time	Days	10	21	28	37	19	115
	Cost (Dollars)		3,300	51,150	39,600	54,450	16,500	$165,000
	Achievement		6	15	15	14	11	60

47	Time	Days	7	21	28	21	13	90
	Cost (Dollars)		1,350	24,300	39,150	40,500	29,700	$135,000
	Achievement		0	10	7	7	7	31
48	Time	Days	0	14	20	10	6	50
	Cost (Dollars)		0	12,720	11,660	15,900	12,720	$53,000
	Achievement		0	26	18	19	8	70
49	Time	Days	5	14	18	18	8	63
	Cost (Dollars)		810	16,200	21,870	26,730	15,390	$81,000
	Achievement		5	18	10	14	14	60
50	Time	Days	0	7	7	7	7	28
	Cost (Dollars)		0	6,150	10,250	14,350	10,250	$41,000
	Achievement		0	5	5	5	5	20
51	Time	Days	12	21	30	33	19	115
	Cost (Dollars)		8,850	53,100	44,250	53,100	17,700	$177,000
	Achievement		8	25	20	13	15	80
52	Time	Days	0	12	20	12	11	55
	Cost (Dollars)		0	11,850	15,800	31,600	19,750	$79,000
	Achievement		0	7	8	7	9	30
53	Time	Days	7	28	18	21	6	80
	Cost (Dollars)		2,760	15,640	23,000	27,600	23,000	$92,000
	Achievement		13	24	19	18	18	90
54	Time	Days	7	21	21	28	13	90
	Cost (Dollars)		0	10,710	15,750	22,050	14,490	$63,000
	Achievement		0	6	4	4	6	20
55	Time	Days	14	35	35	60	41	185
	Cost (Dollars)		7,600	32,300	32,300	66,500	51,300	$190,000
	Achievement		5	20	15	20	17.5	77.5
56	Time	Days	12	32	35	42	24	145
	Cost (Dollars)		2,340	23,400	28,080	40,950	22,230	$117,000
	Achievement		7.5	18	20.5	20	14	80
57	Time	Days	4	17	14	12	9	56
	Cost (Dollars)		1,020	6,120	10,200	17,850	15,810	$51,000
	Achievement		3	8	7	7	5	30
58	Time	Days	0	14	21	35	15	85
	Cost (Dollars)		0	10,800	15,840	21,600	23,760	$72,000
	Achievement		0	29	24	20	18	90
59	Time	Days	8	14	20	12	11	65
	Cost (Dollars)		1,740	15,660	22,620	25,230	21,750	$87,000
	Achievement		6	19	19	21	17	80
60	Time	Days	8	12	10	15	5	50
	Cost (Dollars)		5,200	12,350	14,950	17,550	14,950	465,000
	Achievement		2	2	2	2	2	10

<u>Appendix C key Informant's Interviews</u>

<u>Interview</u>

Part A – Warm-up questionnaire

(Please note that all the information provided will be kept confidential and used anonymously. Information will only be used for this study and will be destroyed after the study finishes.)

You name:

Your job title:

Company Name:

Which industry company belongs to?

Number of employees:

Total sales/Turnover:

How would you describe your role and involvement in your company's ERP implementation?

Number of people in project team + external consultant:

Was implementation successful? Yes [ ] No [ ]

Did your implementation completed on time? Yes [ ] No [ ]

Did your project completed inside the allocated budget? Yes [ ] No [ ]

Did you use consultant during the ERP implementation? Yes [ ] No [ ]

<u>Part b- Interview Schedule</u>

<u>Introduction:</u> *I am conducting this interview to study the ERP implementation in SMEs and the role of five critical success factors (CSFs) during implementation, allocation of resources and to evaluate the performance of developed simulation model. The information you provide will be recorded and it will be kept confidential and used anonymously. Information will only be used for this study and will be destroyed after the study finishes.*

** Practical Action: Spend 5 minutes showing the CSFs model to participants and explaining the 5 main CSFs that have been used.*

Part 1

In this section I will obtain information about general views on the need and importance of a prediction model.

1. Your views on the prediction model for ERP implementation?

    [Possible follow up: its importance/ practical operational value]

Notes: Body language/face expression upon hearing question/ explaining with examples/Focussed/Relaxed or in a rush etc.

Part 2

I would like to have your opinion on role of critical success factors in general and Five CSFs selected for this study in particular during implementation.

1. The Critical Success Factors applied in this model are most cited in the ERP literature.

    a). Please indicate level of importance you suggest for selected CSFs in Table 1.

    b). Based on your practical experience and expertise, are there other CSFs that you think can play essential role in implementation?

Notes: Body language/face expression upon hearing question/ explaining with examples/Focussed/Relaxed or in a rush etc.

Part 3

Now, in this section I will discuss with you the variables which are applied in this model to evaluate CSFs. The variables include; time, cost and achievement.

1. How would you rank the relative importance of variables of time, cost and achievement in ERP implementation?

a) Which is the more important?

b) In your view are they good predictors of implementation results?

Notes: Body language/face expression upon hearing question/ explaining with examples/Focussed/Relaxed or in a rush etc.

Part 4

In this section I will ask you questions in regards to simulation model demonstration that we just observed.

1. What do you think about the potential overall performance of the model?

   a) Can you suggest any changes to improve its effectiveness in decision making or effort prediction?

   b) How effective can it be in assisting a company's resources allocation (money and time)?

Notes: Body language/face expression upon hearing question/ explaining with examples/Focussed/Relaxed or in a rush etc.

Part 5

Every critical success factor is defined by its attributes. In this section I would like to find out, in the light of your experience and expertise, what are the key attributes of following CSFs?

