Information Technology Business Value Model for Engineering and Construction Industry

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DECLARATION

I certify that except where due acknowledge has been made, this report (as part of PhD thesis) is produced by the undersigned alone. The report is submitted under the University of Salford regulations for the award of a PhD degree by research; it has not been submitted before, in whole or in part to any university or other institute of learning to qualify for any academic award.

Signed: ....

Yahuza Hassan Kassim

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DEDICATIONS

Dedicated to:

My wife Fatima who has always supportive of all my endeavours

My Children: Fawziyyah, Yasir, Al-Kassim, and Khadija;

They paid the price of living without total dedication
of husband and father during the
period of this study.

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LIST OF ABBREVIATIONS

BCC	Banker, Charnes and Cooper
BWE	Business Work Environment
CA	Competitive Advantage
CCR	Charnes, Cooper and Rhodes
CIO	Chief Information Officer
COST	Cost Performance Parameter
CRS	Constant returns to scale:
CUSTO	Customer Satisfaction Parameter
CVC	Construction Value Chain
DEA	Data Envelopment Analysis
DMU	Decision Making Unit
DRS	Decreasing Returns to Scale
EMR	Experience Modification Rating
IT	Information Technology
ITBA	Information Technology Business Applications
ITBV	Information Technology Business Value
ITHS	Information Technology Human Skills
ITI	Information Technology Infrastructure
ITSI	Information Technology Shared Infrastructure
MPSS	Most Productive Scale Size
PROFI	Profit Performance Parameter
RBV	Resource-Based View
SAFETY	Safety Performance Parameter
SCHD	Schedule Performance Parameter
TFP	Total factor productivity
VC	Value Chain
VRS	Variable Return to Scale

MATHEMATICAL NOTATIONS

Symbol	example	Meaning
$\in$	$a \in A$	is an element in set A
$\notin$	$a \notin A$	is not an element of set A
$\subseteq$	$A \subseteq B$	Set A is a subset of set B
$\varnothing$	$A = \varnothing$	A is an empty set
$\{a \in A : *\}$		a subset of A formed by the elements satisfying property *
$\cup$	$A \cup B$	$\{x : x \in A \text{ and } x \in B\}$
$\cap$	$A \cap B$	$\{x : x \in A \text{ or } x \in B\}$
$\backslash$	$A \backslash B$	$\{x : x \in A, x \notin B\}$
$+$	$A+B$	
$\Re^N$		Euclidean space of dimension N
$\geq$		$x, y \in \Re^N, x \geq y$ if and only if $x_n \geq y_n$ $n = 1, 2, \ldots.., N$
$\geq$		$x \geq y$ if and only if $x \geq y$ and $x \neq y$
$\sum$		Sum sign
$\Leftrightarrow$		if and only if
$\Rightarrow$		
$\forall$		for all
$\exists$		there exists
s.t.		subject to
$\to +\infty$		tends to $+\infty$
$\boldsymbol{\varepsilon}$		Epsilon is a very small positive constant

ABSTRACT

The idea that the deployment and strategic utilization of information technology (IT) resources as factors of production can be used by organisations to improve performances has been around for many decades. The contributions of the IT resources in improving organisation's performances give rise to what is termed IT business value (ITBV). There have been varieties of conceptualizations and attempts to measure the ITBV by different researchers. However, most of these attempts to quantify ITBV have led to inconsistencies and paradoxes. Furthermore, a major part of the literature in the area continues to be anecdotal and primarily descriptive. Therefore, there is little evidence of an accepted theoretical framework for applying the ideas and there is even less in the way of empirical evidence concerning the validity and utility of these concepts.

The research adopts multi-theoretical concepts of process-based, resource-based and microeconomics views as the theoretical framework in order to mitigate the absence of structured theoretical framework in the previous studies. A non parametric approach of Data Envelopment Analysis was used for empirical testing of the model developed.

The findings present an empirically tested model for benchmarking IT-induced productivity in construction industry. Also the outcome of the research establishes that IT provides business value in undertaking the engineering and construction business processes, which leads to significant impact on the organisations performances in the areas of project delivery, customer relationship and overall profit growth.

For practical purposes, the model could be used to provide support to managers in decision making on IT investments, utilization of the IT resources and how combination of strategic IT resources with other organizational resources could in increase efficiency in delivering project value chains.

Key Words: Information Technology Business Value, Engineering and Construction Organisations, Construction Management, Performance Measurement and Data Envelopment Analysis.

CHAPTER ONE
BACKGROUND

1.0 Background

The strategic impacts of Information Technology (IT) on the organisations' performances have been of interest to both managers and researchers for decades (Benjamin *et al.,* 1984; Bakos and Treacy, 1986; Tan, 1996; Davis *et al.,* 2003). Studies in the field have led to the suggestion that IT-enabled strategies could be used to gain competitive advantage. The argument is that IT resources do offer strategic advantage to organisations through efficient and cost effective delivery of the organisation's value chain.

However, most of these studies were carried out through imprecise and unstructured theoretical constructs that seem to lead to equivocal results (Porter and Millar, 1985; Mahmood and Soon, 1991; Lee, 2001). Furthermore, there is a dearth of empirically validated frameworks used in most of the studies (King *et al.,* 1989). Attempts to explain the inconsistencies in the various studies on the impact of IT on organisation performance ascribed difficulties associated with modelling and measurements of the return of IT investment, mode of data collection and sampling, industry type, and choice of dependent variables as some of the major reasons (Brynjolfsson, 1993; Kohli and Devaraj, 2003; Oh and Pinsonneault, 2007).

Despite a multitude of studies on ITBV and the concept of an organisation's competitive advantage using IT-enabled strategies, there is no known model in literature that measures the ITBV value addressing the unique nature of the construction industry. On the other hand, most of the concepts of competitive advantage (CA) in strategic management are derived with particular reference to manufacturing industries, hence, not directly applicable to services industry such as construction. Therefore, the objective of this research is to contribute in mitigating these drawbacks thereby filling the vacuum in the literature of evaluating IT investments in the construction organisations and construction management.

1.1 Definition of the Problem

In scoping the research problem a detailed literature review on how the utilization of IT resources impact on performance of engineering and construction organisations was initiated. Thus, the gap in knowledge related to how the impact could be evaluated was identified. This invariably led to formulating the following research question.

1.2 Research Questions

To increase the understanding of the impact of utilization of IT in the execution of engineering and construction organizations value chains and their performances; the research study addressed the following question:

> *"What are the possible impacts of deploying and utilizing IT resources in the presence of other complementary organisational resources on the performances of engineering and construction organisations in United Kingdom?"*

1.3 Research Aim

The research was to develop and empirically validate information technology business value model strategy for engineering and construction organisations.

1.4 Research Objectives

The objectives of the research include:

- To investigate the impact of IT resource utilizing on the performance of engineering and construction industry in the UK.
- To develop a comprehensive process-oriented model of ITBV to investigate the impact of IT resources on the performance of engineering and construction organisations.
- To use the organisations' value chain for delivering construction project to measure the intermediate impacts of the IT resources and

then aggregate to organisational level to establish the overall organisational performances.

- To use the non parametric technique of DEA to benchmark the engineering and construction organizations' IT-induced performances

1.5 Scope of Research

The study considered the level of IT resources deployed and used by the UK engineering and construction organisations as a form of automation to investigate and reported the findings of their impact on the organisations' performances. The study integrated three theoretical perspectives of process-based, microeconomic and resource-based views to develop a conceptual model for the research. Using a non-parametric technique of Date Envelopment Analysis (DEA) the conceptual model was empirically tested and validated.

1.6 The Research Processes

The research processes adopted towards achieving the objectives of the research included reviewing and synthesising the current literature on the related field of the research; developing a new concept to describe the area and subject of the research, empirical testing and presentation of the findings in form of new knowledge (Sarantakos, 1993).

The overall strategy adopted for this research was survey questionnaire with unstructured interviews; and the processes of the research is showing the stages involved is depicted in Figure 4.1 in chapter four.

The first phase of the research involved reviewing the existing literatures in filed of management strategy, information technology as a factor of production, competitive advantage, engineering and construction processes and management, construction management research methodology, data analysis techniques, among others. Gaps and drawbacks in previous studies were identified which provided the basis and foundation for the current research (Davis *et al.*, 1989). The research aim and objectives were established leading to defining the research question.

In order to provide a medium for answering the research question, a conceptual model was derived using the theories and paradigms from the literature as the second phase of the research processes. The model derivation is presented in further detail in chapter three.

The third stage of the process involved the mapping of the conceptual model to the DEA mathematical model, empirical testing of the DEA model using a pilot survey study in order to provide a first hand 'real world' experience on issues related to the research design, conceptualization, interpretation of findings (Kezar, 2000; Nyatanga, 2005; Thabane *et al.,* 2010). The outcome of the pilot study provided a guideline:

- To help validate the proposed engineering and construction value chain and the work functions,
- To improve the internal validity of the data collection techniques and the set of questionnaires,
- To improve the data collection methods including establishing the sample size to satisfy the DEA protocols requirements.

The remaining parts of the research design including the strategy are presented in the subsequent chapters. This chapter explain the processes for determining the research methods appropriate for answering the research question, the data collection approach and tools. The final processes involved the choice of data analysis approach, tool, interpretation and presentation of the findings with conclusion.

1.7 Contribution to Knowledge

The outcome of the research provides a theoretically improved structured and empirically tested model for evaluating IT business value in engineering and construction organisations. The model could be used to benchmark and establish the relative IT-induced performances of the organisations within strategic groupings of construction industry. For practical purposes, the model could be used to provide support to managers in decision making on IT investments, utilization of the IT resources and how combination of strategic IT resources with other organizational resources could provide sources of sustained competitive advantage in their organisations.

The research has made significant contributions in the areas of construction management, alignment of IT and business strategies for better performance in the industry, practical application of non-parametric technique for evaluating productivity of IT-enable engineering and construction business strategy. Specifically the research contributions to the body of knowledge in these fields include:

- The DEA ITBV model provides mitigation against the limitations of the existing IT investments evaluation frameworks and addressed the unique nature of the engineering and construction value chain.
- The model could be used to benchmark and establish the relative competitive advantages of the engineering and construction organisations within strategic groupings of the construction industry.
- The empirical evidence established that IT provides business value in undertaking the engineering and construction business processes leading to significant impact on the organisations performances in the areas of project delivery, customer relationship and overall profit growth.

1.8 Thesis Structure

The thesis is structured into the following chapters:

Chapter one: This chapter provides the summary of the seven chapters that made up of this thesis from background to conclusion.

Chapter two: This chapter reviews the literature in detail utilizing the paradigm funnel approach in the areas of information technology, organisation performance, construction management, strategic management, engineering and construction value chain, theory of competitive advantage, economic theory of production, resource based theory and the concept of information technology business value among others. The chapter starts with a broad review of concepts and empirical works in these fields and narrows down to the current research objectives focusing on the current IT research methodology in engineering and construction management. The insight gained led to the research proposition, aim and objective with the view to contribute and fill in the vacuum found in the literature of IT business value in engineering and construction organisation. The findings lead to challenging some of the ontological and epistemological core assumptions of the previous studies.

Chapter Three: This chapter provides a detailed description and analysis that led to the conceptualisation and derivation engineering and construction industry value chain and the formulation of research question and hypotheses; conceptual ITBV model and variables measures operationalisation. ITBV is viewed as the positive outcome of deployment and implementation of IT resources in the delivery of engineering and construction projects value chain as a measure of the performance metrics including cost, schedule, profitability, safety and customer satisfaction.

Chapter Four: The justification for the overarching research philosophical stance, methodology, methods and techniques adopted are presented in this chapter. The chapter highlights the researcher's understanding of the assumptions of different paradigms and how they were deployed in the research processes to bring about a good fit between paradigms and methods. The chapter addresses the research methodology, justifying the choice of strategy and method adopted. These issues include philosophy, philosophy branches, paradigm, paradigm types, research approach, research strategy, research choices, time horizons, data collection techniques, testing/validation/evaluation, etc. The chapter also distinguishes between research methodology and method. The chapter presented methods adopted to ensure the validity and reliability of the research process. Both the methodology and the research strategy were outlined, linked to literature, and appropriately justified in line with literature.

Chapter five: The chapter presents an analysis of primary data that was collected from a pilot study. The aim of the pilot study was to help test the methods and procedures proposed for the research. The outcome of the pilot study provides a guide used to fine tune the research design, establish the effectiveness of the research methodology, sampling and the internal validity of data collection techniques data collection tools, validation of the proposed primary activities of the engineering and construction value chain and their corresponding work functions, establish the validity of use of the DEA in evaluating the survey data.

Chapter six: Following the pilot study reported in chapter 5, another survey with larger sample size aimed at (1) satisfying the DEA protocols requirements and (2) covering most of the construction industry sectors was launched. This chapter presents the results and analysis that lead to findings and conclusion of the research.

Chapter seven: The chapter presents the conclusions drawn from the analysis and findings of chapter six. It highlights the contributions to knowledge from the research findings, recommendations, business management applicability and future research.

CHAPTER TWO
THE RESEARCH THEORITICAL PARADIGMS

2.0 Introduction

This chapter reviews the literature in detail in the areas of information technology, organisation performance, construction management, strategic management, engineering and construction value chain, theory of competitive advantage, economic theory of production, resource based theory and the concept of information technology business value among others.

An extensive review of the information technology business value (ITBV) literature utilizing the paradigm funnel approach (Berthon *et al.* 2003) was carried out. Thus, understanding of the metaphysical assumptions upon which streams of research in the areas of strategic applications of information technology in delivery of engineering and construction organisations value chains to gain competitive advantage was gained.

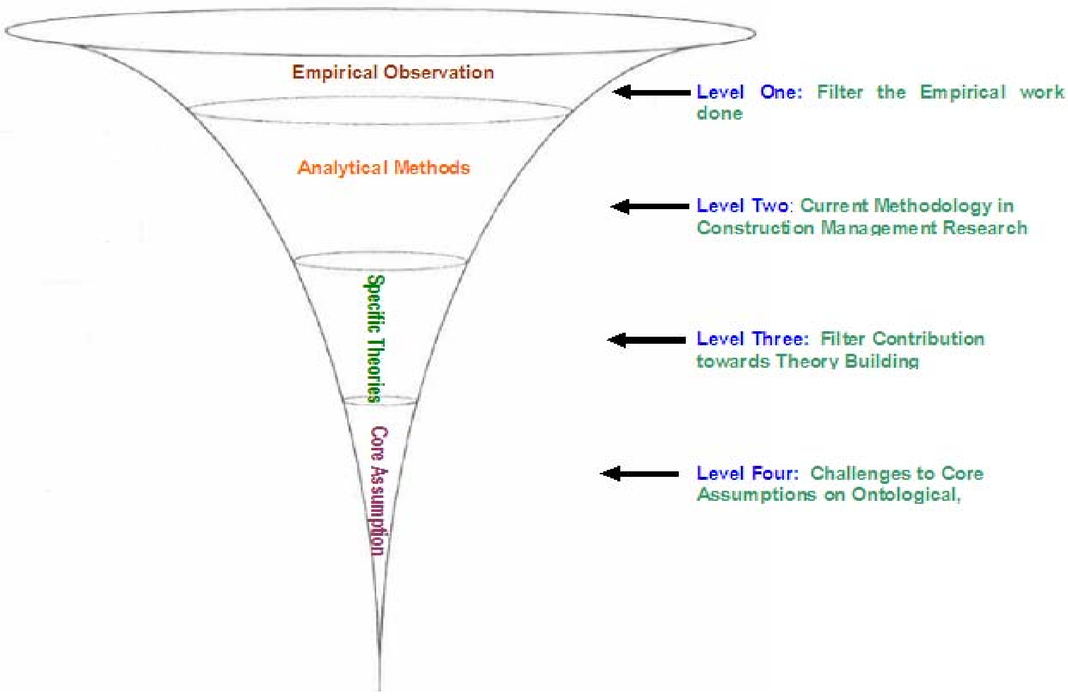

Figure 2.1 The Paradigm Funnel (Berthon et al. 2003)

The chapter presents what has been researched, how it has been researched, and what the key issues therein distilled at different levels as depicted in Figure 2.1. The applicability and criticisms of the main theories, frameworks and concepts related to the areas of the study were reviewed and noted in a continuous cyclic process as part of the research strategy. A brief catalogue of the previous research work in the same area of the proposed study, with in depth analysis and selective enlistment of opinions, propositions from previous research are presented in the next subsections.

The review include a number of surveys conducted in the construction industry to investigate the status of IT applications in the industry in several countries were identified. These include countries such as Saudi Arabia (Shash, Ali and Al-Amir, 1997; O'Brien and Al-Biqami, 1999); Scandinavia (Howard, Kiviniemi, and Samuelson, 1998); Australia (Stewart, Mohamed and Marosszeky, 2004; Peansupap and Walker, 2005; Chen, *et al.,* 2001); UK (O'brien, and Al-Soufi, 1994; Aouad and Price, 1994); Japan (Pen˜a-Mora, and Tanaka, 2002); USA (Hansen; and Groák, 1998); Singapore (Ofori, 2004); China (Jia Du and Feicheng, 2004); Brazil (Chavez and Canongia, 2004); Taiwan (Tan, 1996); Europe(Hannus *et al*., 1999); Canada (Hugues, 2000); New Zealand (Doherty, 1997); Sweden, Denmark and Finland (Howard and Samuelsson, 1998, Howard et al., 1998); Hong Kong (Futcher and Rowlinson, 1998; 1999).

The relationship between strategy and information technology (Weill 1992; Mahmood and Mann, 1993; Tan, 1996; Kettinger *et al.,* 1995; Chan *et al.,* 1997; Palvia, 1997; Li and Ye, 1999; Palmer and Markus, 2000; Dans, 2001; Davis *et al*., 2002; Hyvönen, 2007) was then reviewed intensively examined in the literature.

The chapter highlights filtered review of the broad empirical work on the IT business value that were not engineering and construction domain specifics, and then narrowing and focusing on the current IT research methodology in engineering and construction management. The findings lead to challenging some of the ontological and epistemological core assumptions of the previous studies.

2.1 Concepts of Competitiveness

The term competitiveness originated from the Latin word, *competer,* which means involvement in a business rivalry for markets. One popular view of *Competitiveness* is as a comparative concept denoting the ability and performance of a given country, industry or an organisation. Thus, competitiveness is viewed from these three levels of abstraction (Buckley *et al*., 1988; Momaya and Selby, 1998; Murths, 1998; Ambastha and Momaya, 2004; Henricsson *et al.,* 2004; Flanagan *et al.*, 2005; 2007).

The sources of competitiveness for an organisation to gain Competitive Advantage include its assets and processes. The competitiveness processes are defined as those processes, which help identify the importance and current performance of core processes such as strategic management processes, human resources processes, operations management processes and technology management processes (Ambastha and Momaya, 2004) and defined in the organisation's value chain.

Porter (1990) argues that there was no accepted definition of competitiveness, while Turner (1991) submits that the definition of the concept of competitiveness is not important as long as the outcome of it is good. On the other hand, Henricsson *et al*. (2004) stress that defining competitiveness matters. These and other views led Flanagan *et al* *(*2007:990) to conclude:

> *"..researchers have failed to reach a consensus on the meaning of competitiveness despite its widespread use in academia and industry."*

Nevertheless there are variety of working definition for the concept of competitive advantage, theories for the sources of competitive advantage and sustainable competitive advantage.

Day and Wensley (1994) insist that a complete definition of competitive advantage must describe not only the state but also how that advantage is gained. Sustained competitive advantage flows from organizational capabilities and resources that are rare, valuable, non-substitutable, and imperfectly imitable (Barney, 1991; 2001; Lado and Wilson, 1994). It is obtained by firms implementing strategies that exploit their internal strengths, through responding to environmental opportunities, while neutralizing threats and avoiding internal weaknesses (Byrd and Turner, 2001).

2.2 Theories of Competitive Advantage

Competitive Advantage (CA) can result either from implementing a value-creating strategy that is not being simultaneously implemented by any current or potential competitors (Barney, 1991) or through superior execution of the same strategy as competitors. Hofer and Schendel (1978: 25) describe CA as “the unique position an organisation develops vis-à-vis its competitors”. CA is mainly derived from resources and capabilities.

Resources have been termed “assets”, “strengths and weaknesses” and “stocks of available factors” (Amit and Shoemaker, 1993; Wernerfelt, 1984). The capabilities of an organisation are what it can do as a result of teams of resources working together.

An organisation is said to have a sustained CA when it is implementing a strategy that is not simultaneously implemented by many competing organisation and where these other organisations face significant disadvantage in acquiring the resource necessary to implement this strategy (Maa *et al.*, 1995).

A variety of factors have been shown to have an important impact on the ability of organisations to obtain CA, including the relative cost position of the organisation (Porter, 1980), the organisation’s ability to differentiate its products (Caves and Williamson, 1985; Porter, 1980) and the ability of organisations to corporate in strategic alliances (Kogut, 1988).

Amongst the plethora of theories explaining how organisations could achieve competitive advantage, three main schools were identified (Flanagan *et al.*, 2007) as most prominent:

- The CA and competitive strategy models (Porter, 1980, 1985)
- The resource-based view and core competence approach (hereafter the RBV) (e.g. Wernerfelt, 1984; Prahalad and Hamel, 1990; Barney, 1991) and
- The strategic management approach (e.g. Chandler, 1962; Ansoff, 1965).

2.2.1 Porter's Theory

Porter's theory for organisation's competitiveness is characterized as the industrial organization view of CA, which was grounded on the earlier works of Mason (1939) and Bain (1959) in the area of industrial organization economics (Flanagan *et al.*, 2007; Kale, 2002). Porter (1986:3) states:

> *"Competitive advantage grows fundamentally out of the value a firm is able to create for its buyers that exceeds the organisation's cost of creating it. Value is what buyers are willing to pay, and superior value stems from offering lower prices than competitors for equivalent benefits or providing unique benefits that more than offset a higher price. There are two basic types of CA: cost leadership and differentiation."*

Porter's definition of competitive advantage seems to implicitly equates competitive advantage to profitability, and sustainable advantage to sustainable profitability (Ma, 2000). Major components in Porter's theory are the five competitive forces model, the three generic competitive strategies, and the value chain.

2.2.2 The Porter's Five Competitive Forces Model

Porter´s (1980) assumed five variables to model the competition within an industry (Figure 2.2). The forces consists of(Thompson and Strickland, 2001):

1. "threat of new entrants";
2. "power of suppliers";

3. "power of buyers";

4. "threat of substitution" and

5. "jockeying for position".

Porter (1980) suggested that the threat of new entrants within an industry could be influenced by factors such as economies of scale; product differentiation; large capital requirements and cost disadvantages associated with learning curves and experience curves. Betts and Ofori (1992) suggest that, "….the threat of new entrants is not particularly potent within the construction industry"; however, they excluded large construction projects and high–tech end of the construction sector in their analysis (Olugbekan, 1991; Aniekwu, 1995).

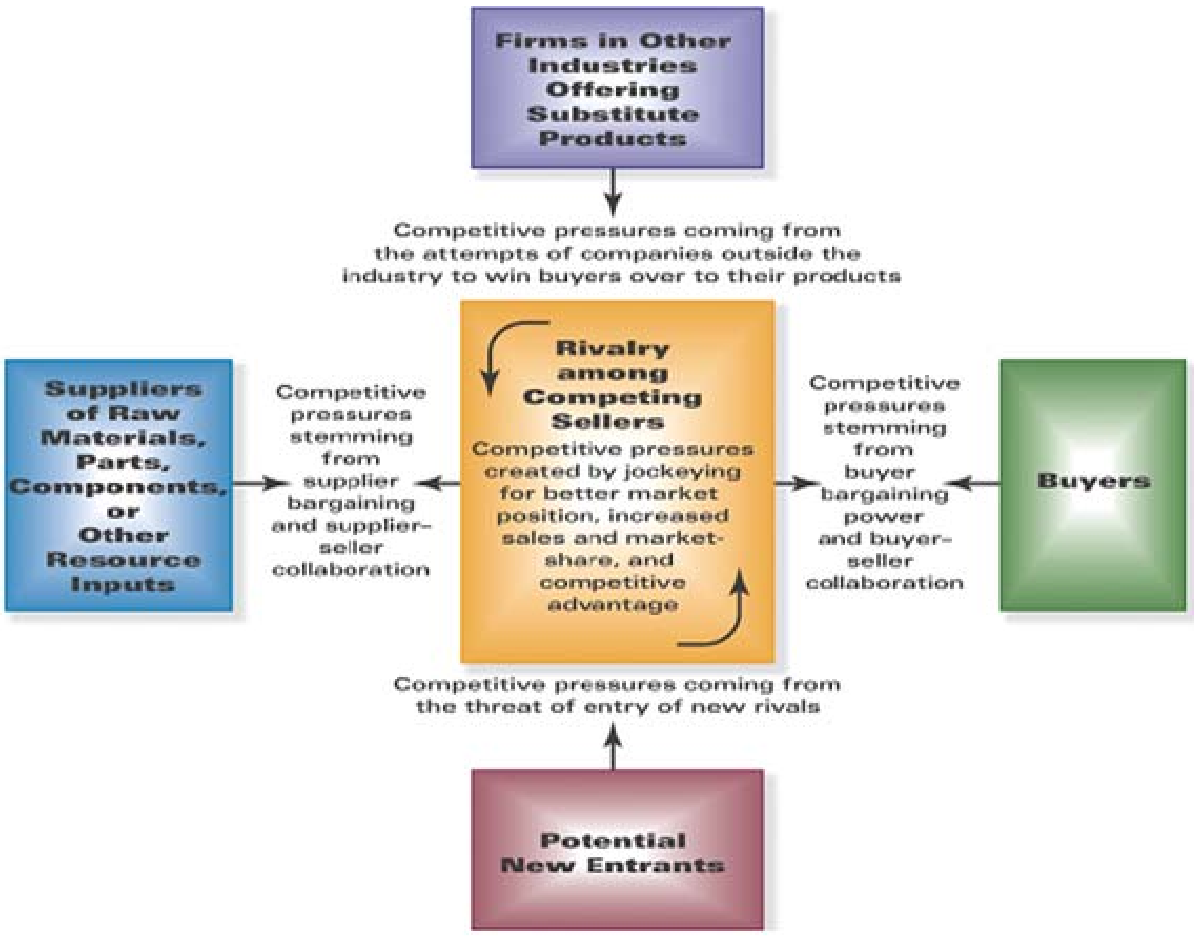

Figure 2.2 Five Competitive Forces Model (Thompson and Strickland, 2001)

The CA to be gained from powerful supply relationships is greatest when few organisations dominate supply, where there is no competing product, and when the supplier holds a threat of forward integration over the buyer. A forward integration business model allows an organisation to take direct control of how its products are distributed; thereby helps achieve greater economies of scales or higher market share. In the construction industry, there are many different suppliers of many products and services (Betts and Ofori, 1992). A backward integrating of an organisation's value chain tends to increase the competitive advantage over its peers (Kassim, 2006). Furthermore, the potential for substitute products give scope for competitive advantage within an industry.

There is evidence to suggest that the jockeying for position is strong within the engineering and construction industry due to the relative size of the competitors, the slow growth of the industry and the difficulties to differentiate their products and or services (Betts and Ofori, 1992).

Despite Tatum (1988) suggesting that the construction industry has a high fit with each component of the five force model, Betts and Ofori (1992) contend that there is little evidence to suggest that construction organisations are systematically examining these forces and their relevance to the strategic planning and management of their firms.

Nevertheless, Porter's choice of the five forces was criticized. It was argued that the choice was arbitrary and there was no indication on how to operationalize any analysis based on them (O'Schaunessy, 1984; Shahid *et al.,* 1999). Porter's five forces model tends to assume a perfect market situation and does not seem to explain today's dynamic business environment.

However, Chaffey (2002) supports Porter's classic model of the five main competitive forces and he says that it still provides a valid framework for reviewing threats arising in the e-business era. The value of Porter's model enables managers to think about the current situation of their industry in a structured, easy-to-understand way as a starting point for further analysis

2.2.3 The Three Generic Competitive Strategies

According to Porter (1998a; 1988b), for an organisation to find a competitive edge within the five forces model it must adapt one of three generic strategies (Figure 2.3): *cost leadership, differentiation, or focus*. He called these 'generic strategies' because they can be applied to an organisation in any industry. A cost leadership strategy is one in which an organisation strives to have the lowest costs in the industry. A firm that uses a differentiation strategy is one that tries to offer products or services with unique features that customers value. The value added by the uniqueness lets the organisation command a premium price. The focus strategy can be either a cost leadership or differentiation strategy aimed toward a narrow market.

Figure 2.3 Porter (1998) Generic Strategies

2.2.4 Organisation Value Chain

Porter (1998a) suggests that a systematic way of examining a firm's business processes and how the individual activities interact is necessary for analysing source of competitive advantage. The tool for these analyses proposed by Porter is termed value chain.

A value chain disaggregates an organisation into its strategically relevant activities and potential sources of CA. The value chain divides the organisation's activities into technologically and economically distinct value providers. A company's value chain is a system of interdependent activities, which are connected by linkages. Linkages exist when the way in which one activity is performed affects the cost or effectiveness of other activities (Porter and Miller, 1998). The organisation gains competitive advantage by performing these strategically important activities more cheaply or better than its competitors (Porter, 1998a).

Porter (1985) argues that to identify the potential for competitive advantage it is necessary to look at the individual parts of the whole organisation using the value chain concept. He suggested that the difference between value chains are a key source of competitive advantage between competitors and stresses the importance of IT to value chain analysis. Betts and Ofori (1992) state that there are no published examples of specific application of the concept in construction enterprises, although the principles are apparent in some other industries.

An important concept that highlights the role of IT in competition is the 'value chain'. This concept divides an organisation's activities into the technologically and economically distinct activities it performs to do business in line with Porter's value chain concept (Porter and Miller, 198).

Careful management of linkages is often a powerful source of competitive advantage because of the difficulty rivals have in perceiving them and in resolving trade-offs across organizational lines.

Though there is no universally accepted application of the concept of value chain in the construction industry (Betts and Ofori, 1992); however, engineering and construction organisation being a project based industry; many authors have suggested phases of the construction process as the primary activities of the value chain (Baden and Baden, 1993; Garnett and Pickrell, 2000; O'Connor *et al*., 2000; Back and Moreau 2000). The engineering and construction project phases identified include front-end design, procurement, construction management, construction execution, commissioning and start up, operation and maintenance.

CA in either cost or differentiation is a function of a company's value chain. A company's cost position reflects the collective cost of performing its value activities relative to rivals. Similarly, a company's ability to differentiate itself reflects the contribution of each value activity toward fulfilment of buyer needs (Porter and Miller, 1998).

Competitive scope is a powerful too for creating CA. A broad scope can allow the company to exploit interrelationship between the value chains serving different industry segments, geographic areas, or related industries. By selecting a narrow scope, on the other hand, a company may be able to tailor the value chain to a particular target segment to achieve lower cost or differentiation (Porter and Miller, 198).

The value chain provides a rigorous way to understand the source of buyer value that will command a price, and why one product or service substitutes for another. An organisation's value chain is a system of interdependent activities, which are connected by linkages.

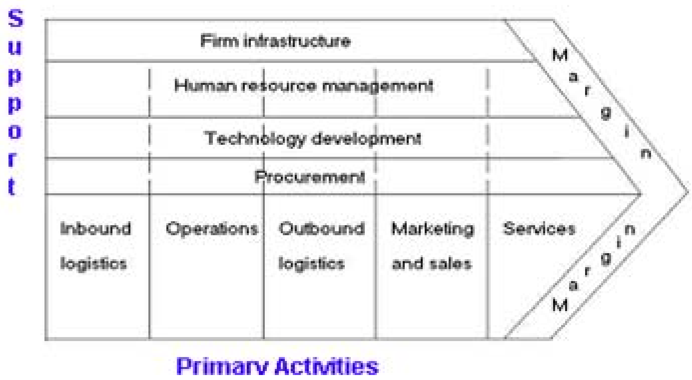

Figure 2.4 Typical Value Chain

A typical value chain as in Figure 2.4 disaggregates a firm into its strategically relevant activities and potential sources of CA. An organisation gains CA by performing these strategically important activities (the value chain) more cheaply or better than its competitors.

2.2.5 Merits of Porter's Theory

In analysing the competitiveness of firms, Porter's theory has been the dominant tool for the past two decades (Flanagan *et al.*, 2007). Its various merits include its simplicity (Miller and Dess, 1993) and its strong theoretical underpinnings (White, 1986),

Miller and Dess (1993) evaluated Porter's model of generic strategies on the basis of its simplicity, accuracy (predictive and explanatory power), and generalizability and conclude thus:

- Even though it is a simple framework, it captures a great deal of complexity.
- It does not provide a completely accurate portrayal of strategy-performance relationship of the ability and durability of combining strategic advantage, and
- The generalibility of the generic strategies is questionable.

2.2.6 Criticism of Porter's Theory

Murry (1988) argue that Porter's generic strategy concept does not satisfy the desire for a solid theoretical framework. He further stressed that for a theory to be useful, it should guide empirical research; however, such research generated by the concept (e.g. Dess and Davis, 1982; 1984; Hambrick, 1983; Miller and Friensen, 1986a, 1986b; White, 1986) are not comparable, and the results are contradictory concluded Murry (1988).

The concept does not address the internal mechanisms by which a company converts the influence of a challenging external environment into useful internal abilities (Lado *et al.,* 1992). For some companies, the pursuit of more than one generic strategy simultaneously is viable (Kassim, 2006; Hambrick, 1983).

As a way to overcome the stated weakness of the concept, Murry (1988) suggested a contingency approach. He postulated that the concept could be clarified by linking each strategy to a set of environmental pre-conditions. Developing these pre-conditions also allows the key question by Miller and Friesen (1986) on the compatibility of generic strategies to be resolved and facilitates a discussion of the link between strategies and the strategic means used to implement them (Dess and Davies, 1982, 1984).

On the other hand, Ma (2000: 16) inquire whether either cost advantage or differentiation advantage is sufficient and necessary for superior performance; assuming a negative answer he concluded that "competitive advantage, within Porter's perspective (1980, 1985) at least, does not equate to performance." He further argues that superior performance could also come from other types of competitive advantage, such as speed (Stalk, 1990; Eisenhard and Brown, 1998) or flexibility (Sanchez, 1993, 1995). CA and performance are two different constructs and their relationship seems to be complex.

2.3 Process-based View

Porter's concept of generic strategy was criticized for not satisfying a solid theoretical framework (Murry, 1988). It was argued that the concept does not address the internal mechanisms by which a company converts the influence of a challenging external environment into useful internal abilities (Lado *et al.*, 1992). Furthermore, for some organisations, the pursuit of more than one generic strategy simultaneously is found to be viable (Hambrick, 1983; Kassim, 2006).

However, Porter (1998) suggests that a systematic way of examining an organisation's business processes and how the individual activities interact to gain CA is by analysing the organisation's value chain. He further argued that an organisation gains CA by performing these strategically important activities more cheaply or better than its competitors (Porter, 1998). Thus, Porter's value chain concept satisfies process-based view, which postulates that IT investments create competitive advantages by improving operational efficiency of intermediary business processes, which in turn, under the appropriate conditions, lead to better organisation-level performance (Barua *et al*, 1995; Qing and Jing, 2005).

2.4 The Resource-Based View (RBV)

The RBV shifts the focus from the industry structure to the resources developed by a firm (Flanagan *et al.*, 2007). A major contribution of the

RBV is that it provides valuable suggestions for an organisation to focus on those organisational specific internal resources. Therefore, it largely complements the limitations that are inherent in Porter's theory (Miller and Shamsie, 1996). However, the concept of resources remains an amorphous one that is rarely operationally defined and tested in different competitive environments (Miller and Shamsie, 1996).

The main propositions of the RBV are:

- An organisation can be viewed as a collection of resources.
- CA does not depend on market and industry structures but stems from the resources inside a firm.
- Not all resources are necessarily the source of an organisation's CA, it is only the organisation specific resources that meet the criteria of valuable, rare, non-substitutable, imperfect limitability and imperfectly mobile.
- An organisation must identify and strengthen those organisation specific resources in developing its core competence.
- Usually, 'resources' here refer to not only the possession of organisation-specific resources, but also to the effective utilization of these resources to achieve CA.

The RBV proposed that the deployment and exploitation of valuable, rare resources, and capabilities contributes to an organisation's CA, which in turn contributes to its performance (Barney, 1991). Based on this paradigm it could be argued that IT-enabled strategy can improve organisational performance by creating sustainable competitive advantage via unique, immobile, and path-dependent strategic resources and capabilities (Bharadwaj, 2000; Sambamurthy *et al.,* 2003; Newbert, 2008).

The RBV shifts the focus from the industry structure to the resources developed by an organisation (Flanagan *et al.*, 2007). It is mainly based on Selznick's (1957) seminal work on 'distinctive competences' and on Penrose's (1959) early argument that an organisation is a collection of resources and its performance depends on its ability to use them (Ambrosini, 2003). The perspective really took off in the 1990s, when a number of conceptual papers were published (e.g. Barney, 1991; Conner, 1991; Mohoney and Pandian, 1992; Peteraf, 1993). Prahalad and Hamel (1990; 1994) promoted the principles by proposing that organisations should develop unique resources in order to achieve core competence and sustain growth.

The future of the RBV relies heavily on the search for clear empirical evidence. There is also a need to know which resources are valuable in which contexts and how resources can be managed in such a way as to sustain CA. Critics also pointed out that its inward focus may risk ignoring the nature of market conditions (Hooley *et al.,* 1997). It appears that the strengths of the RBV are the aspects where Porter's theory presents limitations (Flanagan *et al.*, 2007).

The theory has come also under critical scrutiny, partly because of the assumptions it makes with respect to the philosophy of science (Priem and Butler, 2001; Williamson, 1999). In particular, critics have focused on its validity as a *theory*, i.e. whether it makes its assumptions clear and empirically testable. The argument against it has been that it is tautological, in that it rests on statements that are not theoretically contestable or falsifiable. While the RBV has been spiritedly defended (Barney, 2001), what is especially striking is the manner in which the argument has been augmented by overt references to the philosophical positions held by the theorists. For instance, Priem and Butler (2001: 22) announce that their analysis "is undertaken from a logical-positivist rather than a post-positivist perspective "(Mir and Watson, 2001).

The RBV of an organisation emphasizes the importance of heterogeneous advantages, as firm heterogeneity lies in the core argument of that view: unique, difficult to imitate, and organisational specific resources generated CA (Barney, 1991).

2.5 Micro Economic Theory

The microeconomics-based view postulates that IT investments create excess return over other types of capital investments in production processes of organisations (Brynjolfsson and Hitt, 1996; Dewan and Min, 1997). Microeconomic theory is useful in conceptualizing the process of production and providing empirical specifications enabling estimation of the economic impact of IT (Melville *et al.*, 2004). This led to the argument that microeconomic production theory is the natural choice for investigating the productivity impact of IT (Mukhopadhyay, *et al.*, 1997). In microeconomics, the combination of feasible inputs and outputs is called the productivity possibility set. The economic view of IT value is that of input in the production function of an organisation and there is a substituting effect between IT and other production factors (Dewan and Chung-ki, 1997 The concept allows estimation of the measure of IT resources usage as an economic production function using a non-parametric technique such as DEA.

2.6 Strategic grouping

In addition to using industry structure to determine the performance of an organisation (Bain, 1956; Scherer, 1970; Porter1981) or using a resource based approach (Wernerfelt, 1984; Barney, 1991; Grant, 1991); a business could analyse the relationship between industry and the organisation using strategic grouping (Thompson and Strickland, 2001; Claver *et al.*, 2003).

A strategic group consists of those rival organisations with similar competitive approaches and positions in the market. They provide an intermediate frame of reference between viewing an industry as a whole and considering each organisation separately (O'Farrell, *et al.*, 1993; Chen, 1996; Flavian and Polo, 1999). There has been limited attention in the field of research on strategic management and strategic groups in the construction industry (Claver *et al.*, 2003). Using this concept to answer the research question could facilitate generalization of findings on the industry.

2.7 Impact of IT on Organisations' Performance

Several studies have suggested that when an IT-enabled strategy is implemented in the presence of heterogeneous organisation capabilities, such an organisation will be able to gain a sustained CA (Porter, 1980; Barney, 1991; Clemons, 1986; 1991; Clemons and Kimbrough, 1986; Clemons and Row 1987; 1991a; Feeny, 1988; Feeny and tves, 1990; Mata *et al.,* 1995). Such studies both theoretical and empirical provide evidences indicating that organisations implementing IT-enabled strategy are able to improve their performance and gain competitive advantage over their direct competitors (Mata *et al.,* 1995; Porter and Millar, 1995; Dehning and Stratopoulos, 2003).

2.8 IT Business Value (ITBV)

The contribution of IT to the improvement of various measures of an organisation's performance metrics such as productivity, profitability, cost, differentiation and market share is variously termed as "IT business value", "strategic value of IT", "strategic advantage", "competitive weapons", and "IT-dependent strategy" by different researchers (Melville *et al.*, 2004; Piccoli and Ives, 2005; Oh and Pinsonneault, 2007). In this study ITBV is viewed as the outcome of the implementation of IT resources in the construction project value chain on its performance metrics including cost, schedule, profitability, safety and customer satisfaction.

2.9 ITBV and Process view Paradigm

There is a strong argument for the need to investigate the impact of IT on the performances of organisations at process level (Barua *et al.,* 1995 and Melville *et al.,* 2004). Porter (1985) value chain concept is adopted to satisfy the process-based view which hypothesised that IT investments create CAs by improving operational efficiency of intermediary business processes, which in turn, under the appropriate conditions, lead to better organisational-level performance (Barua, *et al.*, 1995; Soh and Markus, 1995; Mooney *et al.*, 1996; Qing and Jing, 2005; Newbert, 2008).

Business process is defined as 'the specific ordering of work activities across time and space, with a beginning, an end, and clearly identified inputs and outputs' (Davenport, 1993:5). An organisation executes numerous business processes to achieve its strategic objectives, thereby providing a range of opportunities for the application of information technology to improve processes and organisational performance (Porter and Millar 1985; Straub and Watson 2001).

2.10 ITBV and RBV Paradigm

It has been argued that IT resources alone do not confer sustainable competitive advantage (SCA) to organisations deploying them (Carr, 2003) since such resources are necessary, but not sufficient, for SCA (Clemons and Row, 1991). Rather, it was submitted that IT resources form part of a complex chain of assets and capabilities that may lead to sustained performance (Wade and Hulland 2004). Therefore, another theoretical base is needed to explain the complex interaction of IT with other organisational resources to provide SCA to an organisation. One of such theoretical postulation is the RBV. Many authors including Bharadwaj (2000), Santhanam and Hartono (2003), Ravinchandran and Lertwongsatien (2005) have suggested that adopting RBV as a theoretical framework in IT business study can help address the 'productivity paradox'.

The RBV proposed that the deployment and exploitation of valuable, rare resources, and capabilities contributes to an organisation's CA, which in turn, contributes to its performance (Barney, 1991). Based on this paradigm it could be argued that an IT-enabled strategy can improve organisational performance by creating SCA via unique, immobile, and path-dependent strategic resources and capabilities (Clemons and Row, 1991; Mata *et al.*, 1995; Powell and Dent-Micallef, 1997; Bharadwaj, 2000; Sambamurthy, Bharadwaj and Grover, 2003; Newbert, 2008).

Furthermore, RBV recognises the role of resource complementarities in creating and providing sources of SCA to organisations.

2.11 Complementary Organizational Resources

The concept of resource complementarities hypothesizes that the presence of a resource enhances the strategic values of other resources it complements (Teece, 1986). Drawing upon the concept RBV which suggests that organisations exploiting the complementarily among their resources and capabilities can create complex resource/capability networks as barriers to imitation, thus enhancing the potential of achieving durable CA (Collis & Montgomery, 1998; Barney, 2002; Colbert, 2004). Recent empirical studies have shown that the combinative effects of complementary resources and capabilities influence the competitive performance of organisations (Carmeli and Tishler, 2004; Song *et al.*, 2005). Song *et al.* (2005), for instance, found a synergistic effect between two complementary organizational capabilities (marketing-related and technology-related) on organisation performance in the high turbulence environment (Zhang, 2007).

There are studies that investigated complementarities between IT resources and non-IT resources at various levels of abstraction. For example, Breshnahan *et al.*, (2002) suggest that organisation-level productivity increases when the level of IT spending on computers is accompanied by work reorganization investments. Similarly, Brynjolfsson and Hitt (1998) examine the complementarities between IT spending and business work practices, and conclude that organizational work practices are important determinants of IT demand and productivity. Powell and Dent-Micallef (1997) concluded that IT alone does not explain variation in measures of organisation performance, but that the advantages gained by some organisations can be explained by their ability to combine explicit *technology* (IT) resources with complementary human and business resources. Similarly, Zhu (2004) found evidence of complementarities between e-commerce capability and IT infrastructure, and at the industry level, Mittal and Nault (2008) found indirect effects of IT investment on the productivity of labor and non-IT capital. At the process level, Ray *et al.,* (2005) investigate the differential effects of various types of IT resources and the moderating role of shared knowledge, but did not consider complementarities between IT and non-IT resources. Jeffers *et al.,* (2008) empirically investigate complementarities between IT resources, especially tacit IT resources, and non-IT resources at the process level. They argue and empirically demonstrate that complementarity is but one potential outcome of how IT resources could interact with non-IT resources in the bundle; those resources can interact as *substitutes* as well.

Therefore, while technology is a core component of IT-dependent strategic initiatives, enabling the system of value-adding activities, its successful implementation requires a number of other complementary organizational resources to be mobilized (Piccoli and Ives, 2005). Previous research has investigated the role of information systems in leveraging these organizational resources via co-presence or co-specialization (Clemons and Row 1991b; Powell and Dent-Micallef 1997).

Although it is possible to apply IT for improved organizational performance with few organizational changes (McAfee 2002), successful application of IT is often accompanied by organizational – wide change (Brynjolfsson and Hitt 2000; Brynjolfsson *et al.,* 2002; Cooper *et al.,* 2000), including policies and rules, organizational structure, workplace practices, and organizational culture. When synergies between IT and other organisation resources exist, the latter are called complementary organizational resources. Applying Barney's (1991) classification of organisation resources, complementary organizational resources may include non-IT physical capital resources, non-IT human capital resources, and organizational capital resources, e.g. formal reporting structures and informal relationships within and among organisations. Similarly, Grant

(1991) classifies non-IT resources into five categories: physical, human, organizational, reputation, and financial (Melville *et al.*, 2004).

Complementary organizational resources include scale of operations and market share (Clemons and Row 1991a; Kettinger *et al.*, 1994), organizational structure or governance (Feeny and Ives 1990), slack resources (Kettinger et al. 1994), access to distribution channels (Feeny 2001), physical assets (Feeny and Ives 1990), ownership structure (Piccoli and Applegate 2003), corporate culture (Barney 1986; Feeny and Ives 1990; Powell and Dent-Micallef, 1997), top management commitment (Henderson and Venkatraman 1993; Keen 1991), competitive scope (Clemons and Row 1991a; Feeny and Ives, 1990), and software and process patents (Atkins 1998; Mykytyn *et al.*, 2002). Organisations with a unique activity system (Siggelkow, 2001) or unique business processes (Davenport, 1993) may also be able to leverage these resources to create value for customers. External resources, such as inter-organizational relationships (Dyer and Singh 1998), brand recognition, image, and trust, are intangible and developed over time (Porter 1991). They can be valuable components of IT-dependent strategic initiatives as well (Hart and Saunders 1997; Kotha, 1995).

Melville *et al.*, (2004) operationalize the IT resource, by melding other formulations with Barney's (1991) classification of organisation resources of physical capital, human capital, and organizational capital resources, the former two containing components of the IT resource, while all three contain components of complementary organizational resources.

2.12 ITBV and Economic Theory

Many studies on payoffs of IT investments have adopted the microeconomic concepts of productivity to explain relationship between IT investment and various measures of economic performance. The microeconomics-based view postulates that IT investments create excess return over other types of capital investments in production processes of organisations (Brynjolfsson and Hitt, 1996; Hitt and Brynjolfsson, 1996; Dewan and Min, 1997; Siegel, 1997; Lehr and Lichtenberg, 1999). Microeconomic theory provides a rich set of well-defined constructs interrelated via theoretical models and mathematical specifications. Such formulation is particularly useful in conceptualizing the process of production and providing empirical specifications enabling estimation of the economic impact of IT (Brynjolfsson and Hitt 1995; Melville *et al.,* 2004). This led to the argument that microeconomic production theory is the natural choice for investigating the productivity impact of IT (Mukhopadhyay *et al.,* 1997). In microeconomics, the combination of feasible inputs and outputs is called the productivity possibility set (PPS). This set is characterized by free disposal and replicability, and is monotonic and convex. The concept of a production function has been developed over the decades to link quantities and qualities of inputs via transformation processes to well defined outputs.

As IT is typically a cross-sectional business function rather than a primary business process, recent literature on the business value of IT suggests a rather indirect and more complex relation between IT and its business value (Lee, 2001). Notably, Melville *et al.* (2004) propose a unified conceptual model on IT business value. They show how the RBV has provided very instructive general insights into how to use the IT resource to generate and maintain a SCA. Still, like most parts of the literature, their framework relies on broad constructs and is quite general. As a consequence, the transformation process from IT to value still largely resides in a black box and it is difficult to both, empirically substantiate the ways in which IT creates value and to derive concrete managerial guidelines on how to develop the IT resource (Wagner and Weitzel, 2007).

The fundamental argument of the economic view of IT value is that IT can be treated as an input in the production function of an organisation and there is a substituting effect between IT and other production factors (Dewan and Min, 1997). Thus, IT creates value for an organisation when IT capital or IT labour produces higher return than ordinary capital and labour (Brynjolfsson and Hitt, 1996; Hitt and Brynjolfsson, 1996). The impact of IT investments can be estimated using an economic production function. Significant returns on IT investments have been reported in many similar studies at the organisation level (Barua and Lee, 1997; Rai *et al.,* 1997; Lehr and Lichtenberg, 1999; Kudyba and Diwan, 2002), industry-specific sectors (Siegel, 1997; Devaraj and Kohli, 2000; Menon *et al.,* 2000), and country level (Kraemer and Dedrick, 1993; Dewan and Kraemer, 1998). With a few exceptions (Loveman, 1994; Berndt and Morrison, 1995), overall, the published empirical studies using the economic production function approach have found significant impact of IT investments on productivity and performance (Kohli and Devaraj, 2003).

The economic view of IT value, essentially a variance theory (Markus and Robey, 1988), however, fails to explain where and why such impact occurs (Soh and Markus, 1995; Mooney *et al.,* 1996). In light of this, the process view of IT value considers IT investments as a necessary but not sufficient condition for superior organisation performance. It postulates that the impact of IT investments on organisation performance is the result of interactions among three processes: the IT conversion process in which IT investments become IT assets, the IT use process in which IT assets create impacts, and the competitive process in which IT impacts are converted into organisation performance (Soh and Markus, 1995). Each of these processes is influenced by a multitude of technological, organizational, industry, and competitive environmental factors. There is plenty of empirical evidence that supports the process view. For example, Barua *et al.* (1995) suggested that IT has first-order effects on operational level variables such as capacity utilization and inventory turnover for manufacturing organisations and these intermediary variables in turn affect higher-level variables such as productivity and profitability.

Based on the microeconomic-view the starting point of the analysis is to capture the underlying production state of the construction organization highlighting the impact of IT (Alpar and Kim 1990).

The production transformation function can be represented by equation (2.6) below:

$$\mathbf{Y} = F(\mathbf{X}) \quad \text{............} \quad 2.6$$

Where, **Y** is the vector of outputs representing the performance metrics of the organisations and **X** is the vector of inputs representing the IT and non-IT resources.

To understand the possible contribution of IT on an organisations' performance, the definitions of IT, classification of the IT resources used in deriving the conceptual IT business value model for the construction industry are presented in the subsequent subsections.

2.13 Information Technology Resource

Information Technology (IT) is variously referred to as a collective integration of computing technology and information processing as something that includes equipment, applications and services that are used by organisations to deliver data, information, and knowledge to individuals and processes (Mentor, 1997; Turk, 2000; Alshawi and Faraj, 2002).

Resources are viewed as the assets and capabilities organisations utilise to develop and implement a given strategy. Based on RBV and production theory the term resource is variously called as assets, capabilities, inputs and competencies. For the purpose of this study resource is viewed in the broader general sense that encompassed all of the descriptions above (Grant, 1991; Amit and Schoemaker, 1993; Makadok, 2001 and Jeffers *et al.*, 2008). IT resources, according to Grover *et al.*, (1995), consist of IT shared infrastructure (ITSI), IT competence, and organizational expertise in employing and sustaining IT-enabled strategy. IT resources are considered to be the tangible and intangible organisation's assets that are related to the implementation of IT-enable strategy (Piccoli and Ives, 2005).

IT-dependent strategic initiatives consist of identifiable competitive moves that depend on the use of IT to be enacted and are designed to lead to sustained improvements in an organisation's competitive position (Ross *et al*. 1996).

2.13.1 The IT infrastructure

McKay and Brockway (1989) define IT infrastructure (ITI) as the enabling foundation of shared information technology capabilities upon which business depends. They view ITI as the shared portion of the IT architecture. Earl (1989) defines ITI as the technological foundation of computer, communications, data and basic systems. He views ITI as the technology framework that guides the organization in satisfying business and management needs. Duncan (1995) refers to ITI as the set of IT resources that make feasible both innovations and the continuous improvement of IT systems. Weill (1993) noted that ITI was a foundation for capability across business and/or functional units. Davenport & Linder (1994) referred to ITI as that part of the organization's information capacity intended to be shared. They concluded that an ITI is an organisation's institutionalized IT practice – the consistent foundation on which the specific business activities and computer applications are built. Broadbent *et al.* (1996) describe ITI as the base foundation of budgeted-for IT capability (both technical and human), shared throughout the organisation in the form of reliable services, and usually managed by the information system group. Rockart *et al.* (1996) reflected the ideal goals of an ITI in referring to an 'IT infrastructure' of telecommunications, computers, software, and data that are integrated and interconnected so that all types of information can be expeditiously – and effortlessly, from the users viewpoint – routed through the network and redesigned processes (Bruce *et al.,* 2003). ITI, according to Mitchell and Zmud (1999), offers an organization the ability to effectively leverage IT resources.

Broadly, ITI refers to enabling technologies, outsourcing arrangements, and policies (Mitchell and Zmud, 1999).

ITI provides the foundation for the delivery of business applications and services (Will & Broadbent, 2000; Melville *et al.*, 2004; Piccoli and Ives, 2005). Therefore, ITI is an important organizational capability that can be an effective source of value (Bharadwaj, 2000; Broadbent and Weill 1997, Ross *et al.,* 2004; Sambamurthy, 2000; Bhatt and Grover, 2005). ITI provides organisations with the ability to share information across different functions, innovate, and exploit business opportunities, and the flexibility to respond to changes in business strategy (Weill *et al.,* 2002). However, the existence of open architectures and standardized enterprise packages suggest that this capability might not be heterogeneously distributed across organisations and / or the access to infrastructure is not restrictive (Carr, 2003). Therefore, despite some contrary evidence ITI is argued to be valuable but not a source of competitive advantage (Bhatt and Grover, 2005).

ITI represents a composite of shared technical components communications technologies, data integration, software applications, and human skills (Byrd and Turner 2000).

Thus, different authors have operationalised ITI in dimensions and viewed from different perspectives. Mudie and Schafer (1985) view ITI in process terms having the following components: data architecture, communication networks infrastructure, and support organizations. Duncan (1995) suggested that the components of an organizational ITI include networks, databases, practices, and applications. Broadbent *et al.,* (1996) argued that ITI consists of both technical and organizational capabilities to provide the opportunities to share IT resources within and across the organisations (Broadbent et al., 1999). Using some of these postulations, Bhatt (2000) hypothesized four dimensions of ITI: extent of intra-organisation infrastructure; extent of inter-organisation infrastructure; extent of infrastructure flexibility; and extent of data integration. She further combined the first three dimensions into one and called it network infrastructure measuring the extent of network connectivity and network flexibility. The second component of IT as conceptualized by Bhatt (2000) was data integration with a measure of level of availability and consistency of data across different departments of an organisation.

Bruce *et al* (2003) operationalised ITI using eight dimensions of Chief Information Officer (CIO), IT planning, IT security, technology integration, advisory committee, enterprise model, information integration and data administration. The CIO dimension measures both technical and business knowledge of the head of IT section. IT planning views alignment of IT strategy with business strategy and the security awareness is captured under IT security dimension. Level of automation and integration is represented by technology and information integration dimensions. The advisory committee monitors end user participation and senior manager's participation.

Fink and Neumann (2009) identified three theoretical approaches to ITI including technical-oriented approach consisting of platforms, networks and telecommunications, data, and core applications, component-oriented approach involving technical and human components and process-oriented approach which incorporates organizational processes and activities utilizing the rest of the components.

Fusing McKay and Brockway (1989), Weill (1993) and Bhatt (2000) ITI concepts, a four-layer conceptualization of ITI is derived (Figure 2.5). Therefore, for the purpose of this study IT resources are refer to as IT infrastructure (ITI) that include both tangible and intangible assets of the organisation, and are conceptualized in four dimensions of shared technical components, IT Human competence, IT application, and business process (Bhatt, 2000). The shared technological component of the ITI model (Figure 2.5) consists of the hardware portion of the infrastructure. They represent what Bhatt (2000) called network infrastructure including data integration.

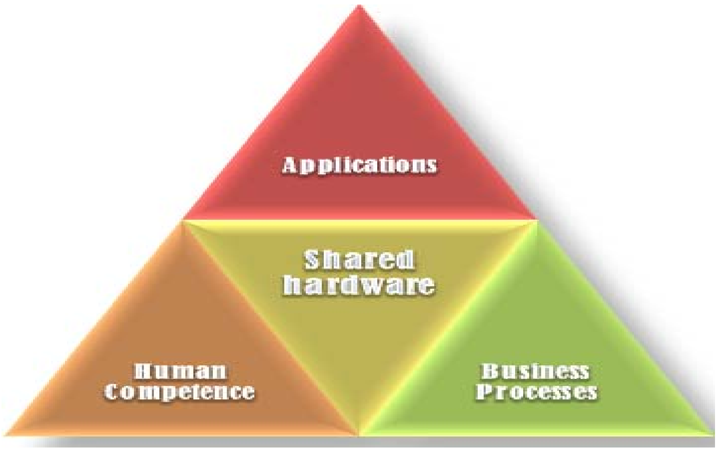

Figure 2.5 Conceptualization of ITI (Kassim et al., 2009b)

The other component is the human IT capabilities (Ross *et al.,* 1996; Bharadwaj, 2000; Melville *et al.,* 2004) that are needed to effectively utilize, leverage and bind other components into robust and functional IT services. McKay and Brockway (1989) refer to those human and organizational capabilities as "mortar." Duncan (1995) refers to them as infrastructure planning and management factors. This layer represents capabilities that combine and deploy the technological components into a shared set of capabilities or services that are fundamental to the operation of the business. The elements of this layer allow other "direct purpose" uses of technology to be feasible, and allow the successful implementation of the IT architecture.

IT human skills (ITHS) represent not only the technical skills but also the managerial and organizational skills of IT professionals to innovate and support critical business processes. IT planning and management practices produce the architectures, plans, standards, policies and rules that govern the development of the technological components of IT infrastructure across the organization.

IT business applications (ITBA) refer to any application that is important to running and delivery of the engineering and construction organisations' value chains, these may include engineering analysis packages, administration software, planning and schedule control, purchasing systems, sales analysis tools.

2.14 Nature of Construction Industry

The Construction Industry is made up of organisations and all enterprises that are engaged in some or all of the following activities: engineering design, engineering consultancy, project management, architectural designs, procurement of construction material, and construction management activities (Betts and Ofori, 1992). The construction process is made up of the whole life cycle of a project, including pre-design, design, construction, and operation and maintenance (El-Ghandour, and Al-Hussein, 2004). The process is heavily dependant on exchange of large and complex data. Successful completion of a project depends on accuracy, effectiveness and timely communication and exchange of critical information and data between the project teams (Akinsola *et al.,* 2000)**.**

The construction industry has been characterizations as fragmented as a result of many stakeholders and phases involved in a typical construction project (Nitithamyong, and Skibniewski, 2004). Most construction projects involve many phases such as feasibility, design, construction and maintenance. Each phase involves communication and coordination among many project participants/stakeholders such as the owner, contractor, designer, consultant, subcontractors, and suppliers.

The fragmented nature of the industry has made it difficult to achieve economies of scale and made it information intensive (Chen *et al.*, 1993; Latham 1994; Egan, 1998; Howard *et al.,* 1989, Crawford, 1999; Johnson *et al.,* 2002; Macomber, 2003; Nitithamyong and Skibniewski, 2004). A large volume of information is required to run a typical construction project, which involves the different parties and phases that are normally geographically dispersed. Further difficulties in capturing, sorting, communicating and acting on project information are also attributable to the fragmentation (Ng *et al.*; 2001; 2005).

As a result traditional management practice within this construction environment has been criticized for not being conducive to improving construction productivity (Latham 1994).

Rather than changing the nature of the construction industry, Egan (1998) suggested that the construction workforce should be wary of attempts to improve construction productivity and process by blindly adopting innovation such as new management techniques, construction techniques or IT. Any adoption of innovation should be mindful of existing industry constraints to overcome barriers with a more systemic approach to change rather than undertaking isolated piecemeal change initiatives.

Construction is a major industry throughout the world accounting for a sizeable proportion of most countries gross domestic product (GDP) (Crosthwaite, 2000). For example construction contributes some 7% of the GDP in most OECD countries and up to 12 to 14% in Japan and Korea (Gann, 2000), while in developing countries investments in construction projects could be as high as 50-60% of national budgets (Dharwadker, 1979).

In United Kingdom construction is one of the largest industry. The sector, according to NESTA report (2007), generates around ten per cent of GDP – about £90 billion – from more than 182,000 firms employing 1.17 million people (NESTA, 2007). The UK construction industry contributes significantly to the economy and calls for improving productivity and performance of the industry have been made through Latham (1994) and Egan (1998) reports.

The decline in profit margin from 2010 reflects the squeeze on contractors' margins from falling tending prices and the rising cost of materials fuel due to higher world commodity prices argued the UK Construction Industry KPI report (2011). However, the productivity jumped sharply as contractors made more efficient use of a slimmed down workforce as shown in Figure 2.6

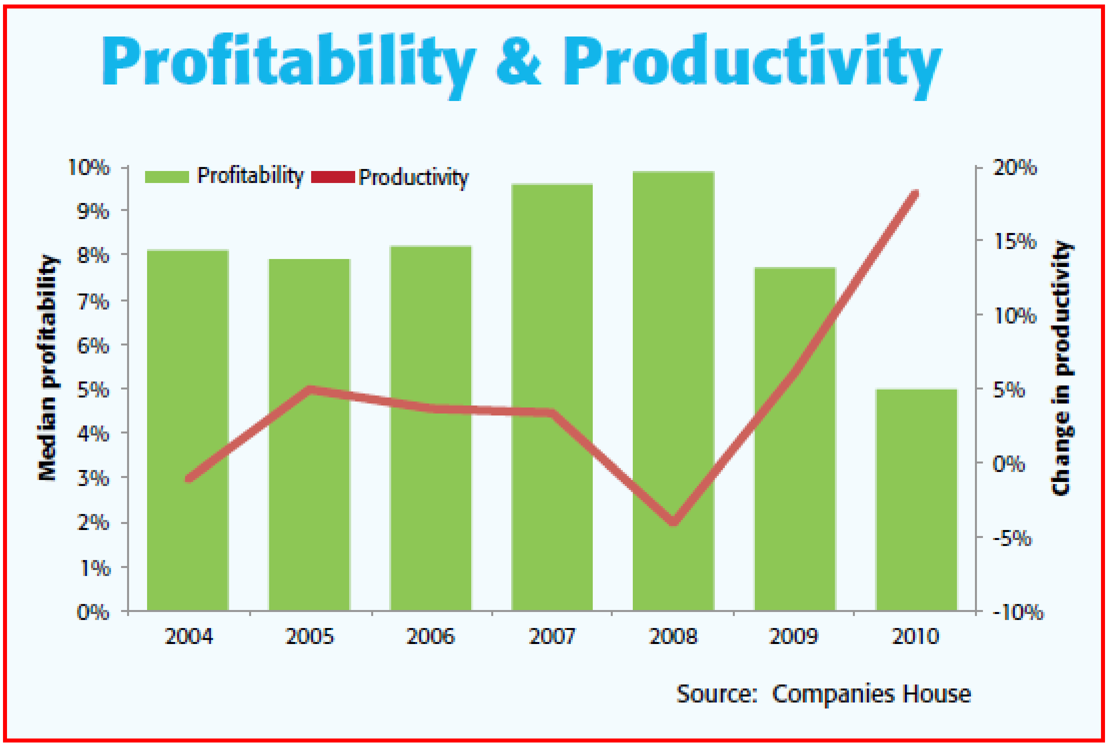

Figure 2.6 The UK Construction Industry Profitability and Productivity

Nevertheless, due to the significant business contribution of the construction industry to nations economies many studies were undertaken in order to find ways to overcome the problems caused by fragmentation such as communication (Aouad and Alshawi, 1996; O'Brien, 1996); and to improve construction management methods and techniques that could increase industry productivity (Hampson and Tatum, 1994; Hampson and Tatum, 1997; Lenard and Bowen-James, 1996; Tatum, 1988). They finally lead to identifying the nature of construction industry practice as a barrier to improving its productivity (Latham, 1994).

Suggestions for the use of IT in order to increase efficiency, communication and productivity in the construction industry were also made (McMahon, 1996; Sachin, 2003; Charoenngam *et al.*, 2003; Skibniewski and Nitithamyong, 2004; Zhen *et al.*, 2005).

The need for effective information processing and exchange increases with the increasing degree of task-uncertainty, number of organizational units involved, and extent of interdependence among the units. By sharing information within the organizational units as well as among the participating organizations significant integration in construction processes can be achieved (Ahmad and Ahmed, 2001).

2.15 Competitive Strategy in Construction

For the purpose of this research, the construction industry includes all organisations that engage in engineering consultancy, project management, architecture, procurement, construction management and maintenance activities (Betts and Ofori, 1992). The industry is project based (Garnett and Pickrell, 2000) with a typical project life cycle consisting of the following phases: bidding and contractor selection, conceptual and detail engineering design, construction and construction management, and operation & maintenance. Despite the sizable contribution of construction to a nation's GDP, the UK construction industry, in particular, is being criticized for its inefficiencies and has been identified as under-performing (Egan, 1998; Latham, 1994; Kagioglou *et al.* 2001). To improve the competitiveness of the industry through increased efficiency, communication and productivity, a strategic use of IT is suggested in delivering projects (Zhen *et al.,* 2005). Such strategy involved careful management of the construction value chain through deployment of IT resources couple with the organisational complementary resources.

The concept of strategic thinking has increasingly become important in construction organizations (Junnonen, 1998). This is partially due to long-term, survival need of the construction organizations operating in a highly turbulent and competitive environment (Price and Newson, 2003; Betts and Ofori, 1992).

Early writers (Betts and Ofori, 1992; Warszawski 1996) dealt with the theoretical concept of strategic choices in the construction industry, while Jennings and Betts (1996) provide an empirical analysis of strategies in the industry.

Attempts to establish the relationship of the competitive positioning with the construction firms' performance was also made (Akintoye and

Skitmore, 1991; Hampson and Tatum, 1997; Kale and Arditi, 2002), and recently by Flanagan *et al.*, (2005; 2007). However Green *et al.,* (2008) argued that generally, the understanding of the competitive strategy of construction firms has stagnated within recent years.

As they gained prominence quickly, the general theories on firms' competitiveness have been introduced into the construction sector. Introduction, adaptation and application of these theories into the sector have attracted enduring research interest as the industry has long been viewed as heterogeneous. Porter's theory for firm competitiveness has had certain popularity in the construction industry (e.g. Male and Stocks, 1991; Betts and Ofori, 1992, 1994; Langford and Male, 2001). The RBV has also been explored in the construction sector. Haan et al. (2002) demonstrate its validity in construction. Kale (2002) engages it as an essential part of his framework for identifying the sources of competitiveness for construction firms. The strategic management approach is also used to achieve construction firms' CA. Typical works on strategic management in construction include Fellows *et al.,* (1983), Newcombe *et al.* (1990), Warszawski (1996), Venegas and Alarcon (1997). The above-reviewed studies have provided different levels of insight into the achievement of competitive advantage for construction firms. Nonetheless they were criticized for having adopted an anecdotal or descriptive research approach (Kale and Arditi, 2002). The lack of rigorous empirical data has resulted in minimal improvement in our realistic understanding. This leads to recent empirical competitiveness research at the construction firm level. Some findings that are different from Porter's original propositions have been reported. For example, contractors in the US market who adopt a neutral strategy that falls between a narrow and a broad strategy can also achieve CA (Kale and Arditi, 2002) whereas according to Porter (1980; 1985) contractors with such a neutral strategy also called 'stuck in the middle', possess no CA.

2.16 Competitive Domains for the Research

Buckley *et al*. (1988) suggested three categories of competitiveness measures, as actual performance, the generation of assets and the process, *which* may turn assets into performance (Henricsson and Ericsson, 2004). Also *national*, *industrial* and the *firm* are identified as the three levels of abstraction for measuring competitiveness (Momaya and Selby, 1998; Flanagan et al., 2005) while Flanagan *et al*., (2007) extend the levels to include project in case of construction industry.

Furthermore, Flanagan *et al*. (2007) provide taxonomy for analysing competitiveness of the construction sector within the four domains. Nevertheless, they did not seem to categorically answer their question 'Is there a research domain for competitiveness of industry?' Flanagan *et al,* (2004) concluded that competitiveness can be measured at any of the four levels abstraction and the choice of approach will dependent of the level (Flanagan *et al*., 2005).

2.16.1 National Competitive Domain

There is no apparent agreement on how to view national perspectives as a domain for analysing the construction sector. However, Different researchers use variety of models, while deploying different methodologies to investigate a nation' competitiveness in construction sector. A summary from Dikmen and Birgninul (2006) is shown the Table 2.1.

Table 2.1 Construction Management Research Domains

Author	Study/Survey/Research	Model
Arditi and Gutierrez (1991)	Factors that affected the competitiveness of US contractors working abroad during 1980s	
Crosthwaite (1998)	International performance of British construction companies.	
Ofori (1994)	Formulation of a programme for developing Singapore's construction industry	Used Porter's (1998) diamond Model
Pheng *et a*l. (2004)	Explored the advantages of top British and Chinese contractors in the global market	Used internationalisation ratios in the OLI + S (ownership, locational and internalisation advantages + specialty advantages) model,
Oz (2001)	Investigated the sources of competitive advantage of Turkish contractors in international markets	Used Porter's (1998) diamond model
Seymour (1987)	Analyse the multinational construction industry	Used Dunning's (2000) eclectic paradigm
Pheng and Hongbin (2003	Investigated the internationalisation of Chinese construction enterprises	Used Dunning's (2000) eclectic paradigm
Cuervo and Pheng (2003)	Analysed the significance of ownership advantage and the disadvantage factors of Singaporean transnational construction corporations in the international construction market	
Pheng and Hongbin (2004)	Proposed an OLI + S model for measuring the degree of internationalisation of multinational corporations	Used Dunning's (2000) eclectic paradigm

Examining the competitiveness of construction in relation to a nation is viewed the same as analysing how the construction organisation within the nation competes with rest in the world (Flanagan *et al.*, 2007).

2.16.2 Industrial Competitive Domain

To summarize, firm competitiveness is related to market performance, with high productivity and low costs being the keys to success. By moving one level higher, to the industry level, the analysis is likely to lose a significant level of detail. Often, a valid sample of projects or firms' performance is aggregated to represent the industry's performance. However, whilst this gives an interesting overview, it makes it very difficult to analyse cause outcome- relationships. (Flanagan *et al.,* 2005).

An organisation's competitiveness is related to market performance, with high productivity being the key to success. The objective of firm competitiveness, after having secured survival, is the creation of new growth options that create value for shareholders. Hence, competitiveness is associated with achieving an objective. In other words, competitiveness is not an end but a means to an end (Buckley *et al*., 1988).

2.16.3 Organizational Competitive Domain

Firm-level competitiveness is of great interest among practitioners. It has been argued that nations can compete only if their firms can compete (Porter, 1998). Porter says, "It is the firms, not nations, which compete in international markets." The environmental factors are more or less uniform for all competing firms. The variance in profitability could be attributed to the firms' characteristics and actions (McGahan, 1999). Other pro-firm views (Bartlett and Ghoshal, 1989; Prahalad and Doz, and 1987; Prahalad and Hamel, 1990) focus on individual firm and their strategies for global operations, and resource positions to identify the real sources of their competitiveness.

Parson (1983) explained the three-level impact of IT in detail. At the industry level, it changes an industry's products and services, market and production economies. At firm level, it affects the five key competitive forces. At the strategic level, it affects the firm's strategy in low-cost leadership, product differentiation and concentration on market or product niche (Tan, 1996).

For a firm to gain SCA it must continuously seek to add value to its activities. This could be done through continuous improvement of operational effectiveness, efficiency, improve business performance and increase stakeholder satisfaction (Porter, 1998; Nicoletti and Scarpetta, 2003; Flanagan *et al.*, 2004).

At the firm level, all projects completed in one fiscal year may be aggregated to show the firm's performance in delivery and profitability. However, firms are often interested in more overall financial and market performance, which is not covered by the project approach (Flanagan *et al.*, 2005).

2.16.4 Project Competitive Domain

In summary, national competitiveness often includes elements of successful trade performance in the international markets that will in turn lead to sustained and rising standards of living in terms of rising real incomes. In other words, the objectives of the competitiveness of nations centre on human development, growth and improved quality of life (Flanagan *et al.*, 2005).

2.17 IT-enabled Competitive Strategies

IT-enabled strategy involves organisation's strategic moves of deploying IT resources to support the delivery of its value chain for sustainable improvement in its competitive position (Bharadwaj, 2000; Stratopoulos and Dehning, 2000).

Results from previous researchers on the impact of IT-enabled strategies on the performances of organisations have been equivocal. Some reasons for the inconsistencies include lack of contextualisation of the studies based on business specifics, choices of inconsistent variables, impact of lag between investment and outcome and methods of data analysis (Kohi and Devaraj, 2003). Some of these drawbacks are highlighted below and mitigation incorporated in the model proposed in this study.

The need to develop a model that appropriately represents IT's value in a business context is recognised as an important step in evaluating IT payoffs correctly (Thouni *et al.*, 2008). There were limited theoretical frameworks used in previous studies to provide a basis for investigating the impact of IT on an organisation's performance within a business context (Lee, 2001; Kohli and Devaraj, 2003). Therefore in order to understand the unique characteristics of ITBV in the construction industry, a conceptual model is developed using the typical industry value chain for examining the effect of IT through a 'web of intermediate level contribution' (Barau *et al.*, 1995).

The equivocal results from different IT payoff studies are also attributable to the use of inconsistent input and output variables (Weill, 1988). The contemporary IT investment evaluation approach has focused on varieties and inconsistent quantitative financial assessment and appraisal methods (Chen *et al.*, 2006; Tallon and Kraemer, 2006). There were also emphases in using monetary values in the form of IT related expenditure to represent independent variables. Sigala *et al.,* (2004) argue that using such financial metrics do not provide insight to the actual usage of the IT since the outcome is more likely to be dependent on the IT resources that are deployed and used. Therefore, the impact of IT investment on the construction organisation performance is operationalised through a measure of availability, degree of usage and the level of integration of its IT resource as a complement to certain unique and heterogeneous resources such as work practices, organisational structure and culture residing in the organisation. However, data is required to empirically test any declaration of the relationship between the selected variables. Thus, the type of data and the method of analysis have significant impact on the outcome.

The realisation of the benefits from IT investments may not be accounted for at the time of data collection due to maturity issues and the lag between the investment and the payoffs (Brynjofsson, 1993). Also Weil (1988) suggested that because of the time lags among the variables, a priori reasoning on the direction of causality is often difficult. The use of longitudinal or panel data in examining the impact of IT investment is suggested to improve the accuracy of the results, since it allows researchers to examine the lag effects (Devaraj and Kohli, 2000). With the difficulty in collecting longitudinal data, cross-sectional data to simulate a time series can provide good insight as suggested by Shafer and Bryd (2000).

O'Connor and Yang (2004) suggested that increased integrated usage of IT resources may contribute significantly to project performance in terms of cost and schedule success. El-Mashaleh et al. (2006) found a similar quantitative result, when they also examined the impact of IT on construction firm performance specially cost and schedule.

2.18 Chapter Summary

This chapter reviewed the literature on the application of IT from a high level of a country to the organisational level. While numerous studies have investigated performance measures and strategy, and information technology and strategy, research on the combination of performance measures, strategy and information technology is sparse. Thus, the literature review highlighted the dearth of research in field of strategic utilization of IT in construction management evaluate IT induced productivity.

The review focused on the strategic application of Information Technology in the execution of engineering and construction business to gain competitive advantage. The insight gained lead to the research proposition, aim and objective with the view to contribute and fill in the vacuum found in the literature of IT business value in engineering and construction organisations.

The next chapter introduces the conceptual model for the ITBV, which has been developed using the theories and paradigms described in the literature along with establishing the hypotheses and identifying the variables and their measures of the research.

CHAPTER THREE
IT BUSINESS VALUE CONCEPTUAL MODEL

3.0 Introduction

This chapter presents the conceptualization and development of the ITBV model using the theories and views described in chapter two. ITBV is viewed as the positive outcome of deployment and implementation of IT resources in the delivery of engineering and construction projects value chain as a measure of the performance metrics including cost, schedule, profitability, safety and customer satisfaction.

The chapter also contains the derivation of hypotheses along with providing definitions and selections of the input and output variables in addition to the techniques deployed for quantifying them.

3.1 Conceptual IT Business Value Model

Diverse conceptual models and frameworks at different levels of analysis have been used by different researchers to study the impact of deploying and using IT resources as factors of production on the organisational performance. Some of the concepts and theories used to formulate and explain the relationships between the strategic application of IT resources and organizational performance include economics, strategy, accounting, and operations research, philosophy, and sociology (Brynjolfsson 1993; Wilson 1995; Brynjolfsson and Yang 1996; Ross *et al.*, 1996; Bharadwaj, 2000; Dehning and Richardson, 2002; Dedrick *et al.*, 2003; Melville *et al.*, 2004; Piccoli and Ives, 2005).

On the other hand, other researchers have taken an alternative approach in modeling IT Business Value (ITBV) by focusing on the attributes of IT and other organizational resources that together may confer a competitive advantage. For example Bharadwaj (2000) models three key IT resources and their relationship to a firm's capability to deploy IT for improved performance: IT infrastructure, human IT resources, and IT enabled intangibles. However, Clemons and Row (1991b) argued that IT is widely available to all firms and can only confer a sustainable competitive advantage if applied to leverage differences in strategic resources. Mata *et al.,* (1995) derive a resource based conceptual framework mapping the attributes of IT to competitive advantage (Melville *et al*., 2004).

On the other hand, Weill's model (1992) focuses on the ability of organisations to convert IT assets into organisational performance, identifying several conversion effectiveness factors that mediate the IT-performance relationship. Francalanci and Galal (1998) propose that managerial choices regarding the mix of clerical, managerial, and professional employees mediate the relationship between IT and organisation performance. Soh and Markus (1995) develop a conceptual framework which posits that IT investment leads to IT assets, IT assets to IT impacts, and IT impacts to organizational performance (Melville *et al*., 2004).

However, most of these constructs do not provide adequate methodologies for measuring and analysing ITBV. Furthermore, there is no specific integrated ITBV model addressing the unique nature of the construction industry. Difficulties in formulating performance measurement have been identified as a contributing factor in the apparent lack of positive findings for IT impact on performance at organisational level (Barau *et al.,* 1995). Most of the early models seem to have focused on an aggregate level of analysis (e.g. Bailly and Chokrabarti, 1988; Jonscher, 1983; Roach, 1987 and Stabell, 1982). Such studies attempt to relate IT expenditure directly to output variables at the organisation level using microeconomic production function as a model; thus, the intermediate processes representing the organisation's value chain through which IT impacts arise are ignored (Barau *et al;* 1995). Therefore, it was argued that the effect of deploying IT resources on organisational performance could best be identified through a 'web of intermediate level contribution' within the organisation's processes (Crownston and Tracy, 1986;

Kauffman and Kriebel, 1988a, 1988b; Mukhopadhyay and Cooper, 1992; 1993; Barau *et al.,* 1995); in line with organisational value chain analysis suggested by Porter (1985).

The varieties of theoretical frameworks used in modelling and evaluating the ITBV have led to fractured research streams with many simultaneous but non-overlapping outcomes (Chan, 2000). Thus, in order to accommodate the multiple theoretical frameworks and account for the complex linkage of how IT resources impact on organisational performance, multiple theoretical paradigms were used to conceptualize and model ITBV (Melville *et al.,* 2004).

Therefore, to develop a conceptual model for evaluating ITBV in engineering and construction organisations multi-theoretical perspectives (Qing and Jing, 2005) of process-view (Barau *et al.,* 1995; Porter, 1985; 1998; Melville *et al.,* 2004); resource-based view (Clemons and Row, 1991; Mata *et al.,* 1995; Powell and Dent-Micallef, 1997; Bharadwaj, 2000; Sambamurthy, Bharadwaj and Grover, 2003; Newbert, 2008) and microeconomic-view (Soh and Markus, 1995; Mooney *et al.,* 1996; Brynjolfsson and Hitt, 1996; Hitt and Brynjolfsson, 1996; Siegel, 1997; Devaraj and Kohli, 2000; Menon *et al.,* 2000; Kohli and Devaraj, 2003) were adapted.

The proposed model is developed at the organisational domain level within the construction industry domain as shown in Figure 3.1. The level of analysis was focal organisations and its related value chain for the delivery of engineering and construction projects. The level analysis used a web of intermediate levels of construction project processes, in line with the value-chain analysis suggested by Porter (1985). Several conference papers (Kassim *et al.,* 2009a; 2009b; 2010a; 2010b; 2010c) were published during the stages of the development and testing of the proposed model. Applying strategic group concept when sampling for data collection minimized the impact of industry structure variations.

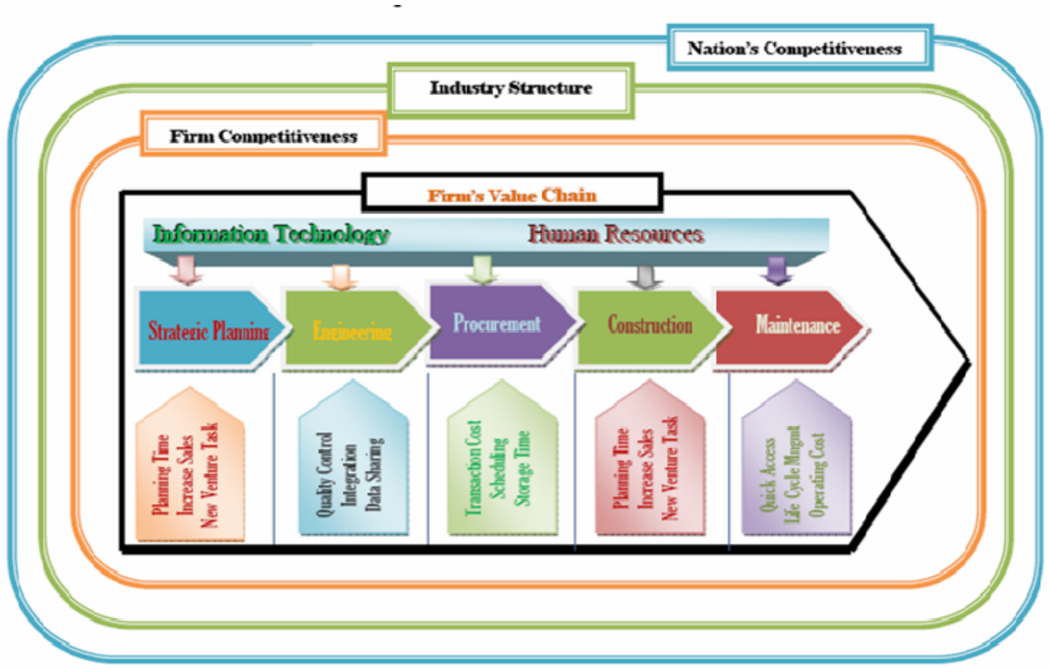

Figure 3.1 The Research Domain (Kassim *et al.*, 2009, 2010a)

The economically distinct activities of focal organisations are represented by its value chain within the research domain as depicted in Figure 3.1. Using the process-based Porter (1985) a typical engineering and construction value chain consisting of five primary activities of strategic planning, engineering design, procurement, construction and start-up and operation and maintenance were identified shown in Figure 3.2.

Figure 3.2 Typical Engineering and Construction Value Chain

Based on the literature (O'Connor *et al.*, 1999; Back and Moreau, 2000; O'Connor and Yang, 2004; Yang *et al.*, 2006; Yang 2007) and discussions with managers in field of engineering and construction; the primary activities of the engineering and construction projects value chain were further broken down into work functions as depicted in Figure 3.3 and Table 3.1. The degree of IT resources deployment, utilisation and integration of hard and software applications was measured at the level of the work functions (O'Connor and Yang, 2004).

Table 3.1 Lists of Primary Activities and Work Functions

Primary Activities	Work Functions (WFs)	ITw				
		1	2	3	4	**5**
Strategic Planning	Conduct market analysis					
	Control of bidding process					
	Prepare contract strategy					
	Develop bid packages					
	Review potential bidders					
	Develop manpower plan					
Engineering Design	Develop Design Basis					
	Engineering deliverables					
	Preliminary Estimate					
	Project master schedule					
	Execution plan					
	Interface management					
	Quality and safety issues					
Procurement	Material specifications					
	Material requisition					
	Issue Inquiry					
	Bid Evaluation					
	Delivery and Expediting					
	Inspection					
Construction & Commissioning	Field document control					
	Safety Management					
	Test packages control					
	System turnover control					
	Fabrication status control					
	Materials inventory					
	Field request for information					
Maintenance and Operation	Conduct pre-operations testing					
	Train facility operators					
	Track and analyze maintenance history					
	Develop maintenance plans					
	Monitor & assess equipment operations					
	Track maintenance / modifications requests					
	Update as-built drawings					
	Monitor/track/control energy usage					
	Monitor environmental impact					
Project Management	**Detail schedule preparation**					
	Detail cost estimate					
	Track project progress					
	Document Management					
	Change Management					
	Progress reporting					
	Invoicing process					

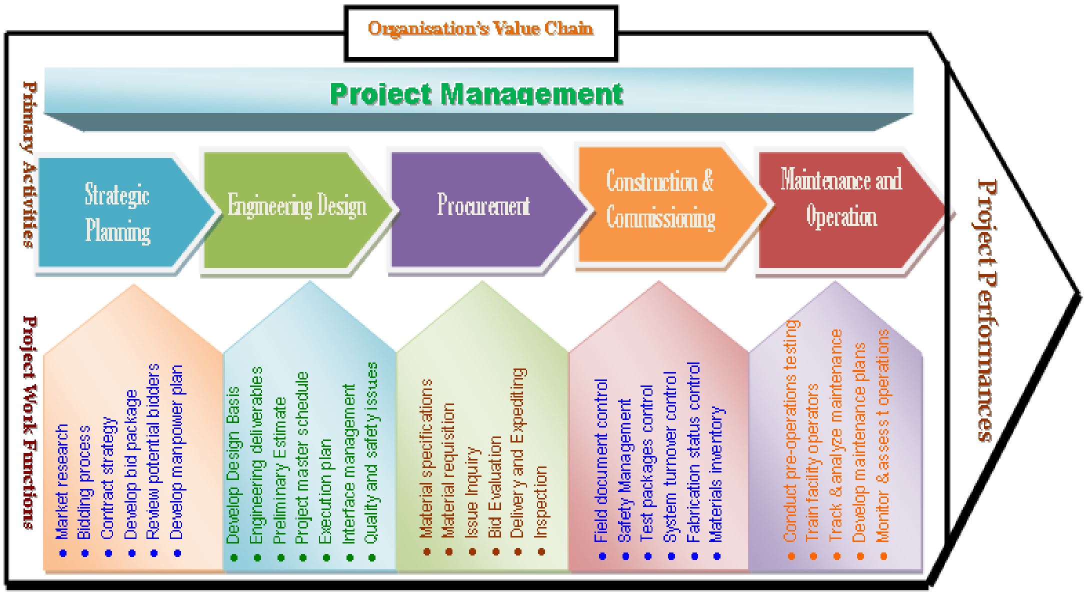

Figure 3.3 Integrated Value Chain with WFs (Kassim et al., 2009, 2010a)

The value chain concept provides a typical business process of an engineering and construction organisation. The components of the critical activities (Porter, 1985: 37) representing the work functions for each primary activity of the value chain are further developed. A critical activity is one, which has a large impact on the organisational CA. This means that an activity becomes critical if it creates a large potential for cost reduction or differentiation (Michael and Deigan, 1989). Using these guidelines each of the primary activities of the value chain in Figure 3.2 was further broken down at the process level. For example, the primary activity of strategic planning is subdivided into: (a) market research, (b) bidding process, (c) contract strategy, and (d) manpower planning etc. These subdivisions of the primary activities of value chain are referred to as work functions (WFs) in line with O'Conner *et al.,* (2000) and El-Mashaleh *et al.,* (2006). Production processes in engineering and construction organisations are significantly different from those in the manufacturing organisations; thus, work functions where technologies are identified to be applied were adopted (Seaden *et al.,* 2003). The detail breakdown of the primary activities of the construction value chain into the respective critical work functions is presented in Table 3.1. The breakdown was derived from the literature (O'Connor *et al.,* 1999; O'Connor and Yang, 2004; Yang *et al.*, 2006; Yang 2007) and with extensive discussion with managers in the industry. The individual WFs were validated through the pilot survey through questionnaire as described in Chapter 4.

3.2 Engineering and Construction Value Chain

Careful management of linkages is often a powerful source of competitive advantage because of the difficulty rivals have in perceiving them and in resolving trade-offs across organizational lines.

There is no universally accepted application of the concept of the value chain in the construction industry (Betts and Ofori, 1992). However, with construction being a project based industry (Baden and Baden, 1993; Garnett and Pickrell, 2000), a typical value chain for engineering and construction processes was proposed by Back and Moreau, (2000) and O'Connor *et al.*, (2000).

In order to predict the impact of information management-driven process changes on project schedule and cost, Black and Moreau (2000) developed primary activities for conducting engineering, procurement and construction (EPC) processes. They established the EPC main levels of activities in a hierarchical form based on the consensus of 40 engineering and construction organisations surveyed. The first level of Black and Moreau (2000) primary EPC activities were: (1) Pre-project planning (2) Engineering Design (3) Materials management (4) Construction (5) Start-up. This level was further broken down to the second and third levels. The third level of the activities were mainly project level specific rather than at the organisational domain.

3.2.1 Strategic Planning

Generally business strategic planning could be viewed as the selection of ideas and assets to deliver the long-term goal of an organisation. Nevertheless, Bob and Ron (2000) insisted that there is no general agreement on the fundamental areas of business strategy. However, they conceptualised strategy in three dimensions of process which represents the manner in which the strategy come about; the content referring to the outcome of the strategic planning and context to highlight the environment the organisation operates.

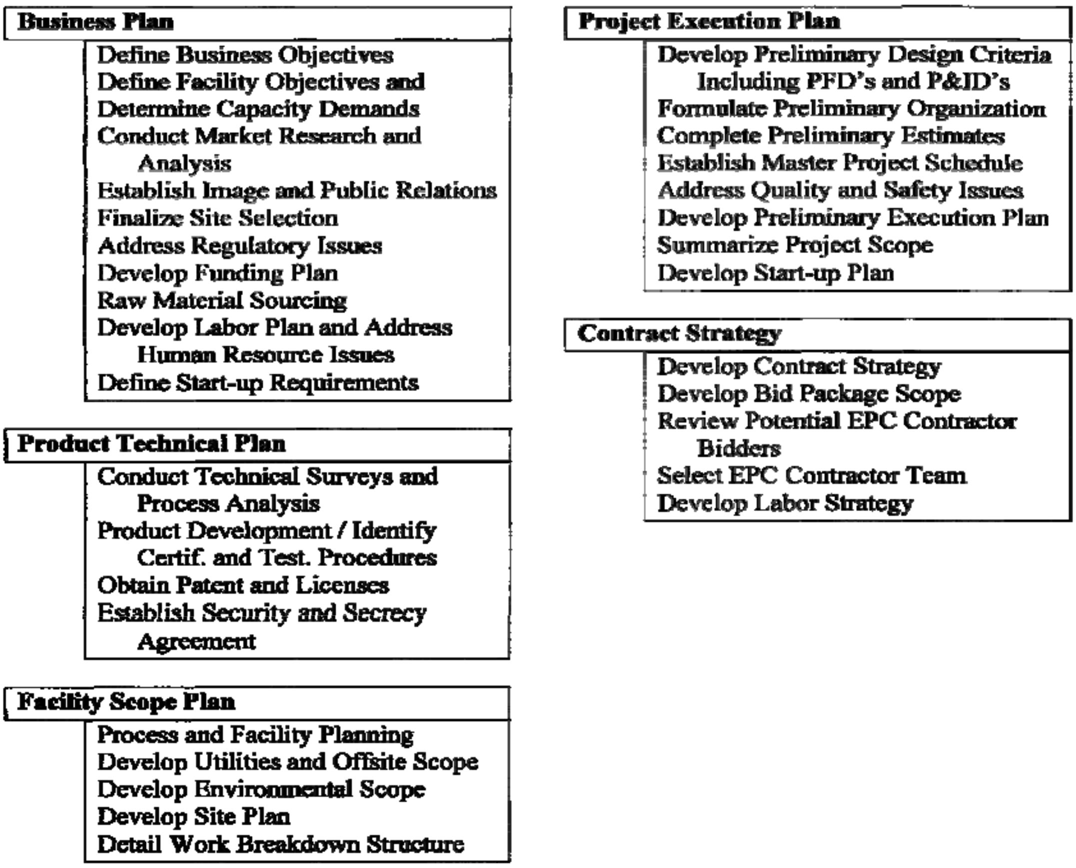

Figure 3.4 Pre-Project Activities (Back and Moreau, 2000)

Back and Moreau (2000) used pre-project activities to capture the planning process at the organisational domain to set up engineering and construction business. Some of the level 2 activities include business planning, business technical plan. However, including project strategy and contracting strategy tend to include project domain at this level.

3.2.2 Engineering Design

Engineering design is a creative, iterative and often open-ended process of conceiving and developing components, systems and processes Engineering design process, thus, is systematic and creative application of scientific and mathematical principles that proceeds manufacture or construction of product or facility (Saraforde, 2006).

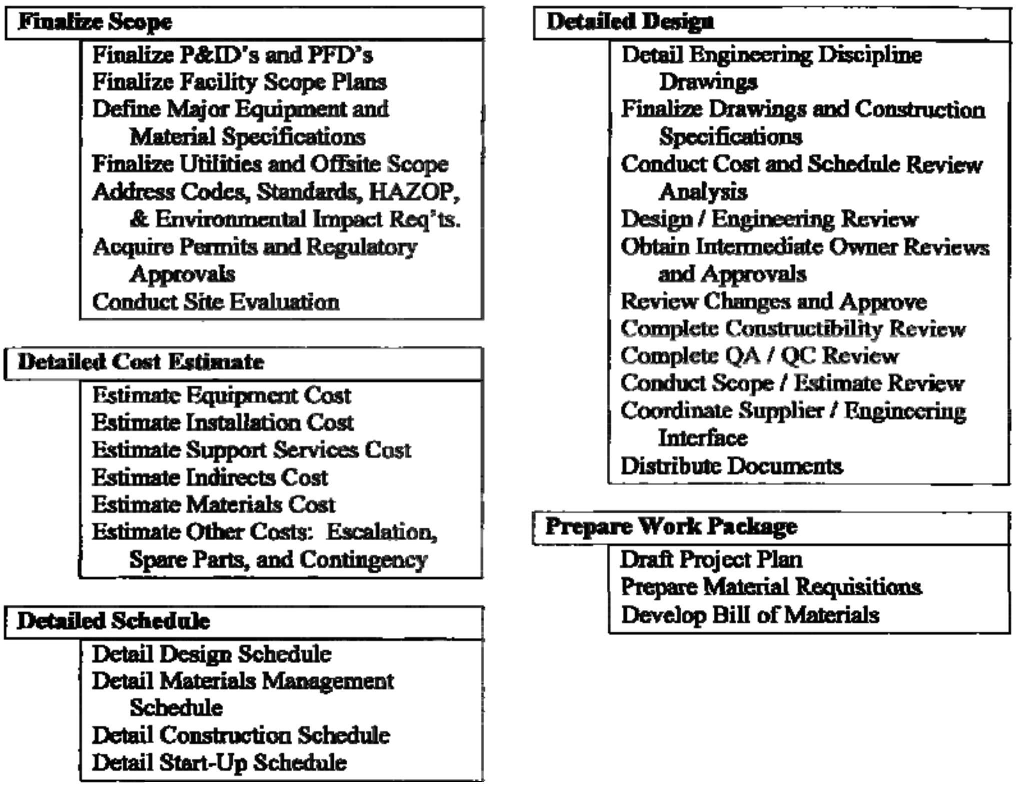

Figure 3.5 Engineering Design work functions (Back and Moreau, 2000)

Gwendolyn and Vreede (2009) argued that regardless of the domain, the act of designing involves proving a solution to a problem. Engineering design is a multi-disciplinary and multi-step process that includes research, conceptualization, feasibility assessment etc. (Ertas and Jones, 1996; Eggert, 2010).