Top Management support

Users

Project Management

Infrastructure/Database

Vendors Support

b) . How the staff was allocated to each CSF (Table 2)?

Table 1.

CSFs	Level of Importance in your view		
	Very Important	Neutral	Unimportant
Database/Infrastructure	☐	☐	☐
Project Management	☐	☐	☐
Top Mgmt. Support	☐	☐	☐
Users	☐	☐	☐
Vendor’s Support	☐	☐	☐

Table 2

Staff allocated to each CSF

CSFs	No. of Staff allocated
Database/Infrastructure	
Project Management	
Top Mgmt. Support	
Users	
Vendor’s Support	

Appendix D: Probability distribution of t_i

n_{t_1}	$Prob(t_1)$	t_2	n_{t_2}	$Prob(t_2)$	t_3	n_{t_3}	$Prob(t_3)$	t_4	n_{t_4}	$Prob(t_4)$	t_5	n_{t_5}	$Prob(t_5)$
7	0.11	4	2	0.03	3	1	0.02	3	1	0.02	3	1	0.02
1	0.02	5	1	0.02	10	3	0.05	4	1	0.02	5	4	0.07
1	0.02	7	1	0.02	14	2	0.03	7	1	0.02	6	5	0.08
2	0.03	9	1	0.02	15	1	0.02	10	3	0.05	7	1	0.02
4	0.07	12	4	0.07	16	1	0.02	11	1	0.02	8	1	0.02
7	0.12	14	5	0.08	17	1	0.02	12	3	0.05	9	2	0.03
4	0.07	17	2	0.03	18	5	0.08	14	2	0.03	10	3	0.05
1	0.02	18	1	0.02	19	1	0.02	15	3	0.05	11	3	0.05
8	0.13	20	5	0.08	20	5	0.08	18	3	0.05	13	2	0.03
2	0.03	21	8	0.13	21	7	0.12	20	4	0.07	14	6	0.10
8	0.13	23	1	0.02	25	3	0.05	21	5	0.08	15	2	0.03
2	0.03	25	2	0.03	28	5	0.08	24	1	0.02	18	2	0.03
3	0.05	28	5	0.08	30	8	0.13	27	1	0.02	19	2	0.03
2	0.03	30	4	0.07	33	1	0.02	28	3	0.05	20	6	0.10
1	0.02	32	1	0.02	35	6	0.10	30	4	0.07	21	2	0.03
5	0.08	35	4	0.07	36	1	0.02	33	1	0.02	24	1	0.02
1	0.02	40	1	0.02	40	1	0.02	35	4	0.07	25	2	0.03
1	0.02	42	1	0.02	42	1	0.02	37	1	0.02	26	1	0.02
		45	1	0.02	49	1	0.02	39	1	0.02	27	1	0.02
		50	1	0.02	60	1	0.02	40	1	0.02	28	1	0.02
		52	1	0.02	70	1	0.02	42	1	0.02	30	5	0.08
		56	1	0.02	90	2	0.03	50	2	0.03	33	1	0.02
		60	3	0.05	180	1	0.02	56	1	0.02	40	2	0.03
		76	1	0.02				60	2	0.03	41	1	0.02
		90	1	0.02				63	1	0.02	44	1	0.02
		130	1	0.02				65	1	0.02	90	1	0.02
								70	2	0.03			
								180	1	0.02			

Appendix E: Confidence interval

The confidence interval is an interval estimate of a population parameter and is used to indicate the reliability of the estimate and can be interpreted as the range of values that would contain the true population value 95% of the time if the survey is repeated on multiple time.

In this research confidence interval of the average project outcome from the DSS_ERP is calculated to verify the veracity of the model. In order to determine the confidence interval, the upper limit and the lower limit of the confidence is estimated which is the product of margin of error and average values, as shown in Table 1 below;

	Project duration	**Implementation cost**	**Performance level**
Average	129	131676	66
Std. Deviation	48.55	48747.00	7.95
Sample Size	60	60	60
Confidence Coefficient	1.99	1.99	1.99
Margin of error	2	1684	0.27
Upper Bound	**131**	**133360**	**66.27**
Lower Bound	**127**	**129991.65**	**65.73**
Max	117141.00	119341144010.00	82.99
Min	1.96	1.96	1.96
Range	117139.04	119341144008.04	81.03

Table 1 Data for determination of Confidence interval

Therefore, as show in Table 2, the average project outcome values fall within the the 99% confidence interval values verifying that the analytical model closely resemble the real life implementation.

Observed results	128	131,806	66
99% confidence interval	127,131	129,991,133,360	65.76,66.27
Simulation results	129	131,676	66

Table 2 Comparison of results

Appendix F: Publications generated during the PhD study

During the PhD study, three papers have been published or submitted for possible publication in scientific journals, as listed below:

- Ali, M. and Xie, Y. (2011) A decision support system for ERP systems Implementation in Small and Medium Enterprises (SMEs), Communication in Computer and Information Science, 219, pp. 310-321
- Ali, M. and Xie, Y. (2012) The quest for successful implementation: A new dynamic model for ERP system implementation Innovation, International Journal of Innovation in Business, 1(2), pp. 113-133
- Xie Y., Allen C. and Ali M. (2013 forthcoming), "An integrated decision support system for ERP implementation in SMEs", accepted to be published in *Journal of Enterprise Information Management*

Book chapter

- Ali, M., Xie, Y. and Cullinane, J. (2013) 'A decision support system for ERP systems Implementation in Small and Medium Enterprises (SMEs)', IGI Global Publications, Hershey, PA