3.2.3 Procurement

Procurement is viewed as an activity in the project construction life cycle that involves the acquisition of goods and/or services from preparation and processing of a requisition through to receipt and approval of the invoice for payment. It commonly involves (1) development of specifications (2) issue for inquiry to suppliers (3) analysis and evaluations of bids submitted and (4) making the purchase (5) expediting the delivery and (6) contract administration (Shaw, 2010).

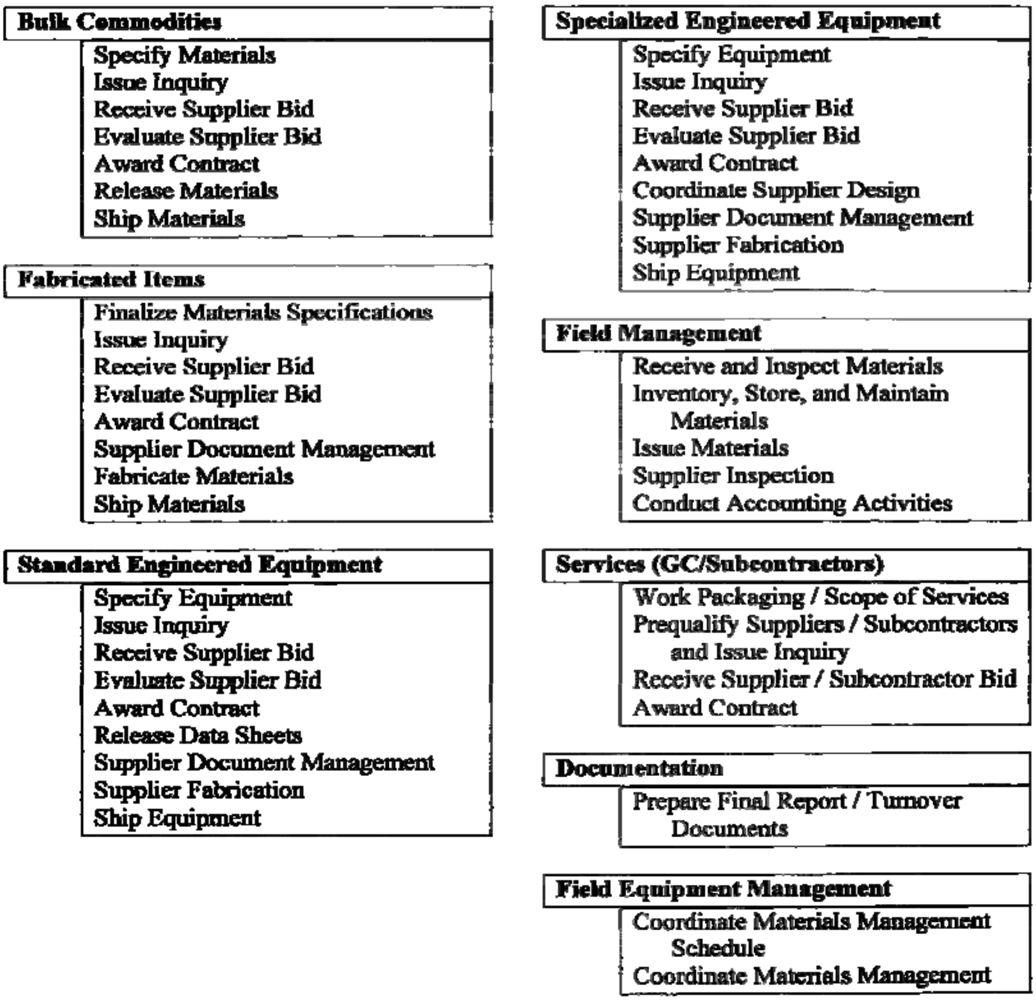

Figure 3.6 Procurement Activities (Back and Moreau, 2000)

Back and Moreau (2000) categorised the procurement process under material management, giving it a specific reference to construction project activities as depicted in Figure 3.6.

3.2.4 Construction and Commissioning

Construction is the process that translates the completed design and procured materials into fabricating, erecting and or installing finished facilities such as buildings, bridges, road, refineries, petroleum rigs, and jetties.

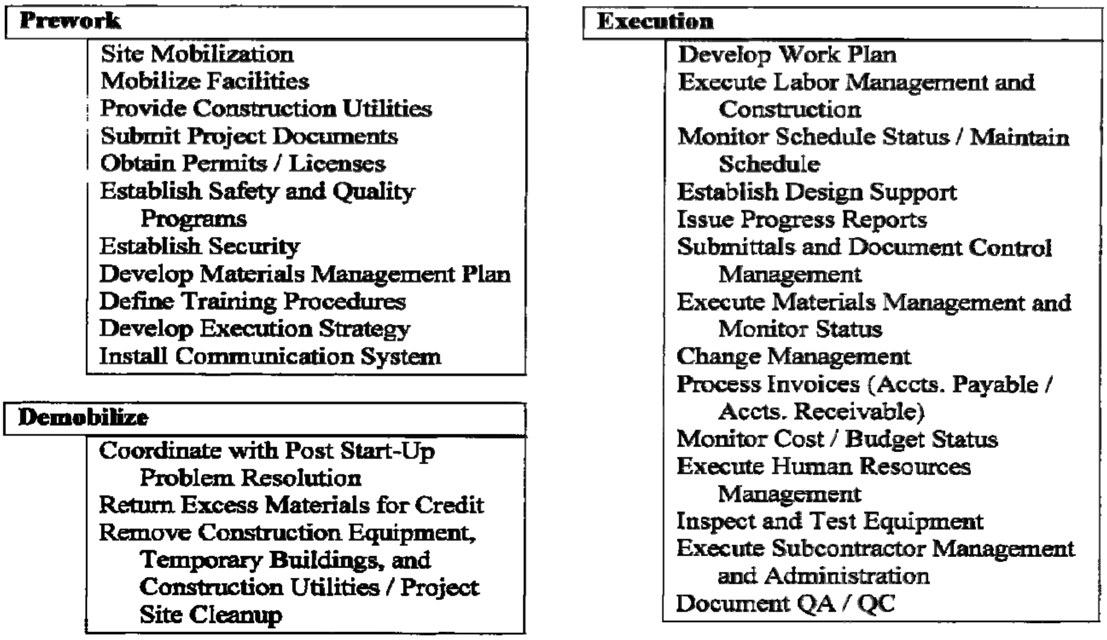

Figure 3.7 Construction Activities (Back and Moreau, 2000)

The final stages of construction projects include pre-commissioning, commissioning and start-up. Pre-commissioning especially in oil and gas construction projects include the process of installation of all instrument loops, equipment items and electrical supplies. With the establishment of overall facility functionalities n safety and controls the commissioning of activities were conducted.

3.2.5 Maintenance and Operation

Operations and Maintenance are the decisions and actions regarding the control and upkeep of property and equipment. To achieve this, the main activities involved the following, no necessary in the same sequence: (1) Conduct pre-operations testing (2) Develop maintenance plans (3) Monitor & assess equipment operations (4) Track and analyse maintenance history (5) Track maintenance / modifications requests (6) Monitor/track/control energy usage (7) Update as-built drawings (8) Monitor environmental impact (9) Train facility operators. The aim of operations and maintenance activities is to prevent failure of facilities or equipment, decline in efficiency, reliability, and safety of the facility Sullivan (*et al.*, 2010).

3.2.6 Project Management

Project management is a methodical approach to planning and guiding project processes from start to finish. According to the Project Management Institute, the processes are guided through stages that include (1) initiation, (2) planning, (3) executing, (4) controlling, and (5) closing. The project management concept can be applied to almost any type of project and industry. A project is typically viewed as any temporary endeavour with a defined start and end, further constrained by specification and cost undertaken to meet unique goals and objectives (Martin, 2002; Paul *et al.*, 2005)

The primary challenge of project management is to achieve all of the project goals (Lewis, 2006) and objectives while honoring the preconceived constraints (Paul *et al.*, 2005). Typical constraints are scope, time, and budget (Harold, 2003). The secondary—and more ambitious—challenge is to optimize the allocation of necessary inputs and integrate them to meet pre-defined objectives PMI (2010).

3.3 IT Application Areas in Construction

Different IT systems are used at country, organizational and projects levels. IT systems used at organizational level are mainly related to data processing on finances, business strategies and investments decisions. Example such IT systems deployed at organizational level include geographical information system, expert systems, inter-organisational information sharing, communication systems, etc., (Hassan and McCaffer, 2002; Kaklauskas, 2007). The deployment of IT at organizational levels has recorded several empirical impacts on the organisations performances as exemplified in Table 3.2.

Table 3.2 IT on Organisations' Performance

Impact of IT on Organisations' Performance	Reference
Improve their market share and profitability through innovative use of IT	Ives and Learnmonth, 1984; McFarlan, 1984, Porter and Miller, 1985; Rockoff *et al*., 1985
Possible role in creating sustained competitive advantages for firms	Barney, 1991; Byrd and Turner, 2001; Clemons, 1986; 1991, Clemons and Kimbrough, 1986; Clemons and Row, 1987; 1999; Feeny, 1988; Feeny and Ives, 1990; King et al., 1989; Parson, 1983
Achieving a competitive advantage through the application of IT	Betts et al, 1991; Betts and Ofori, 1992; 1994; Porter and Miller, 1985; Tan, 1996; Yeo, 1991, Melville, et al., 2004
IT can improve a company's performance and competitive position	Dehning and Stratopoulos, 2003; Bharadwaj, 2000; Stratopoulos and Dehning, 2000)
Advantage granted by IT is short lived because such advantages are easily replicated by rivals	Alter, 1998; Ballou and Slater, 1994, Carr, 2003
Theoretical and empirical evidences indicate that company implementing IT-enabled strategy are able to gain competitive advantage over their direct competitors	Andersen, 2001; Bharadwaj, 2000; Feeny and Ives, 1990; Konsynski and McFarlan, 1990; Mata *et al,* 1995; McFarlan, 1984; Porter and Millar, 1995; Stratopoulos and Dehning, 2000; Kassim, 2006
Sustained competitive advantage through barriers to entry, switching costs, and mobility barriers	Porter, 1979; 1980; Mata *et al*., 1995; McFarlan, 1984; Sambamurthy, 2000
Sustained competitive advantage would require bundling IT with differences in the value chain	Clemons and Row, 1987; Clemons and Row, 1991
Sustained competitive advantage would require bundling IT with tangible or human resources	Ciborra, 1994
IT can bring competitive advantage to companies within an entire supply chain	Salmela and Turunen, 2003
IT-dependent strategic initiatives contribute to sustained competitive advantage	Piccoli and Ives, 2005

The areas of IT systems application at project level include those that encompass project planning, scheduling, cost control, project management, construction methods, and human resource management (Mohan 1990; Kaklauskas, 2007). Others include web-based tendering processes (Alshawi and Ingirige, 2003), a web-based construction monitoring (Cheung et al., 2004; Ryoo *et al.,* 2010), e-procurement (Kong *et al.,* 2004; Tai *et al.,* 2010), Building Information Modeling (BIM)(Eastman *et al.,* 2010), etc. Table 3.3 below provides examples of the IT systems applications within the construction project life cycle and value chain.

Table 3.3 IT Application Areas in Construction Projects

Primary Activities	Application Areas	Reference
Strategic Planning	Expert system and decision support system Bidding Strategy Integrating simulation with expert systems	Mohan, 1990; Ahmad, 1990; Dawood, 1995; Touran, 1990; Artiba and Aghezzaf, 1997; Fayek, 1998; Wu *et al.*, 2005; Bee-lan *et al.;* 2010
Engineering Design	Planning and Scheduling	Levitt *et al.*, 1988; Moselhi and Nicholas, 1990; Morad and Belivean, 1991; Aouad and Price, 1994; Dawood, 1995b; Dawood and Sriprasert, 2006; Perera and Imriyas, 2004
	BIM	Succar *et. Al.*, 2007; Kaner *et al.*, 2008; Eastman *et al.*, 2010
	Cost Estimation	Smith, 2002; Adnan *et al.*, 2005; Gu *et al.*, 2011
	Quality and Safety	Nobe *et al.*, 1999
	CAD systems	Choi and Ibbs, 1990; Sanvido and Medeiros, 1990; Reinschmidt *et al.*, 1991; Gibson and Bell, 1992; Heath *et al.*, 1994; Mahoney and Tatum, 1994
	Building Information Modelling	Succar et. Al., 2007; Kaner *et al.*, 2008; Eastman et al., 2010
Procurement	Construction Material Information Material specifications Delivery and Expediting	Kong *et al.*, 2004 Nicholas and Edwards, 2003; Hassanein and Moselhi, 2005; Ryoo *et al.*, 2010
	E-sourcing and electronic data interchange (EDI) Web-based e-procurement	Talluri, *et al.*, 2007; Keating, 2011 Oyegoke *et al.*, 2009; Tai *et al.*, 2010

Construction & Commissioning	Bar-coding	Rasdorf and Herbert, 1990; Stukhart and Cook, 1990; McCullouch and Lueprasert, 1994
	Radio frequency identification (RFID)	Aksoy *et al.*, 2004
	CAD systems	Aound, Lee and Wu, 2005; Kang *et al.*, 2005; Howard, 2006; Moum, 2006; Akinci, *et al.*, 2008; Xuetao *et al.*, 2009; Russell *et al.*, 2009; Benjaoran, and Bhokha, 2010
Maintenance and Operation	Electronic Data Interchange (EDI)	Gibson and Bell, 1990; O'Brien and Al-soufi, 1993
	Maintenance History RFID Tags	Schell 2001; Jaselskis and El-Misalami 2003; Ergen *et al., 2007*
Project Management	Project Monitoring	McGartland and Hendericken, 1995; Elazouni et al., 2010; Mahaney and Lederer, 2010; De Marco, A.; Briccarello and Rafele, 2009
	Cost Estimation	Adnan et al., 2005
	Data communication	O'Brien and Al-soufi, 1994; Tai *et al.*, 2009; Eastman *et al.*, 2010

3.4 The Components of the Model

Many researchers have asserted that the utilization of IT resources might be able to create sustained competitive advantage for organisations, however, early work in this area was relatively underdeveloped, both empirically and theoretically (Jarvenpaa and Ives, 1990; Mater, Fuester and Barney, 1995).

It was further argued that any performance advantage granted by IT is short lived because such advantages are easily replicated by competing organisations (Alter, 1998; Ballou and Slater, 1994, Carr, 2003). Others argued that rivals will attempt to neutralize the competitive advantage of the successful users by copying and possibly improving the IT use

(Kettinger *et al.*, 1994; Mata *et al.*, 1995); hence IT–enabled strategies may not provide a platform for a sustainable competitive advantage.

Nevertheless, the theoretical argument for ITBV is that sustainability is possible and can be attributed to certain IT resources and capabilities that are difficult to imitate (Feeny and Ives, 1990). When an IT-enabled strategy is combined with such resources and capabilities, organisations will be able to gain a sustained competitive advantage through barriers to entry, switching costs, and mobility barriers, high performance relative to its peers (Porter, 1979; 1980; Mata *et al.*, 1995; McFarlan, 1984; Sambamurthy, 2000).

The general hypothesis therefore, is that organisations can sustain strategic IT innovation and differentiate business success by developing superior IT capabilities (Sambamurthy, 2000). These IT resources include managerial IT skills, Technical IT skills and IT infrastructure (Melville *et al.*, 2004; Piccoli and Ives, 2005).

3.5 The Research Question and Hypotheses

To increase the understanding of IT business value diffusion, implementation status, areas of application, and the perceived impacts therein in the delivery of value chain of engineering and construction organisations; the research addressed the following question:

> *What are the outcomes of deploying and utilizing IT resources in the delivery of engineering and construction projects value chains on the measure of the performance metrics including cost, schedule, profitability, safety and customer satisfaction.*

In order to answer the research question a set of IT resources and other organisational capabilities and resources are identified based on multiple theoretical perspectives. Using these elements hypotheses were derived. Combining the hypotheses with the concept of the value chain and process view, a schematic conceptual model was developed as depicted in Figure 3.4.

The following sections describe the IT resources and other complementary organisational resources.

3.5.1 *IT Shared Infrastructure (ITSI)*

IT shared infrastructure (ITSI) is the shared technology that provides reliable shared services across an organization which forms the base foundation of the organisation's IT capability, and is coordinated centrally, usually by the information group (Will and Broadbent, 2000; Melville *et al.*, 2004; Piccoli and Ives, 2005). As such, the ITSI provides the foundation for the delivery of business applications and services (Broadbent and Weill 1997). ITSI has been described as an important organizational capability that can be an effective source of value (Bharadwaj, 2000; Broadbent and Weill 1997, Ross *et al.*, 2004; Sambamurthy, 2000; Bhatt and Grover, 2005).

ITSI can provide organisations with the ability to share information across different functions, innovate, and exploit business opportunities, and the flexibility to respond to changes in business strategy (Weill *et al.*, 2002). However, the existence of open architectures and standardized enterprise packages suggest that this capability might not be heterogeneously distributed across organisations and / or the access to such infrastructure is not restrictive (Carr, 2003). Therefore, despite some contrary evidence ITSI is argued to be valuable but not a source of competitive advantage (Bhatt and Grover, 2005).

***H_1*:** *the technological components of ITI are readily available in the marketplace therefore; ITSI may not have significant impact on the performance of engineering and construction organisations.*

3.5.2 *IT Business Application (ITBA)*

IT Business applications (ITBA) refer to any application that is important to running of engineering and construction businesses; this may include administration and decision support, engineering analysis, organisational communication, design and project management computer software. These computer applications are used to execute the work functions of the primary activities of the focal organisation's value chain. They may be deployed on standalone computers or as networked integrated systems within the organisation. Due to their direct involvement in the organisational business processes the following hypothesis was put forward, and this is represented by H_2 on the conceptual model diagram in Figure 3.8.

H_2: *IT business applications (ITBA) will have positive impact on construction organisation performance.*

3.5.3 IT Human Skills (ITHS)

Another category of IT resource is the expertise and knowledge of the IT personnel (Barney 1991), which is termed as IT human resources (Melville *et al.,* 2004). This denotes both technical and managerial knowledge (Ross *et al.,* 1996; Bharadwaj 2000; Dehning and Richardson 2002).

Technologies are inherently dissimilar, thus they create unique challenges for organisations. Neverthless, organisations could developed unique sets of IT capabilities over period of time, thorugh experience (McKenney *et al.,* 1995). Thus, positioning them in a better position than their rivals in using and managing these technologies (Ross *et al*., 1996; Bharadwaj 2000; Dehning and Stratopoulos 2003; Wade and Hulland 2004; Ross, 2004). IT human resources that have received research attention include technical skills, IT management skills, and relationship assets (Piccoli and Ives, 2005).

IT technical skills refer to the ability to design, develop and implement effective information systems. As such, they include proficiency in system analysis and design, infrastructure design and programming (Ross et *al.*, 1996). Technical IT Skills are typically mobile as it is not difficult for competitors to hire away this value-creating resource from their competitors at their market price (Mata *et al.,* 1995), giving rise to the following hypothesis.

IT Management Skills involve skills in managing IT projects, evaluating technology options, conceiving, developing, and exploiting IT applications and managing changes. Such skills are developed over time through accumulation of experience in a form of organisational learning. The theoretical concepts of IT management skills lead directly to the following hypothesis represented by H_3 on the conceptual model diagram in Figure 3.8.

H_3 *Superior IT human capabilities (ITHS) will have a positive impact in providing a source for engineering and construction organisations' competitive advantage*

3.5.4 Complementary organisational resources

Although it is possible to apply IT resource for the improvement of organisational performance, according to RBV, in order to have sustainable competitive advantage it requires other complementary organisation resources to be mobilized and be in alignment with the IT-enable strategies. These complementary resources include the organisational policies, rules and work practices, organisational structure, workplace practices, and organisational culture conceptualised as 'business work environment' (BWE). This is represented by H_4 on the conceptual model diagram in Figure 3.8:

H_4: *Complementary organisational resources (BWE) will have positive impact in creating ITBV in engineering and construction organisations*

The elements of the four hypotheses above form the inputs into the organisational value chain in the model as depicted in Figure 3.8. The IT and organisational complementary resources constructs form the inputs to the engineering and construction project value chain. The output measures are represented by the project performance metrics, thus establishing the productivity, efficiency and effectiveness of the IT on the value chain leading to the creation of competitive advantage. The model assumes the presence of IT investment within the focal organisations. The measure of the IT investments and the resources in the operationalisation of the model will be based on the level of application and diffusion in the sampled organisations.

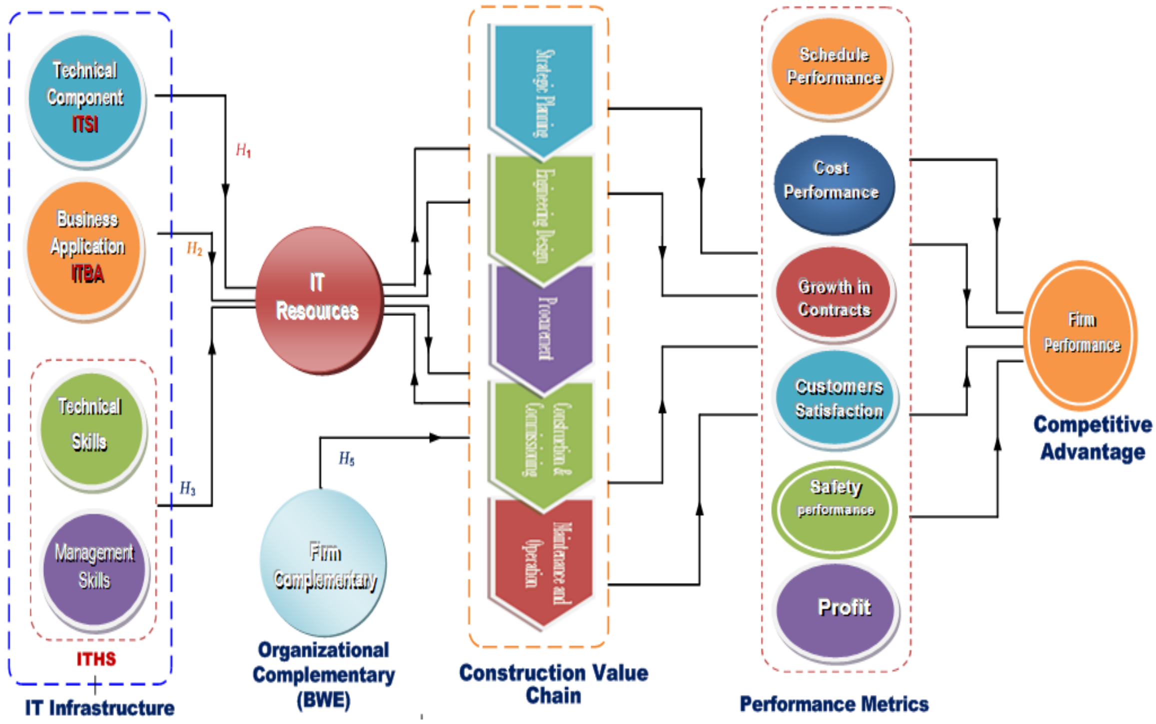

Figure 3. 8 Conceptual ITBV Model Scheme for Construction Organisation (Kassim et al., 2009a, 2010c)

Starting from the left-hand side of the model in Figure 3.8, IT infrastructure (ITI) represents the IT resources as input factors to the execution of work functions within the organisation's value chain. The IT resources are conceptualized in four dimensions: IT shared infrastructure (ITSI), IT Human Skills (ITHS), IT Business Applications (ITBA) applications, and business process (Bhatt, 2000). The measure of the IT resources is conceptualised as level of utilization rather than as a monetary value of the IT investments (Tallon and Kraemer, 2007). The level of IT usage has widely been accepted as an important indicator of IT success within organizations (Mahmood *et al.*, 2001). The next input factor is the organisational complementary resources represented by the business work environment (BWE). Drawing from Porter (1998) value chain concept primary and critical activities of the engineering and construction organisations were proposed. Primary activities consist of strategic planning, engineering design, procurement, construction and start up and operation and maintenance represent the construction business process. These primary activities were further broken down into work functions. This process was facilitated through the experiences of the researcher in delivering variety of construction projects (Alarco´n and Mourgues, 2002), the literatures such as O'Connor and Yang (2003); O'Connor and Yang (2004) and Yang *et al.* (2006; 2007) and constructions organisations from different sectors that participated in a pilot study. The performance measures are represented by six variables of schedule performance (SCHD), cost performance (COST), customer satisfaction (CUSTO), growth in contracts (CONTR), safety (SAFETY) and profits (PROFI) mainly hinged on project performance. Variables such as contract growth is included to highlight the extent of IT and business strategies alignment. The selection of the variables was based on a multi-criteria analysis of Analytical Hierarchy Process (AHP) (Saaty, 1990) and attempted to ensure both owner's and contractor's perspectives were covered.

3.6 Measuring ITBV

This section provides a detailed description of the technique used for the quantification of the ITBV variables used for the subsequent data collection and analysis.

3.7 Input Variables

The above elements of the hypotheses are operationalised as the independent variables. The measure of the variables are conceptualised at the level of utilization in conducting the construction business, rather than their monetary value because of the difficulties in getting monetary value of organisation's IT investments (Kumar, 2004). Tallon and Kraemer (2007) established that a significant positive correlation exists between objective (performance measure) and perceptual measures of ITBV. The measure of the dimensions of ITI and complementary resources are used as input variables. The following are the descriptions of the inputs variables.

3.7.1 IT Business Applications (ITBA)

Advanced computing technologies have the potential to empower project managers and construction engineers to make quick decisions based on accurate information that can be visualized, studied, optimized, and quantified with greater accuracy (Salem and Mohanty, 2008).

Several researchers have investigated the impacts of different technologies on project performance. The most detailed of these studies, O'Connor and Yang (2004), investigated the extent to which technologies contribute to project success. Technology usage metrics analyzed in their research include those at the project level, the phase level, the task automation level, the integration link level and those for industry-wide high-tech and industry wide low-tech work functions (Yang, 2007).

For the purposes of this research, automation and integration are defined as the use of electronic systems to manipulate data or produce deliverables in the course of executing construction project and the sharing of information between project participants or melding of information sourced from separate systems respectively (O'Connor *et al.*, 1999; O'Connor and Yang, 2004). Thus, the impact of the use of mechanical equipment or technology in executing construction physical tasks such as site preparations; installation, etc. is not part of the scope of this study.

Several studies have developed metrics for the assessment of technology utilization. Issues discussed include the use of automation technologies for specific project tasks, technology strategy, information technology and the application of integration.

In line with O'Connor *et al.* (1999); O'Connor and Yang (2004); Yang *et al.* (2006) and Yang (2007), metrics of measuring the adoption and use of ITBA in the execution of identified work functions are developed.

The ITBA metrics evaluated are at the primary activity of the construction value chain phase and the corresponding work functions for each of the primary activity as in Table 3.1. The participant will consider projects executed over the period of last three years to assess the level of deployment of the ITBA in executing their work functions. The use of the average level of inputs over a three-year period was to address the time lag between investment in IT and the accrual of benefits (Shafer and Byrd 2000).

For each primary activity phase the ITBA index (IT_p) is calculated as an average scope for all the work function under the phase (El-Mashaleh *et al.,* 2006; Yang, 2007):

$$IT_p = \frac{\sum_{i=1}^{W} IT_w}{W} \qquad 3.1$$

Where:

IT_p = automation and integration index (IA) for each primary activity of the organisations'' value chain.

IT_w = IA work functions score on the Likert scale from 1- 5 for each primary activities of the organisations' value chain

W = the total number of the work functions

An overall project ITBA automation index is computed as the average score of IA across the six primary activities of the organisations' value chains. These score are at organisation level where projects executed over a period of three years are to be considered. Therefore, ITBA index as of the components of the IT resources for this research as an independent input is calculated as follows:

$$ITBA = \frac{\sum_{i=1}^{l} (IT_p)_i}{W} \qquad 3.2$$

Where:

ITBA = Organisation measure of IT business application automation and integration,

λ = The number of primary activities in the organisations value chain, which is 6 for this research

3.7.2 *IT Shared Infrastructure (ITSI)*

There is little consensus on the dimension of ITSI or how it should me be measured. However, Man *et al.,* (2008) suggest that previous conceptualisation of IT capability include managerial capability (Sambamurthy and Zmud, 1992; Ross, Bealth and Goodhue, 1996). The lack of appropriate approaches and instruments for measuring ITSI may have contributed to the scant efforts to empirically study the characteristics and organizational roles of ITSI.

Kumar (2004) modelled the measures of ITSI using three streams of value of *reliability,* the ability to operate with low downtime; *flexibility,* the ability to quickly and economically adapt to changing business requirements; and *upgradability,* the ability to quickly and economically adapt to or deploy multiple, complex technologies as required.

ITSI is generally and often intertwined with organizational structure and business processes thus; it can be either an enabler or a barrier for planning and implementing new competitive strategies and organizational changes (Broadbent *et al.,* 1999). Nath (1988) developed a scale to measure the IS managers' perspectives on the value of local area networks (LANs). Star and Ruhleder (1996) characterize an infrastructure in terms of seven dimensions: embeddedness, transparency, reach or scope, links with conventions of practice, embodiment of standards, built on an installed base, and becomes visible upon breakdown. Bhatt (2000) adopted the following dimensions 1) extent of inter-organisation infrastructure; 2) extent of infrastructure flexibility; and 3) extent of data integration to measure organisation's ITSI.

Based on content analysis the share technological is operationalised using the extent of the following dimensions:

- Corporate data can be seamlessly accessed from remote locations.
- Customers and suppliers are connected with the organisation
- Departments can share data and applications on the communication networks.
- Network architecture can be modified minimum disruption

- Procedures and policies are used in managing networks.
- Share data and applications

In addition to ITSI, Alshawi (2007) identified people, process, and work environment as the required competencies for an organisation to derive ITBV. The processes of engineering and construction organisations are modelled in the form of the suggested value chain. The ITSI is conceptualisation is described in sections above.

3.7.3 Human IT Skills (ITHS)

The organisational IT Human skills and competencies (ITHS) measure are conceptualised in the following dimensions:

- Designs future opportunities for the business
- Manage resources to obtain optimal results
- Responsible for application development
- Align IT strategy with business strategy
- Provide training for IT team
- Prepare IT strategy for future business requirements

3.7.4 Complementary Resources (BWE)

Drawing from the concept of resource complementarities, certain organizational resources and capabilities that relate to the work environment are considered as part of the production factors that could compliment the IT resources for organisation to gain competitive advantage.

Alshawi (2007) suggested that work environment is considered to be the main enabler in generating IT business value. Work environment is conceived as encompassing the dimensions of organisational complementary resources. The concept of complementarities is often used to explain the productivity paradox and the wide variation observed between IT usage and its business value (Thouin *et al.*, 2008). The complementary relationship between IT and other organisation resources have led some to posit that the relationship between IT and business value may, in large part, be indirect and difficult to measure. The major contribution of IT is that it complements existing organisation-level resources to increase their value in a moderating fashion (Barua & Mukhopadhyay, 2000).

Dimensions for measuring complementary resources include (Powell and Dent-Micallef, 1997; Al-Mashiri and Zairi, 2000; Alshawi, 2007).

- Leadership
- Business work practices
- Employee empowerment
- Open communication
- Project management competency

The constructs of the IT and non-IT resources as inputs along with the dimensions for measuring them are summarised in Table 3.4.

Table 3.4. IT Resources Constructs

Constructs	Dimension	Indicators
IT Shared Infrastructure (ITSI)	Physical platform for Sharing IT Services	• Network Architecture Performance • Clients and Suppliers Networking • Remote Accessibility of Corporate Data • Use of Standard Procedures and Policies
IT Business Application (ITBA)	Implementation Level	• Level of Deployment and Integration of Computer Applications in the Delivery of the Work Functions
IT Human Skills (ITHS)	Proficiency in System Analysis and Design, Programming Evaluating Technology Options	• Alignment of IT Strategy with Business Strategy • Extent of Application Development • Designs Future Opportunities for the Business
Complementary Organisational Resources (BWE)	Non- IT Organizational Resources	• Leadership • Employee empowerment • Open communication • Project management competency

3.8 Output Variables

Some of the difficulties associated with the evaluation of the impact of deployment IT resources on the organisational performance have been identified in the literature review. The contemporary IT investment evaluation approach has focused on quantitative financial assessment and traditional appraisal methods such as Return on Investment (ROI), Net Present Value (NPV) or Internal Rate of Return (IRR), (Chen *et al.*, 2006; Tallon and Kraemer, 2006). The popular financial measures used include sale, return on assets and return on management (Hitt and Brynjolfsson, 1996; Bresnahan *et al.*, 2002; Tallon and Kraemer, 2006). The major problems with these techniques concern the difficulties involve in quantifying intangible benefits and costs. To help ease this difficulty Construct IT For Business (1998) proposes the use of a subjective scoring mechanism to assess the impacts of improved business effectiveness. Organizational performance measurement in construction has traditionally relied on efficiency, return on capital, and profitability, which have been criticized as narrow, reactive, and mostly financial (Bassioni *et al.*, 2004).

Lin and Shen, (2007) highlighted the deficiencies and limitations in traditional performance measurement as recorded by other researchers: (1) they are historical in nature (Dixon et al. 1990); (2) they give little indication of the link between work carried out at present and performance in the future (Kaplan 1983); (3) they encourage a focus on short-term profits, not on long-term strategies (Kaplan 1986); (4) they hinder innovation (Skinner 1986); and (5) they are internally rather than externally focused, with little regard for competitors and customers (Kaplan and Norton 199). Robinson *et al.*, 2005 further argued that traditional financial measures alone are not sufficient performance measures for understanding a dynamic business environment, as it encourages short-termism leading to a lack of strategic focus and failure to provide data on quality (Kagioglou *et al.*, 2001). Other metrics include the Foundation for Quality Management (EFQM) excellence model, key performance indicators (KPI), and the Balanced Scorecard. The business process performance metrics used in prior IT business value research include on-time shipping (McAfee 2002), customer satisfaction (Devaraj and Kohli 2000), and inventory turnover (Barua *et al.*, 1995).

However, with the construction industry being project-oriented in nature (Wegelius-Lehtonen 2001; Bassioni *et al.*, 2004), a focus on the aggregation from project performance to organisational performance has been recognized (Love and Holt 2000; Kagioglou *et al.*, 2001). Construction projects are typically evaluated in terms of cost, time, and quality (Ward *et al.* 1991; Kagioglou *et al.*, 2001; Bassioni *et al.*, 2004). Therefore, schedule performance, cost performance, customer satisfaction, safety performance, growth in contracts and profit are adopted as the output dependent variables (El-Mashaleh *et al.*, 2006 and Kassim *et al.*, 2009), which will sum up to the organisation's performance.

researchThe output dependent variables for the model are a measure of the construction organisation performance metrics. The performance measurement in engineering and construction organisations is traditionally based on financial metrics alone, which is narrow and reactive (Bassioni *et al.,* 2004). Some of the financial measures aggregating IT impacts into firm-level financial measures include: (1) sales (Lehr and Lichtenberg, 1993; Bresnahan *et al.*, 2002; Brynjolfsson and Hitt, 1996), (2) value added (Hitt and Brynjolfsson, 1996; Dewan and Min, 1997), (3) financial accounting ratios such as return on assets (Jeffrey, 2003; Kohli and Devaraj, 2003; Tallon *et al.*, 2000; Tallon and Kraemer, 2006).

3.8.1 Schedule Performance (SCHD)

On a project level of analysis the schedule performance measurement technique is used to measure and give visibility to schedule variances from plan. The technique is also known as the earned value analysis (Pajares and López-Paredes, 2011).

A schedule variance (SV) is calculated as the difference between Budgeted Cost of Work Scheduled (BCWS), and Budgeted Cost of Work Performed (BCWP), thus (Kharbanda *et al.*, 1980; Humphreys, 1992; Arthur and Charle, 1986; Sang-chul Kim, 2009; De Marco *et al.,* 2010):

SV = BCWS-BCWP--- 3.4

The schedule performance is measure via a schedule performance indicator (SPI) defined as the ratio of Budgeted Cost of Work Performed (BCWP) to Actual Cost of Work Performed (ACWP), thus:

SPI = BCWP/ ACWP --- 3.5

If the Schedule Performance Indicator (SPI) has a value less than one, this indicates that the budgeted costs for work scheduled to date exceed the budgeted costs for the work performed to date. This does not necessarily mean that the project is behind schedule but it does indicate that work is not being performed as scheduled, thus warning of the potential for a schedule overrun situation. If the SPI is decreasing over time, the situation is potentially worsening.

At organisational level schedule performance is measured by averaging the individual projects performances over a period of time. This could be expressed as a fraction, percentage or frequency at which the organisation delivered projects within or above the original scheduled duration of projects (O'Connor and Yang, 2004; Yang *et al.*, 2006; Yang, 2007).

Thus, on organisational level, schedule performance (SCHD) refers to the measure of the projects schedules that over or under run as a percentage of the initial estimated durations. The SCHD is measured as the frequencies at which projects are delivered on/ahead of schedule in the last 3 fiscal years within a focal organisation. An average is calculated of the projects with schedule performances within or ahead of the original estimated duration divided by the total projects delivered within the last three fiscal years, thus:

$$SCHD = \frac{\text{Number of Projects Delivered on or ahead of Schedule}}{\text{Total Number of Projects}} \qquad \ldots\ldots\ldots\ldots 3.6$$

3.8.2 Cost Performance (COST)

A similar expression and measures of cost performances is obtainable both at project and organisational levels.

Thus, at organisational level, cost performance (COST) refers to the measure of the projects costs that over or under run as a percentage of the initial estimated budgets. The COST is measured as the frequencies at which projects are delivered within or above budgets in the last 3 fiscal years within the focal the organisation. An average is calculated of the projects with cost performances within or ahead of the original estimated budget divided by the total projects delivered within the last three fiscal years, thus:

$$COST = \frac{\text{Number of Projects Delivered within or above budget}}{\text{Total Number of Projects}} \qquad \ldots\ldots\ldots\ldots\ldots 3.7$$

3.8.3 Customer Satisfaction (CUSO)

Given that customer satisfaction is both individualistic and situational makes the definition of the concept elusive (Oliver, 1981, 1997; Jianxi *et al*., 2006; Forsythe, 2007). However, the importance of the concept was highlighted in the literature. Both Latham and Egan Reports (Latham, 1994; Egan, 1998) identified the customer as being at the core of construction process. It has been argued that customer satisfaction is a necessary precondition for customer loyalty, which is, in turn, a key driver of profit growth and performance (Reichheld 1993; Heskett *et al.,* 1997). Also customer satisfaction contributes towards obtaining competitive advantage in the market place (Drucker, 1954; Cronin and Taylor, 1992; Victor and Boyton, 1998; Forsythe, 2007); increase market share (Buzzel and Gale, 1987), improve profitability (Business International, 1990), increase repeat sales (Oliver and Linda, 1981) and increase word-of-mouth recommendation (Vandermerwe, 1994); customer satisfaction is associated with higher customer loyalty and enhanced reputation (Fornell, 1992; Anderson and Sullivan, 1993; Wangnheim and Bayon, 2004).

Despite the elusive nature of the customer satisfaction concept, Churchill and Surprenant (1982) define it as an outcome of purchase and use resulting from the buyers' comparison of the rewards and costs of the purchase in relation to the anticipated consequences. Others define customer satisfaction as a post-consumption evaluative judgment concerning a product or a service (Churchill and Surprenant, 1982; Gundersen *et al.,* 1996; Markovi *et al.,* 2010). It is the result of an evaluative process that contrasts pre-purchase expectations with perceptions of performance during and after the consumption experience (Oliver, 1980; Markovi *et al.,* 2010).

In the construction industry, the measurement of client satisfaction is often associated with performance and quality assessment in the context of products or services received by the client (Parasuraman *et al.,* 1985; 1988; Soetanto and Proverbs, 2004).

Several models are used to measure the customer satisfaction in the construction industry including EFQM (2005) business excellence (Walker, 1995; Gable, 1996; Jianxi *et al.*, 2006). Kaplan and Norton (1997) argued that the three important performance drivers of customer satisfaction are price, time, and quality.

Another approach for measuring customer satisfaction is the frequency of repeat orders. A high frequency indicates that customers are satisfied with the company. Moreover, since old customers, as a rule, are more profitable than new ones, this key indicator also tells you something about your profitability potential. The willingness of customers to place repeat orders is further an indication of customer-perceived quality and whether or not the company has found the right customers (Wangnheim and Bayon, 2004).

3.8.4 Safety Performance (SAFETY)

Safety management system aims at positively impacting on employee's attitudes and behaviours with regard to safety hazards in order to mitigate their unsafe acts. Thus, awareness is created on occupational health and safety (Beriha *et al.,* 2011).

Hinze and Godfrey (2003) hilighted several types of safety performance measures that can be utilized on construction projects; these include: Occupational Safety and Health Administration (OSHA), recordable incidence rates and experience modification rate (EMR) (Jaselisks *et al.,* 1996; Hinze and Godfrey, 2003; El-Mashaleh *et al.,* 2009; Beriha *et al.,* 2011).

OSHA recordable incidence rates are based on the US Occupational Safety and Health Act (1970). EMR, on the other hand, is established by independent rating bureaus. OSHA requires employers to record and report accident information while EMR dictates the contractor's premium of the workers' compensation insurance (El-Mashaleh *et al.,* 2009).

Organisations have adopted different subjective approaches to measure their safety performances. The measures were mainly based on either a frequency of occurrence, which is based on the number of accidents, or both frequency and severity measure. (Hassanein and Hanna, 2008). A low safety performance by an organization could have adverse effects on the organisation's competitiveness (Beriha *et al.,* 2011).

Several studies related to the measure of construction organisations' safety performances were reported in the literature. The benchmarking of the construction organisations' safety performances were also reported (El-Mashaleh *et al.,* 2005; 2007; 2009). The road safety performance in the construction process, benchmarking among contractors and proposing composite index were undertaken using mainly DEA methodology by (Hermans *et al.,* 2008; Shen *et al.,* 2009; Hermans *et al.,* 2009).

3.8.5 Contract Growth (CONTR)

Another indicator in addition to profitability for measuring the performances of engineering and construction organisations is the measure of the growth in contract won (Kale and Arditi, 2002). The approach is to determine annual increase in contract awarded to the organisation over a given period of time.

3.8.6 Overall Profitability (PROFI)

Various profitability measures are often used for measuring the competitiveness of firms. Return-on-sales reveals how much a company earns in relation to its sales, while return-on-assets determines an organisation's ability to make use of its assets, and return-on-equity indicates what return investors are getting for their investments.

The advantages of financial measures are the easiness of calculation and that definitions are agreed worldwide (Tangen, 2003). However, despite the wide use of profitability measures, their shortcomings have been well documented (Bourne *et al.,* 2000).

Among the criticism is that financial information is constantly lagging by the least one reporting period and hence only shows the outcome of already made decisions (Bassioni *et al.,* 2004). Moreover, the narrow focus on the bottom-line may pressure managers into short-term maximisation and consequently discourage longer-term beneficial improvements (Crawford and Cox 1990). As a third piece of criticism, financial measures do not accurately penalise overproduction or appreciate the cost of quality (Bitichi, 1994).

The research captures how often an organization records net profit after tax or an increase of the profit over the period of three years.

Table 3.5 summarised the inputs variables and their measurement methods

Table 3.5 Performance Metrics that Compose Firm Performances

Metric	Measurement Method
Schedule Performance	Frequency of projects delivered on/ahead of schedule
Cost Performance	Frequency of projects delivered on/under budget
Customer Satisfaction	Frequency of repeat business customers
Safety Performance	Annual improvement of safety records
Profit	Increase in Net profit after tax as a % of total sales

The dimensions for measuring the inputs and output variables for the empirical test of the model are presented in Table 3.6 below.

Table 3.6. Inputs and Outputs Variables

Input Metric (x_i)	Output Metric (y_r)
Measure of shared Infrastructure ITSI Measure of IT human skills (ITHS) Measure of IT business applications (ITBA) Complementary resources (BWE)	Schedule performance (SCHD) Cost performance (COST) Customer satisfaction (CUSO) Safety performance (SAFETY) Contract growth (CONTR) Overall profitability (PROFI)

3.9 Chapter Summary

This chapter has presented the conceptualization and development of the ITBV model for engineering and construction organisations. To mitigate the shortcomings of the previous attempts in developing and measuring the impact of IT on the organisational performance and to fill in the absence of such established model for the engineering and construction organisation; a multiple theoretical approach was described.

The chapter described a unique approach of integrating the organisational theories of process-based view, resources based view and micro-economic view to derive both the input and out variables of the ITVB model. These variables provide the parameters for another unique data analysis approached of DEA as described in chapter 5.

Thus, this chapter further contributes to the body of knowledge towards understanding the impact of IT on the performance of construction organisations filling the gap in the current literature. The next chapter explains the philosophy, methodology and approached used in deriving the model, data collection and the empirical testing of the model.

CHAPTER FOUR
RESEARCH PARADIGMS AND METHODOLOGY

4.0 Introduction

> *"If philosophical positions determine research findings, then reality has no input to and control over scientific research. Each and every one of various incommensurable philosophical positions will determine its own findings. No research findings can be neutrally assessed, criticized or falsified. Besides being rather implausible, this view quickly leads to epistemological relativism"* (Kai-Man Kwan *et al.*, 2001:1164)

This chapter provides an overview of research philosophies leading to establishment of the basis for the research stance. Thus, the chapter explains the research's paradigm views on what constitutes knowledge and how it is created and developed (Saunders *et al.*, 2003: 83). The views facilitated the understanding of the multi-disciplinary positions and how they interrelate (Basden, 2008) within the context of the research.

The chapter highlights the researcher's understanding of the assumptions of different paradigms and how they were deployed in the research processes to bring good fit between paradigms and methods (Lincoln and Guba, 1985; Kirkwood and Campbell-Hunt, 2007).

Thus, the chapter presents the methodology, methods and approaches adopted in scoping, defining the aim and objectives, developing the conceptual framework, data collection and analysis leading to the findings presented in Chapter five.

4.1 Research Processes and Strategy

Research is viewed as a systematic and methodical process of inquiry and investigation that increases knowledge and/or solves a particular problem (Sekaran, 1992). The processes adopted towards achieving the purpose of the research include reviewing and synthesising the current literature on the related field of the research; developing a new concept to describe the area and subject of the research, validating and presented the findings in the form of new knowledge (Sarantakos, 1993).

The different approaches adopted by researchers in answering their research questions are referred to as research strategies. These include but not limited to survey, case study, action research, ethnography and experiment (Saunders *et al.,* 2003; Oates, 2006).

While the overall strategies adopted for this research were survey questionnaire and interview; the processes in undertaking the research involved stages as depicted in Figure 4.1. The stages include reviewing the existing literature as described in chapter two which provides the basis and foundation for the research (Davis *et al.,* 1989). The research aim and objectives were established leading to defining the research question. In order to provide a medium for answering the research question, a conceptual model was derived using the theories and paradigms from the literature. The model derivation was detailed in chapter three. The remaining parts of the resaerach design including the strategy are presented in the subsequent chapters. This chapter explain the processes for determining the research methods appropriate for answering the research question, the data collection approach and tools. The final processes involved the choice of data analysis approach and tool; interpretation and presentation of the findings with conclusion.

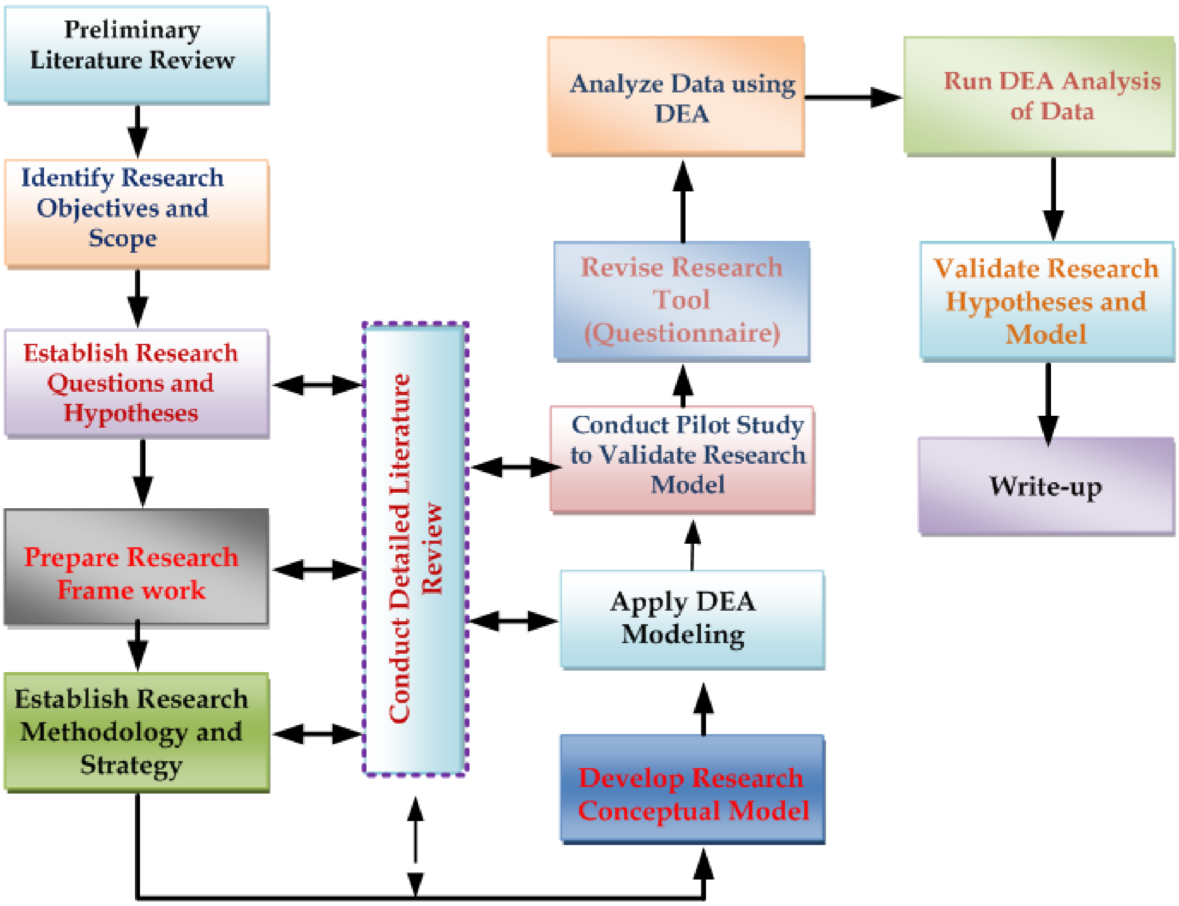

Figure 4.1 Schematic Representation of Research Process

4.2 Research Philosophy

""Philosophy is at once the most sublime and the most trivial of human pursuits..." William James - "The Present Dilemma in Philosophy"

Ontology is a philosophical stance concerned with what is known or what constitutes social reality. The ontological stance of a research represents the researcher's view regarding what makes up social reality (Crotty, 2003). The two prominent ontological positions are positivism and constructivism. Under the positivism paradigm knowledge is assumed to be out there waiting to be discovered while constructivism views knowledge as socially constructed by the interaction of the participants within the environment. There was no agreed philosophical stance for conducting research under engineering and construction management related fields mainly due to the multi-disciplinary nature of the field, from sociology to economics and science each with a different ontological stance. Indeed, there is limited declaration by researchers in the field of construction management on their respective philosophical stances; the determination of the paradigm views tend to be at the level of research methods. The ontological argument for this research is described in this chapter with a clear statement of the research stance.

On the other hand, epistemology is the other branch of philosophy of knowledge that is concerned with how we come to know reality. The two major positions under epistemology are positivism and interpretivism. Positivism focuses on using natural science methods for gathering knowledge. Positivists argued that such approach is needed for quantitative measures required to test hypotheses that could further allow possible generalization of research findings (Raftery *et al.,* 1997). Thus, positivism is a philosophical view mainly adopted in scientific research requiring hypothesis testing. Interpretivism takes the opposite view; it argues that cultural, historical and other issues that allow people to interact are fundamental to knowledge creation.

4.2.1 Positivism

The positivism paradigm assumes implicitly or explicitly that reality can be measured by viewing it through a one way, value-free mirror (Rana and Perry, 2006). However, it has been criticised for its exclusion of the discovery dimensions in inquiry and the under-determination of theory (Deshpande, 1983; Guba and Lincoln, 1994). Despite positivism having been viewed as a "scientific" paradigm (Buzzell 1963; Mills 1961; Lee 1965; Robin 1970; Ramond 1974), it has been argued that positivism could be used as framework for construction management research (Crook et al. 1996; 2008). The first phase of this research involved a comprehensive literature review in the relevant fields which led to the development of a conceptual model using multiple theoretical paradigms as a framework and hypotheses were developed addressing the research objectives and scope. Thus, at this level the research adopted a deductive approach

(Loose, 1993) with positivism view because of the reliance on the current body of knowledge to develop the research model and hypotheses (Sutrisna, 2009).

4.2.2 Constructivism

Constructivism is one of the varying strands within interpretive paradigm. Constructivism is a philosophical school of thought arguing that research is fundamentally theory-dependent. According to constructivists, the theoretical position held by researchers not only guides their basic position, but also determines what gets construed as a research problem, what theoretical procedures are used, and what constitutes observations and evidence (Boyd, 1991: 202). Thus, constructivists challenge the notion that research is conducted by impartial, detached, value-neutral subjects, who seek to uncover clearly discernable objects or phenomena. Rather, they view researchers as craftsmen, as toolmakers (Spivey, 1995: 314) who are part of a network that creates knowledge and ultimately guides practice (Mir and Watson, 2000). The paradigm argues that the world is "constructed" by people and that these constructions should be the driving forces investigated in social science research (Rana and Perry, 2006).

Seymour *et al* (1997) argued for using constructivist paradigm for construction management research. Also it has been argued for the potential of constructivism as a methodology for strategy research (Spender, 1996; Scherer and Dowling, 1995). Thus, for the second phase of the research a constructivist view was adopted. This phase involved validation of the proposed conceptual model through an unstructured interview and an open–ended survey questionnaire to validate the proposed engineering and construction work function as described in chapter 3. The choice of this approach at this phase of the research is informed by the requirement to carry out a holistic in-depth investigation of the complex phenomenon of IT business value of a construction organisation within the context it occurs (Benbasat *et al.*, 1987; Feagin *et al.*, 1991; Yin 1994).

4.2.3 Realism

Realism is a philosophical position which posits that reality exists independently of the researcher's mind, that is, there is an external reality (Bhaskar, 1978). This external reality consists of abstract things that are born of people's minds but exist independently of any one person, it "is largely autonomous, though created by us" (Magee, 1985, pp 61).

Both positivism and realism have been subjected to various epistemological challenges. Phenomenology, for example, emphasizes the fundamental place of consciousness, interpretation, meaning, hermeneutics, communication, subjectivity and relativity with each of these aspects suggesting both a foci of attention in research and an imperative for methodology. In different ways, in most phenomenological approaches, prevailing worldviews or ontological positions are questioned. This necessitates researchers' values, prejudices, beliefs and attitudes being stated and interrogated, and their likely influence on the research being appraised (Fawcett *et al.*, 2004).

4.2.4 Pragmatism

Pragmatists advocate integrating methods within a single study (Creswell, 1995). Moreover, Sieber (1973) articulated that because both approaches have inherent strengths and weaknesses, researchers should utilize the strengths of both techniques in order to understand better social phenomena. Indeed, pragmatists ascribe to the philosophy that the research question should drive the method(s) used, believing that 'epistemological purity does not get research done' (Miles and Huberman, 1984 pp. 21). In any case, researchers who ascribe to epistemological purity disregard the fact that research methodologies are merely tools that are designed to aid our understanding of the world (Onwuegbuzie and Leech, 2005).

The research utilizes quantitative and qualitative techniques within the established framework, thus, pragmatically the research incorporates the strengths of both approaches. This view allows for cognizant recognition of the research techniques thus, facilitates adoption of research methods with respect to their value that helps address the underlying research questions, rather than with regard to some preconceived paradigm which is hegemony in a given field of research.

4.3 Paradigm Incommensurability

Burrell and Morgan (1979) claimed that differences in ontology, epistemology, and methodology as well as assumptions about human nature construct insurmountable barriers between paradigmatic perspectives. Each paradigm portrays a specific perspective thereby preventing combinations of concepts derived from individual paradigm. As each paradigm defines a different domain in which theories can be conceived, there is little or no possibility of effective communication between their adherents (Majken and Mary, 1996). This leads to the paradigm incommensurability which insisted that researchers must choose the paradigm under which they do research from among the alternatives on offer (Mingers, 2001). They must then commit themselves to a single paradigm, although sequential movement over time is permissible. Thus, the main reason for prescribing multimethod research was the supposedly irreconcilable objectivist/subjectivist ontological and epistemological dichotomies that exist between the empirical-analytic and interpretive paradigms, respectively (Tashakkori and Teddlie 1998).

There are however several arguments within philosophy, social theory, and organization studies against a strong view of paradigm incommensurability (Majken and Mary, 1996). Thus, it is argued that the characterization of paradigms as separate and mutually exclusive domains may have been overstated (Gioia and Pitre 1990). Therefore, Majken and Mary (1996) identified two metatheoretical positions for doing multiparadigm research: *paradigm integration* and *paradigm crossing*.

Paradigm integration proposed that it is possible to assess and synthesize a variety of contributions, thus ignoring the differences between competing approaches and their paradigm (Willmott, 1993). The arguments against paradigm incommensurability include the fact that distinctions that are generally drawn between different paradigms are fuzzy and questionable, and there is no one agreed-upon set of paradigms (Smaling 1994). Secondly, it is not necessary to accept that research methods are wholly internal to a single paradigm (Mingers and Brocklesby 1997, Smaling 1994). Rather, it is quite possible to disconnect a particular method from its normal paradigm and use it, consciously and critically, within another setting. For example, the use of quantitative data need not imply the acceptance of a positivist, objectivist epistemology. Rather, such data should be interpreted in the light of relevant social meanings, and their production as a social construction. Third, it is claimed that the whole idea of paradigm incommensurability based upon the objective-subjective duality is fundamentally flawed (Orlikowski and Robey 1991, Weaver and Gioia 1994). Structuration theory has been used to demonstrate that it is not possible to separate out objective and subjective dimensions. Reality, according to Structuration theory, emerges out of the dialectic interplay of forces of structure and meaning (Giddens, 1984). Finally, it is suggested that different paradigms provide different perspectives into a reality that is more complex than theories can capture (Booth 1979, Guba 1990, Smaling 1994). It is, therefore, quite wrong to wholly accept the postulates of any one paradigm.

The focus of *paradigm crossing* is on how multiple paradigms might be engaged by individual researchers. Under this assumption, the researcher recognizes and confronts multiple paradigms, rather than ignoring them as in the integrationist position, or refusing to confront them as in the incommensurability position. Using this concept Majken and Mary (1996) further identified sequential and parallel as two main strategies for conducting multiparadigm research. Under sequential strategy paradigms are mutually complementary rather than exclusive. Paradigms operate as complements by revealing sequential levels of understanding within an integrated research project. Within organizational research, Lee (1991) presented a sequential multiparadigm model, in which interpretive methods are used prior to the application of functionalist methods, so that the insights derived from interpretive studies serve as inputs to functionalist research. Similarly, Gioia, Donnellon, and Sims (1989) demonstrated that functionalist research can inform interpretive studies, thereby inverting the more typical sequence from interpretivism to functionalism. The sequential strategy allows one paradigm to inform another; however, this influence only operates in one direction. Thus, the sequential strategy constructs the relationship between paradigms as linear and unidirectional, although it can move in either direction. A second strategy is termed *parallel,* because different paradigms are all applied on equal terms rather than sequentially. Hassard (1988, 1991) provided an illustration of the parallel strategy in his study of the British Fire Service, in which he applied a theory and methodology from each of Burrell and Morgan's four paradigms.

The sequential strategy also assumes non-permeability of paradigm boundaries; however, in this case, a specific form of cross-fertilization occurs. Researchers using this strategy transpose the findings from studies conducted in one paradigm into the theoretical frameworks offered by another. This transposition allows the findings of one paradigm to be recontextualized and reinterpreted in such a way that they inform the research conducted within a different paradigm.

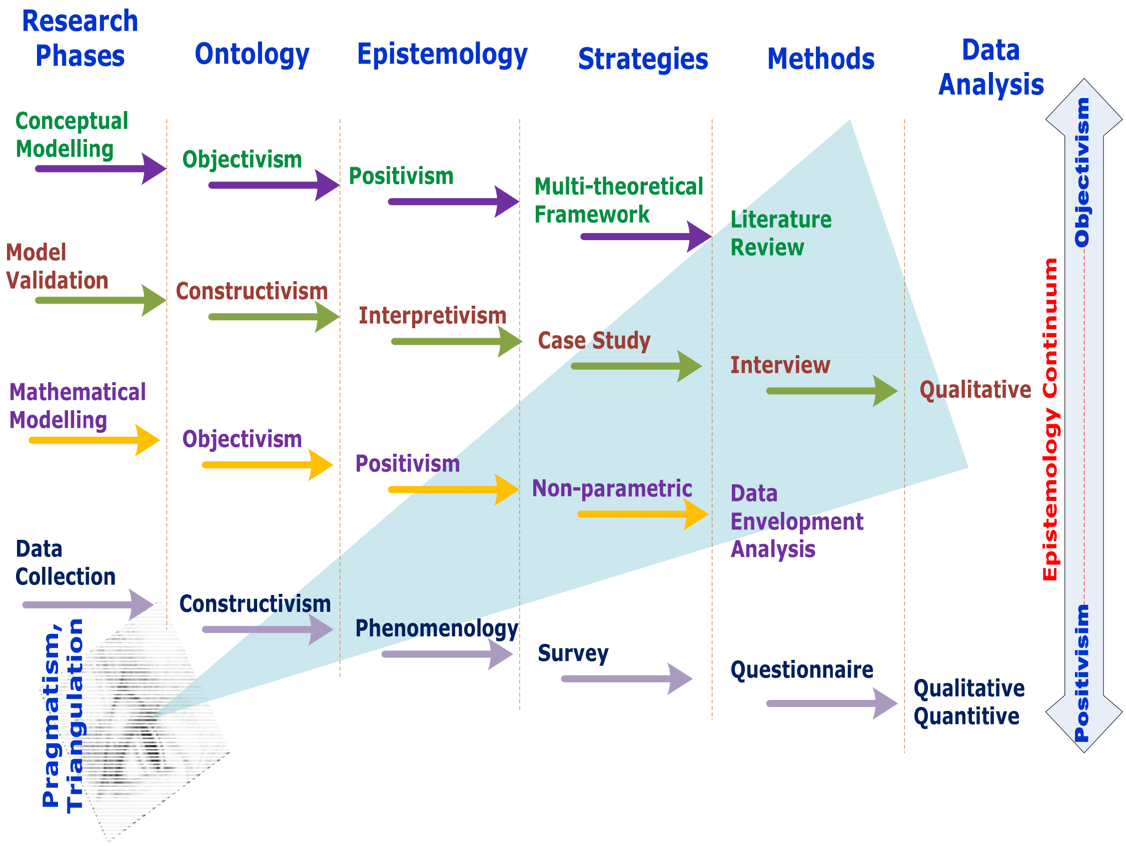

Figure 4.2: Multiple Paradigm Approach (Crott, 2003; Kassim et al., 2010c)

Mingers (2001) argues in favour of paradigm pluralism in research by suggesting that a research study is not usually a single, discrete event but a process that typically proceeds through a number of phases; these phases pose different tasks and problems for the researcher. Using this argument the different phases of the research with the corresponding paradigm views are illustrated in Figure 4.2. However, research methods tend to be more useful in relation to some phases than others, so the prospect of combining them has immediate appeal. The second argument is that research is not a discrete event but a process that has phases or, rather, different types of activities, which will predominate at different times. Particular research methods are more useful for some functions than others, and so a combination of approaches may be necessary to provide a more comprehensive research outcome.

4.4 Construction Management Research Paradigm

For many decades there has been a fervent debate over the choice of paradigm to conduct research by several disciplines. Similar debates within the construction management field have been raging too (Seymour and Rooke, 1995; Raftery *et al.*, 1997; Runeson, 1997; Seymour *et al*,. 1997; Chau *et al.*, 1998; Holt and Faniran, 2000). The proponents of phenomenological inquiry insist that there is a need to apply a naturalistic approach when investigating issues related to construction management in order to understand the phenomena within its contextual setting. The positivists however argue for quantitative measures to help test hypotheses and possible generalization. Raftery *et al.* (1997) argue for a case where multi-paradigmatic approach is embraced. Chau *et al.* (1998) suggest pragmatic approach is likely to generate practical solution since construction management is a practical subject. Peter *et al.*, (2002) are of the view that construction management research should be in an era of methodological pluralism and paradigm diversity. Underlying the debate on the choice of a research paradigm is the argument of incommensurability of the positivist and interpretive paradigms (Burrell and Morgan, 1979). However, Kirkwood and Campbell-Hunt (2007) reported that multiple paradigms can be bridged while recognizing each paradigm's different world views and assumptions in an epistemological and methodological pluralism approach. Furthermore, research methods can be detached from a paradigm and used critically within a context that makes different assumptions (Minger 2001). Therefore, both qualitative and quantitative orientations can be used at different stages of a research as a form of triangulation (Denzin, 1989).

4.5 The Research Methodology

The term research methodology is used in two inter-related ways which are often not very clearly separated. According to Crott (2003:5), methodology is "the strategy, plan of action, process or design lying behind the choice and use of methods to the desired outcomes."

While some researchers argue that the positivist and interpretive paradigms are incommensurable (eg. Burrell and Morgan, 1979), others suggest it is possible to bridge multiple paradigms, while recognizing each paradigm's different world views and assumptions (eg. Gioia, Donnelion and Sims Jnr, 1989; Gioia and Pitre, 1990; Kelemen and Hassard, 2003). A multiple paradigm approach is also sometimes referred to as epistemological and methodological pluralism (Curran and Blackburn, 2001; Grant and Perren, 2002), or paradigm plurality (Kelemen and Hassard, 2003). While a multiple paradigm approach may be "provocative" (Lewis and Grimes, 1999 pp 672), it offers "the possibility of creating fresh insights because they start from different ontological and epistemological assumptions" (Gioia and Pitre, 1990 pp 591).

At this stage, it is important to note that a multiple paradigm approach involves more than triangulation. Triangulation involves the use of multiple methods of measurement to assemble information on a phenomenon, with the aim of improving the validity of measurement. However, if all measurements are interpreted from within a single paradigm, the research is not considered to be multiple paradigmatic. A multiple paradigm approach may be considered to be an expanded form of triangulation (Gioia *et al,* 1989; Gioia and Pitre, 1990; Lewis and Grimes, 1999), from which to view a phenomenon from different methodological viewpoints (Brewer and Hunter, 1989). In other words, different lenses are used (Kelemen and Hassard, 2003), rather than just different research methods.

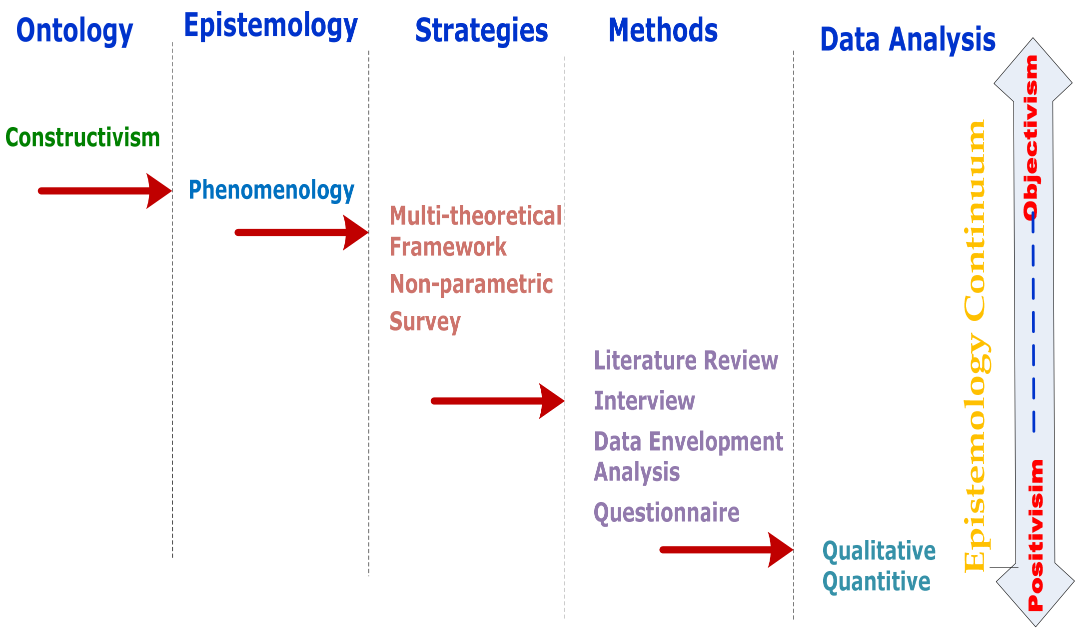

Figure 4.3: The Research Methodology (Kassim et al., 2010c)

The research processes involved different phases each posing different tasks and problems. The first phase of the processes involved a comprehensive literature review in the relevant fields, which led to the development of a conceptual model using multiple theoretical concepts as a framework and hypotheses were developed addressing the research objectives and scope. Thus, at this level the research adopted a deductive approach (Loose, 1993). The process relied on the current body of knowledge and theories in developing the research model and hypotheses, thus, by definition adopted positivism paradigm view (Sutrisna, 2009). Applying Majken and Mary (1996) concept of sequential strategy for conducting multi-paradigm research a constructivist paradigm with phenomenological epistemology was deployed in the second phase of the research (Figure 4.3). This phase involved validation of the proposed conceptual model and the engineering and construction value chain through unstructured interviews in the form of case studies of selected organisations as a follow up to responses of a pilot questionnaire. The choice of case study strategy at this phase of the research is informed by the requirement to carry out a holistic in-depth investigation of the complex phenomenon of IT business value of a construction organisation within the context it occurs (Yin 1994). The validated conceptual framework is then extended and modified through mathematical modelling using Data Envelopment Analysis (DEA). The final phase involved detailed data collection via online survey questionnaire designed to include closed-ended items with numerical responses as well as open-ended items that could support discovery of new information. Thus, as argued by Lewis & Grimes (1999), in the analyses of a common phenomenon paradigm images need not operate at the extremes, but may overlap and foster counterintuitive insights. Therefore, a sequential overlap of multiple paradigms was deployed within the different phases of the research.

However, since the overarching aim of the research is investigating the IT impact on the organisation's performance as socially constructed interaction between employees and their environment, the epistemological stance adopted for the research is phenomenological with constructivism as its ontology.

The basic premise of the multi-method approach is that the particular limitations of a given method will be compensated by the counter-balancing strengths of another (Fidel, 1993; Rohner, 1977). The use of multiple methods will create the confidence that observed variance between subjects is a product of subject attributes rather than of method (Campbell and Fiske, 1959).

4.6 The Research Methods

Research method is the techniques or procedures deployed to gather and analyse data to answer the research question or test hypotheses. The choice and use of research methods is one that is secondary to that of methodological paradigms, but it is essential that there is a good fit between paradigms and methods.

Corresponding to the two respective ends of the positivist-constructivist paradigm continuum are the quantitative-qualitative research techniques. Furthermore, on the quantitative-qualitative paradigm continuum three schools of thoughts of purists, situationalists and pragmatists are identified (Rossman and Wilson, 1985). The difference between these three perspectives relates to the extent to which each believes that quantitative and qualitative approaches co-exist and can be combined (Onwuegbuzie and Leech, 2005).

The purists tend to focus on the differences between the quantitative and qualitative philosophies rather than on their similarities. According to purists, distinctions exist between quantitative and qualitative researchers with respect to ontology, epistemology, axiology, rhetoric, logic, generalizations and causal linkages (Bryman, 1984; Collins, 1984; Tashakkori and Teddlie, 1998; Johnson and Onwuegbuzie, 2004; Onwuegbuzie and Leech, 2005). Pragmatists on the other end of the continuum do not see dichotomy between quantitative and qualitative approaches (Newman and Benz, 1998). These proponents believe that quantitative methods are not necessarily positivist, nor are qualitative techniques necessarily interpretive (Sieber, 1973; Cook and Reichardt, 1979; Daft, 1983; Miller and Fredericks, 1991). Although phenomenological approaches are often associated with qualitative orientations and positivist positioning with quantitative techniques, this is by no means always the case. The research used both qualitative and quantitative orientations at different phases of the process as argued by Bryman (1992); Brannen (1993) and Barbour (1999). Thus, it is recognised that "*it is possible to detach research methods (and perhaps even methodologies) from a paradigm and use them, critically and knowledgeably, within a context that makes different assumptions*" (Minger, 2001:243).

4.7 Triangulation

Denzin (1978) distinguishes different types of triangulations (Cox and Hassard, 2005):

a) *Data triangulation*, where data is collected at different times or from different sources. This is not applicable to this research despite the fact that the data is collected from different organisations since they are all in the similar business and the collection was conducted within the same time period of the research.

b) *Investigator triangulation*, where different researchers or evaluators independently collect data on the same phenomenon and compare results. The evaluation of the data collected was done by a single researcher in this case, thus this type of triangulation did not apply.

c) *Methodological triangulation*, where multiple methods of data collection are used. Data were collected through literature review, unstructured interviews and questionnaire surveys. Therefore, the research process adopted methodological triangulation.

d) *Theory triangulation*, where different theories are used to interpret a set of data. Many theories were adopted to form the framework for the research, however, the analysis of the data was based on the non-parametric concept.

Furthermore, the research framework involved a combination of multi-disciplinary theories and concepts including information technology/system, business strategy, and construction management leading to interdisciplinary triangulation (Janesick, 1994). Therefore, part of this research strategy is triangulation through the use of multiple theories and use of qualitative and quantitative data generation. Moreover, some elements of meta-triangulation have been incorporated into the strategy by the sequential use of different paradigms throughout the research phases.

The meta-triangulation is supported by the argument for a hybrid approach for deploying multiple paradigms simultaneously (Blackwood *et al.,* 1997; Holt and Faniran, 2000; Peter *et al.,* 2002) despite the heated debate on the choice of ontological and epistemological stance for conducting construction management research that tend to disagree (Seymour and Rooke, 1995; Raftery *et al.*, 1997; Runeson, 1997a; Seymour *et al,*. 1997; Chau *et al.*, 1998; Li and Love, 1998; Holt and Faniran, 2000). Triangulation also helped to minimise the problems of bias and validity

(Blaikie, 1991; Blaikie, 2000; Scandura and Williams, 2000; Cox and Hassard, 2005).

4.8 The Data Collection Technique

Generally, research methodology comprises of research strategy, data collection techniques and data analysis. The adopted data collection strategy is the utilization of interviews and survey questionnaire in a form of data generation triangulation. Multiple theories were used to develop a conceptual ITBV model from which a set of hypotheses were derived as presented in Chapter 3. This type of process lends itself to a deductive research approach, thus, using the positivist paradigm. Data was generated to validate the proposed model using experts' opinions in the industry. A pilot survey was also conducted and analysed in the process of validating the model derived in Chapter 3. The final data was generated using survey questionnaire. The next section explains the data collection methods and the description of the questionnaire design.

4.9 The Survey Questionnaire Design

A survey questionnaire was designed to include closed-ended items with numerical responses as well as open-ended items that could support discovery of new information (Appendix A). Thus, as argued by Lewis & Grimes (1999), analyses of a common phenomenon paradigm images need not operate at the extremes but may overlap and foster counterintuitive insights. The questions were designed to be relevant, easily understood, and not challenge the respondents' competency (El-Mashaleh, 2003). A consent form is included inline with ethical approval guidelines of the University. The consent form provides brief explanations of the research theme, aim and objectives and anticipated benefits of the outcome of the research to the participants. The consent form also highlighted the right of participant to withdraw from the research project at any stage of the project. Furthermore, the signed consent form declared that all research findings to be published will protect of confidentiality and privacy of the participants by not identifying the individuals or organisations.

The questionnaire consisted of six sections: Section 1 assesses the strategic grouping of the respondents' organisations, and the profile of individual's position within the organisations. Section 2 aims at evaluating the degree of utilization of information technology business applications (ITBA) in executing work functions within the organisations value chain. The extent of utilization of the organisations' information technology shared infrastructure (ITSI) in delivering the business process is captured in section 3. Section 4 evaluates the capabilities and competencies of organisations IT human skills (ITHS). Section 5 identifies a composite factor for the organisational complementary resources (BWE) as a measure of unique work environments. Sections 1-5 represent the input variables. The measure of the organisational performance is captured in section 6; this measure represents the set of the output variables. The questionnaire template is provided in Appendix A.

The measure is based on the 5-point Likert scale with the 1 representing the manual execution of a task with no application of an electronic system and at the other end of the scale a score of 5 indicates fully integrated used application of computing packages. Levels 1, 2, 3, and 5 are associated respectively with "nil", "lowest", "medium low", "medium high" and "highest" levels of technology utilization in executing work functions.

4.10 Mail versus Web Survey Modes

It was argued that for targeted respondents that have regular internet access, web-based survey are a useful mode of conducting research surveys (Sills and Song 2002). Using web-based surveys has potential benefits of cost savings associated with eliminating printing and postage (Cobanoglu *et al.,* 2001). A web-based survey provides a link in an email, which when clicked by respondents leads directly to a web page where the questions are provided for completing. However, Tse-Hua and Xitao (2008) in a meta-analysis showed that Web survey modes generally have lower response rates than mail survey modes by about 10%. Therefore a mixed mode strategy has been suggested as a means for exploiting the advantages of Web surveys and minimizing non-response (Schaefer and Dillman 1998; Dillman 2000; Kaplowitz *et al.,* 2004).

However, both the pilot and final survey questionnaires were mainly distributed via email using a survy software called "Survey Methods", sending the prospective respondents a link. Due to time constraints, no surface mail of the questionnaire was sent, only a consistent follow up via the e-mails. The software provides for follow ups and reminders to those participants yet to respond or who submitted partial responses.

4.11 Data Analysis

The most common data analysis techniques in production and operation management literature seems to be descriptive statistics with such measures as mean, median, standard deviation, and frequency distribution which provide a broad description of the data (Gupta *et al.,* 2006). Some of parametric approaches utilized in exploring relationships between variables in management and performance literature include: Bi-variate correlations, ANOVA, t-tests, chi-Square tests, linear regression and structural equation modeling (Lefebvre *et al.,* 1992; Ittner and MacDuffie 1995; Gupta and Somers 1996; Crandall and Markland 1996; Upton and McAfee 1998; Stewart and Chase 1999; Pagell and Handfield 2000; Hays and Hill 2001; Kathuria and Davis 2001; Klassen, 2001; Boyer and Lewis 2002; Melnyk, Sroufe, and Calantone 2003; Klassen and Vachon 2003;Keizers, Bertrand, and Wessels 2003; Anand and Ward 2004; Lapre and Scudder 2004; Gupta *et al.,* 2006; González, 2007; Sanders, 2007).

Other multi-criteria decision making techniques include analytic hierarchy process (AHP), analytic network process (ANP), case-based reasoning (CBR), fuzzy set theory, genetic algorithm (GA), mathematical programming, simple multi-attribute rating technique (SMART), and their hybrids (Ho *et al.,*2010).

A Case-Based Reasoning approach uses past cases and experiences to find a solution to current problems (Juan, *et al.,* 2006). The activities in CBR techniques involve identify the current problem situation, find a past case similar to the new one, use the case to suggest a solution to the current problem, evaluate the proposed solution, and update the system by learning from this experience (Jeng and Liang, 1995; Shin and Han, 2001).

Critics of CBR however, argued that it is an approach that accepts anecdotal evidence as its main operating principle. Thus, without statistically relevant data for backing and implicit generalization, there is no guarantee that generalization derived from such approach could be correct.

Another powerful tool for solving complex decision problems is the analytic hierarchy process (AHP) methodology developed by Saaty (1980). AHP is used to organize critical aspects of a problem into a hierarchical structure similar to a family tree (Chin *et al.* 1999). It is extensively used in Multi-Criteria Decision-Making (MCDM) methods. In this approach the decision problem is structured hierarchically at different levels with each level consisting of a finite number of decision elements. The upper level of the hierarchy represents the overall goal, while the lower level consists of all possible alternatives. One or more intermediate levels embody the decision criteria and sub-criteria (Partovi 1994). However, the drawbacks of this approach include the assumption that in the standard separated analysis, inputs and outputs are considered to have equal weight (Mehmet *et al.*, 2007).

A prior assumption of functional relationships between input and output variables is the main philosophy of most parametric data analysis approaches. This tends to introduce errors as a result of such assumption and specifications of the functional relationships (Sigala *et al.*, 2004).

Unlike the parametric technique, DEA does not need a priori assumption on the functional form characterizing the relationships between IT investment or resources usage and organisation performance measures (Zhu, 2002). Another major strength of the DEA approach is its relative simplicity in requiring only the output and input measures without needing to include the prices. This allows the use of the measure of the IT resource usage in place of a monetary value which is also difficult to estimate IT payoffs. DEA is increasingly being adopted for researching the "productivity paradox" (Dasgupta *et al.,* 1999; Shafer and Byrd 2000; El-Mashaleh *et al., 2006*).

4.12 Data Envelopment Analysis

Data envelopment analysis (DEA) is a non-parametric linear programming based technique for measuring the relative efficiency of a set of similar units, usually referred to as decision making units (DMUs). It was introduced by Charnes *et al.* (1978) based on Farrell's pioneering work. They generalized the single-output to single-input ratio definition of efficiency to multiple inputs and outputs. In their original DEA model, Charnes, Cooper and Rhodes (CCR model) proposed that the efficiency of a DMU can be obtained as the maximum of a ratio of weighted outputs to weighted inputs, subject to the condition that the same ratio for all DMUs must be less than or equal to one.

The use of parametric techniques such as linear regression in modelling ITBV has led to errors due to specification and assumption of linear direct functional relationships between the variables (Sigala *et al.,* 2004). In order to mitigate this drawback a non-parametric technique called Data Envelopment Analysis (DEA) is used in the research design to model the ITBV for engineering and construction organisations.

Using DEA to model the ITBV eliminates the error of specification as a result of a priori assumption on the functional relationships between IT investment and organisation performance (Zhu, 2002). Also with DEA there is no need to assign weights to the different inputs and outputs as they are derived directly from the data and thereby avoids arbitrary and subjective weightings. Furthermore, the measurement units of the different inputs and outputs need not be congruent (El-Mashaleh, 2007). Another major strength of the DEA approach is its relative simplicity in requiring simply the output and input without needing to include cost associated with the IT investments, a data that is not readily available due to its confidentiality nature. Therefore, the adoption of DEA allows the use of measure of the IT resource usage in place of a monetary value of the IT resources to evaluate the IT investment payoffs in engineering and construction organisations.

There is evidence for deploying DEA to measure the organisational performances in the literature. El-Mashaleh *et al.* (2005) used a conceptual approach with DEA application to measure and compare construction subcontractor productivity at the organisational level. The final results helped in benchmarking and ranking the subcontractors' performances. Also El-Mashaleh *et al.* (2010) measured the relative efficiencies of construction organisations in utilizing safety expenses as input factors to minimize accident occurrences using DEA. The outcome identified best performing organisations with which the inefficient organisations were benchmarked. Other applications of DEA in construction management include McCabe *et al.* (2005), Pilateris and McCabe (2003), Vinter *et al.* (2006), Cheng *et al.* (2007), Chiang *et al.* (2006) and Xue *et al.* (2008). Thus, researchers in construction management fields have quickly recognized that DEA provides an excellent and easily used methodology for modelling and evaluating enterprises' operational performance including the IT "productivity paradox" (Shafer and Byrd 2000; El-Mashaleh *et al.*, 2006).

Many different DEA models have been developed and deployed by various researchers depending on the nature type of applications to solve. Two basic models are CCR (Charnes, Cooper and Rhodes (1978)) and BCC (Banker, Charnes and Cooper (1984)). However, there are numerous models and the selection of an appropriate model depends on the nature of production-technology. In general, these models differ in their Orientation - Input-orientation, Output-orientation, Returns to Scale, Constant Return to Scale (CRS), Variable Return to Scale (VRS), etc.

4.13 DEA Versus Regression Modelling

The use of parametric techniques such as linear regression in modelling and evaluation of ITBV would require specification and assumption of linear direct functional relationships between the variables (Sigala *et al.*, 2004). Furthermore, a form of distribution defining the functional relationship between IT investments as inputs and some performance metrics as outputs has to be assumed. Based on the sets of inputs and outputs a linear regression will predict an average behaviour in a straight line, a non-parametric technique such as Data Envelopment Analysis (DEA) will establish a best practice frontier while enveloping the whole data as depicted in Figure 4.4.

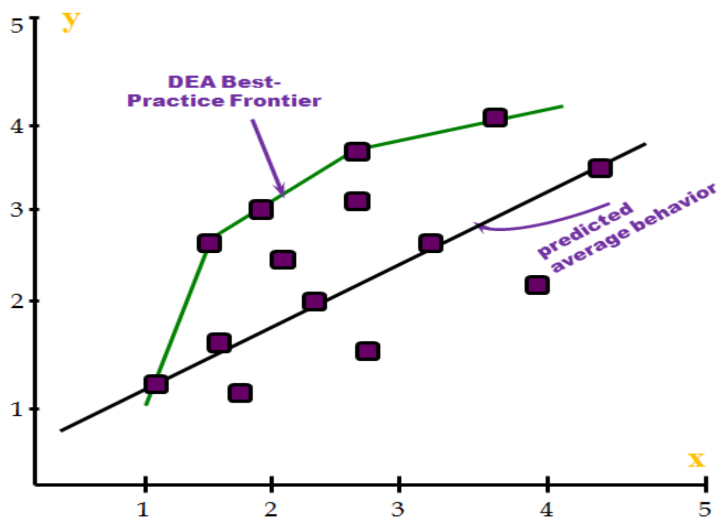

Figure 4.4 Graphical representation of DEA versus Regression

(Kassim *et al.*, 2010c)

Unlike the parametric technique, DEA does not need a priori assumption on the functional relationships between IT investment and organisation performance (Zhu, 2003). Also using DEA there is no need to assign weights to the different inputs and outputs as they are derived directly from the data and thereby avoids arbitrary and subjective weightings. Furthermore, the measurement units of the different inputs and outputs need not be congruent (El-Mashaleh, 2007). Another major strength of the DEA approach is its relative simplicity in requiring simply the output and input without needing to include cost of IT investments. This allows substituting the investment value with level of utilization of the IT resources to evaluate the impact on organisation's performance.

4.14 DEA Models

There are two basic DEA models named after the respective researchers who first introduced them: the Charnes Cooper Rhodes (CCR) and the Banker Charnes Cooper (BCC) models. The two models are normally distinguished by the type of their envelopment surfaces and orientations. The envelopment surfaces include the form depicting a constant-return-to-scale (CRS) or variable return-to-scale (VRS) represented in the CCR and the BCC models, respectively. An organisation is said to exhibit CRS if an increase in inputs will result in a proportional increase in its outputs. The CRS frontier surface is represented by a straight line that starts at the origin and passes through the first organisation that it meets as it approaches the observed population (Figure 4.5). The models orientation is either input implying that an inefficient organisation may be made efficient by reducing the proportions of its inputs but keeping the output proportions constant or output indicating that an inefficient organisation may be made efficient by increasing the proportions of its outputs while keeping the input proportions constant (Zhu, 2003).

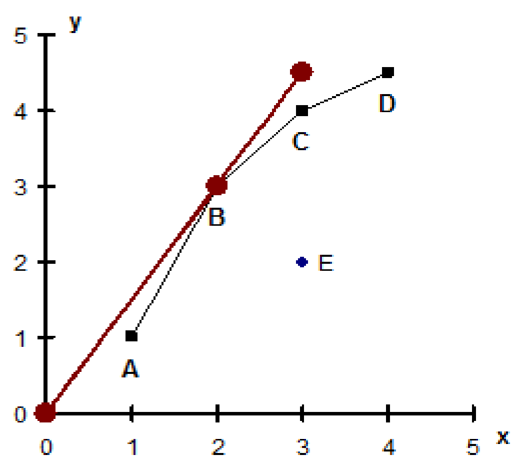

Figure 4.5 CRS Frontier Surface (Zhu, 2003)

The linear programming formulation of the CCR model assumes that outputs increase proportionally when inputs are increased, i.e. constant returns to scale. However, it is possible that the outputs of a production unit may vary with varying output sets. Banker *et al.*, (1984) suggested a formulation that captures this phenomenon of variable returns to scale in DEA, which is referred to as the BCC model. Therefore, the VRS model allows an increase in input values to result in a non-proportional increase of output levels — increasing returns to scale (IRS) occur below the point where CRS and VRS meet, and decreasing returns to scale (DRS) (Figure 4.5).

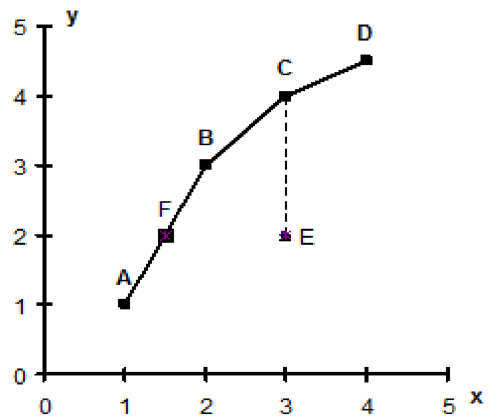

Figure 4.6. VRS Frontier Surface (Zhu, 2003, Kassim et al., 2010c)

For example in Figure 4.6, frontier AB exhibits increasing return to scale (IRS); at point B there is constant return to scale (CRS) and sections BC and CD exhibit decreasing return to scale (DRS) Zhu (2003).

4.14.1 CCR Model

The CCR model evaluates both technical and scale efficiencies via the optimal value of the ratio. The term 'envelopment' reflects the fact that DEA measures efficiency within a production possibility set which 'envelops' all input-output correspondences.

The weights are specified as a mathematical programming problem:

$$\theta = \max \frac{\left(\sum_{r=1}^{S} \alpha_{r,j0} x_r \right)}{\left(\sum_{i=1}^{M} \mu_{i,j0} y_i \right)}$$

Subject to:

$$\frac{\left(\sum_{r=1}^{S} \alpha_{r,j0} x_r\right)}{\left(\sum_{i=1}^{M} \mu_{i,j0} y_i\right)} \leq 1 \quad \mu_r, \alpha_i \geq \varepsilon > 0; \ \forall r, i \tag{4.1}$$

Where:

θ = relative efficiency of the j_0^{th} organisation;

α_i = weight for the ith input;

μ_r = weight for the rth output;

M =number of inputs;

S = number of outputs;

N = number of DMUs (construction organisations);

j_0 = index of the organisation being evaluated;

X_{ij} = observed amount of the i^{th} input for the j^{th} organisation,

ε = non-Archimedean infinitesimal value

The solutions to equation (4.1) involve finding values of α and μ such that the efficiency measure of the j_0 DMU is maximised, subject to the constraint that all efficiencies must be less than or equal to one. This could have an infinite number of solutions; if (μ^*, α^*) is optimal solution, then ($\tau\mu^*$, $\tau\alpha^*$) is also optimal for $\tau>0$. Furthermore, the fractional linear programming formulation above assumes that a proportional increase in inputs results in a proportionate increase in outputs referred to as constant return to scale (CRS).

Equation 4.1 is a nonlinear, nonconvex functional program. Its objective function maximizes the sum of the weighted output relative to the weighted inputs for the j_0^{th} DMU. Thus, equation 4.1 can be written in linear programming form (LP) as follows:

$$\max \sum_{r=1}^{S} \mu_r y_{rjo} \quad \text{4.2a}$$

Subject to:

$$\sum_{i=1}^{M} \alpha_i x_{ij} = 1 \qquad \text{4.2b}$$

$$and \left(\sum_{r=1}^{S} \mu_r y_{rj} \right) - \left(\sum_{i=1}^{M} \alpha_i x_{ij} \right) \geq 0, \forall i, j \qquad \text{4.2c}$$

$$\mu_r, \alpha_i \geq \varepsilon > 0; \ \forall r, i \qquad \text{4.2d}$$

Equation 4.2a maximizes the weighted output of the j_0^{th} DMU subject to the constraint that weighted inputs equal one as in equation 4.2b. The optimal vector weights μ*, α* represents that weights that will provide DMU under consideration with the highest efficiency rating possible, while maintaining feasibility for the remaining N-1 DMUs in a given N sample groups. The values of μ* and α* may vary for each organisation as unit evaluated.

For every inefficient DMU, DEA identifies a set of corresponding efficient units that can be utilized as benchmarks for improvement. The benchmarks can be obtained from the dual problem shown in equation 4.3:

$$\theta^* = \min\theta \qquad \text{4.3a}$$

Subject to:

$$\sum_{j=1}^{N} \lambda_j x_{ij} \leq \theta x_{i0} \qquad \text{4.3b}$$

$$\sum_{j=1}^{S} \lambda_j y_{rj} \geq y_{r0} \qquad \text{4.3c}$$

$$\lambda_j \geq 0 \qquad \text{4.3d}$$

Where:

θ = efficiency score, and

λ_j = dual variables.

The model in equations 4.3a-d conforms to the assumption of "strong disposal" and referred to as "weak efficiency" in economic and operations research literatures, respectively (Cooper *et al.,* 2004).

DEA models can be distinguished by the objective of a model: input-oriented model or output-oriented model. The input-oriented model is to minimize inputs with given outputs as in equation 4.3a; whereas the output-oriented model is to maximize outputs with given inputs (Adler *et al*, 2002, Seol *et al*.; 2008) such as equation 4.2 a-d.

Solving equations 4.3 a-d provides efficiency scores of the organisations under consideration.

By setting $\theta = 1$ and $\lambda_k = 1$ with $\lambda_k = l_0$ and all other $l_j = 0$, a solution to equations 4.3 will have real values and the solution implies $\theta^* \leq 1$. The optimal solution, θ^*, yields an efficiency score for a particular DMU_j. The process is repeated for each *j,* i.e. solve equations 4.3 a-d, with $(\mathbf{X}_0, \mathbf{Y}_0) = (\mathbf{X}_k, \mathbf{Y}_k)$ where $(\mathbf{X}_k, \mathbf{Y}_k)$ represent vectors with components, x_{ik} , y_{rk} and, similarly $(\mathbf{X}_0, \mathbf{Y}_0)$ has components x_{ok} , y_{ok} . DMUs for which $\theta^* < 1$ are inefficient, while DMUs for which $\theta^* = 1$ are boundary points.

Some boundary points may be "weakly efficient" because of nonzero slacks; to avoid this the following linear program in which the slacks are taken to their maximal values are considered.

The CCR model cannot discriminate efficiency of scale from pure technical efficiency due to the CSR assumption (Seol *et al.,* 2008). In order to solve the linear-programming problem, three characteristics of the model must be specified, they include: input-output orientation of the model; the returns-to-scale; and the relative weights of the evaluation system. Borges and Barros (2008) suggested that the choice of input-oriented or output-oriented DEA is based on the market conditions of the DMU. Thus, in competitive markets, DMUs are output-oriented, with the assumption that inputs are under the control of the DMU, which aims to maximize its output subject to market demand. Therefore, an output-oriented DEA model was adopted in analysing the performance of the construction organisations.

4.14.2 BCC Model

To take into account variable returns to scale (VRS) between inputs and outputs, Banker *et al.* (1984) extended the CCR model. Banker, Charnes and Cooper developed the BCC model (named after them) which assumes that an increase in unit inputs production does not produce a proportional change in its outputs or VRS.

The linear programming formulation of the CCR model, shown as equation (4.3a), assumes that outputs increase proportionally when inputs are increased, i.e. constant returns to scale. However, it is possible that the outputs may increase at a decreasing rate as the inputs are increased, i.e. decreasing returns to scale.

Banker *et al.* (1984) suggested a formulation that captures this phenomenon of variable returns to scale in DEA, which is referred to as the BCC model. The BCC model is represented by equations 4.3 a-d, which is the dual formulation of equations 4.2 a-d with the added convexity constraint.

Equations 4.4 a-e provide information on how inputs and outputs of inefficient DMUs can be adjusted as indicated in their respective slacks in order for them to be considered efficient.

$$\phi^{*} = max\,\phi - \varepsilon\left(\sum_{i=1}^{M} S_i^{-} + \sum_{r=1}^{S} S_r^{+}\right) \quad \text{4.4a}$$

Subject to:

$$\sum_{j=i}^{N} \lambda_j x_{ij} + S_i^{-} = x_{io} \quad \text{4.4b}$$

$$\sum_{j=i}^{N} \lambda_j y_{rj} - S_r^{+} = \phi y_{ro}, \quad \text{4.4c}$$

$$\lambda_j \geq 0, \forall i, j \quad \text{4.4d}$$

$$\sum_{j=i}^{N} \lambda_j = 1 \quad \text{4.4e}$$

Where:

ϕ^* represents the efficiency score of an organisation

s_i^- and s_r^+ are the input and output slacks respectively.

An organisation is efficient if and only if ϕ^*=1 and s_i^{-*} = s_r^{+*} = 0; $\forall i, r$; an organisation is weakly efficient if ϕ^*=1 and $s_i^{-*} \neq 0$ and/or $s_r^{+*} \neq 0$; $\forall i, r$ ε > 0 where ε is non-Archimedean element. Equation (4.4e) is additional constraints while calculating only technical or managerial efficiency.

4.14.3 *DEA Models Extensions*

Borges *et al.*, (2008) report four other basic DEA models in the literature: the additive model of Charnes *et al.* (1985), the multiplicative model of Charnes *et al.*, (1982), the Cone-Ratio DEA model of Charnes *et al*. (1990) and the Assurance-Region DEA model of Thompson *et al.* (1986, 1990). The latter two models include *a priori* information such as expert opinion, opportunity costs, rate of transformation or rate of substitution used to restrict the results to just one best DMU (Assurance-Region DEA model) or to link DEA with multi-criteria analysis (Cone-Ratio DEA model).

By making the DEA model a little more complicated, the range of topics it can explore is increased. Particularly interesting is the decomposition of the technical efficiency score into components resulting from: the scale of operations; surplus inputs which cannot be disposed of; and a residual or 'pure' technical efficiency. A further extension which is often important is to allow for differences in operating environments; this involves trying to adjust for factors which might be beyond managers' control, and which thus possibly give some organisations an artificial advantage or disadvantage. Each of these issues is addressed in turn below.

4.15 Operationalising DEA Concept

To apply the DEA concept in analysing the data generated in this research; the measure of input and output variables are substituted into BCC output oriented DEA model equations 4.4 a-e.

For establishing the mathematical model in equations 4.4a-e a number of assumptions were made. Consider N number of engineering and construction organisations referred to as DMUs each utilizing sets of IT and complimentary organisational resources as input vector $\mathbf{x} \in \Re_{+}^{m}$ to execute projects involving engineering design, procurement and construction activities leading to the project performance outcome as output vector $\mathbf{y} \in \Re_{+}^{s}$ including measure of cost and schedule performance, contract growth and profitability. The observed ordered pair (x, y) is regarded as a feasible production plan; while the collection of all feasible production plan forms production possible sets (Φ) such that $\Phi \equiv \{(\mathbf{x}, \mathbf{y}) | \mathbf{x} \text{ can produce } \mathbf{y}\}$. Using the output-oriented model the efficiency of the j_0 construction organisation under consideration could be evaluated by solving equations 4.4a-e. The solution maximizes the weighted output of the j_0 organisation subject to the constraint that weighted inputs equal one. The optimal weights represents that weights that will provide the organisation under consideration with the highest efficiency rating possible while maintaining feasibility for the remaining N-1 organisations in a given N sample groups. The values of the weights may vary for each organisation as unit evaluated. The equation needs solving N times, once for each organisation. The section below describes the steps followed in solving the mathematical model as a form of algorithm.

4.16 DEA Algorithm for Computing ITBV

The following actions are the steps taken while undertaking evaluation of comparative efficiency of the set of construction organisations using DEA in line with Golany and Roll (1989) and Thanassoulis (2003):

(1) definition and selection of the organisations;

(2) identification of the input-output variables;

(3) construction of the production possible sets (PPS);

(4) establishment of the type of efficiency to be assessed;

(5) determination of organisations' sample size;

(6) determination of a DEA model;

(7) solving the linear program of the identified DEA model for all organisations;

(8) presentation and analysis of the outcome.

4.16.1 Strategic Grouping

There are always differences in the way organisations are managed that may lead to different decision making. Therefore, while the objectives of DEA analysis include identifying the differences in the performances of the organisations assessed, there is the requirement to have the organisations to be homogenous (Farrell, 1957).

The homogeneity of the operating enterprise to be assessed using DEA was ensured by conducting strategic group analysis of the identified engineering and construction organisations. A strategic group consists of those rival firms with similar competitive approaches and positions in the market. The detailed concept of strategic group in the construction industry was provided in section 2.6 of chapter two. Strategic groups provide an intermediate frame of reference between viewing an industry as a whole and considering each firm separately (Flavian and Polo, 1999; Dikmen *et al.*, 2009).

4.16.2 Organisations' Sample Size

The next step is to determine the size of the comparison group (N). A large population size of the organisations will tend to increase the probability of capturing high performance organisations which would determine the efficiency frontier. However, a rule of thumb is that the number of sampled firms should be at least twice the sum of the number of inputs and outputs variables (Ali *et al.*, 1988; Bowlin, 1987).

4.16.3 Inputs and Outputs Variables

One of the fundamentals for the assessment of comparative efficiency by DEA is the construction of the production possible set (PPS) containing all input-output level ‘correspondences’ which are capable of being observed. Correspondence of inputs and outputs in this context is based on a relationship of exclusivity and exhaustiveness between the two sets of variables (Thanassoulis, 2003).

The initial list of the variables to be considered for assessing organisational performance should be as wide as possible. Every dimension, the changes which may affect the organisations to be evaluated, should be included in the initial list. The input variables should capture all resources and the output variables all the outcomes having a bearing on the type of efficiency being assessed. In addition, contextual factors impacting the transformation of inputs to outputs should also be reflected which in our case include complimentary organisational resources. The initial set of potential input-output variables can be refined using a combination of statistical test and/or sensitivity analysis (Boussofiane, *et al.,* 1991; Thanassoulis, 2003).

4.16.4 Solving a DEA Model

The linear program (LP) formulations are a function of a particular organisation about which we need to determine its efficiency classification. The procedure based on solving one LP for each of the organisations using the entire data set is standard. This is presented as follows (Ali, 1993; Dulá 2008):

1 For $j = 1$ to N

2 Initialize $j^* \leftarrow j$

3 Define $x_0 \leftarrow x_j$, $y_0 \leftarrow y_j$

4 Solve equation (4.4) for ϕ^* s^* and λ^*

5 Increase $j \leftarrow j+1$ for $j<N$

6 If $j<1$ go to 3

7 If $j=N$ terminate

This process is presented in a form of a flow chart in Figure 4.7

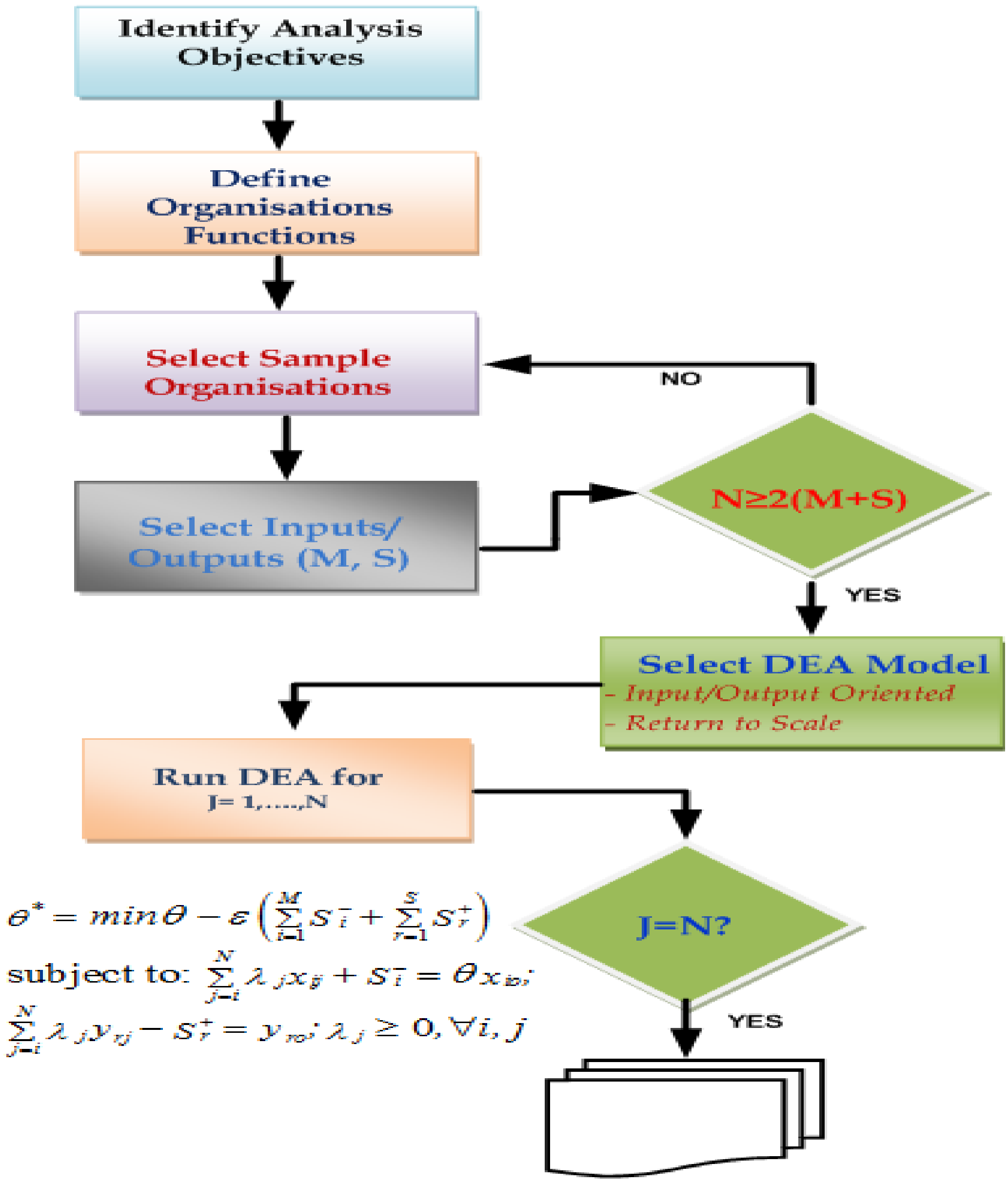

Figure 4.7 DEA Algorithm (Kassim et al., 2010c)

4.16.5 Interpreting DEA Model

DEA is used to measure the technical efficiency of enterprises; the transformation of inputs such as IT resources into outputs in a form of an organisation's performances which is compared to a best practice organization. Thus DEA was applied to identify construction organisations that have efficiently utilized its IT resources, hence justify the investments with better performance. The inefficient organization (s) could be benchmarked and have role models that can guide them in learning how they can improve the implementation of IT resources in their operations for competitive advantage (Jui-Chi, 2006).

Based on Pareto optimality the concept DEA defined an enterprise as 100% efficient when and only when (Wöber *et al.*, 2004):

1. None of its outputs can be increased without either
   a. increasing one or more of its inputs,
   b. decreasing some of its other outputs; and
2. None of its inputs can be decreased without either
   a. decreasing some of its outputs, or
   b. increasing some of its other inputs.

Thus an organisation is Pareto efficient if and only if it is not possible to improve any input or output without worsening some other input or output. (Cooper *et al*, 2006: 45).

DEA may be viewed from two perspectives: envelopment and multiplier (Seiford and Thrall, 1990). In the envelopment form of DEA, for each DMU taken in turn the linear combination of all DMU's is defined so that (Maital and Vaninsky, 1999):

(i) minimal inputs be achieved with outputs no less than existing ones, or

(ii) maximal outputs are obtained with inputs no more than actually used.

The first approach is called the input minimization DEA model, and the second, the output maximization.

DEA starts by building a relative ratio consisting of total weighted outputs to total weighted inputs for each organisation in a given data set. The best organisations in the data set form an "efficient frontier" and the degree of the inefficiencies of the other units relative to the efficient frontier are then determined using a linear programming algorithm (Wöber *et al.,* 2004).

The capability and possible outcome of using DEA in evaluating the performance of organisations include that DEA is (Chiang, 2006):

i. capable of analytically identifying the relatively more effective organizations from the less effective organizations;

ii. capable of deriving a single summary measure of the relative effectiveness of organizations, in terms of their utilization of resources and environmental factors, to produce desired outcomes;

iii. able to handle non-commensurate, conflicting multiple outcome measures, multiple resource factors and multiple environmental factors that lie outside the control of the organization being evaluated, and not be dependent on a set of a priori weights or prices for the resources utilized, the environmental factors, or the outcome measures;

iv. able to handle qualitative factors such as participant satisfaction, the extent of information processing available, the degree of competition, etc.;

v. able to provide insights into which factors contribute to the relative effectiveness ratings;

vi. able to maintain evaluation equity. (Lewin and Minton, 1986).

Most importantly, DEA allows for identification of the best practices and benchmarks for the poor performing units. The ability of DEA to identify possible peers or role models as well as simple efficiency scores gives it an edge over other measures such as total factor productivity indices.

4.17 Reliability and Validity

Reliability is about whether the evidence and the measures used are consistent and stable (Remenyi *et al.,* 1998). In other words, would another team of researchers have reached the same results at another time, using the same methods and techniques (Winter, 2000; Golafshani, 2003).

The research design including data collection technique was aimed at minimizing the risks of bias and ensures reliability and replicability of the process.

4.17.1 Validity

"An account is valid or true if it represents accurately those features of the phenomena, that it is intended to describe, explain or theorise" Hammersley's (1987: p. 69).

Yin (1994) mentions three basic kinds of validity: construct, internal and external. Construct validity is about establishing correct operational measures for the concepts being studied. This was ensured through using several sources of data. Also the process of data collection, questionnaires were designed to minimise bias.

Validity addresses whether the research explains or measures what it set to measure or explain. Thus, validity confirms appropriateness of the research method adopted to answer the research question According Mason's (1996:147) validity answer the question: "how well matched is the logic of the method to the kinds of research questions you are asking and the kind of social explanation you are intending to develop".

Internal validity aims at ensuring that the findings or results of the research are related to and are caused by the phenomena under investigation and not other unaccounted for influences (Winter, 2000). The choice of research framework, the variables, and the data collection tool were to ensure the internal validity of the process.

4.17.2 Reliability

Generally the concept of 'reliability' is used for testing or evaluating research that lends itself to objectivist epistemology and positivist paradigm with quantities method. Thus, Stenback (2001) argues that reliability has no relevance in qualitative research, therefore irrelevant matter in the judgement of quality of qualitative research.

On the other hand Patton (2001) insisted that both validity and reliability are two factors qualitative researcher should be concerned about while designing a study, analysing results and judging the quality of the study. Thus, research reliability provides a measure of quality of data collected and whether published result is replicable by another group of researchers. Reliability addresses how accurate your research methods and techniques produce data.

To ensure the reliability of the study adopted Methodological triangulation, where multiple methods of data collection are used; Theory triangulation, where different theories are used to interpret a set of data. Many theories were adopted to form the framework for the research; however, the analysis of the data was based on the non-parametric concept. The idea behind triangulation is that the more agreement of different data sources on a particular issue, the more reliable the interpretation of the data.

The pilot study presented in next chapter provided the test of the realibility of research design, and an opportunity to adjust were necessary.

4.18 Chapter Summary

This chapter addresses the research methodology, justifying the choice of strategy and method adopted. These issues include philosophy, philosophy branches, paradigm, paradigm types, research approach, research strategy, research choices, time horizons, data collection techniques, testing/validation/evaluation, etc. The chapter also distinguishes between research methodology and method. The chapter presented methods adopted to ensure the validity and reliability of the research process. Both the methodology and the research strategy were outlined, linked to literature, and appropriately justified in line with literature.

CHAPTER FIVE
PILOT STUDY

5.0 Introduction

In this chapter, analysis of the primary data that was collected from a pilot study is presented. The pilot study was designed to help test the methods and procedures proposed for the research. The chapter presents the outcome of the pilot study; therefore providing a guide on issues related to the research design, conceptualization and an interpretation of findings (Kezar, 2000; Nyatanga, 2005; Thabane *et al.,* 2010).

The bulk of the data is coded from qualitative perception to quantitative and was analysed using Frontier Analyst® version 4.

5.1 Organisations' General Information

A survey questionnaire was used to collect data on the set of variables developed in chapter three. The analysis of the result provided an insight to the validity and reliability of the research design.

Sixty organisations in the engineering and construction industry were sampled and a total of 19 responded giving a 38% response rates.

The sectors within the construction industry targeted for the pilot study include: (1) Civil Engineering and Building Contracting (2) Engineering, Architectural and Construction Services (3) Facilities Management, Building Maintenance and Repair (4) Construction and Project Management and (5) Infrastructure Support Services and (6) Oil and Gas Facilities Engineering Construction. The categorization are used to view sets of the organisations as falling within a given strategic grouping.

About 10% of the surveyed organisations are engaged mainly in general build civil construction activities, 32% are in consultancies including project management; 26% are engaged in oil and gas sector; another 26% are engaged in engineering and architectural services; 30% are involve with facilities management and the remaining 30% are into infrastructure support services as shown in Figure 5.1.

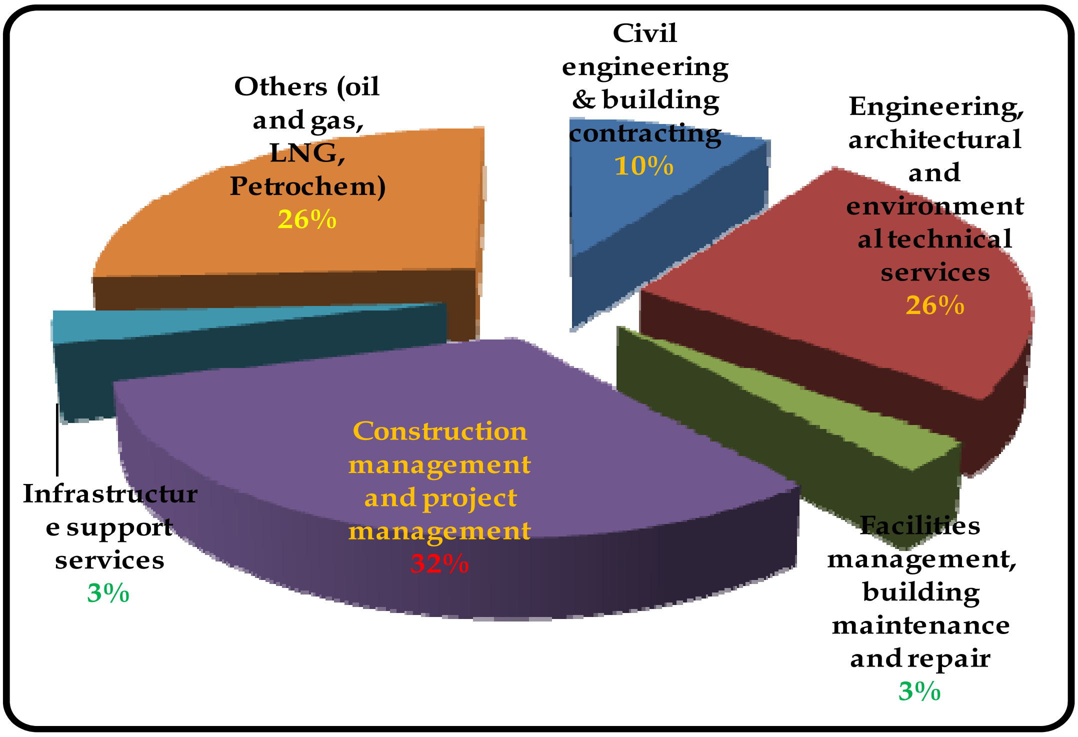

Figure 5.1 Grouping of the Sampled Organisations

Another cateria used for the grouping the organisation as their reported average annual turnover. The spread of the annual turn over of the responding organisations are as presented in Figure 5.2 follows: 14% reported an annual sale between £5 million and £50million, another 1% recorded annual earnings between £50million and £100million annual. 27% reported earnings between £100million and £500million. The bulk of the organisations (54%) reported earning between £500 million and £1billion.

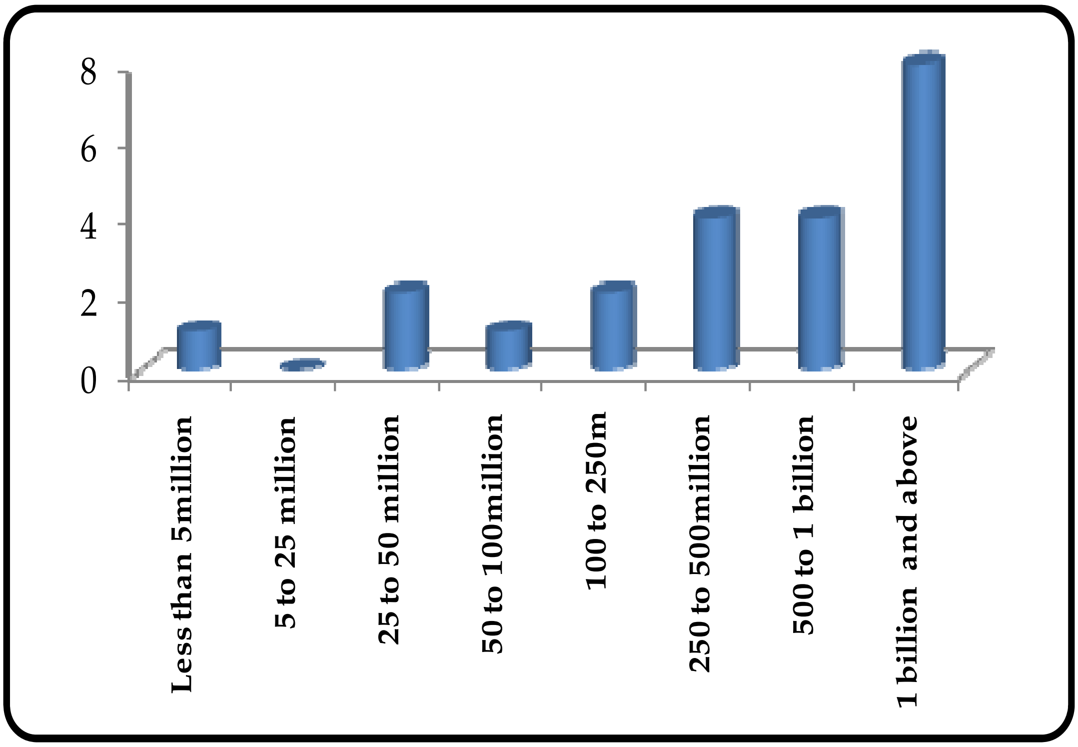

Figure 5.2 Distribution of Turnover

The raw data from the survey was captured using online survey tools, the 'surveymethods', which was translated into Micorsoft Excel for further analysis.

Using equation 3.1 the automation and integration indexes of each primary activity of the organisations' value chains were computed. The overall ITBA indexes are then calculated using equation 3.3 and values recorded as in Table 5.1.

Table 5.1 Inputs/Outputs Data

DMUs	Inputs						Outputs			
	ITBA	ITSI	ITHS	BWE	SCHD	COST	SAFETY	CUSTO	CONTR	PROFI
A	4.63	1.80	1.40	1.40	1.00	2.00	2.00	2.00	2.00	2.00
B	4.02	4.20	5.20	4.60	4.00	3.00	3.00	2.00	3.00	3.00
C	3.51	2.40	2.00	2.40	4.00	5.00	3.00	2.00	3.00	4.00
D	3.85	2.20	2.60	2.00	3.00	3.00	2.00	3.00	3.00	4.00
E	3.98	1.40	2.20	2.20	4.00	3.00	1.00	2.00	3.00	2.00
F	3.20	2.80	2.60	2.60	4.00	4.00	4.00	3.00	3.00	5.00
G	4.17	2.00	2.40	1.80	3.00	3.00	1.00	2.00	4.00	4.00
H	4.55	2.00	2.20	2.80	2.00	3.00	2.00	4.00	3.00	3.00
I	3.81	2.80	2.40	3.20	2.00	2.00	1.00	1.00	1.00	2.00
J	4.27	2.00	2.40	2.00	2.00	2.00	2.00	2.00	2.00	2.00
K	3.73	1.60	2.40	1.60	5.00	5.00	2.00	3.00	3.00	3.00
L	2.83	2.20	3.60	2.00	3.00	3.00	2.00	2.00	2.00	3.00
M	5.00	1.80	2.40	2.00	2.00	2.00	2.00	2.00	2.00	2.00
N	3.74	3.00	3.40	2.60	4.00	3.00	2.00	2.00	2.00	1.00
O	4.02	3.00	2.40	2.40	2.00	1.00	1.00	1.00	1.00	1.00
P	3.45	3.80	2.80	3.40	5.00	5.00	4.00	4.00	4.00	4.00
Q	4.39	1.20	1.80	1.00	4.00	3.00	1.00	1.00	2.00	1.00
R	4.26	2.60	3.00	2.20	2.00	2.00	1.00	1.00	3.00	2.00
S	3.67	2.60	3.60	2.00	4.00	4.00	2.00	4.00	4.00	4.00

5.2 Analysis and Interpretation

The data in Table 5.1 was analysed using Frontier Analysts® software. The analysis adopted DEA BCC, output-oriented model with VRS assumption. The framework of the analysis was the IT resources induced competitiveness of the sampled organisations. Borges and Barros (2008) suggested that the choice of input-oriented or output oriented DEA model is based on the market conditions of the organisations under investigation. Thus, in competitive markets, organisations are output-oriented, with the assumption that inputs are under their control, which aims to maximize its output subject to market demand. Based on the competitive nature of the organisations and the overall research design, output-oriented DEA model was adopted in analysing the performance of the sampled organisations. Furthermore, in order to accommodate the differences in the scales of operations across the sampled engineering and construction organisations, the BCC model with variable return to scale (VRS) was deployed.

The result returned thirteen organisations as being on the frontier, thus, recording IT induced efficiency of 100% as depicted in Table 5.2 and Figure 5.3.

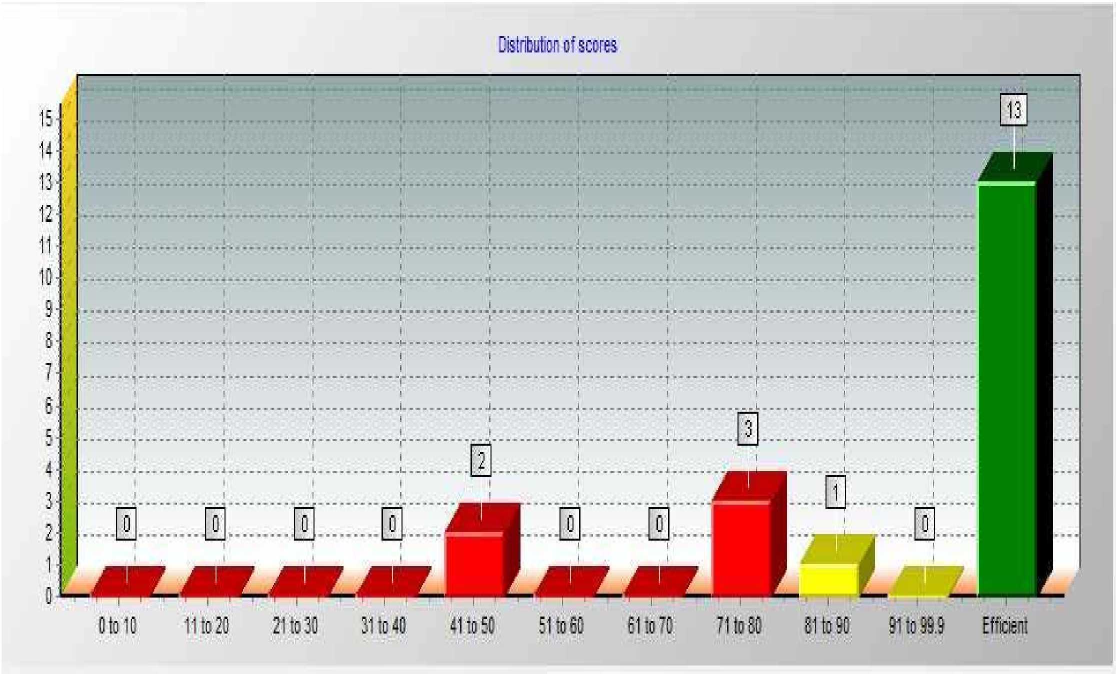

Figure 5.3 Distribution of Scores

The high number of efficient organisations was mainly due to low discriminatory power of the model as a result of high ratio of number variables to number of sampled organisation. The rule of thumb N>SxM (where N is the number of the sample organisations, M and S are the number of input and output variables).

Table 5.2 Efficiency Scores

Unit Name	Efficiency Score	RTS	Actual									
			Inputs				Outputs					
			ITBA	ITSI	ITHS	BWE	SCHD	COST	SAFETY	CUSTO	CONTR	PROFI
A	100	0	4.6	1.8	1.4	1.4	1.0	2.0	2.0	2.0	2.0	2.0
B	100	0	4.0	4.2	2.0	4.6	4.0	3.0	3.0	2.0	3.0	3.0
C	100	0	3.5	2.4	2.0	2.4	4.0	5.0	3.0	2.0	3.0	4.0
D	100	0	3.9	2.2	2.6	2.0	3.0	3.0	2.0	3.0	3.0	4.0
E	100	0	4.0	1.4	2.2	2.2	4.0	3.0	1.0	2.0	3.0	2.0
F	100	0	3.2	2.8	2.6	2.6	4.0	4.0	4.0	3.0	3.0	5.0
G	100	0	4.2	2.0	2.4	1.8	3.0	3.0	1.0	2.0	4.0	4.0
H	100	0	4.6	2.0	2.2	2.8	2.0	3.0	2.0	4.0	3.0	3.0
I	47	1	3.8	2.8	2.4	3.2	2.0	2.0	1.0	1.0	1.0	2.0
J	76	-1	4.3	2.0	2.4	2.0	2.0	2.0	2.0	2.0	2.0	2.0
K	100	0	3.7	1.6	2.4	1.6	5.0	5.0	2.0	3.0	3.0	3.0
L	100	0	2.8	2.2	3.6	2.0	3.0	3.0	2.0	2.0	2.0	3.0
M	86	-1	5.0	1.8	2.4	2.0	2.0	2.0	2.0	2.0	2.0	2.0
N	80	1	3.7	3.0	3.4	2.6	4.0	3.0	2.0	2.0	2.0	1.0
O	41	1	4.0	3.0	2.4	2.4	2.0	1.0	1.0	1.0	1.0	1.0
P	100	0	3.5	3.8	2.8	3.4	5.0	5.0	4.0	4.0	4.0	4.0
Q	100	0	4.4	1.2	1.8	1.0	4.0	3.0	1.0	1.0	2.0	1.0
R	75	1	4.3	2.6	3.0	2.2	2.0	2.0	1.0	1.0	3.0	2.0
S	100	0	3.7	2.6	3.6	2.0	4.0	4.0	2.0	4.0	4.0	4.0

Three organisations are in the range of 41-50% efficient, one is recorded in the range of 81-90%. The detail reports on the efficiency scores, areas of suggested improvements for inefficient organisations, reference set and peers are provided in Appendixes B-1.1.

5.2.1 Input/Output Variable Correlation Analysis

One of the main aims of the pilot study was to validate the choice of the variables as representative of the phenomenon under study. To achieve this, a correlation analysis of all the variables was carried out. Thus, if a variable has a strong positive correlation with another variable, it implies both variables represent the same phenomenon. One of the variables then should be eliminated, since it would suggest that they both represent the same phenomenon. Further, optimizing the variables by eliminating any variable that does not contribute to the study, will lead to increasing the level of power of discrimination of the DEA model, and thus allow for more accurate results. Similarly, a large negative correlation can indicate that the values of one factor are associated with low values of another factor, and provide additional insights about the relationships of those variables. All the variables passed the test without showing significance correlation.

Figures 5.4 through to 5.7 provides a sample plots showing variables correlations.

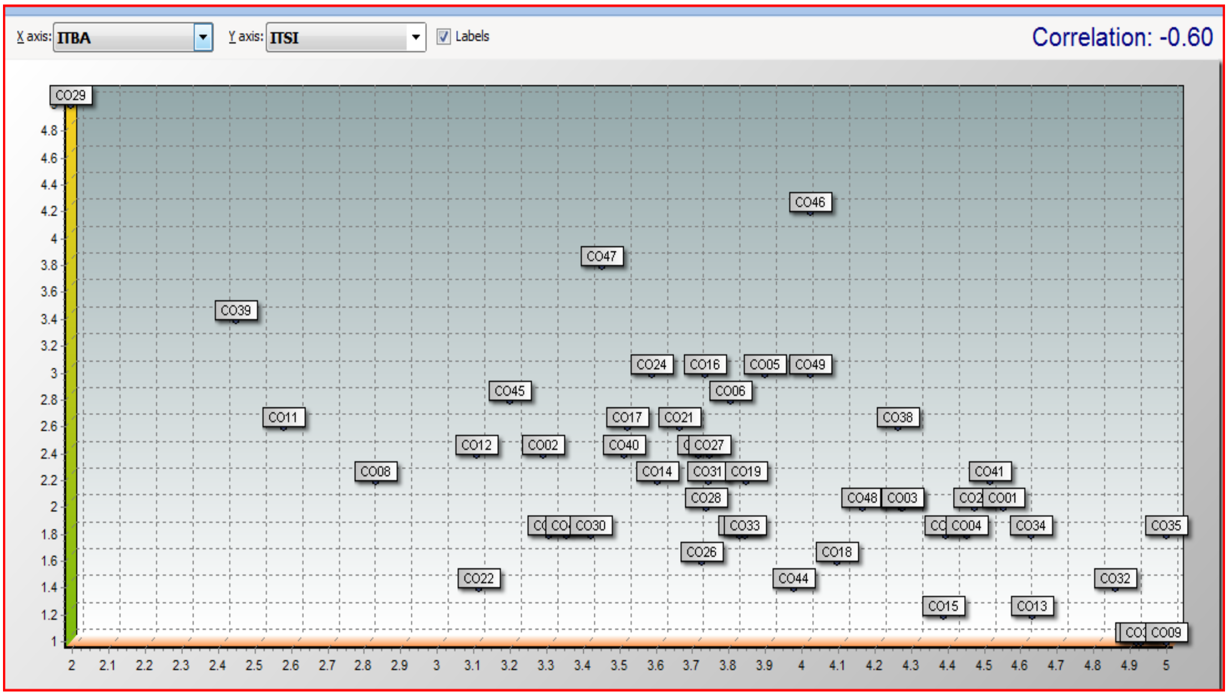

Figure 5.4 ITBA-ITSI correlations across all sampled organisations

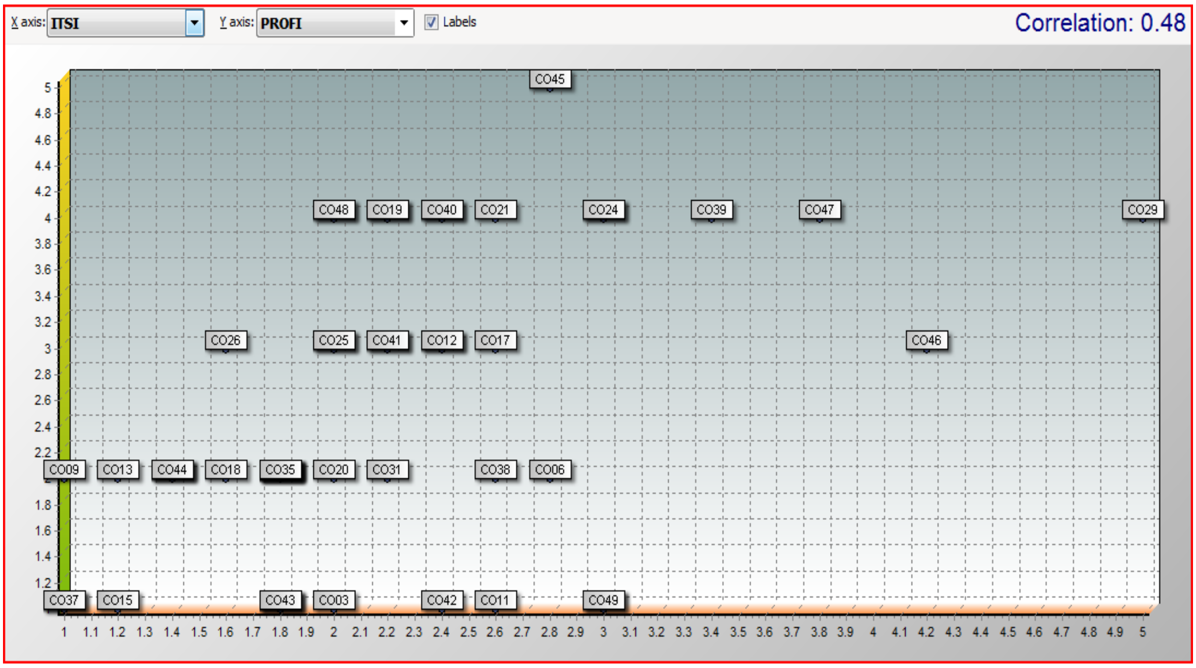

Figure 5.5 ITSI - PROFI correlations across all sampled organisations

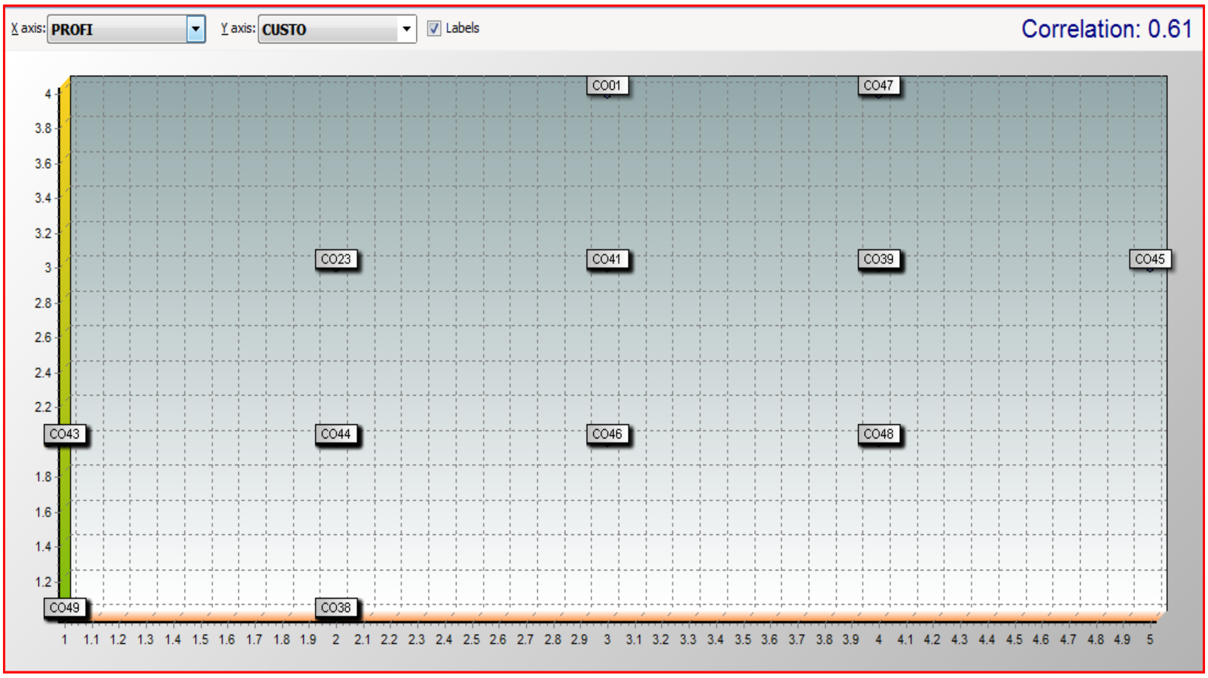

Figure 5.6 PROFI – CUSTO correlations across all sampled organisations

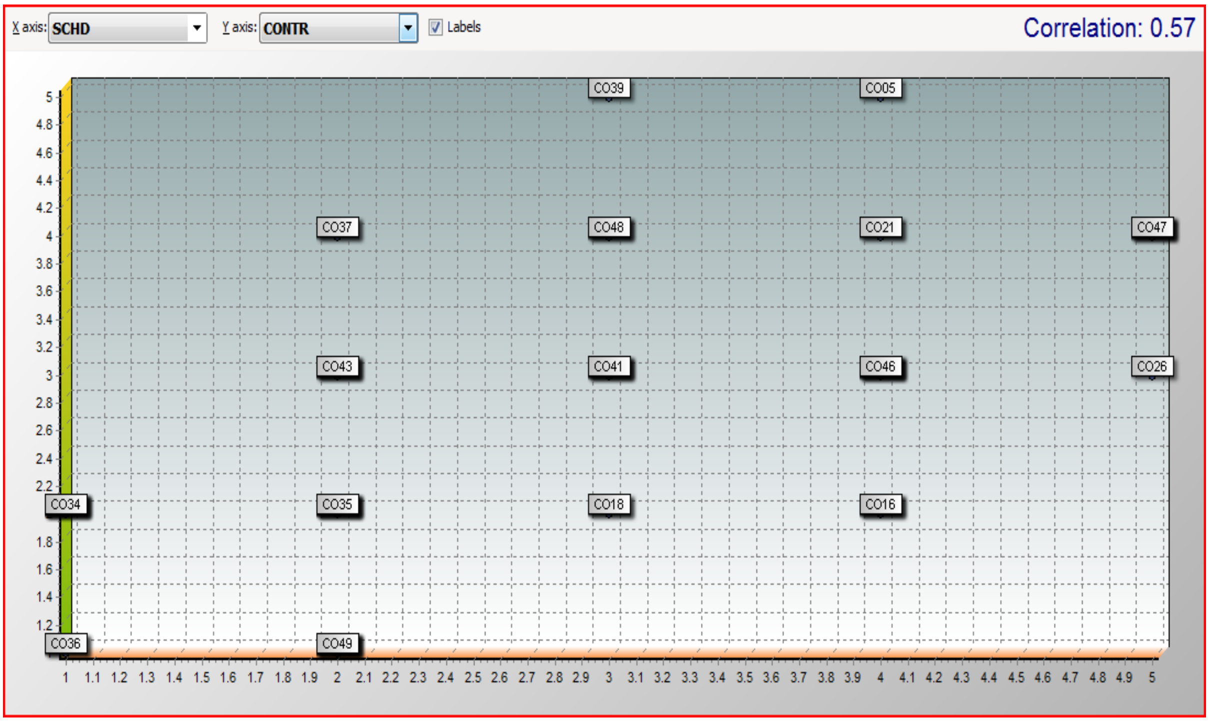

Figure 5.7 SCHD – CONTR correlation across all sampled organisations

5.3 Parameters for Data Analysis

The parameters used for the analysis of the pilot study data in DEA include:

(1) potential improvements

(2) refernce set frequency analysis

(3) input/output contrubutions

(4) reference contribution analysis and

(5) efficiency plot analysis.

Figures 5.8 and 5.9 show the parameters as a screen shot an inefficient and efficient organisations respectively. They are described in the following sections.

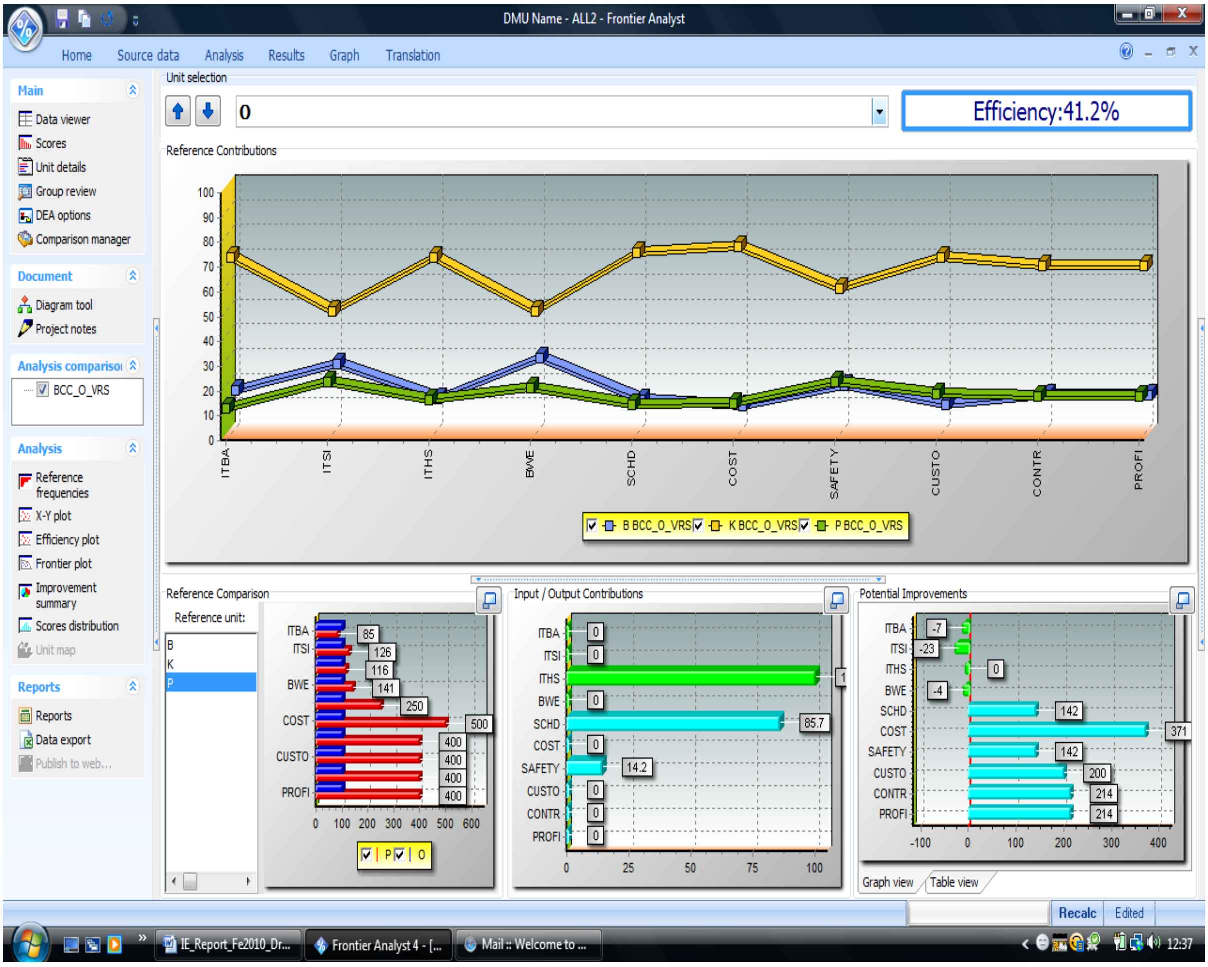

Figure 5.8 Screen Shot of Inefficient Organisation

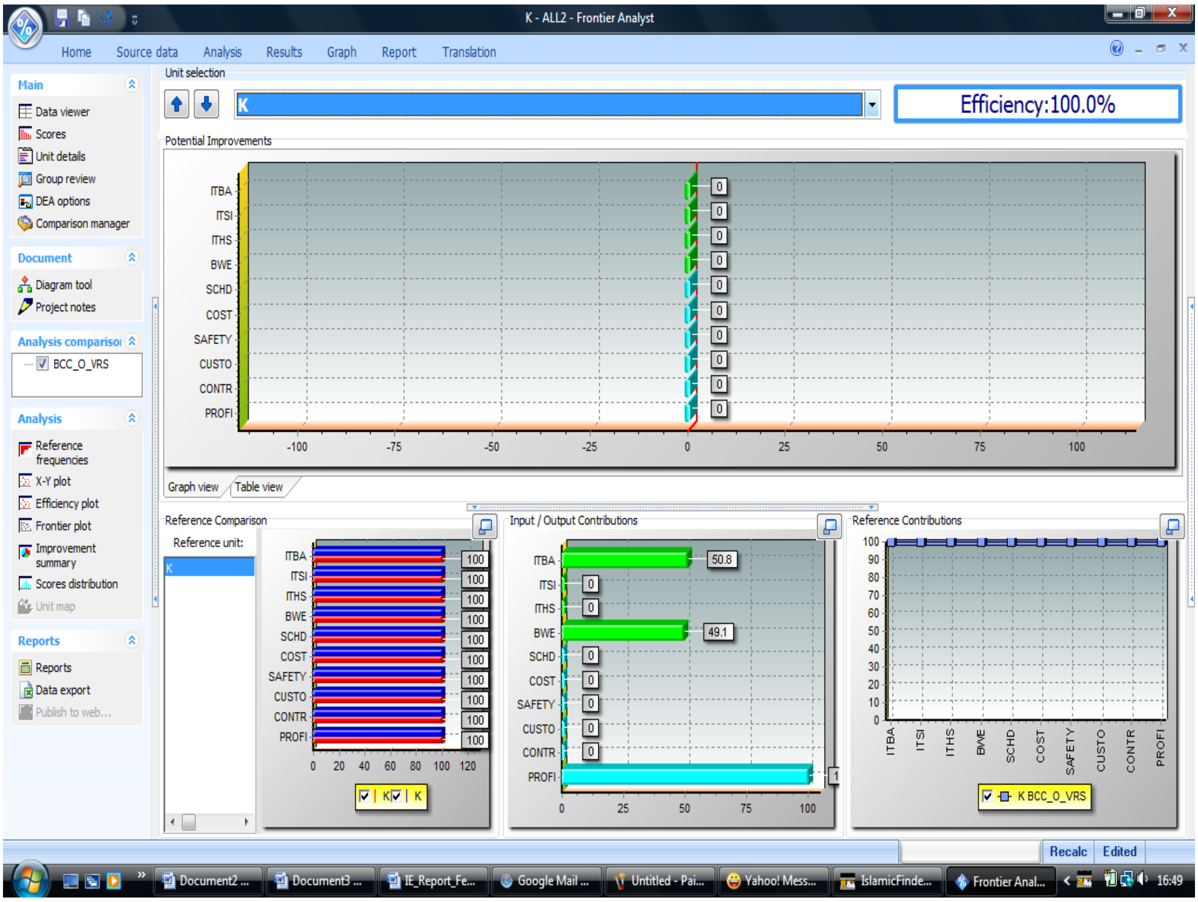

Figure 5.9 Screen Short of Efficient Organisation

5.3.1 Potential improvements

The potential improvement record provides information about the potential improvements which can be made to the input and output variables and compares this information to its reference peers, providing a benchmark to help determine which input variables are most affecting outputs. The term is the same as *slacks* in the DEA literature.

A slack represents the under production of output or the over use of input. It provides for the measure of the improvements needed to make an inefficient organisation to become efficient. These improvements are achieved through an increase/decrease of in input or output factors.

The values of slacks for each organisation are generated from the solutions of equations 4.4 a-e, thus:

$$\phi^{*} = max\,\phi - \varepsilon\left(\sum_{i=1}^{M} S_i^{-} + \sum_{r=1}^{S} S_r^{+}\right) \text{ Subject to:}$$

$$\sum_{j=i}^{N} \lambda_j x_{ij} + S_i^- = x_{io}\,; \sum_{j=i}^{N} \lambda_j y_{rj} - S_r^+ = \phi y_{ro}\,; \lambda_j \geq 0, \forall i, j\,; \sum_{j=i}^{N} \lambda_j = 1$$

Where, ϕ* represents the efficiency score of an organisation and s_i^- and s_r^+ are the input and output slacks respectively.

An organisation is efficient if and only if ϕ*=1 and $s_i^{-*} = s_r^{+*} = 0$; $\forall i, r$; an organisation is weakly efficient if ϕ*=1 and $s_i^{-*} \neq 0$ and/or $s_r^{+*} \neq 0$; $\forall i, r$ ε

The organisation "O" potential improvement plot in figure 5.10 indicates that it was not efficient since the values of the slacks s_i^- and s_r^+ are not equal to zero. Therefore, certain production variables need to be adjusted to improve the performance of "O" relative to its peers to remain competitive in the same market.

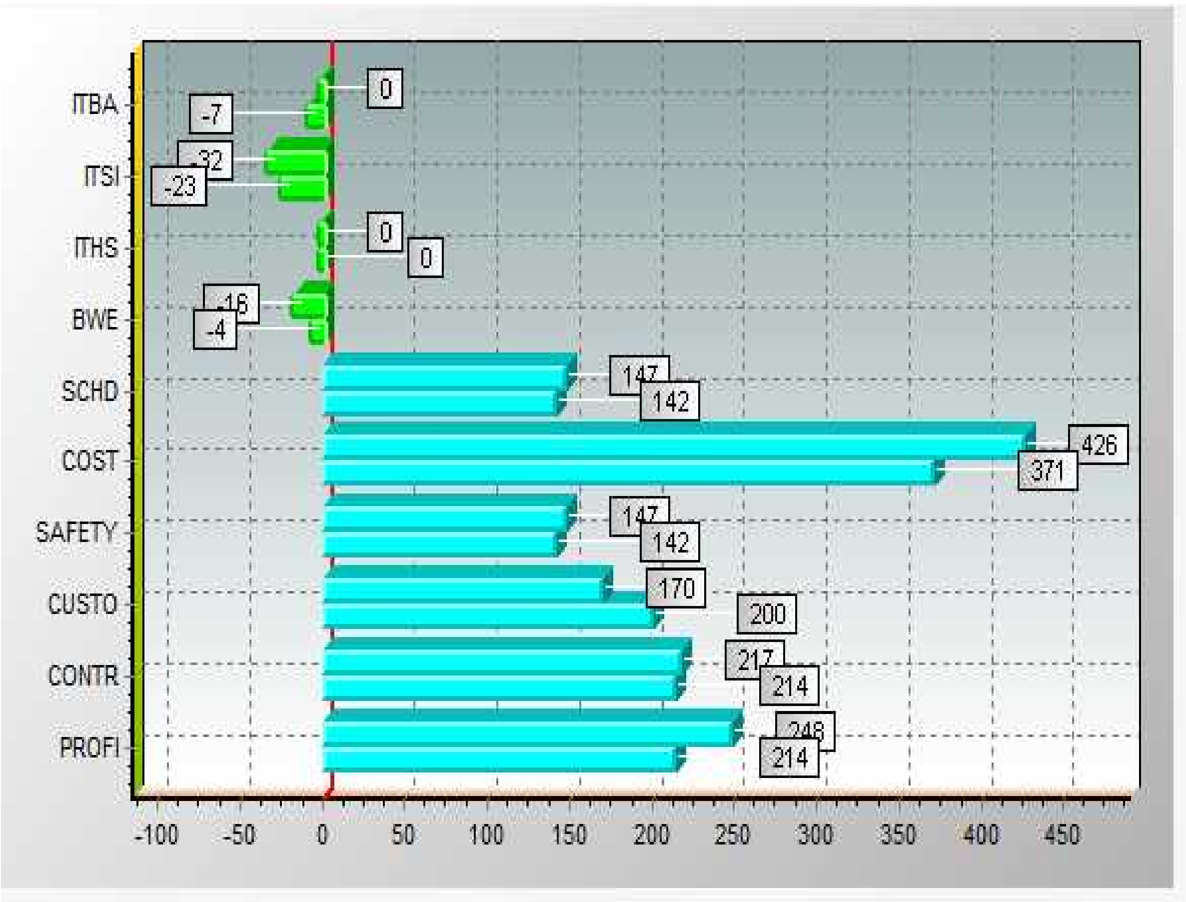

Figure 5.10 Potential improvements graph for "O"

Table 5.3. Potential improvements (Slacks) for "O"

	Input/ Output	Actual	Target	Potential Improvement
Input	ITBA	4.02	4.02	0.0%
	ITSI	3.00	2.02	-32.8%
	ITHS	2.40	2.40	0.0%
	BWE	2.40	2.00	-16.7%
Output	SCHD	2.00	4.96	147.8%
	COST	1.00	5.26	426.2%
	SAFETY	1.00	2.48	147.8%
	CUSTO	1.00	2.70	170.0%
	CONTR	1.00	3.17	217.4%
	PROFI	1.00	3.48	248.0%

Table 5.3 and Figure 5.10 gave the indications of how organisation "O" utilised the input factors leading to the low performance. To improve its performance organisation "O" needs to ensure efficient utilisation of some of the input variables. From Table 5.3 organisation "O" was not using its IT shared infrastructure facilities effectively. The slack of 32.8% indicated the lost of efficiency in the utilisation of the infrastructure. Since the dimension for measuring ITSI includes managerial capability, low performance in the effective utilisation of ITSI provides knock on effect on the business work environment (BWE). Some of the factors worth considering for improvement within organisation "O" include the need for 'open communication', 'project management competency' and 'general business work practices'.

Output variable slacks (s_r^+) for organisation "O" as presented in Table 5.3 are greater than zero. In order to improve the competitiveness of "O" relative to its peers in the sample, the aggregate performance of the projects outputs executed by "O" have to be improved in the same percentages indicated in Table 5.3 For example the output slacks required to be increased ranging from 148% for SCHD to 248% for PROFI.

Table 5.4. Potential Improvements (Slacks) for "P"

	Input / Output	Actual	Target	Potential Improvement
Input	ITBA	3.45	3.45	0.0%
	ITSI	3.80	3.80	0.0%
	ITHS	2.80	2.80	0.0%
	BWE	3.40	3.40	0.0%
Output	SCHD	5.00	5.00	0.0%
	COST	5.00	5.00	0.0%
	SAFETY	4.00	4.00	0.0%
	CUSTO	4.00	4.00	0.0%
	CONTR	4.00	4.00	0.0%
	PROFI	4.00	4.00	0.0%

From the solutions of equations (4 a-e) an organisation is considererd to be efficient if and only if the efficiency score (ϕ*) is 100% in addition to both slacks been zero (s_i^{-*} = s_r^{+*} = 0; $\forall i,r$); an example of such organisation is "P". The slacks for "P" are depicted in Table 5.4 and graphically represented in Figure 5.11. On the other hand even when an organisation scores 100% (ϕ*=1), it is considered weakly efficient provided either or both of the slacks are not equal to zero ($s_i^{-*} \neq 0$ and/or $s_r^{+*} \neq 0; \ \forall i,r \ \ \varepsilon > 0$) where ε is non-Archimedean element.

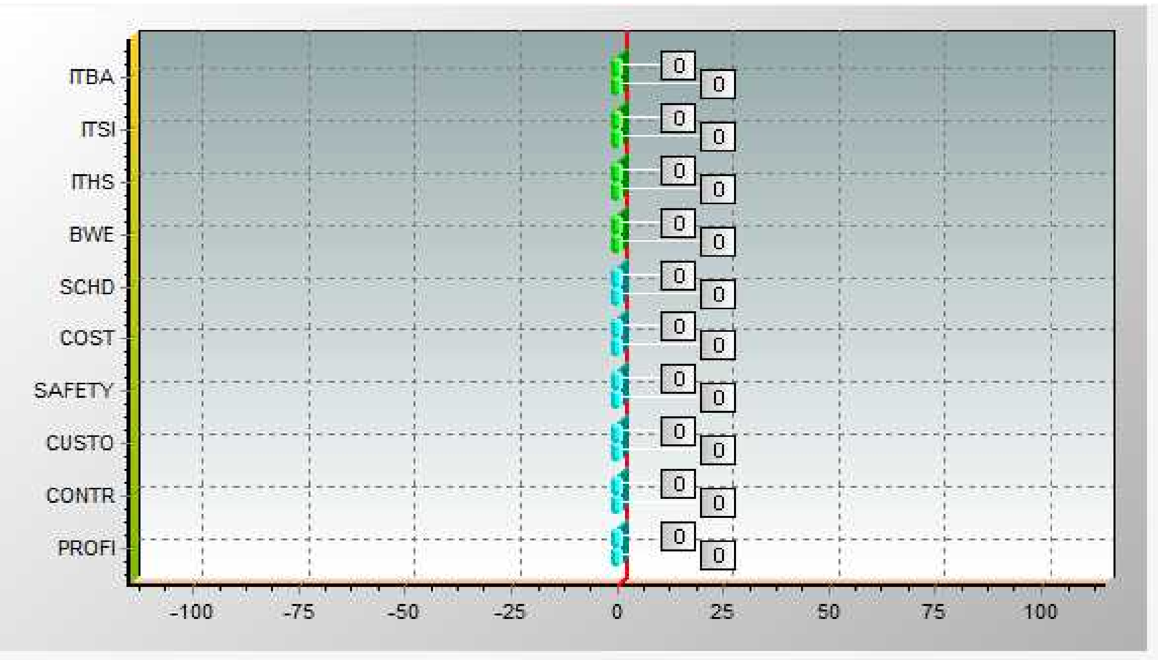

Figure 5.11 Potential improvements for "P"

5.3.2 *Reference Set Frequency Analysis*

A reference set frequency is one of the Frontier Analyst® reports which provide information on how many times an efficient unit appears in an inefficient unit's reference set. That is, how many times each efficient unit is used in calculating the virtual efficient units for each inefficient unit.

The report indicates the most efficient organisations since, the higher the frequency of inclusion in the reference sets of other organisations, the more likely the efficient unit is an example of a best performer among the sample tested.

5.3.3 *Input / Output Contributions*

Input-Output contributions shows in-depth information about how each input/output variable was actually weighted. The report on the input / output contribution provides an indication of variables used in determining the efficiency of of an organisation ad those that were not ignored.

For example in Figure 5.8, the organisation ("O") used IT Human Skills (ITHS) as the only contributing input factors 'efficiently' while SCHD and SAFETY are the output factors that contributed to its performance. All other varibale

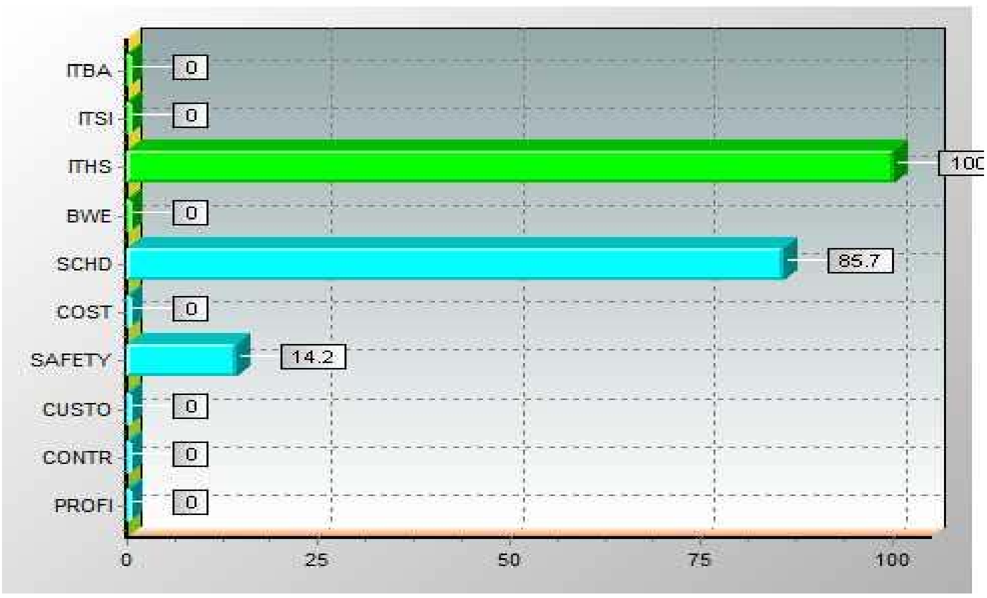

Figure 5.12 Input-Output Contributions for "O"

5.3.4 Reference Contributions Analysis

A reference comparison analysis reveals the level of similarity between the input and output variables in the organisation being analyzed, and those in its reference set. Reference organisations are considered efficient and they are directly compared against the inefficient organisations. The reference contribution provides information on which members of an organisation's reference set have had the most influence to setting its targets for potential improvements. This allows for identification of the key organisations to compare its performance.

5.3.5 Efficiency Plot Analysis

The efficiency plot analysis shows the spread of unit efficiencies against all input and output variables. This analysis can help identify if certain characteristics, in general lead to efficiency or inefficiency.

5.4 Graphical Repsentation of the Hypotheses

A graphical analysis was conducted using a radar plot and ranking of the parameters in the derived hypotheses to establish the level of significance of the parameters, thus provide a non-statistical test of the hypotheses.

For the first hypothesis the parameter in the data required to establish level of significance in order to prove the alternative hypothesis below is ITSI:

> ***H_1:*** *the technological components of ITI are readily available in the marketplace therefore, ITSI may not have significant impact on the performance of engineering and construction organisations.*

The second hypothesis requires the investigating the level of significance of the ITBA input variable in the sample data to test the following hypothesis:

> **H_2:** *IT business applications (ITBA) will have positive impact on construction organisation performance.*

The variable to use in testing the next hypothesis is ITHS:

H_3 *Superior IT human capabilities (ITHS) will have positive impact in providing a source for engineering and construction organisations' competitive advantage*

For testing of the last hypothesis the variable to analyse is BWE:

H_4: *Complementary organisational resources (BWE) will have positive impact in creating ITBV in engineering and construction organisations*

The contributions of these variables on the changes in performances of the organisations are provided in Table 5.5. Detailed results of the analysis interms of the impact of each input variable on the performace of the organisations are presented in Appendix B-.1.1.1 to B- 1.1.4

Table 5.5 Impacts of Different Inputs

Organisation	ITBA	ITHS	ITSI	BWE	All-Inputs
Efficiency Scores %					
A	50	100	86	100	100
B	80	100	80	80	100
C	100	100	100	100	100
D	88	90	100	98	100
E	80	93	100	85	100
F	100	100	100	100	100
G	100	100	100	100	100
H	100	100	100	100	100
I	44	47	45	44	47
J	50	58	75	70	76
K	100	100	100	100	100
L	100	67	74	77	100
M	50	58	86	70	86
N	80	80	80	80	80
O	40	41	40	40	41
P	100	100	100	100	100
Q	80	100	100	100	100
R	75	75	75	75	75
S	100	100	100	100	100

Each of the variables (ITBA, ITHS, ITSI, and BWE) was used as the sole input while maintaining the same output variables to produce the efficiency score of the organisations shown in Table 5.5. While it can be seen that some of the parameters led to more efficient organisations compared to other, it is difficult to establish their level of significance. This is because by using a single variable in the analysis, zero weights are indirectly imposed on the rest of the variables. Therefore, the process did not allow for the prior assumption of none contribution of the rest of the variable in the performance of the organisations.

As indicated in the inputs/outputs contribution analysis, different combinations of variables are used to establish the performance of each organisation. This analysis is presented in Table 5.6.

Table 5.6 Inputs/Outputs Contribution for Efficient Organisations

DMUs	Inputs/Outputs Contributions									
	Inputs				Outputs					
	ITSI	ITHS	ITBA	BWE	SCHD	COST	SAFETY	CUSTO	CONTR	PROFI
A	-	1.4	-	-	-	-	2.0	-	-	-
B	-	2.0	-	-	3.2	-	0.6	-	-	-
C	-	-	3.2	-	-	-	-	-	3.0	-
D	-	1.5	-	0.9	-	-	-	1.3	-	2.3
E	1.4	-	-	-	-	-	-	2.0	-	-
F	-	2.6	-	-	-	-	4.0	-	-	-
G	-	0.3	3.0	0.3	-	-	-	-	4.0	-
H	1.0	0.8	2.6	-	-	-	-	4.0	-	-
K	-	-	1.9	0.8	-	-	-	3.0	-	-
P	-	-	-	3.4	2.6	-	1.9	-	-	-
Q	-	-	-	1.0	4.0	-	-	-	-	-
S	-	-	2.2	0.8	-	-	-	4.0	-	-

From Table 5.6 it can be seen that based on the frequencies of the resources utilization (ITSI, ITHS, ITBA, BWE) by the efficient organisations, the level of significance of the variables are in the following descending order: BWE, ITBA, ITHS and ITSI.

The most significant varables contributing to an organisation's ITBV is found to be complementary organistional resources (BWE). This is also in agreement with the hypothesis put forward based on the literuature that *Complementary organisational resources (BWE) will have positive impact in creating ITBV in engineering and construction organisations.*

Furthermore, a radar plot is used to present the significance of the input variables as depicted in Figures 5.13 and 5.14.

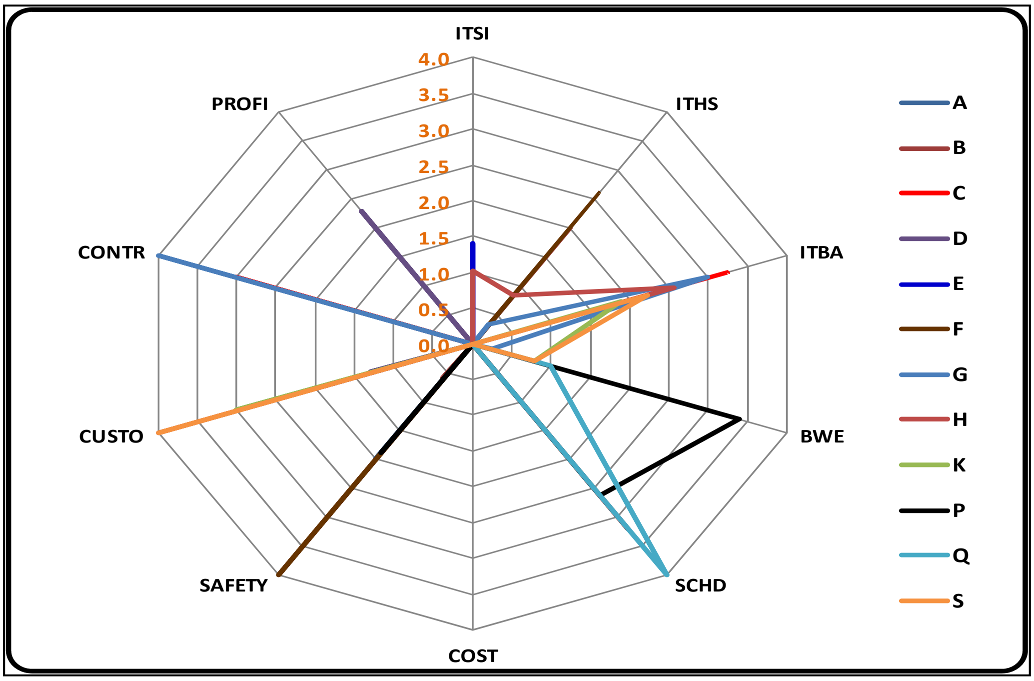

Figure 5.13 Radar Chat of Inputs/Outputs Contributions

Radar chart (Chambers, *et al.*, 1983: 158-162) is a useful way to display multivariate data in the form of a two-dimensional chart with an arbitrary number of variables. Each variable is represented as a star-shaped figure with one ray for each variable. For a given variable, the length of each ray is made proportional to the size of that variable.

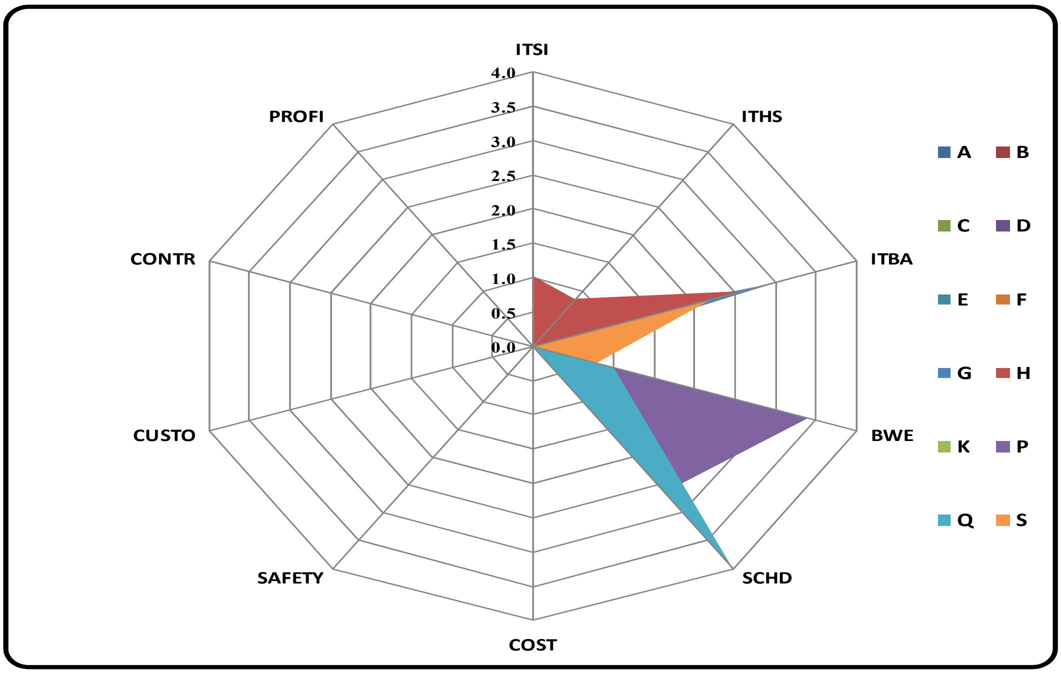

Figure 5.14 Radar Chat of Input/Output Contributions

From the plots, it could be deduced that the dominant variable is ITBA, BWE and ITHS. Furthermore, the most frequent variable as factor used by the efficient organisations is the ITBA follows by the BWE.

From this observation, a non statistical analysis of the hypotheses, the parameters ITBA, BWE, ITHS are found to have a significant impact on the performance of the organisations. ITSI has no significant impact on the performance of the organisations.

5.5 Chapter Summary

In this chapter the following contributions have been demonstrated:

- Validation of the proposed engineering and construction value chain and the work functions,
- Established the effectiveness of the research methodology, sampling and the internal validity of data collection techniques,
- Established the validity of use of DEA in evaluating the survey data.

Thus, the research from the first test of the pilot study indicates the validity of the process and contributes to the body of knowledge in the field of IT and strategic management.

The next chapter extends the validated processes to evaluate and analyse a more comprehensive data and higher sample size. The higher sample size is aimed at satisfying the DEA requirement for high discriminatory power during analysis and minimize errors.

CHAPTER SIX
DATA ANALYSIS AND RESULTS

6.0 Introduction

The DEA analysis of the data in pilot study reported in chapter 5 was characterised by low discriminatory power of the model returning large number of the sampled organisations as efficient mainly due low ratio of the sample size to the number of the variables in the data used. Thus, a wider survey was conducted and the results, analysis and conclusions are presented in this chapter.

The additional data were collected using the same instrument of questionnaire described in section 4.10 and deployed when conducting the pilot study reported in chapter 5. Thus, input and output variables were identified and measured based on 5-point likert scale. The sampled organisations were categorized strategic groups as represented in Figure 6.1.

The bulk of the data is coded from qualitative perception to quantitative values using survey software called *Survey Methods*. The software is an online tool that allows designing of questionnaire and launching the same via e-mails. Responses were collected and exported into Microsoft Excel, Microsoft Words and Portable Document Format (PDF) for further analysis. The compiled data was sorted and categorised into input / output variables before analysed using *Frontier Analyst®* version 4 software. The *Frontier Analyst®* is a Windows® based efficiency analysis tool, which uses DEA technique to examine the relative performance of organisations or units therein referred to as a decision making units (DMU).

6.1 Data Sample Characteristics and DEA Protocols

A successful implementation of DEA to evaluate the relative efficiencies of decision-making units (DMU) requires adhering to certain protocols and methodology related to data collection and analysis. Some of the keys issues addressed in sampling the data are related to:

(1) Strategic grouping of the sample.
(2) Homogeneity of the sample;
(3) Variables size and;
(4) How the variables were measured among others (Dyson *et al.*, 2001; Ibrahim *et al.*, 2011).

6.1.1 Strategic Grouping

Strategic group analysis is the first step in structural analysis of industries to understand the strategies of all significant competitors (Porter 1980). It is used to determine the different strategic positions of the rival organisations, intensity of competitive rivalry within and between industry groups, the profit potential of the various strategic groups in an industry, and implications for the competitive position of the firm under analysis. However, members of a strategic group, while pursuing similar strategies, are not necessarily in competition with one another. For example, due to the differences in locations, submarkets, etc., companies in the same strategic group may not be direct competition.

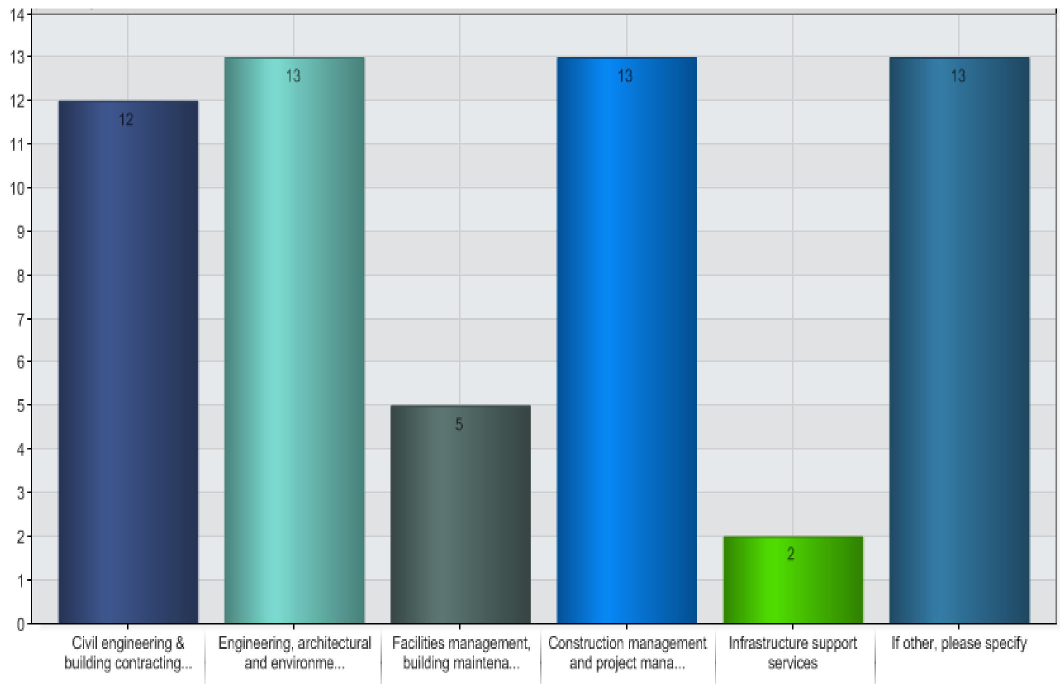

Figure 6.1 Strategic Grouping of the Sampled Organisation

Mode and scope of competition are the two strategic dimensions proposed for strategic grouping (Porter, 1980). Mode of competition refers to an organisation's decisions on how to achieve competitive advantage, whereas scope of competition refers to an organisation's decisions on the breadth of its operations. Thus, the performance differences between firms can be explained by different competitive positions resulting from different strategic choices.

Strategic group analysis is known to be more a descriptive rather than a predictive tool. It is unlikely to offer much insight into why some organisations in an industry perform better than others. However, it can increase understanding about the structure of the industry, strategic perspectives, and dynamics of the competitive environment (Grant 1995).

Kale and Arditi (2002) claimed that differences in construction companies' performances could be partly explained by their choices of mode and scope of competition. It was found that construction companies that outperform their rivals adopt a hybrid mode, rather than a single mode of competition. However, no statistically significant finding was found on the impact of scope on performance.

Claver *et al.* (2003) studied the linkage of strategic groups and performance by examining the business strategies of Spanish contractors. However, the empirical findings demonstrate that no significant differences exist between the performances of organisations that belong to different groups.

The sampled organisations were grouped into six strategic groups based on the scope of competition and areas of specialisations as in Figure 6.1

6.1.2 Homogeneity of the sampled organisations

The organisations in the sampled data were selected to ensure homogeneity in that they are providing comparable services with common output for engineering and construction project delivery. Another homogeneity factor satisfied by the sample characteristic is the fact that all targeted organisations is within same economic environment of the UK. The organisations were further grouped based on strategic group analysis for the construction organisation (Dikmen *et al.*, 2009). The potential existence of economies of scale was another form of non-homogeneity of the organisations under consideration. To mitigate the effect of the scale, a variable return to scale (VRT) model of DEA was used in analysing the data (Banker *et al.*, 1984).

6.1.3 Size of Input / Output Factors

One of the fundamentals for the assessment of comparative efficiency by DEA is the construction of the production possible set (PPS) containing all input-output level 'correspondences' as defined by the research model. Correspondence of inputs and outputs in this context is based on a relationship of exclusivity and exhaustiveness between the two sets of variables (Thanassoulis, 2003).

The initial list of the variables considered for assessing the organisational performance was as wide as possible in the form of work functions within each primary value chain activity. The input variables captured all IT resources and the output variables all the outcomes having a bearing on the type of efficiency being assessed. In addition, contextual factors impacting the transformation of inputs to outputs should also be reflected in our case these include complimentary organisational resources (Boussofiane, *et al.*, 1991; Thanassoulis, 2003). The variables quantified satisfied the 'isotonicity' relations, which assumed that an increase in any input should not result in a decrease in any output for a given organisation.

Meeting the minimum requirements of the relationship between the sample size and the number of input and output variables lead to a reasonable level of discrimination of the DEA functions and results. While it is feasible to apply DEA to a small sample size (Evanoff and Israilevich, 1991), the analysis loses discriminatory power where the sample size is not greater than the product of number of inputs and number of outputs.

This is termed as first rule of thumb (*Ali et al.,* 1988; Bowlin, 1987), thus, N>(S*M). A second rule of thumb is to select a sample size at least two times the sum of the number of inputs and outputs N≥ 2(S+M) (Dyson *et al.,* 2001). The data should be collected in a common time frame in order to arrive at meaningful conclusion (Sherman and Gold, 1985; Avkiran, 2006).

The sample size was derived from 150-targeted organisations involved in the business of engineering, architectural, construction and project management in the UK. 55 responded with 6 uncompleted leaving a valid sample size of 49 representing 32% response rate. There are 4 set of input variables (M=4) (ITBA, ITSI, ITHS and BWE) derived by calculating the average scores against each work functions of the primary value chain activity using equation 1. The output variables are six in number (S=6) including (SCHD, COST, SAFETY, CUSTP, CONTR and PROFI). This implies that the sum of the number of the variables is 10 and their products 24. With a sample size of N=49, the data satisfied the first and second rules of thumb for a minimum requirement to ensure discriminatory power from solving equation 4.

6.1.4 Measure of the Input / Output Variables

One major assumption on the measurement of the variables in DEA analysis is that they should have equal intervals of the scale and equal values (Shephard, 1970; Banker *et al,* 1984; Dyson *et al.,* 2001). Thus, input and output variables were measured using a 5–point likert scale questionnaire, hence, satisfying this assumption.

6.2 Data Analysis

Borges and Barros (2008) suggested that the choice of input-oriented or an output-oriented DEA model is based on the market conditions of the organisations under investigation. Since, in competitive markets, organisations are output-oriented, with the assumption that inputs are under their control, the aim of the organisation is to maximize its outputs subject to market demand. Based on the competitive nature of the organisations and the overall research design, output-oriented DEA model was adopted in analysing the performance of the sampled organisations. Furthermore, in order to accommodate the differences in the scales of operations across the sampled engineering and construction organisations, the BCC model with variable return to scale (VRS) was deployed.

The DEA model for ITBV of engineering and construction organisations as represented in equation 4 is simulated and solved using *Frontier Analysts®* Software based on the data collected in Table 6.1.

Different analyses were provided through the *Frontier Analyst* software product, which are organized in the following sections:

- Summary Efficiency Scores Analysis
- Total Potential Improvement Analysis
- Reference Set Frequencies Analysis
- Unit Potential Improvement and Comparison Analysis
- Unit Reference Comparison Analysis
- Input/output Variable Correlation Analysis
- Efficiency Plot Analysis

Table 6.1. Quantified Input/output Variables

DMUs	Inputs (X_i)				Outputs (Y_j)					
	ITBA	ITSI	ITHS	BWE	SCHD	COST	SAFETY	CUSTO	CONTR	PROFI
CO_{01}	4.55	2.00	1.83	2.80	2.00	3.00	2.00	4.00	3.00	3.00
CO_{02}	3.29	2.40	2.50	3.00	5.00	4.00	3.00	3.00	4.00	3.00
CO_{03}	4.28	2.00	1.50	1.00	1.00	2.00	1.00	2.00	2.00	1.00
CO_{04}	4.45	1.80	1.33	2.00	4.00	4.00	2.00	3.00	2.00	2.00
CO_{05}	3.90	3.00	2.17	2.00	4.00	4.00	1.00	3.00	5.00	4.00
CO_{06}	3.81	2.80	2.00	3.20	2.00	2.00	1.00	1.00	1.00	2.00
CO_{07}	3.83	1.80	2.17	1.60	2.00	2.00	1.00	1.00	2.00	2.00
CO_{08}	2.83	2.20	3.00	2.00	3.00	3.00	2.00	2.00	2.00	3.00
CO_{09}	5.00	1.00	1.00	1.00	2.00	2.00	1.00	1.00	1.00	2.00
CO_{10}	3.31	1.80	1.33	2.60	2.00	1.00	4.00	2.00	2.00	2.00
CO_{11}	2.58	2.60	1.50	2.40	2.00	2.00	3.00	1.00	1.00	1.00
CO_{12}	3.11	2.40	2.17	2.40	3.00	3.00	2.00	2.00	3.00	3.00
CO_{13}	4.63	1.20	1.17	2.00	1.00	2.00	2.00	1.00	2.00	2.00
CO_{14}	3.60	2.20	2.00	2.20	3.00	3.00	3.00	2.00	4.00	4.00
CO_{15}	4.39	1.20	1.50	1.00	4.00	3.00	1.00	1.00	2.00	1.00
CO_{16}	3.74	3.00	2.83	2.60	4.00	3.00	2.00	2.00	2.00	1.00
CO_{17}	3.52	2.60	2.33	2.40	4.00	4.00	4.00	3.00	4.00	3.00
CO_{18}	4.10	1.60	2.00	2.40	3.00	4.00	1.00	1.00	2.00	2.00
CO_{19}	3.85	2.20	2.17	2.00	3.00	3.00	2.00	3.00	3.00	4.00
CO_{20}	4.27	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
CO_{21}	3.67	2.60	3.00	2.00	4.00	4.00	2.00	4.00	4.00	4.00
CO_{22}	3.11	1.40	2.33	3.00	3.00	3.00	3.00	3.00	3.00	2.00
CO_{23}	4.39	1.80	2.17	2.00	2.00	4.00	2.00	3.00	4.00	2.00
CO_{24}	3.59	3.00	2.33	4.20	5.00	4.00	4.00	2.00	4.00	4.00
CO_{25}	4.47	2.00	1.83	1.80	2.00	2.00	2.00	2.00	3.00	3.00
CO_{26}	3.73	1.60	2.00	1.60	5.00	5.00	2.00	3.00	3.00	3.00
CO_{27}	3.75	2.40	2.67	2.80	3.00	2.00	2.00	2.00	4.00	4.00
CO_{28}	3.74	2.00	2.33	2.40	4.00	4.00	3.00	3.00	3.00	4.00
CO_{29}	2.00	5.00	5.00	3.80	5.00	5.00	2.00	3.00	4.00	4.00
CO_{30}	3.42	1.80	1.83	2.00	1.00	1.00	1.00	2.00	2.00	1.00
CO_{31}	3.75	2.20	2.00	1.60	2.00	2.00	2.00	2.00	2.00	2.00
CO_{32}	4.86	1.40	1.00	1.40	1.00	3.00	2.00	2.00	2.00	2.00
CO_{33}	3.84	1.80	1.67	1.60	1.00	1.00	1.00	1.00	1.00	1.00
CO_{34}	4.63	1.80	1.17	1.40	1.00	2.00	2.00	2.00	2.00	2.00
CO_{35}	5.00	1.80	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
CO_{36}	4.92	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
CO_{37}	4.93	1.00	1.00	1.60	2.00	2.00	2.00	2.00	4.00	1.00
CO_{38}	4.26	2.60	2.50	2.20	2.00	2.00	1.00	1.00	3.00	2.00
CO_{39}	2.45	3.40	3.67	4.00	3.00	4.00	5.00	3.00	5.00	4.00
CO_{40}	3.51	2.40	1.67	2.40	4.00	5.00	3.00	2.00	3.00	4.00
CO_{41}	4.52	2.20	2.83	2.00	3.00	3.00	3.00	3.00	3.00	3.00
CO_{42}	3.72	2.40	2.00	2.00	2.00	2.00	2.00	1.00	1.00	1.00
CO_{43}	3.35	1.80	2.83	2.40	2.00	1.00	1.00	2.00	3.00	1.00
CO_{44}	3.98	1.40	1.83	2.20	4.00	3.00	1.00	2.00	3.00	2.00
CO_{45}	3.20	2.80	2.17	2.60	4.00	4.00	4.00	3.00	3.00	5.00
CO_{46}	4.02	4.20	4.33	4.60	4.00	3.00	3.00	2.00	3.00	3.00
CO_{47}	3.45	3.80	2.33	3.40	5.00	5.00	4.00	4.00	4.00	4.00
CO_{48}	4.17	2.00	2.00	1.80	3.00	3.00	1.00	2.00	4.00	4.00
CO_{49}	4.02	3.00	2.00	2.40	2.00	1.00	1.00	1.00	1.00	1.00

6.3 Result and Discussion

Table 6.2 presents the relative efficiency scores of the organisation, which, generally indicated that the utilization of IT resources has resulted in values in the form of efficiency gained.

Table 6.2. Efficiency Scores and Slacks

DMU	Efficiency	RTS	Slacks									
	Scores %		ITBA	ITSI	ITHS	BWE	SCHD	COST	SAFETY	CUSTO	CONTR	PROFI
CO$_{01}$	100.00	(1.00)	-	-	-	-	-	-	-	-	-	-
CO$_{02}$	100.00	1.00	-	-	-	-	-	-	-	-	-	-
CO$_{03}$	100.00	(1.00)	-	-	-	-	-	-	-	-	-	-
CO$_{04}$	100.00	(1.00)	-	-	-	-	-	-	-	-	-	-
CO$_{05}$	100.00	(1.00)	-	-	-	-	-	-	-	-	-	-
CO$_{06}$	46.67	1.00	0.08	-	-	0.07	-	0.06	0.29	0.11	0.23	-
CO$_{07}$	65.19	(1.00)	-	0.03	0.04	-	0.30	0.30	0.06	0.32	-	-
CO$_{08}$	100.00	(1.00)	-	-	-	-	-	-	-	-	-	-
CO$_{09}$	100.00	(1.00)	-	-	-	-	-	-	-	-	-	-
CO$_{10}$	100.00	1.00	-	-	-	-	-	-	-	-	-	-
CO$_{11}$	100.00	(1.00)	-	-	-	-	-	-	-	-	-	-
CO$_{12}$	100.00	(1.00)	-	-	-	-	-	-	-	-	-	-
CO$_{13}$	100.00	(1.00)	-	-	-	-	-	-	-	-	-	-
CO$_{14}$	100.00	(1.00)	-	-	-	-	-	-	-	-	-	-
CO$_{15}$	100.00	(1.00)	-	-	-	-	-	-	-	-	-	-
CO$_{16}$	80.00	1.00	0.03	0.04	0.13	-	-	0.25	0.12	0.26	0.21	0.46
CO$_{17}$	100.00	(1.00)	-	-	-	-	-	-	-	-	-	-
CO$_{18}$	80.00	(1.00)	0.07	-	-	0.17	0.25	-	0.15	0.44	0.10	0.10
CO$_{19}$	100.00	1.00	-	-	-	-	-	-	-	-	-	-
CO$_{20}$	69.04	1.00	0.12	-	-	-	0.27	0.26	-	-	0.06	-
CO$_{21}$	100.00	(1.00)	-	-	-	-	-	-	-	-	-	-
CO$_{22}$	100.00	(1.00)	-	-	-	-	-	-	-	-	-	-
CO$_{23}$	100.00	1.00	-	-	-	-	-	-	-	-	-	-
CO$_{24}$	100.00	1.00	-	-	-	-	-	-	-	-	-	-
CO$_{25}$	90.57	(1.00)	0.11	0.03	-	-	0.23	0.30	-	0.04	-	-
CO$_{26}$	100.00	1.00	-	-	-	-	-	-	-	-	-	-
CO$_{27}$	97.14	1.00	-	-	0.08	0.12	0.02	0.26	-	0.07	-	-
CO$_{28}$	100.00	1.00	-	-	-	-	-	-	-	-	-	-
CO$_{29}$	100.00	(1.00)	-	-	-	-	-	-	-	-	-	-
CO$_{30}$	79.78	(1.00)	-	-	-	-	0.52	0.49	0.27	-	-	0.24
CO$_{31}$	97.65	(1.00)	-	0.04	0.04	-	0.21	0.28	-	0.09	0.10	-
CO$_{32}$	100.00	(1.00)	-	-	-	-	-	-	-	-	-	-
CO$_{33}$	48.21	(1.00)	-	-	-	-	0.16	0.20	-	0.08	0.07	-
CO$_{34}$	100.00	(1.00)	-	-	-	-	-	-	-	-	-	-
CO$_{35}$	71.74	1.00	0.28	-	0.01	-	0.27	0.22	-	-	0.03	-
CO$_{36}$	100.00	(1.00)	-	-	-	-	-	-	-	-	-	-
CO$_{37}$	100.00	(1.00)	-	-	-	-	-	-	-	-	-	-
CO$_{38}$	62.75	1.00	0.05	-	0.09	0.02	0.06	0.08	-	0.30	-	0.03
CO$_{39}$	100.00	1.00	-	-	-	-	-	-	-	-	-	-
CO$_{40}$	100.00	(1.00)	-	-	-	-	-	-	-	-	-	-
CO$_{41}$	100.00	1.00	0.18	0.02	0.13	-	0.30	0.30	-	-	0.10	-
CO$_{42}$	64.65	(1.00)	-	0.02	-	-	-	0.02	-	0.25	0.33	0.15

CO_{43}	90.60	(1.00)	-	-	0.10	-	0.36	0.60	0.33	0.19	-	0.35
CO_{44}	99.16	(1.00)	-	-	0.01	0.11	-	0.17	0.19	0.12	-	0.03
CO_{45}	100.00	(1.00)	-	-	-	-	-	-	-	-	-	-
CO_{46}	80.00	1.00	0.11	0.08	0.40	0.26	-	0.25	0.05	0.38	0.05	0.05
CO_{47}	100.00	1.00	-	-	-	-	-	-	-	-	-	-
CO_{48}	100.00	(1.00)	-	-	-	-	-	-	-	-	-	-
CO_{49}	40.91	1.00	0.06	0.18	-	0.08	-	0.49	-	0.19	0.13	0.13

Using all the input factors, thirty-two organisations were recorded having efficiency scores of 100% (θ*=1) and zero slacks ($s_i^{-*} = s_r^{+*} = 0; \forall i, r$); making them Pareto efficient. The rest of the organisations scored less than 100% efficiencies (θ*<1) and they recorded none zero slacks, therefore, are not relatively efficient (Figure 6.2).

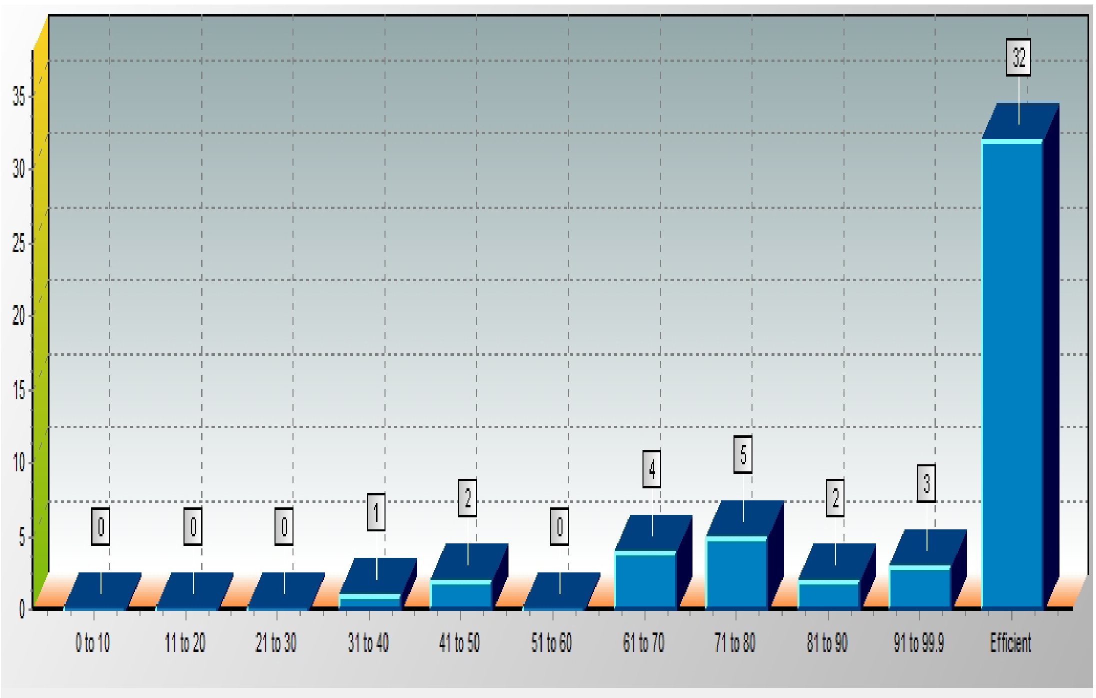

Figure 6.2 Distribution of efficiency scores

6.3.1 Reference Set Frequency Analysis

A reference set frequency is one of the Frontier Analyst® reports which provide information on how many times an efficient unit appears in an inefficient unit's reference set. That is, how many times each efficient unit is used in calculating the virtual efficient units for each inefficient unit. The reference set frequency analysis is shown in Figure 6.3.

The graph indicates the most efficient organisations since the higher the frequency of inclusion in the reference sets of other organisations the more likely the efficient unit is an example of a best performer among the sample tested. For example, Figure 6.3 shows that organisation CO_{26} is the most frequently occurring reference set with frequency of 14.

Organisation CO_{45}, CO_{17} and CO_{10} are second in ranking in terms of efficient utilization of IT resources using their unique complementary resources recording a frequency of referrers by similar organisations as peers 6 times. Organisation CO_{41} has no referral indicating its non-competitiveness among its peers. It records the efficiency score 79.78% as indicated in Table 6.5 based all inputs.

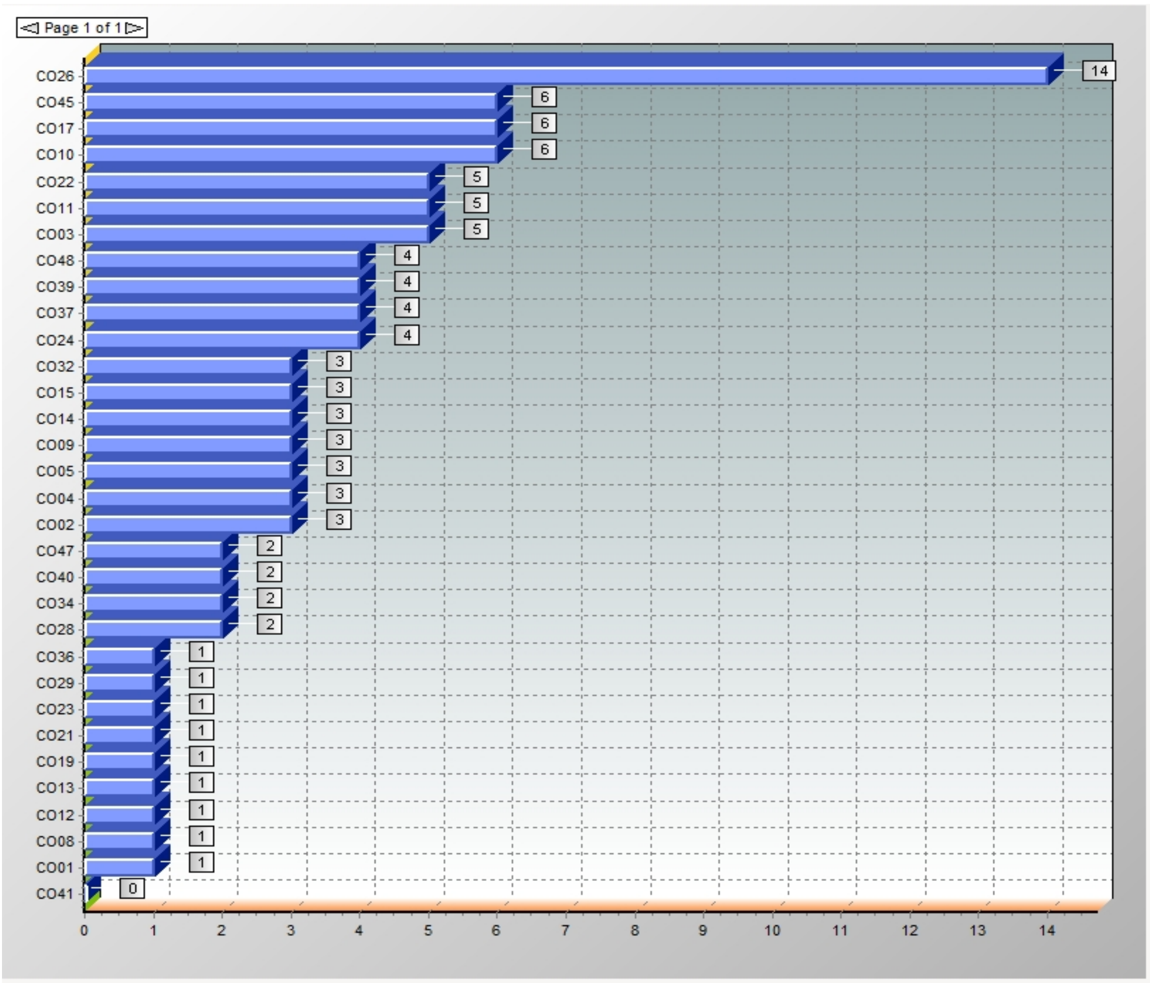

Figure 6.3 Reference Set Frequencies

6.3.2 *Input / Output contributions*

Input-output contributions show in-depth information about how each input/output variable was actually weighted.

There is judicial utilization of the input variables by CO_{26} to be the efficient organisation in the set. However, customer satisfaction (CUSTO) was the only contributing output factor to its performance as depicted in Figure 6.4.

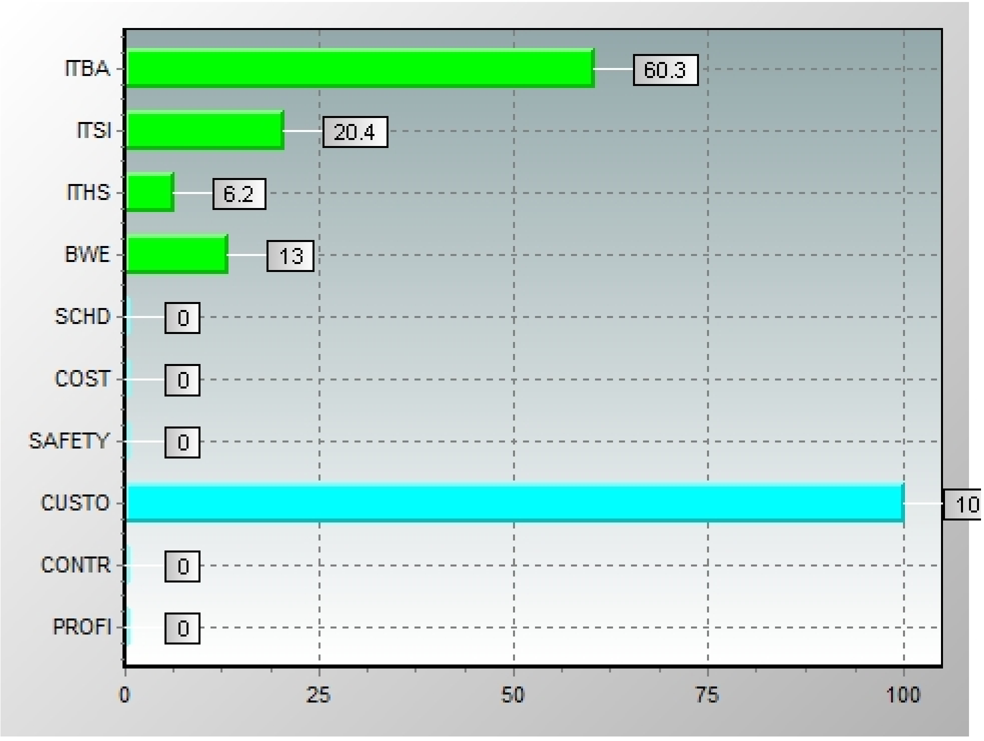

Figure 6.4 Input / Output contributions of CO_{26}

6.3.3 *Potential improvements*

A detailed analysis of each organisation provides information for the required effort to improve the efficiency rating of each inefficient organisation. The potential improvement analysis provides information about improvements which can be made to the input and output variables and compares this information to its reference peers, providing a benchmark to help determine which input variables are most affecting outputs.

By examining the potential improvements suggested by the DEA for one of the least efficient organisations in the sample it is evident that the organisation with lowest performance is CO_{49} with 40.91% and CO_{41} with zero reference.

Amongst the organisations with 100% efficiency scores, CO_{41} recorded zero reference as shown in Figure 6.3. This implies that the organisation is not competitive within the set. In order for the organisation CO_{41} to improve its competitiveness among its peers, the analysis provided in Table 6.3 and Figure 6.4 provide guidance.

Table 6.3. Inputs / Outputs Slacks for CO_{41}

	Input / Output	Actual	Target	Potential Improvement
Input	ITBA	4.52	3.62	-19.7%
	ITSI	2.20	2.10	-4.5%
	ITHS	2.83	2.17	-23.5%
	BWE	2.00	2.00	0.0%
Output	SCHD	3.00	4.50	50.0%
	COST	3.00	4.50	50.0%
	SAFETY	3.00	3.00	0.0%
	CUSTO	3.00	3.00	0.0%
	CONTR	3.00	3.50	16.7%
	PROFI	3.00	3.00	0.0%

Table 6.3 provides a mathematical interpretation of the reasons for the low performance of the organisation CO_{41}. The negative figures of ITBA and ITHS imply there is 'inefficient' utilization of such resources to produce maximum competitive outputs.

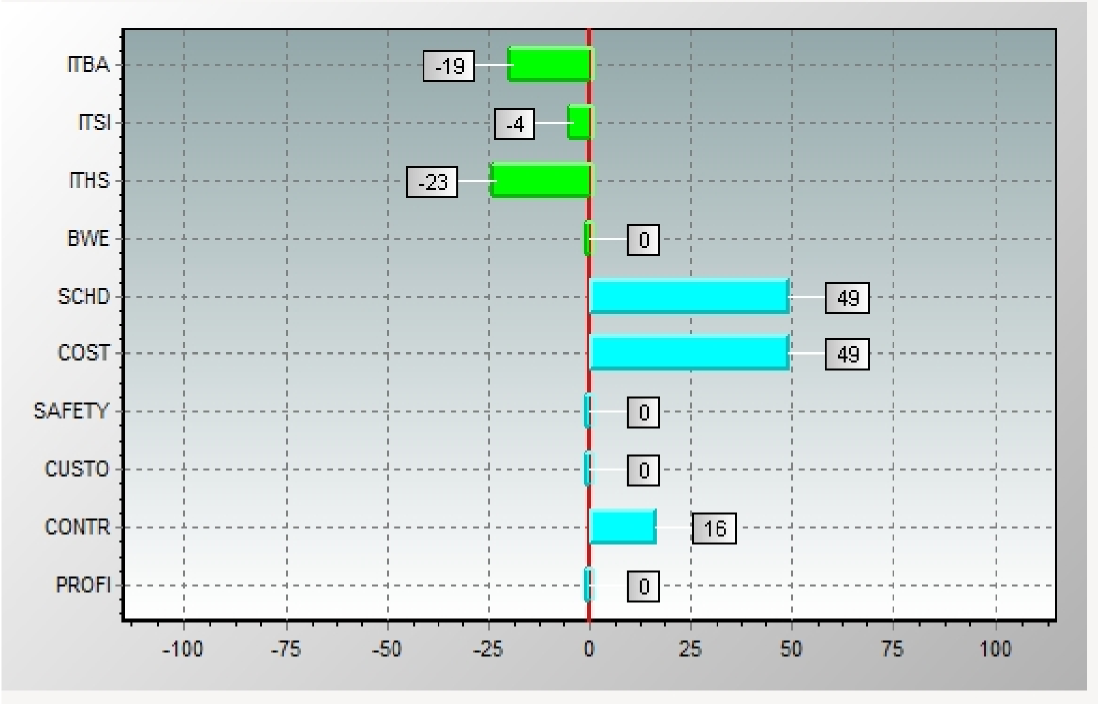

Figure 6.5 Potential improvements graph for CO_{41}

The DEA model used (equation 4) assumes maximization of outputs while keeping inputs constant. In this respect organisation CO_{41} has over utilized some of its inputs relative to other organisations for a maximum performance. Mathematically these are indicated by the slack (potential improvement) values in Table 6.3. A slack provides for the measure of the improvements needed to make an inefficient organisation to become efficient.

So for CO_{41} to become competitive relative to its peers there is needed to utilize some of its inputs factors more efficiently. For example the efficiency of utilization of ITBA to has to be increased by 19.7%. ITBA is measure of degree of computer application usage and integration in executing different task within the value chain of construction organisation. The negative value recorded against CO_{41} implies that other organisation produces higher value of outputs with lower value on IT integration. This level of inefficient utilization of input factors by CO_{41} compare to its peers are recorded as negative percentages in table 6.3 and depicted graphically in Figure 6.5.

The positive values for the input factors gave an indication the percentage increased required for CO_{41} to be efficient and competitive within its peers.

Another example is for CO_{49} to be efficient it has to more than double some of its output factors such as the COST, CONTR and PROFI. This implies that the utilization of IT input factors which are also related to the IT investment since the resources have to be there to be utilized did not translate into improve productivity as compared with its peers such as organisation CO_{26}.

Table 6.4 Inputs / Outputs Slacks of CO_{49}

	Input / Output	Actual	Target	Potential Improvement
Input	**ITBA**	**4.02**	**3.78**	**-6.1%**
	ITSI	**3.00**	**1.93**	**-35.6%**
	ITHS	**2.00**	**2.00**	**0.0%**
	BWE	**2.40**	**2.22**	**-7.4%**
Output	SCHD	2.00	4.89	144.4%
	COST	1.00	4.67	366.7%
	SAFETY	1.00	2.44	144.4%
	CUSTO	1.00	2.78	177.8%
	CONTR	1.00	3.11	211.1%
	PROFI	1.00	3.11	211.1%

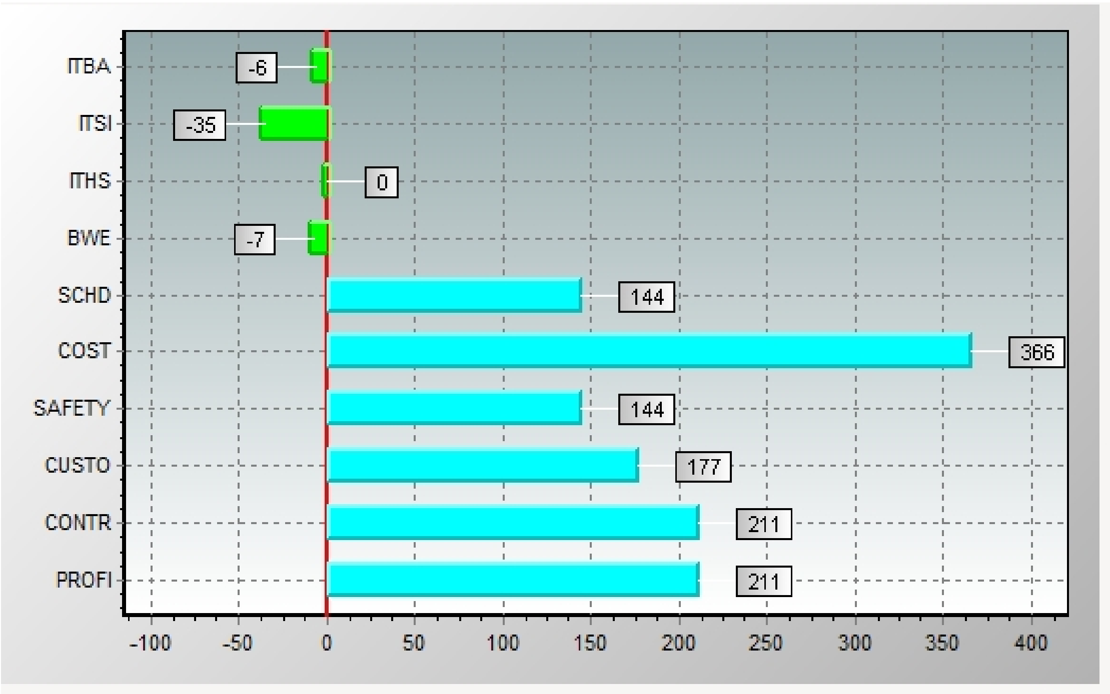

Figure 6.6. Potential improvements graph for CO_{49}

Mathematically, as depicted in Figure 6.6 and Table 6.4, some of the inputs factors such as ITBA, ITSI and BWE could be reduced in order for CO_{49} to perform at the same level of the efficient peers. However, physically such mathematical interpretation may not make sense. For example, the suggestion to reduce utilization of ITBA will not reduce the cost of the original investment. The negative input factors for CO_{49} implies that the efficient organisations are utilizing their IT resources in more productive manner than CO_{49}.

6.4 Summary of the Chapter

The chapter presents descriptive statistics of the participating organisations in terms of business types and ownership, size, annual turnover, job function of the questionnaire respondents and number or projects delivered over the last three years before the survey, which helped in attempting to place the organisations in strategic groups.

The chapter also presents detailed results of the outcome of the evaluations of the data collected using DEA program. Both mathematical and physical interpretations of the results were presented. These analyses and interpretations led to the conclusions on the findings and contributions of the research as presented in the next chapter.

CHAPTER SEVEN
CONCLUSION AND RESEARCH CONTRIBUTION

7.0 Conclusion

Previous studies on IT business value have not been able to conclusively establish a strong relationship between IT investments and the performance of construction organisations.

The literature review in the fields of ITBV, strategic management and construction management has indicated that the equivocal results of the previous studies could be attributed to the difficulties in modeling and measurement of the return of IT investment, lack of structured theoretical constructs, data availability and choice of dependent variables among others.

The current research was designed with the overarching aim of investigating the impact of IT-enabled strategies on the competitiveness of engineering and construction organisations so as to provide a model that mitigates some of the drawbacks identified in the literature.

This research adopted multiple theoretical concepts of process-based; resource-based and microeconomic-views and developed a conceptual model of ITBV (Kassim *et al.*, 2009a). Then an extension of this model was derived using the non-parametric technique of Data Envelopment Analysis (Kassim *et al.*, 2009b).

The model provides a methodology for evaluating the impact of utilization of IT resources on the productivity of engineering and construction processes. Using the DEA concept, the model computes using empirical data a surface (frontier) that 'envelops' the most efficient organisations. The efficient frontier can be used for benchmarking organisations' performances and thus, provides a measure for their IT-induced competitive advantage.

The Empirical results the model provide information on how inefficient organisations can improve their performances by adjusting their input and output factors such that they become Pareto-efficient.

This information is obtained by comparing the values of their input and output variables with the exemplars in the strategic groups which are determined to be Pareto efficient.

For practical purposes the model developed could be used to benchmark the IT-induced productivity of construction organisations by identifying:

- Levels of all input / output variables contributions in determining the performance of each organisation
- The measure of improvements needed to make any of the input / output variables of an inefficient organisations in relation to its peers to become competitive
- The most competitive organisation with the timeline of measurement of the performance by returning high level of referencing by its peers.

Thus, this approach has mitigated the difficulties associated with previous studies such as, lack of theoretical framework in modeling ITBV, the prior assumption required or the relationship between IT investment and firm performance, and the arbitrary and subjective assignment of weight factors.

This is the first time data envelopment analysis has been used for quantitative evaluation of IT business value

In the research design the overarching ontological stance was constructivism; the research investigated how IT impacts on the organisation's performance by socially constructing models through the perception of the employees of the organisations in their respective environments.

As the first stage for empirical test of the ITBV conceptual model, a pilot study was conducted which established the validity of:

- A process oriented model of ITBV for evaluating impact of IT resources on the performances of engineering and construction organisations.
- The use of non parametric technique of data envelopment analysis within a framework for benchmarking the construction organizations IT-induced performance.

Thus, the research from the first test of the pilot study indicates the validity of the process and contributes to the body of knowledge in the field of IT and strategic management.

The analysis of the data from the pilot study was characterised by low discriminatory power of the DEA function, returning large number of the sampled organisations as efficient mainly as result of low ratio of the sample size to the number of the variables (N<(S*M)). Thus, a wider survey with larger sampled data in propotion to the number of the variables was conducted. The data satisfied the first and second rules of thumb for a minimum requirement to ensure discriminatory power from solving DEA function in equation 4 of chapter four. The results, analysis and conclusions are presented in this chapter.

7.1 Research Overview

The research was designed as an attempt to increase the understanding of the impact of utilization of IT in the execution of engineering and construction organizations value chains and their performances.

A detailed literature review on how the utilization of IT resources impacts on performance engineering and construction organisations suggested that IT-enabled strategies could be used to gain competitive advantage. Thus, IT resources used as factor of production tend offer strategic advantage to organisations through efficient and cost effective delivery of the organisation's value chain. However, there were limited empirically validated of such suggestions. Some of the previous empirical studies were carried out through imprecise and unstructured theoretical constructs that seem to lead to equivocal results. The inconsistencies results known as 'IT productivity paradox' on the impact of IT on organisation performance were ascribed to the difficulties associated with modelling the relationship between the IT investment and the organisational performance; techniques for measurements of the return of the IT investment; the mode of data collection and sampling; the industry type, and the choice of dependent variables as some of the major reasons (Brynjolfsson, 1993; Kohli and Devaraj, 2003; Oh and Pinsonneault, 2007).

The research was designed in three-phase methodologically triangulated process. The first phase involved the development of a conceptual model using hybrid of Porter's (1980; 1985) competitive advantage and competitive strategy models with organisation resource-based view and core competence approach (Barney, 1991). This phase was complemented by a comprehensive literature review in the field of IT business value, construction management and strategic management; identification and operationalization of IT resources on the construction project value chain; establishing and defining project performance metrics.

The first phase relied on the current body of knowledge and theories in developing the research model and hypotheses, thus, by definition adopted positivism paradigm view (Sutrisna, 2009).

The second phase involved the validation of the proposed conceptual model and the engineering and construction value chain through responses of a pilot questionnaire. Using non parametric approach of Data Envelopment Analysis (DEA), the model was empirically tested where the performances of the construction organization based on the identified and operationalized IT resources as inputs were measured

Applying Majken and Mary (1996) concept of sequential strategy for conducting multi-paradigm research a constructivist paradigm with phenomenological epistemology was deployed in the second phase of the research

The final phase involved detailed data collection via online survey questionnaire designed to include closed-ended items with numerical responses as well as open-ended items that could support discovery of new information. Thus, as argued by Lewis & Grimes (1999), in the analyses of a common phenomenon paradigm images need not operate at the extremes, but may overlap and foster counterintuitive insights. Therefore, a sequential overlap of multiple paradigms was deployed within the different phases of the research.

7.2 Research Findings

After detailed literature review in the field of information technology, organisation performance, construction management, strategic management, engineering and construction value chain, theory of competitive advantage, economic theory of production, resource based theory and the concept of information technology business value among others, .the research set out a focus research question with the aim of understanding the possible impact of IT-enabled business strategy on the performance of engineering and construction organizations in United Kingdom, Thus:

> *"What are the possible impacts of deploying and utilizing IT resources in the presence of other complementary organisational resources on the performances of engineering and construction organisations in United Kingdom?"*

This led to driving set of hypotheses and a conceptual model used to test empirically the set aim and objectives of the research

The research has successfully achieved the set aim through establishing and testing a model using multi-theoretical framework adopting a sequential strategy for conducting multi-paradigm research.

The findings from the empirical tests showed evidence of consistent positive impact of utilizing IT resources in achieving competitive advantage in the production process of engineering and construction organisation when deployed in the presence of other unique complementary organisational resources. The findings agreed with general postulation of RBV theory as discussed in sections 2.4, 2.10, 2.11 and 3.5.4. Therefore, the empirical results support the paradigm that IT-enabled strategy could improve organizational performance and create sustainable competitive advantage mainly in the presence of other complementary organizational resources that are unique and immobile. Consequently the research findings returned a positive outcome on the hypothesis H_4:

> **H_4:** *Complementary organisational resources (BWE) will have positive impact in creating ITBV in engineering and construction organisations*

However, using individual IT-resources as identified in each hypothesis tend to record different level of impact on the performances of the organizations. Using ITSI, ITBA and ITHS as the only individual input factors separately, the number of efficient organisations reduced considerably in each case (see Table 6.5). Also the record of the reference set frequency for each scenario changed, presenting a different set of organizations with high reference set frequency records. Thus, while ITSI, ITBA and ITHS do provide positive impact on the performances of the engineering and construction organizations, they do not provide a sustainable competitive advantage to the respective organization by when deployed as the only factor of production. Nevertheless, the research findings have validated the hypotheses H_1, H_2 and H_3 thus:

> ***H_1*:** *the technological components of ITI are readily available in the marketplace therefore; ITSI may not have significant impact on the performance of engineering and construction organisations.*

> **H_2:** *IT business applications (ITBA) will have positive impact on construction organisation performance.*

> ***H_3*** *Superior IT human capabilities (ITHS) will have a positive impact in providing a source for engineering and construction organisations' competitive advantage*

7.3 Research Contributions

This research makes significant contributions to field of IT business value in construction organisations research and practice. Some of these contributions include:

- The development of an IT business conceptual model that addresses the limitations of the existing IT investments evaluation frameworks. The model was based on multi-theoretical framework addressing the unique nature of the construction organisation value chains. Furthermore the empirically tested model addresses the errors introduced in using parametric approach to establish the relationships between investments in IT as factors of production and the measure of the organisational performances through prior assumption of a function by using non parametric approach of DEA.
- From the empirical results it has been shown that the model could be used to benchmark and establish the relative competitive advantages of the engineering and construction organisations within strategic groupings of the construction industry.
- As a tool to the construction organisations executive, the model could be used to provide support to managers in decision making on IT investments, utilization of the IT resources and how combination of strategic IT resources with other organizational resources could provide sources of sustained competitive advantage in their organisations.
- The empirical evidence established that IT provides business value in undertaking the engineering and construction business processes leading to significant impact on the organisations performances in the areas of project delivery, customer relationship and overall profit growth.

7.4 Research Limitations

The performances of engineering and construction organisations are partly attributed to their choices of mode and scope of completion (Kale , 163 and Arditi, 2002). The analysis of results presented in this thesis did not take into account this provision that could lead to detail categorization of the sample organisation thorough strategic group analysis.

Another limitation of the research is related to DEA as the tool deployed in data analysis. DEA is a deterministic rather than a statistical technique and, therefore, is sensitive to measurement error (Rodgers and Assaf, 2006; Odeck, 2007). A wrong estimation of an organisation's inputs or output due to error in perception of the respondents of the research questionnaire can significantly distorts the shape of the frontier and reduces the efficiency score of other organizations included in the sample. Furthermore, since DEA is a nonparametric technique, statistical hypothesis tests are difficult to undertake (Trick, 1998), thus, the conclusions based on the non statistic hypothesis has limitations in interpretations.

7.5 Future Research

Since DEA provides for categorization of sample, future research shall include the grouping of the engineering and construction organisations according to their mode and scope of business activities to enhance better understanding of the competitive impact of utilization of IT resources by different construction organisations strategic groupings. This will provide specific guidance to management of such organisations in making IT investment decisions to be in compliance with their strategies and scale of operations to remain competitive.

Future study shall include the use of Stochastic Frontier Analysis (SFA) on the sample data to help eliminate the DEA limitation of sensitive to measurement errors and limits random deviations from the efficiency frontier. Thus, allowing for additional evidence on the true structure of the efficiency frontier (Odeck, 2007).

Furthermore a DEA-based Malmquist productivity index may be required to evaluate the performance changes of the organisation over period of time to establish sustain competitive advantage as a result of deployment of IT resources in the execution of the construction processes. DEA-based Malmquist productivity index measures the productivity and by extention organisational performance changes overtime.

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The purpose of this 20-minute survey is to investigate the relationship between Information Technology (IT) investment and the performance of engineering and construction organisations in UK.

The questionnaire is designed to assess the impact of Information Technology (IT) on the performance of your organisation. The level of IT adoption is assessed by the extent of incorporation of technologies such as computer software and hardware in different tasks used to execute projects. The organisation performance is assessed through measurement of schedule, cost, safety, customer satisfaction of executed projects and contract growth for the last three years.

The anticipated benefits for your participation include

- Benchmarking engineering and construction organizations' IT-induced performance
- continuous improvement in the deployment of IT resources in engineering and construction organisation
- providing a platform for investigating engineering and construction organisation IT readiness

To this end please find enclosed research questionnaires for your kind response. Any personally identifiable information will be kept strictly confidential and all the data will be used only for research purposes. The outcome of the research will be used in a dissertation for the degree of Doctor of Philosophy by University of Salford, UK. Your cooperation is highly important to the success of the project. A consent form is also attached explaining our undertaking to protecting your confidentiality and confirming your consent to participate.

UNIVERSITY OF SALFORD

If you are happy to take part in the research described below we would be grateful if you could sign the attached consent form

Background Information

Project Title: **I.T SoCA - Information Technology as Source of Competitive Advantage in Construction Industry**

Researcher's name: **Yahuza Hassan Kassim**

Supervisor's name: **Dr. Jason Underwood**

Objectives for the research: This survey is being conducted by ***Yahuza Kassim of Salford of University*** to help derive and test IT-business model for construction organisations that could be use for IT capacity planning, assessment of IT readiness and measure of continuous improvement of IT-enable strategy in construction firms.

Details of participation: Participants will be sought from approximately 150 (working on approximately a 30% success return) large UK construction organisations which will be identified through established industry contacts/experts that are currently engaged in the area of construction IT and also have an interested in the focus of this study. The survey consists of 40 questions and will take 20 minutes to complete.

- **I have received information about this research project.**
- **The research project has been explained to me and I fully understand the purpose and my involvement in it.**
- **I understand that I may withdraw from the research project at any stage.**
- **I understand that I may not directly benefit from taking part in the project.**
- **I understand that while information gained during the study may be published, I will not be identified and my personal results will remain confidential.**
- **I understand that I may be audio taped - during an interview. The tapes will be destroyed once they are summarised and at completion of the project.**

Legal Rights and Signatures: I,……………………… consent to participate in *IT in Construction research*_conducted by *Yahuza Kassim*. I have understood the nature of the project and wish to participate. I am not waiving any of my legal rights by signing this form. My signature below indicates my consent.

Signature and Date____________________________

If you have questions about the research in general or about your role in the study, please feel free to contact **Mr. Yahuza Kassim** either by telephone +44 (0) 7892 897330 or by e-mail (Y.H.Kassim@pgr.salford.ac.uk). This research has been reviewed and conforms to the standards of the *Salford of University Research Governance and Ethics Sub- Committee (RGEC).*

Section 1: General Information: The following questions seek to assess the *general* characteristics of your organisation

1 Please select the business sector in which your organisation operates

- ☐ Civil engineering & building contracting
- ☐ Engineering, architectural and environmental technical services
- ☐ Facilities management, building maintenance and repair
- ☐ Construction management and project management
- ☐ Infrastructure support services

Please indicate the range of your turnover (£)

☐ Less than 5million ☐ 5 to 25 million ☐ 25 to 50 million ☐ 50 to 100million

☐ 100 to 250m ☐ 250 to 500million ☐ 500 to 1 billion ☐ 1 billion and above

3. A) Please identify your position within the overall organization

☐ Executive ☐ Middle management

☐ Professional employee (without supervisory responsibility)

3 (b) Is this an IT related position

☐ Yes ☐ No

4. How many permanent employees do you have?

☐ < 10 people ☐ 11 – 50 people ☐ 51 –100 people ☐ 101 - 200 people ☐ > 250 people

5. What is the nature of your company ownership?

☐ Locally/Nationally owned ☐ Foreign/Internationally owned ☐ Mixed/JV between national/international Subsidiary

☐ Others:____

6. How many projects did you deliver in the last three years?

☐ 1 – 10 Projects ☐ 11 – 20 Projects ☐ 21 –30 Projects ☐ > 30 Projects

Section 2 – Technology Usage Measure

The following section assesses the degree of Technology predominantly usage in different tasks used to execute projects in your organization. Please, select the appropriate number in the column to indicate the extent to which you consider the statement applies to your organization.

1. Don't Know 2. Not Applicable 3. No Use of Computer application 4. Uses Stand alone computer application 5. Uses Network Integrated Computer Application

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1. Strategic Planning

Conduct Market research	☐1	☐2	☐3	☐4	☐5
Carry out Bidding process	☐1	☐2	☐3	☐4	☐5
Prepare Contract strategy	☐1	☐2	☐3	☐4	☐5
Develop bid package	☐1	☐2	☐3	☐4	☐5
Review potential bidders	☐1	☐2	☐3	☐4	☐5
Develop manpower plan	☐1	☐2	☐3	☐4	☐5

2. Engineering Design and Analysis

Develop Design Basis	☐1	☐2	☐3	☐4	☐5
Engineering design deliverables	☐1	☐2	☐3	☐4	☐5
Estimation	☐1	☐2	☐3	☐4	☐5
Project planning and schedule	☐1	☐2	☐3	☐4	☐5
Execution plan	☐1	☐2	☐3	☐4	☐5
Interface management	☐1	☐2	☐3	☐4	☐5
Quality and safety issues	☐1	☐2	☐3	☐4	☐5

3. Procurement Process

Development of specifications	☐1	☐2	☐3	☐4	☐5
Material and equipments requisition	☐1	☐2	☐3	☐4	☐5
Issue Inquiry	☐1	☐2	☐3	☐4	☐5
Bid Evaluation	☐1	☐2	☐3	☐4	☐5
Delivery and Expediting	☐1	☐2	☐3	☐4	☐5
Inspection	☐1	☐2	☐3	☐4	☐5

4. Construction & Commissioning

Site document control	☐1	☐2	☐3	☐4	☐5
Safety Management	☐1	☐2	☐3	☐4	☐5
Test packages control	☐1	☐2	☐3	☐4	☐5
System turnover handover control	☐1	☐2	☐3	☐4	☐5
Fabrication status control	☐1	☐2	☐3	☐4	☐5
Materials inventory	☐1	☐2	☐3	☐4	☐5
Management of site request for information	☐1	☐2	☐3	☐4	☐5
Construction human labour management	☐1	☐2	☐3	☐4	☐5

5. Operations and Maintenance

Training simulation for operation	1	2	3	4	5
Use as-built information in personnel training	1	2	3	4	5
Track and analyze the maintenance history	1	2	3	4	5
Develop maintenance plans	1	2	3	4	5
Monitor equipment performance	1	2	3	4	5
Track request for maintenance or modifications	1	2	3	4	5
Update as-built drawings	1	2	3	4	5
Monitor facility energy usage	1	2	3	4	5
Monitor environmental impact	1	2	3	4	5

6. Project Management and Support

Project schedule preparation	1	2	3	4	5
Project cost estimate	1	2	3	4	5
Track project progress	1	2	3	4	5
Document Management	1	2	3	4	5
Change Management	1	2	3	4	5
Progress reporting	1	2	3	4	5
Invoicing process	1	2	3	4	5

Section 3: Measure of Shared IT Infrastructure

Please select the option that best describes your agreement on the extent to which your organisation utilises Shared IT Infrastructure ranging between 1 to 5, where 1 = not at all; 3 = moderate extent; and 5 = very large extent.

Departments can share data and applications on the networks	1	2	3	4	5
Clients and suppliers are connected with the organisation-supply chain	1	2	3	4	5
Network architecture can be modified minimum disruption	1	2	3	4	5
Procedures and policies are used in network usage	1	2	3	4	5
Corporate data can be seamlessly accessed from remote locations	1	2	3	4	5

Section 4: Measure of Human IT Skills

Please select the option that best describes your agreement on the extent to which the Functions of **IT head/CIO as a measure of your Human IT skills** ranging between 1 and 5: where 1 = not at all; 3 = moderate extent; and 5 = very large extent.

Designs future technologies opportunities for the business	☐1	☐2	☐3	☐4	☐5
Prepare IT strategy for future business requirements	☐1	☐2	☐3	☐4	☐5
Align IT strategy with business strategy	☐1	☐2	☐3	☐4	☐5
Manage resources to obtain optimal results	☐1	☐2	☐3	☐4	☐5
-in-house for application development	☐1	☐2	☐3	☐4	☐5
Provide training for IT team	☐1	☐2	☐3	☐4	☐5

Section 5: Measure of Business Work Environment

Please select the option that best describes the strength of the following competencies in your organisation **work environment** ranging between 1 to 5, where 1 = not at all; 3 = moderate extent; and 5 = very large extent.

Leadership	☐1	☐2	☐3	☐4	☐5
Employee empowerment	☐1	☐2	☐3	☐4	☐5
Open communication	☐1	☐2	☐3	☐4	☐5
Project management competency	☐1	☐2	☐3	☐4	☐5

Section 6 Measure of Firm Performance

Please answer the following questions regarding projects performances in your organisation.

For projects closed in the last 3 fiscal years, how often were these projects delivered; ranging 1 to 5, where: 1=Seldom, 2=Sometimes, 3=Often, 4=Usually, 5=Consistently

On or ahead of schedule (Schedule Performance)	☐1	☐2	☐3	☐4	☐5
On or under budget (Cost Performance)	☐1	☐2	☐3	☐4	☐5
Annual improvement of safety (Safety Performance)	☐1	☐2	☐3	☐4	☐5
Repeat business (Customer Satisfaction)	☐1	☐2	☐3	☐4	☐5
Annual Increase in Contract Award (Contract Growth)	☐1	☐2	☐3	☐4	☐5
Annual Increase in Net Profit	☐1	☐2	☐3	☐4	☐5

44.44% **A**

Peers: 2
References: 0

Potential Improvements

Variable	Actual	Target	Potential Improvement
COST	2.00	4.50	125.00 %
ITBA	4.63	3.35	-27.54 %
PROFI	2.00	4.50	125.00 %
SCHD	1.00	4.00	300.00 %

80.00% **B**

Peers: 2
References: 0

Potential Improvements

Variable	Actual	Target	Potential Improvement
COST	3.00	5.00	66.67 %
ITBA	4.02	3.52	-12.44 %
PROFI	3.00	3.75	25.00 %
SCHD	4.00	5.00	25.00 %

100.00% **C**

Peers: 0
References: 3

Potential Improvements

Variable	Actual	Target	Potential Improvement
COST	5.00	5.00	0.00 %
ITBA	3.51	3.51	0.00 %
PROFI	4.00	4.00	0.00 %
SCHD	4.00	4.00	0.00 %

80.00% **D**

Peers: 1
References: 0

Potential Improvements

Variable	Actual	Target	Potential Improvement
COST	3.00	4.00	33.33 %
ITBA	3.85	3.20	-16.88 %
PROFI	4.00	5.00	25.00 %
SCHD	3.00	4.00	33.33 %

80.00% **E**

Peers: 1
References: 0

Variable	Actual	Target	Potential Improvement
	Potential Improvements (λ)		
COST	3.00	5.00	66.67 %
ITBA	3.98	3.73	-6.28 %
PROFI	2.00	3.00	50.00 %
SCHD	4.00	5.00	25.00 %

100.00% **F**

Peers: 0
References: 10

Variable	Actual	Target	Potential Improvement
	Potential Improvements (λ)		
COST	4.00	4.00	0.00 %
ITBA	3.20	3.20	0.00 %
PROFI	5.00	5.00	0.00 %
SCHD	4.00	4.00	0.00 %

80.00% **G**

Peers: 1
References: 0

Variable	Actual	Target	Potential Improvement
	Potential Improvements (λ)		
COST	3.00	4.00	33.33 %
ITBA	4.17	3.20	-23.26 %
PROFI	4.00	5.00	25.00 %
SCHD	3.00	4.00	33.33 %

66.67% **H**

Peers: 2
References: 0

Variable	Actual	Target	Potential Improvement
	Potential Improvements (λ)		
COST	3.00	4.50	50.00 %
ITBA	4.55	3.35	-26.26 %
PROFI	3.00	4.50	50.00 %
SCHD	2.00	4.00	100.00 %

44.44% **I**

Peers: 2
References: 0

Variable	Actual	Target	Potential Improvement
	Potential Improvements (λ)		
COST	2.00	4.50	125.00 %
ITBA	3.81	3.33	-12.73 %
PROFI	2.00	4.50	125.00 %
SCHD	2.00	4.50	125.00 %

44.44% **J**

Peers: 2
References: 0

Variable	Actual	Target	Potential Improvement
	Potential Improvements (λ)		
COST	2.00	4.50	125.00 %
ITBA	4.27	3.33	-22.13 %
PROFI	2.00	4.50	125.00 %
SCHD	2.00	4.50	125.00 %

100.00% **K**

Peers: 0
References: 5

Variable	Actual	Target	Potential Improvement
	Potential Improvements (λ)		
COST	5.00	5.00	0.00 %
ITBA	3.73	3.73	0.00 %
PROFI	3.00	3.00	0.00 %
SCHD	5.00	5.00	0.00 %

100.00% **L**

Peers: 0
References: 1

Variable	Actual	Target	Potential Improvement
	Potential Improvements (λ)		
COST	3.00	3.00	0.00 %
ITBA	2.83	2.83	0.00 %
PROFI	3.00	3.00	0.00 %
SCHD	3.00	3.00	0.00 %

44.44% **M**

Peers: 2
References: 0

Potential Improvements (λ)

Variable	Actual	Target	Potential Improvement
COST	2.00	4.50	125.00 %
ITBA	5.00	3.33	-33.50 %
PROFI	2.00	4.50	125.00 %
SCHD	2.00	4.50	125.00 %

80.00% **N**

Peers: 1
References: 0

Potential Improvements (λ)

Variable	Actual	Target	Potential Improvement
COST	3.00	5.00	66.67 %
ITBA	3.74	3.45	-7.75 %
PROFI	1.00	4.00	300.00 %
SCHD	4.00	5.00	25.00 %

40.00% **O**

Peers: 1
References: 0

Potential Improvements

Variable	Actual	Target	Potential Improvement
COST	1.00	5.00	400.00 %
ITBA	4.02	3.73	-7.21 %
PROFI	1.00	3.00	200.00 %
SCHD	2.00	5.00	150.00 %

100.00% **P**

Peers: 0
References: 8

Potential Improvements (λ)

Variable	Actual	Target	Potential Improvement
COST	5.00	5.00	0.00 %
ITBA	3.45	3.45	0.00 %
PROFI	4.00	4.00	0.00 %
SCHD	5.00	5.00	0.00 %

80.00% **Q**

Peers: 1
References: 0

Variable	Actual	Target	Potential Improvement
	Potential Improvements (λ)		
COST	3.00	5.00	66.67 %
ITBA	4.39	3.73	-15.03 %
PROFI	1.00	3.00	200.00 %
SCHD	4.00	5.00	25.00 %

44.44% **R**

Peers: 2
References: 0

Variable	Actual	Target	Potential Improvement
	Potential Improvements (λ)		
COST	2.00	4.50	125.00 %
ITBA	4.26	3.33	-21.95 %
PROFI	2.00	4.50	125.00 %
SCHD	2.00	4.50	125.00 %

88.89% **S**

Peers: 2
References: 0

Variable	Actual	Target	Potential Improvement
	Potential Improvements (λ)		
COST	4.00	4.50	12.50 %
ITBA	3.67	3.33	-9.40 %
PROFI	4.00	4.50	12.50 %
SCHD	4.00	4.50	12.50 %

Model: BCC OUTPUT ORIENTED WITH VARIABLE RETURN TO SCALE

100.00% **CO_{01}**

Peers: 0
References: 1

Potential Improvements

Variable	Actual	Target	Potential Improvement
BWE	2.80	2.80	0.00 %
CONTR	3.00	3.00	0.00 %
COST	3.00	3.00	0.00 %
CUSTO	4.00	4.00	0.00 %
ITBA	4.55	4.55	0.00 %
ITHS	1.83	1.83	0.00 %
ITSI	2.00	2.00	0.00 %
PROFI	3.00	3.00	0.00 %
SAFETY	2.00	2.00	0.00 %
SCHD	2.00	2.00	0.00 %

Peer Contributions

CO01	BWE	100.00 %
CO01	CONTR	100.00 %
CO01	COST	100.00 %
CO01	CUSTO	100.00 %
CO01	ITBA	100.00 %
CO01	ITHS	100.00 %
CO01	ITSI	100.00 %
CO01	PROFI	100.00 %
CO01	SAFETY	100.00 %
CO01	SCHD	100.00 %

Input / Output Contributions

BWE	1.86 %	Input
ITBA	0.00 %	Input
ITHS	98.14 %	Input
ITSI	0.00 %	Input
CONTR	19.46 %	Output
COST	0.00 %	Output
CUSTO	41.98 %	Output
PROFI	38.56 %	Output
SAFETY	0.00 %	Output
SCHD	0.00 %	Output

Peers

CO01

100.00% **CO_{02}**

Peers: 0
References: 3

Potential Improvements

Variable	Actual	Target	Potential Improvement
BWE	3.00	3.00	0.00 %
CONTR	4.00	4.00	0.00 %
COST	4.00	4.00	0.00 %
CUSTO	3.00	3.00	0.00 %
ITBA	3.29	3.29	0.00 %
ITHS	2.50	2.50	0.00 %
ITSI	2.40	2.40	0.00 %
PROFI	3.00	3.00	0.00 %
SAFETY	3.00	3.00	0.00 %
SCHD	5.00	5.00	0.00 %

Peer Contributions

CO02	BWE	100.00 %
CO02	CONTR	100.00 %
CO02	COST	100.00 %
CO02	CUSTO	100.00 %
CO02	ITBA	100.00 %
CO02	ITHS	100.00 %
CO02	ITSI	100.00 %
CO02	PROFI	100.00 %
CO02	SAFETY	100.00 %
CO02	SCHD	100.00 %

Input / Output Contributions

BWE	12.53 %	Input
ITBA	67.85 %	Input
ITHS	0.00 %	Input
ITSI	19.62 %	Input
CONTR	0.00 %	Output
COST	0.00 %	Output
CUSTO	0.00 %	Output
PROFI	0.00 %	Output
SAFETY	25.75 %	Output
SCHD	74.25 %	Output

Peers

CO02

100.00% **CO03**

Peers: 0
References: 5

Potential Improvements

Variable	Actual	Target	Potential Improvement
BWE	1.00	1.00	0.00 %
CONTR	2.00	2.00	0.00 %
COST	2.00	2.00	0.00 %
CUSTO	2.00	2.00	0.00 %
ITBA	4.28	4.28	0.00 %
ITHS	1.50	1.50	0.00 %
ITSI	2.00	2.00	0.00 %
PROFI	1.00	1.00	0.00 %
SAFETY	1.00	1.00	0.00 %
SCHD	1.00	1.00	0.00 %

Peer Contributions

CO03	BWE	100.00 %
CO03	CONTR	100.00 %
CO03	COST	100.00 %
CO03	CUSTO	100.00 %
CO03	ITBA	100.00 %
CO03	ITHS	100.00 %
CO03	ITSI	100.00 %
CO03	PROFI	100.00 %
CO03	SAFETY	100.00 %
CO03	SCHD	100.00 %

Input / Output Contributions

BWE	58.14 %	Input
ITBA	0.00 %	Input
ITHS	41.86 %	Input
ITSI	0.00 %	Input
CONTR	0.00 %	Output
COST	0.00 %	Output
CUSTO	85.71 %	Output
PROFI	0.00 %	Output
SAFETY	0.00 %	Output
SCHD	14.29 %	Output

Peers

CO03

100.00% **CO04**

Peers: 0
References: 3

Potential Improvements

Variable	Actual	Target	Potential Improvement
BWE	2.00	2.00	0.00 %
CONTR	2.00	2.00	0.00 %
COST	4.00	4.00	0.00 %
CUSTO	3.00	3.00	0.00 %
ITBA	4.45	4.45	0.00 %
ITHS	1.33	1.33	0.00 %
ITSI	1.80	1.80	0.00 %
PROFI	2.00	2.00	0.00 %
SAFETY	2.00	2.00	0.00 %
SCHD	4.00	4.00	0.00 %

Peer Contributions

CO04	BWE	100.00 %
CO04	CONTR	100.00 %
CO04	COST	100.00 %
CO04	CUSTO	100.00 %
CO04	ITBA	100.00 %
CO04	ITHS	100.00 %
CO04	ITSI	100.00 %
CO04	PROFI	100.00 %
CO04	SAFETY	100.00 %
CO04	SCHD	100.00 %

Input / Output Contributions

BWE	65.89 %	Input
ITBA	0.00 %	Input
ITHS	34.11 %	Input
ITSI	0.00 %	Input
CONTR	0.00 %	Output
COST	0.00 %	Output
CUSTO	75.44 %	Output
PROFI	0.00 %	Output
SAFETY	1.17 %	Output
SCHD	23.39 %	Output

Peers

CO04

100.00% **CO05**

Peers: 0
References: 3

Potential Improvements

Variable	Actual	Target	Potential Improvement
BWE	2.00	2.00	0.00 %
CONTR	5.00	5.00	0.00 %
COST	4.00	4.00	0.00 %
CUSTO	3.00	3.00	0.00 %
ITBA	3.90	3.90	0.00 %
ITHS	2.17	2.17	0.00 %
ITSI	3.00	3.00	0.00 %
PROFI	4.00	4.00	0.00 %
SAFETY	1.00	1.00	0.00 %
SCHD	4.00	4.00	0.00 %

Peer Contributions

CO05	BWE	100.00 %
CO05	CONTR	100.00 %
CO05	COST	100.00 %
CO05	CUSTO	100.00 %
CO05	ITBA	100.00 %
CO05	ITHS	100.00 %
CO05	ITSI	100.00 %
CO05	PROFI	100.00 %
CO05	SAFETY	100.00 %
CO05	SCHD	100.00 %

Input / Output Contributions

BWE	0.00 %	Input
ITBA	0.00 %	Input
ITHS	0.00 %	Input
ITSI	100.00 %	Input
CONTR	100.00 %	Output
COST	0.00 %	Output
CUSTO	0.00 %	Output
PROFI	0.00 %	Output
SAFETY	0.00 %	Output
SCHD	0.00 %	Output

Peers
CO05

46.67% **CO_{06}**

Peers: 3
References: 0

Potential Improvements

Variable	Actual	Target	Potential Improvement
BWE	3.20	2.97	-7.14 %
CONTR	1.00	3.29	228.57 %
COST	2.00	4.43	121.43 %
CUSTO	1.00	2.29	128.57 %
ITBA	3.81	3.45	-9.47 %
ITHS	2.00	2.00	0.00 %
ITSI	2.80	2.69	-4.08 %
PROFI	2.00	4.29	114.29 %
SAFETY	1.00	3.57	257.14 %
SCHD	2.00	4.29	114.29 %

Peer Contributions

CO24	BWE	40.38 %
CO24	CONTR	34.78 %
CO24	COST	25.81 %
CO24	CUSTO	25.00 %
CO24	ITBA	29.77 %
CO24	ITHS	33.33 %
CO24	ITSI	31.91 %
CO24	PROFI	26.67 %
CO24	SAFETY	32.00 %
CO24	SCHD	33.33 %
CO40	BWE	34.62 %
CO40	CONTR	39.13 %
CO40	COST	48.39 %
CO40	CUSTO	37.50 %
CO40	ITBA	43.70 %
CO40	ITHS	35.71 %
CO40	ITSI	38.30 %
CO40	PROFI	40.00 %
CO40	SAFETY	36.00 %
CO40	SCHD	40.00 %
CO45	BWE	25.00 %
CO45	CONTR	26.09 %
CO45	COST	25.81 %
CO45	CUSTO	37.50 %
CO45	ITBA	26.53 %
CO45	ITHS	30.95 %
CO45	ITSI	29.79 %
CO45	PROFI	33.33 %
CO45	SAFETY	32.00 %
CO45	SCHD	26.67 %

Input / Output Contributions

BWE	0.00 %	Input
ITBA	0.00 %	Input
ITHS	100.00 %	Input
ITSI	0.00 %	Input
CONTR	0.00 %	Output
COST	0.00 %	Output

CUSTO	0.00 %	Output
PROFI	42.86 %	Output
SAFETY	0.00 %	Output
SCHD	57.14 %	Output

Peers
CO24
CO40
CO45

65.19% **CO07**

Peers: 4
References: 0

Potential Improvements

Variable	Actual	Target	Potential Improvement
BWE	1.60	1.60	0.00 %
CONTR	2.00	3.07	53.40 %
COST	2.00	4.59	129.58 %
CUSTO	1.00	2.80	179.58 %
ITBA	3.83	3.83	0.00 %
ITHS	2.17	1.97	-9.26 %
ITSI	1.80	1.65	-8.34 %
PROFI	2.00	3.07	53.40 %
SAFETY	1.00	1.82	81.85 %
SCHD	2.00	4.57	128.45 %

Peer Contributions

CO03	BWE	1.42 %
CO03	CONTR	1.48 %
CO03	COST	0.99 %
CO03	CUSTO	1.62 %
CO03	ITBA	2.53 %
CO03	ITHS	1.73 %
CO03	ITSI	2.75 %
CO03	PROFI	0.74 %
CO03	SAFETY	1.25 %
CO03	SCHD	0.50 %
CO09	BWE	1.42 %
CO09	CONTR	0.74 %
CO09	COST	0.99 %
CO09	CUSTO	0.81 %
CO09	ITBA	2.96 %
CO09	ITHS	1.15 %
CO09	ITSI	1.38 %
CO09	PROFI	1.48 %
CO09	SAFETY	1.25 %
CO09	SCHD	0.99 %
CO26	BWE	81.85 %
CO26	CONTR	80.03 %
CO26	COST	89.13 %
CO26	CUSTO	87.83 %
CO26	ITBA	79.69 %
CO26	ITHS	83.27 %
CO26	ITSI	79.37 %
CO26	PROFI	80.03 %

CO26	SAFETY	90.02 %
CO26	SCHD	89.57 %
CO48	BWE	15.31 %
CO48	CONTR	17.75 %
CO48	COST	8.89 %
CO48	CUSTO	9.74 %
CO48	ITBA	14.82 %
CO48	ITHS	13.85 %
CO48	ITSI	16.50 %
CO48	PROFI	17.75 %
CO48	SAFETY	7.49 %
CO48	SCHD	8.94 %

Input / Output Contributions

BWE	68.63 %	Input
ITBA	31.37 %	Input
ITHS	0.00 %	Input
ITSI	0.00 %	Input
CONTR	25.62 %	Output
COST	0.00 %	Output
CUSTO	0.00 %	Output
PROFI	74.38 %	Output
SAFETY	0.00 %	Output
SCHD	0.00 %	Output

Peers

CO03
CO09
CO26
CO48

100.00% **CO_{08}**

Peers: 0
References: 1

Potential Improvements

Variable	Actual	Target	Potential Improvement
BWE	2.00	2.00	0.00 %
CONTR	2.00	2.00	0.00 %
COST	3.00	3.00	0.00 %
CUSTO	2.00	2.00	0.00 %
ITBA	2.83	2.83	0.00 %
ITHS	3.00	3.00	0.00 %
ITSI	2.20	2.20	0.00 %
PROFI	3.00	3.00	0.00 %
SAFETY	2.00	2.00	0.00 %
SCHD	3.00	3.00	0.00 %

Peer Contributions

CO08	BWE	100.00 %
CO08	CONTR	100.00 %
CO08	COST	100.00 %
CO08	CUSTO	100.00 %
CO08	ITBA	100.00 %
CO08	ITHS	100.00 %
CO08	ITSI	100.00 %
CO08	PROFI	100.00 %
CO08	SAFETY	100.00 %
CO08	SCHD	100.00 %

Input / Output Contributions

BWE	18.69 %	Input
ITBA	45.37 %	Input
ITHS	0.00 %	Input
ITSI	35.94 %	Input
CONTR	0.00 %	Output
COST	0.00 %	Output
CUSTO	100.00 %	Output
PROFI	0.00 %	Output
SAFETY	0.00 %	Output
SCHD	0.00 %	Output

Peers

CO08

100.00% **CO_{09}**

Peers: 0
References: 3

Potential Improvements

Variable	Actual	Target	Potential Improvement
BWE	1.00	1.00	0.00 %
CONTR	1.00	1.00	0.00 %
COST	2.00	2.00	0.00 %
CUSTO	1.00	1.00	0.00 %
ITBA	5.00	5.00	0.00 %
ITHS	1.00	1.00	0.00 %
ITSI	1.00	1.00	0.00 %
PROFI	2.00	2.00	0.00 %
SAFETY	1.00	1.00	0.00 %
SCHD	2.00	2.00	0.00 %

Peer Contributions

CO09	BWE	100.00 %
CO09	CONTR	100.00 %
CO09	COST	100.00 %
CO09	CUSTO	100.00 %
CO09	ITBA	100.00 %
CO09	ITHS	100.00 %
CO09	ITSI	100.00 %
CO09	PROFI	100.00 %
CO09	SAFETY	100.00 %
CO09	SCHD	100.00 %

Input / Output Contributions

BWE	100.00 %	Input
ITBA	0.00 %	Input
ITHS	0.00 %	Input
ITSI	0.00 %	Input
CONTR	0.00 %	Output
COST	0.00 %	Output
CUSTO	0.00 %	Output
PROFI	0.00 %	Output
SAFETY	100.00 %	Output
SCHD	0.00 %	Output

Peers

CO09

100.00% **CO_{10}**

Peers: 0
References: 6

Potential Improvements

Variable	Actual	Target	Potential Improvement
BWE	2.60	2.60	0.00 %
CONTR	2.00	2.00	0.00 %
COST	1.00	1.00	0.00 %
CUSTO	2.00	2.00	0.00 %
ITBA	3.31	3.31	0.00 %
ITHS	1.33	1.33	0.00 %
ITSI	1.80	1.80	0.00 %
PROFI	2.00	2.00	0.00 %
SAFETY	4.00	4.00	0.00 %
SCHD	2.00	2.00	0.00 %

Peer Contributions

CO10	BWE	100.00 %
CO10	CONTR	100.00 %
CO10	COST	100.00 %
CO10	CUSTO	100.00 %
CO10	ITBA	100.00 %
CO10	ITHS	100.00 %
CO10	ITSI	100.00 %
CO10	PROFI	100.00 %
CO10	SAFETY	100.00 %
CO10	SCHD	100.00 %

Input / Output Contributions

BWE	0.00 %	Input
ITBA	35.46 %	Input
ITHS	64.54 %	Input
ITSI	0.00 %	Input
CONTR	0.00 %	Output
COST	100.00 %	Output
CUSTO	0.00 %	Output
PROFI	0.00 %	Output
SAFETY	0.00 %	Output
SCHD	0.00 %	Output

Peers

CO10

100.00% **CO11**

Peers: 0
References: 5

Potential Improvements

Variable	Actual	Target	Potential Improvement
BWE	2.40	2.40	0.00 %
CONTR	1.00	1.00	0.00 %
COST	2.00	2.00	0.00 %
CUSTO	1.00	1.00	0.00 %
ITBA	2.58	2.58	0.00 %
ITHS	1.50	1.50	0.00 %
ITSI	2.60	2.60	0.00 %
PROFI	1.00	1.00	0.00 %
SAFETY	3.00	3.00	0.00 %
SCHD	2.00	2.00	0.00 %

Peer Contributions

CO11	BWE	100.00 %
CO11	CONTR	100.00 %
CO11	COST	100.00 %
CO11	CUSTO	100.00 %
CO11	ITBA	100.00 %
CO11	ITHS	100.00 %
CO11	ITSI	100.00 %
CO11	PROFI	100.00 %
CO11	SAFETY	100.00 %
CO11	SCHD	100.00 %

Input / Output Contributions

BWE	0.00 %	Input
ITBA	86.89 %	Input
ITHS	13.11 %	Input
ITSI	0.00 %	Input
CONTR	100.00 %	Output
COST	0.00 %	Output
CUSTO	0.00 %	Output
PROFI	0.00 %	Output
SAFETY	0.00 %	Output
SCHD	0.00 %	Output

Peers

CO11

100.00% **CO_{12}**

Peers: 0
References: 1

Potential Improvements

Variable	Actual	Target	Potential Improvement
BWE	2.40	2.40	0.00 %
CONTR	3.00	3.00	0.00 %
COST	3.00	3.00	0.00 %
CUSTO	2.00	2.00	0.00 %
ITBA	3.11	3.11	0.00 %
ITHS	2.17	2.17	0.00 %
ITSI	2.40	2.40	0.00 %
PROFI	3.00	3.00	0.00 %
SAFETY	2.00	2.00	0.00 %
SCHD	3.00	3.00	0.00 %

Peer Contributions

CO12	BWE	100.00 %
CO12	CONTR	100.00 %
CO12	COST	100.00 %
CO12	CUSTO	100.00 %
CO12	ITBA	100.00 %
CO12	ITHS	100.00 %
CO12	ITSI	100.00 %
CO12	PROFI	100.00 %
CO12	SAFETY	100.00 %
CO12	SCHD	100.00 %

Input / Output Contributions

BWE	19.08 %	Input
ITBA	58.14 %	Input
ITHS	9.40 %	Input
ITSI	13.38 %	Input
CONTR	99.73 %	Output
COST	0.00 %	Output
CUSTO	0.27 %	Output
PROFI	0.00 %	Output
SAFETY	0.00 %	Output
SCHD	0.00 %	Output

Peers

CO12

100.00% **CO_{13}**

Peers: 0
References: 1

Potential Improvements

Variable	Actual	Target	Potential Improvement
BWE	2.00	2.00	0.00 %
CONTR	2.00	2.00	0.00 %
COST	2.00	2.00	0.00 %
CUSTO	1.00	1.00	0.00 %
ITBA	4.63	4.63	0.00 %
ITHS	1.17	1.17	0.00 %
ITSI	1.20	1.20	0.00 %
PROFI	2.00	2.00	0.00 %
SAFETY	2.00	2.00	0.00 %
SCHD	1.00	1.00	0.00 %

Peer Contributions

CO13	BWE	100.00 %
CO13	CONTR	100.00 %
CO13	COST	100.00 %
CO13	CUSTO	100.00 %
CO13	ITBA	100.00 %
CO13	ITHS	100.00 %
CO13	ITSI	100.00 %
CO13	PROFI	100.00 %
CO13	SAFETY	100.00 %
CO13	SCHD	100.00 %

Input / Output Contributions

BWE	19.23 %	Input
ITBA	0.00 %	Input
ITHS	0.00 %	Input
ITSI	80.77 %	Input
CONTR	0.00 %	Output
COST	0.00 %	Output
CUSTO	0.00 %	Output
PROFI	42.86 %	Output
SAFETY	57.14 %	Output
SCHD	0.00 %	Output

Peers

CO13

100.00% **CO_{14}**

Peers: 0
References: 3

Potential Improvements

Variable	Actual	Target	Potential Improvement
BWE	2.20	2.20	0.00 %
CONTR	4.00	4.00	0.00 %
COST	3.00	3.00	0.00 %
CUSTO	2.00	2.00	0.00 %
ITBA	3.60	3.60	0.00 %
ITHS	2.00	2.00	0.00 %
ITSI	2.20	2.20	0.00 %
PROFI	4.00	4.00	0.00 %
SAFETY	3.00	3.00	0.00 %
SCHD	3.00	3.00	0.00 %

Peer Contributions

CO14	BWE	100.00 %
CO14	CONTR	100.00 %
CO14	COST	100.00 %
CO14	CUSTO	100.00 %
CO14	ITBA	100.00 %
CO14	ITHS	100.00 %
CO14	ITSI	100.00 %
CO14	PROFI	100.00 %
CO14	SAFETY	100.00 %
CO14	SCHD	100.00 %

Input / Output Contributions

BWE	0.00 %	Input
ITBA	36.76 %	Input
ITHS	0.00 %	Input
ITSI	63.24 %	Input
CONTR	27.04 %	Output
COST	0.00 %	Output
CUSTO	0.00 %	Output
PROFI	72.96 %	Output
SAFETY	0.00 %	Output
SCHD	0.00 %	Output

Peers

CO14

100.00% **CO15**

Peers: 0
References: 3

Potential Improvements

Variable	Actual	Target	Potential Improvement
BWE	1.00	1.00	0.00 %
CONTR	2.00	2.00	0.00 %
COST	3.00	3.00	0.00 %
CUSTO	1.00	1.00	0.00 %
ITBA	4.39	4.39	0.00 %
ITHS	1.50	1.50	0.00 %
ITSI	1.20	1.20	0.00 %
PROFI	1.00	1.00	0.00 %
SAFETY	1.00	1.00	0.00 %
SCHD	4.00	4.00	0.00 %

Peer Contributions

CO15	BWE	100.00 %
CO15	CONTR	100.00 %
CO15	COST	100.00 %
CO15	CUSTO	100.00 %
CO15	ITBA	100.00 %
CO15	ITHS	100.00 %
CO15	ITSI	100.00 %
CO15	PROFI	100.00 %
CO15	SAFETY	100.00 %
CO15	SCHD	100.00 %

Input / Output Contributions

BWE	100.00 %	Input
ITBA	0.00 %	Input
ITHS	0.00 %	Input
ITSI	0.00 %	Input
CONTR	0.00 %	Output
COST	0.00 %	Output
CUSTO	0.00 %	Output
PROFI	0.00 %	Output
SAFETY	0.00 %	Output
SCHD	100.00 %	Output

Peers

CO15

80.00% **CO16**

Peers: 2
References: 0

Potential Improvements

Variable	Actual	Target	Potential Improvement
BWE	2.60	2.60	0.00 %
CONTR	2.00	3.71	85.71 %
COST	3.00	4.29	42.86 %
CUSTO	2.00	3.00	50.00 %
ITBA	3.74	3.42	-8.55 %
ITHS	2.83	2.36	-16.81 %
ITSI	3.00	2.17	-27.62 %
PROFI	1.00	3.00	200.00 %
SAFETY	2.00	2.71	35.71 %
SCHD	4.00	5.00	25.00 %

Peer Contributions

CO02	BWE	82.42 %
CO02	CONTR	76.92 %
CO02	COST	66.67 %
CO02	CUSTO	71.43 %
CO02	ITBA	68.83 %
CO02	ITHS	75.76 %
CO02	ITSI	78.95 %
CO02	PROFI	71.43 %
CO02	SAFETY	78.95 %
CO02	SCHD	71.43 %
CO26	BWE	17.58 %
CO26	CONTR	23.08 %
CO26	COST	33.33 %
CO26	CUSTO	28.57 %
CO26	ITBA	31.17 %
CO26	ITHS	24.24 %
CO26	ITSI	21.05 %
CO26	PROFI	28.57 %
CO26	SAFETY	21.05 %
CO26	SCHD	28.57 %

Input / Output Contributions

BWE	2.55 %	Input
ITBA	38.04 %	Input
ITHS	28.85 %	Input
ITSI	30.55 %	Input
CONTR	0.00 %	Output
COST	0.00 %	Output
CUSTO	0.00 %	Output
PROFI	0.00 %	Output
SAFETY	0.00 %	Output
SCHD	100.00 %	Output

Peers

CO02
CO26

100.00% **CO17**

Peers: 0
References: 6

Potential Improvements

Variable	Actual	Target	Potential Improvement
BWE	2.40	2.40	0.00 %
CONTR	4.00	4.00	0.00 %
COST	4.00	4.00	0.00 %
CUSTO	3.00	3.00	0.00 %
ITBA	3.52	3.52	0.00 %
ITHS	2.33	2.33	0.00 %
ITSI	2.60	2.60	0.00 %
PROFI	3.00	3.00	0.00 %
SAFETY	4.00	4.00	0.00 %
SCHD	4.00	4.00	0.00 %

Peer Contributions

CO17	BWE	100.00 %
CO17	CONTR	100.00 %
CO17	COST	100.00 %
CO17	CUSTO	100.00 %
CO17	ITBA	100.00 %
CO17	ITHS	100.00 %
CO17	ITSI	100.00 %
CO17	PROFI	100.00 %
CO17	SAFETY	100.00 %
CO17	SCHD	100.00 %

Input / Output Contributions

BWE	57.46 %	Input
ITBA	42.54 %	Input
ITHS	0.00 %	Input
ITSI	0.00 %	Input
CONTR	13.61 %	Output
COST	0.00 %	Output
CUSTO	0.00 %	Output
PROFI	0.00 %	Output
SAFETY	86.39 %	Output
SCHD	0.00 %	Output

Peers

CO17

80.00% **CO18**

Peers: 1
References: 0

Potential Improvements

Variable	Actual	Target	Potential Improvement
BWE	2.40	1.60	-33.33 %
CONTR	2.00	3.00	50.00 %
COST	4.00	5.00	25.00 %
CUSTO	1.00	3.00	200.00 %
ITBA	4.10	3.73	-9.06 %
ITHS	2.00	2.00	0.00 %
ITSI	1.60	1.60	0.00 %
PROFI	2.00	3.00	50.00 %
SAFETY	1.00	2.00	100.00 %
SCHD	3.00	5.00	66.67 %

Peer Contributions

CO26	BWE	100.00 %
CO26	CONTR	100.00 %
CO26	COST	100.00 %
CO26	CUSTO	100.00 %
CO26	ITBA	100.00 %
CO26	ITHS	100.00 %
CO26	ITSI	100.00 %
CO26	PROFI	100.00 %
CO26	SAFETY	100.00 %
CO26	SCHD	100.00 %

Input / Output Contributions

BWE	29.96 %	Input
ITBA	47.07 %	Input
ITHS	22.97 %	Input
ITSI	0.00 %	Input
CONTR	0.00 %	Output
COST	100.00 %	Output
CUSTO	0.00 %	Output
PROFI	0.00 %	Output
SAFETY	0.00 %	Output
SCHD	0.00 %	Output

Peers

CO26

100.00% **CO_{19}**

Peers: 0
References: 1

Potential Improvements

Variable	Actual	Target	Potential Improvement
BWE	2.00	2.00	0.00 %
CONTR	3.00	3.00	0.00 %
COST	3.00	3.00	0.00 %
CUSTO	3.00	3.00	0.00 %
ITBA	3.85	3.85	0.00 %
ITHS	2.17	2.17	0.00 %
ITSI	2.20	2.20	0.00 %
PROFI	4.00	4.00	0.00 %
SAFETY	2.00	2.00	0.00 %
SCHD	3.00	3.00	0.00 %

Peer Contributions

CO19	BWE	100.00 %
CO19	CONTR	100.00 %
CO19	COST	100.00 %
CO19	CUSTO	100.00 %
CO19	ITBA	100.00 %
CO19	ITHS	100.00 %
CO19	ITSI	100.00 %
CO19	PROFI	100.00 %
CO19	SAFETY	100.00 %
CO19	SCHD	100.00 %

Input / Output Contributions

BWE	84.34 %	Input
ITBA	0.00 %	Input
ITHS	15.66 %	Input
ITSI	0.00 %	Input
CONTR	0.00 %	Output
COST	0.00 %	Output
CUSTO	18.52 %	Output
PROFI	74.07 %	Output
SAFETY	7.41 %	Output
SCHD	0.00 %	Output

Peers

CO19

69.04% **CO20**

Peers: 6
References: 0

Potential Improvements

Variable	Actual	Target	Potential Improvement
BWE	2.00	2.00	0.00 %
CONTR	2.00	3.18	58.76 %
COST	2.00	4.21	110.31 %
CUSTO	2.00	2.90	44.85 %
ITBA	4.27	3.68	-13.82 %
ITHS	2.00	2.00	0.00 %
ITSI	2.00	2.00	0.00 %
PROFI	2.00	2.90	44.85 %
SAFETY	2.00	2.90	44.85 %
SCHD	2.00	4.23	111.60 %

Peer Contributions

CO04	BWE	6.19 %
CO04	CONTR	3.90 %
CO04	COST	5.88 %
CO04	CUSTO	6.41 %
CO04	ITBA	7.48 %
CO04	ITHS	4.12 %
CO04	ITSI	5.57 %
CO04	PROFI	4.27 %
CO04	SAFETY	4.27 %
CO04	SCHD	5.85 %
CO10	BWE	10.05 %
CO10	CONTR	4.87 %
CO10	COST	1.84 %
CO10	CUSTO	5.34 %
CO10	ITBA	6.94 %
CO10	ITHS	5.15 %
CO10	ITSI	6.96 %
CO10	PROFI	5.34 %
CO10	SAFETY	10.68 %
CO10	SCHD	3.65 %
CO17	BWE	40.82 %
CO17	CONTR	42.86 %
CO17	COST	32.35 %
CO17	CUSTO	35.23 %
CO17	ITBA	32.53 %
CO17	ITHS	39.69 %
CO17	ITSI	44.23 %
CO17	PROFI	35.23 %
CO17	SAFETY	46.98 %
CO17	SCHD	32.16 %
CO26	BWE	37.11 %
CO26	CONTR	43.83 %
CO26	COST	55.15 %
CO26	CUSTO	48.04 %
CO26	ITBA	46.96 %
CO26	ITHS	46.39 %
CO26	ITSI	37.11 %
CO26	PROFI	48.04 %
CO26	SAFETY	32.03 %

CO26	SCHD	54.81 %
CO32	BWE	1.80 %
CO32	CONTR	1.62 %
CO32	COST	1.84 %
CO32	CUSTO	1.78 %
CO32	ITBA	3.40 %
CO32	ITHS	1.29 %
CO32	ITSI	1.80 %
CO32	PROFI	1.78 %
CO32	SAFETY	1.78 %
CO32	SCHD	0.61 %
CO45	BWE	4.02 %
CO45	CONTR	2.92 %
CO45	COST	2.94 %
CO45	CUSTO	3.20 %
CO45	ITBA	2.69 %
CO45	ITHS	3.35 %
CO45	ITSI	4.33 %
CO45	PROFI	5.34 %
CO45	SAFETY	4.27 %
CO45	SCHD	2.92 %

Input / Output Contributions

BWE	38.46 %	Input
ITBA	0.00 %	Input
ITHS	35.90 %	Input
ITSI	25.64 %	Input
CONTR	0.00 %	Output
COST	0.00 %	Output
CUSTO	54.64 %	Output
PROFI	4.12 %	Output
SAFETY	41.24 %	Output
SCHD	0.00 %	Output

Peers

CO04
CO10
CO17
CO26
CO32
CO45

100.00% **CO21**

Peers: 0
References: 1

Potential Improvements

Variable	Actual	Target	Potential Improvement
BWE	2.00	2.00	0.00 %
CONTR	4.00	4.00	0.00 %
COST	4.00	4.00	0.00 %
CUSTO	4.00	4.00	0.00 %
ITBA	3.67	3.67	0.00 %
ITHS	3.00	3.00	0.00 %
ITSI	2.60	2.60	0.00 %
PROFI	4.00	4.00	0.00 %
SAFETY	2.00	2.00	0.00 %
SCHD	4.00	4.00	0.00 %

Peer Contributions

CO21	BWE	100.00 %
CO21	CONTR	100.00 %
CO21	COST	100.00 %
CO21	CUSTO	100.00 %
CO21	ITBA	100.00 %
CO21	ITHS	100.00 %
CO21	ITSI	100.00 %
CO21	PROFI	100.00 %
CO21	SAFETY	100.00 %
CO21	SCHD	100.00 %

Input / Output Contributions

BWE	100.00 %	Input
ITBA	0.00 %	Input
ITHS	0.00 %	Input
ITSI	0.00 %	Input
CONTR	0.00 %	Output
COST	0.00 %	Output
CUSTO	100.00 %	Output
PROFI	0.00 %	Output
SAFETY	0.00 %	Output
SCHD	0.00 %	Output

Peers

CO21

100.00% **CO22**

Peers: 0
References: 5

Potential Improvements

Variable	Actual	Target	Potential Improvement
BWE	3.00	3.00	0.00 %
CONTR	3.00	3.00	0.00 %
COST	3.00	3.00	0.00 %
CUSTO	3.00	3.00	0.00 %
ITBA	3.11	3.11	0.00 %
ITHS	2.33	2.33	0.00 %
ITSI	1.40	1.40	0.00 %
PROFI	2.00	2.00	0.00 %
SAFETY	3.00	3.00	0.00 %
SCHD	3.00	3.00	0.00 %

Peer Contributions

CO22	BWE	100.00 %
CO22	CONTR	100.00 %
CO22	COST	100.00 %
CO22	CUSTO	100.00 %
CO22	ITBA	100.00 %
CO22	ITHS	100.00 %
CO22	ITSI	100.00 %
CO22	PROFI	100.00 %
CO22	SAFETY	100.00 %
CO22	SCHD	100.00 %

Input / Output Contributions

BWE	60.00 %	Input
ITBA	0.00 %	Input
ITHS	0.00 %	Input
ITSI	40.00 %	Input
CONTR	0.00 %	Output
COST	0.00 %	Output
CUSTO	61.39 %	Output
PROFI	0.00 %	Output
SAFETY	38.61 %	Output
SCHD	0.00 %	Output

Peers

CO22

100.00% **CO23**

Peers: 0
References: 1

Potential Improvements

Variable	Actual	Target	Potential Improvement
BWE	2.00	2.00	0.00 %
CONTR	4.00	4.00	0.00 %
COST	4.00	4.00	0.00 %
CUSTO	3.00	3.00	0.00 %
ITBA	4.39	4.39	0.00 %
ITHS	2.17	2.17	0.00 %
ITSI	1.80	1.80	0.00 %
PROFI	2.00	2.00	0.00 %
SAFETY	2.00	2.00	0.00 %
SCHD	2.00	2.00	0.00 %

Peer Contributions

CO23	BWE	100.00 %
CO23	CONTR	100.00 %
CO23	COST	100.00 %
CO23	CUSTO	100.00 %
CO23	ITBA	100.00 %
CO23	ITHS	100.00 %
CO23	ITSI	100.00 %
CO23	PROFI	100.00 %
CO23	SAFETY	100.00 %
CO23	SCHD	100.00 %

Input / Output Contributions

BWE	79.55 %	Input
ITBA	0.00 %	Input
ITHS	0.00 %	Input
ITSI	20.45 %	Input
CONTR	55.42 %	Output
COST	16.87 %	Output
CUSTO	14.46 %	Output
PROFI	0.00 %	Output
SAFETY	13.25 %	Output
SCHD	0.00 %	Output

Peers

CO23

100.00% **CO_{24}**

Peers: 0
References: 4

Potential Improvements

Variable	Actual	Target	Potential Improvement
BWE	4.20	4.20	0.00 %
CONTR	4.00	4.00	0.00 %
COST	4.00	4.00	0.00 %
CUSTO	2.00	2.00	0.00 %
ITBA	3.59	3.59	0.00 %
ITHS	2.33	2.33	0.00 %
ITSI	3.00	3.00	0.00 %
PROFI	4.00	4.00	0.00 %
SAFETY	4.00	4.00	0.00 %
SCHD	5.00	5.00	0.00 %

Peer Contributions

CO24	BWE	100.00 %
CO24	CONTR	100.00 %
CO24	COST	100.00 %
CO24	CUSTO	100.00 %
CO24	ITBA	100.00 %
CO24	ITHS	100.00 %
CO24	ITSI	100.00 %
CO24	PROFI	100.00 %
CO24	SAFETY	100.00 %
CO24	SCHD	100.00 %

Input / Output Contributions

BWE	55.98 %	Input
ITBA	44.02 %	Input
ITHS	0.00 %	Input
ITSI	0.00 %	Input
CONTR	0.00 %	Output
COST	0.00 %	Output
CUSTO	0.00 %	Output
PROFI	0.00 %	Output
SAFETY	0.00 %	Output
SCHD	100.00 %	Output

Peers

CO24

90.57% **CO_{25}**

Peers: 6
References: 0

Potential Improvements

Variable	Actual	Target	Potential Improvement
BWE	1.80	1.80	0.00 %
CONTR	3.00	3.31	10.42 %
COST	2.00	3.49	74.48 %
CUSTO	2.00	2.21	10.42 %
ITBA	4.47	3.93	-12.25 %
ITHS	1.83	1.83	0.00 %
ITSI	2.00	1.80	-10.10 %
PROFI	3.00	3.31	10.42 %
SAFETY	2.00	2.21	10.42 %
SCHD	2.00	3.45	72.40 %

Peer Contributions

CO09	BWE	6.08 %
CO09	CONTR	3.30 %
CO09	COST	6.27 %
CO09	CUSTO	4.95 %
CO09	ITBA	13.93 %
CO09	ITHS	5.97 %
CO09	ITSI	6.08 %
CO09	PROFI	6.60 %
CO09	SAFETY	4.95 %
CO09	SCHD	6.34 %
CO14	BWE	50.93 %
CO14	CONTR	50.31 %
CO14	COST	35.82 %
CO14	CUSTO	37.74 %
CO14	ITBA	38.24 %
CO14	ITHS	45.45 %
CO14	ITSI	50.98 %
CO14	PROFI	50.31 %
CO14	SAFETY	56.60 %
CO14	SCHD	36.25 %
CO26	BWE	28.24 %
CO26	CONTR	28.77 %
CO26	COST	45.52 %
CO26	CUSTO	43.16 %
CO26	ITBA	30.16 %
CO26	ITHS	34.66 %
CO26	ITSI	28.27 %
CO26	PROFI	28.77 %
CO26	SAFETY	28.77 %
CO26	SCHD	46.07 %
CO32	BWE	1.62 %
CO32	CONTR	1.26 %
CO32	COST	1.79 %
CO32	CUSTO	1.89 %
CO32	ITBA	2.58 %
CO32	ITHS	1.14 %
CO32	ITSI	1.62 %
CO32	PROFI	1.26 %
CO32	SAFETY	1.89 %

CO32	SCHD	0.60 %
CO37	BWE	3.24 %
CO37	CONTR	4.40 %
CO37	COST	2.09 %
CO37	CUSTO	3.30 %
CO37	ITBA	4.58 %
CO37	ITHS	1.99 %
CO37	ITSI	2.03 %
CO37	PROFI	1.10 %
CO37	SAFETY	3.30 %
CO37	SCHD	2.11 %
CO48	BWE	9.90 %
CO48	CONTR	11.95 %
CO48	COST	8.51 %
CO48	CUSTO	8.96 %
CO48	ITBA	10.50 %
CO48	ITHS	10.80 %
CO48	ITSI	11.01 %
CO48	PROFI	11.95 %
CO48	SAFETY	4.48 %
CO48	SCHD	8.61 %

Input / Output Contributions

BWE	83.08 %	Input
ITBA	0.00 %	Input
ITHS	16.92 %	Input
ITSI	0.00 %	Input
CONTR	37.50 %	Output
COST	0.00 %	Output
CUSTO	0.00 %	Output
PROFI	37.50 %	Output
SAFETY	25.00 %	Output
SCHD	0.00 %	Output

Peers

CO09
CO14
CO26
CO32
CO37
CO48

100.00% **CO26**

Peers: 0
References: 14

Potential Improvements

Variable	Actual	Target	Potential Improvement
BWE	1.60	1.60	0.00 %
CONTR	3.00	3.00	0.00 %
COST	5.00	5.00	0.00 %
CUSTO	3.00	3.00	0.00 %
ITBA	3.73	3.73	0.00 %
ITHS	2.00	2.00	0.00 %
ITSI	1.60	1.60	0.00 %
PROFI	3.00	3.00	0.00 %
SAFETY	2.00	2.00	0.00 %
SCHD	5.00	5.00	0.00 %

Peer Contributions

CO26	BWE	100.00 %
CO26	CONTR	100.00 %
CO26	COST	100.00 %
CO26	CUSTO	100.00 %
CO26	ITBA	100.00 %
CO26	ITHS	100.00 %
CO26	ITSI	100.00 %
CO26	PROFI	100.00 %
CO26	SAFETY	100.00 %
CO26	SCHD	100.00 %

Input / Output Contributions

BWE	13.06 %	Input
ITBA	60.30 %	Input
ITHS	6.24 %	Input
ITSI	20.40 %	Input
CONTR	0.00 %	Output
COST	0.00 %	Output
CUSTO	100.00 %	Output
PROFI	0.00 %	Output
SAFETY	0.00 %	Output
SCHD	0.00 %	Output

Peers

CO26

97.14% **CO27**

Peers: 4
References: 0

Potential Improvements

Variable	Actual	Target	Potential Improvement
BWE	2.80	2.29	-18.07 %
CONTR	4.00	4.12	2.94 %
COST	2.00	3.35	67.65 %
CUSTO	2.00	2.35	17.65 %
ITBA	3.75	3.73	-0.31 %
ITHS	2.67	2.32	-12.87 %
ITSI	2.40	2.40	0.00 %
PROFI	4.00	4.12	2.94 %
SAFETY	2.00	2.06	2.94 %
SCHD	3.00	3.18	5.88 %

Peer Contributions

CO05	BWE	5.13 %
CO05	CONTR	7.14 %
CO05	COST	7.02 %
CO05	CUSTO	7.50 %
CO05	ITBA	6.14 %
CO05	ITHS	5.49 %
CO05	ITSI	7.35 %
CO05	PROFI	5.71 %
CO05	SAFETY	2.86 %
CO05	SCHD	7.41 %
CO39	BWE	30.77 %
CO39	CONTR	21.43 %
CO39	COST	21.05 %
CO39	CUSTO	22.50 %
CO39	ITBA	11.58 %
CO39	ITHS	27.85 %
CO39	ITSI	25.00 %
CO39	PROFI	17.14 %
CO39	SAFETY	42.86 %
CO39	SCHD	16.67 %
CO45	BWE	13.33 %
CO45	CONTR	8.57 %
CO45	COST	14.04 %
CO45	CUSTO	15.00 %
CO45	ITBA	10.08 %
CO45	ITHS	10.97 %
CO45	ITSI	13.73 %
CO45	PROFI	14.29 %
CO45	SAFETY	22.86 %
CO45	SCHD	14.81 %
CO48	BWE	50.77 %
CO48	CONTR	62.86 %
CO48	COST	57.89 %
CO48	CUSTO	55.00 %
CO48	ITBA	72.20 %
CO48	ITHS	55.70 %
CO48	ITSI	53.92 %
CO48	PROFI	62.86 %
CO48	SAFETY	31.43 %

CO48	SCHD	61.11 %

Input / Output Contributions

BWE	0.00 %	Input
ITBA	0.00 %	Input
ITHS	0.00 %	Input
ITSI	100.00 %	Input
CONTR	39.22 %	Output
COST	0.00 %	Output
CUSTO	0.00 %	Output
PROFI	58.82 %	Output
SAFETY	1.96 %	Output
SCHD	0.00 %	Output

Peers

CO05
CO39
CO45
CO48

100.00% **CO28**

Peers: 0
References: 2

Potential Improvements

Variable	Actual	Target	Potential Improvement
BWE	2.40	2.40	0.00 %
CONTR	3.00	3.00	0.00 %
COST	4.00	4.00	0.00 %
CUSTO	3.00	3.00	0.00 %
ITBA	3.74	3.74	0.00 %
ITHS	2.33	2.33	0.00 %
ITSI	2.00	2.00	0.00 %
PROFI	4.00	4.00	0.00 %
SAFETY	3.00	3.00	0.00 %
SCHD	4.00	4.00	0.00 %

Peer Contributions

CO28	BWE	100.00 %
CO28	CONTR	100.00 %
CO28	COST	100.00 %
CO28	CUSTO	100.00 %
CO28	ITBA	100.00 %
CO28	ITHS	100.00 %
CO28	ITSI	100.00 %
CO28	PROFI	100.00 %
CO28	SAFETY	100.00 %
CO28	SCHD	100.00 %

Input / Output Contributions

BWE	44.44 %	Input
ITBA	0.00 %	Input
ITHS	0.00 %	Input
ITSI	55.56 %	Input
CONTR	0.00 %	Output
COST	0.00 %	Output
CUSTO	3.10 %	Output
PROFI	40.00 %	Output
SAFETY	56.90 %	Output
SCHD	0.00 %	Output

Peers

CO28

100.00% **CO29**

Peers: 0
References: 1

Potential Improvements

Variable	Actual	Target	Potential Improvement
BWE	3.80	3.80	0.00 %
CONTR	4.00	4.00	0.00 %
COST	5.00	5.00	0.00 %
CUSTO	3.00	3.00	0.00 %
ITBA	2.00	2.00	0.00 %
ITHS	5.00	5.00	0.00 %
ITSI	5.00	5.00	0.00 %
PROFI	4.00	4.00	0.00 %
SAFETY	2.00	2.00	0.00 %
SCHD	5.00	5.00	0.00 %

Peer Contributions

CO29	BWE	100.00 %
CO29	CONTR	100.00 %
CO29	COST	100.00 %
CO29	CUSTO	100.00 %
CO29	ITBA	100.00 %
CO29	ITHS	100.00 %
CO29	ITSI	100.00 %
CO29	PROFI	100.00 %
CO29	SAFETY	100.00 %
CO29	SCHD	100.00 %

Input / Output Contributions

BWE	48.57 %	Input
ITBA	51.43 %	Input
ITHS	0.00 %	Input
ITSI	0.00 %	Input
CONTR	0.00 %	Output
COST	0.00 %	Output
CUSTO	100.00 %	Output
PROFI	0.00 %	Output
SAFETY	0.00 %	Output
SCHD	0.00 %	Output

Peers

CO29

79.78% CO30

Peers: 5
References: 0

Potential Improvements

Variable	Actual	Target	Potential Improvement
BWE	2.00	2.00	0.00 %
CONTR	2.00	2.51	25.35 %
COST	1.00	3.71	270.97 %
CUSTO	2.00	2.51	25.35 %
ITBA	3.42	3.42	0.00 %
ITHS	1.83	1.83	0.00 %
ITSI	1.80	1.80	0.00 %
PROFI	1.00	2.47	146.65 %
SAFETY	1.00	2.58	158.17 %
SCHD	1.00	3.87	287.20 %

Peer Contributions

CO10	BWE	21.09 %
CO10	CONTR	12.94 %
CO10	COST	4.37 %
CO10	CUSTO	12.94 %
CO10	ITBA	15.68 %
CO10	ITHS	11.80 %
CO10	ITSI	16.22 %
CO10	PROFI	13.16 %
CO10	SAFETY	25.14 %
CO10	SCHD	8.38 %
CO11	BWE	19.85 %
CO11	CONTR	6.60 %
CO11	COST	8.92 %
CO11	CUSTO	6.60 %
CO11	ITBA	12.47 %
CO11	ITHS	13.53 %
CO11	ITSI	23.89 %
CO11	PROFI	6.71 %
CO11	SAFETY	19.22 %
CO11	SCHD	8.54 %
CO22	BWE	9.92 %
CO22	CONTR	7.92 %
CO22	COST	5.35 %
CO22	CUSTO	7.92 %
CO22	ITBA	6.02 %
CO22	ITHS	8.42 %
CO22	ITSI	5.15 %
CO22	PROFI	5.36 %
CO22	SAFETY	7.69 %
CO22	SCHD	5.13 %
CO26	BWE	47.47 %
CO26	CONTR	71.01 %
CO26	COST	79.98 %
CO26	CUSTO	71.01 %
CO26	ITBA	64.63 %
CO26	ITHS	64.73 %
CO26	ITSI	52.75 %
CO26	PROFI	72.17 %
CO26	SAFETY	45.97 %

CO26	SCHD	76.63 %
CO45	BWE	1.67 %
CO45	CONTR	1.54 %
CO45	COST	1.38 %
CO45	CUSTO	1.54 %
CO45	ITBA	1.20 %
CO45	ITHS	1.52 %
CO45	ITSI	2.00 %
CO45	PROFI	2.60 %
CO45	SAFETY	1.99 %
CO45	SCHD	1.33 %

Input / Output Contributions

BWE	10.42 %	Input
ITBA	62.54 %	Input
ITHS	23.59 %	Input
ITSI	3.45 %	Input
CONTR	0.00 %	Output
COST	0.00 %	Output
CUSTO	100.00 %	Output
PROFI	0.00 %	Output
SAFETY	0.00 %	Output
SCHD	0.00 %	Output

Peers

CO10
CO11
CO22
CO26
CO45

97.65% **CO_{31}**

Peers: 4
References: 0

Potential Improvements

Variable	Actual	Target	Potential Improvement
BWE	1.60	1.60	0.00 %
CONTR	2.00	2.53	26.66 %
COST	2.00	3.44	71.84 %
CUSTO	2.00	2.40	19.88 %
ITBA	3.75	3.75	0.00 %
ITHS	2.00	1.81	-9.64 %
ITSI	2.20	2.00	-9.01 %
PROFI	2.00	2.05	2.41 %
SAFETY	2.00	2.05	2.41 %
SCHD	2.00	3.09	54.37 %

Peer Contributions

CO03	BWE	21.84 %
CO03	CONTR	27.59 %
CO03	COST	20.33 %
CO03	CUSTO	29.15 %
CO03	ITBA	39.88 %
CO03	ITHS	29.00 %
CO03	ITSI	34.91 %
CO03	PROFI	17.06 %
CO03	SAFETY	17.06 %
CO03	SCHD	11.32 %
CO11	BWE	18.98 %
CO11	CONTR	4.99 %
CO11	COST	7.36 %
CO11	CUSTO	5.28 %
CO11	ITBA	8.71 %
CO11	ITHS	10.50 %
CO11	ITSI	16.43 %
CO11	PROFI	6.18 %
CO11	SAFETY	18.53 %
CO11	SCHD	8.20 %
CO17	BWE	20.33 %
CO17	CONTR	21.40 %
CO17	COST	15.77 %
CO17	CUSTO	16.96 %
CO17	ITBA	12.74 %
CO17	ITHS	17.50 %
CO17	ITSI	17.60 %
CO17	PROFI	19.85 %
CO17	SAFETY	26.47 %
CO17	SCHD	17.56 %
CO26	BWE	38.86 %
CO26	CONTR	46.02 %
CO26	COST	56.53 %
CO26	CUSTO	48.62 %
CO26	ITBA	38.66 %
CO26	ITHS	43.00 %
CO26	ITSI	31.06 %
CO26	PROFI	56.91 %
CO26	SAFETY	37.94 %

CO26	SCHD	62.93 %

Input / Output Contributions

BWE	51.48 %	Input
ITBA	48.52 %	Input
ITHS	0.00 %	Input
ITSI	0.00 %	Input
CONTR	0.00 %	Output
COST	0.00 %	Output
CUSTO	0.00 %	Output
PROFI	2.80 %	Output
SAFETY	97.20 %	Output
SCHD	0.00 %	Output

Peers

CO03
CO11
CO17
CO26

100.00% **CO32**

Peers: 0
References: 3

Potential Improvements

Variable	Actual	Target	Potential Improvement
BWE	1.40	1.40	0.00 %
CONTR	2.00	2.00	0.00 %
COST	3.00	3.00	0.00 %
CUSTO	2.00	2.00	0.00 %
ITBA	4.86	4.86	0.00 %
ITHS	1.00	1.00	0.00 %
ITSI	1.40	1.40	0.00 %
PROFI	2.00	2.00	0.00 %
SAFETY	2.00	2.00	0.00 %
SCHD	1.00	1.00	0.00 %

Peer Contributions

CO32	BWE	100.00 %
CO32	CONTR	100.00 %
CO32	COST	100.00 %
CO32	CUSTO	100.00 %
CO32	ITBA	100.00 %
CO32	ITHS	100.00 %
CO32	ITSI	100.00 %
CO32	PROFI	100.00 %
CO32	SAFETY	100.00 %
CO32	SCHD	100.00 %

Input / Output Contributions

BWE	61.25 %	Input
ITBA	0.00 %	Input
ITHS	12.50 %	Input
ITSI	26.25 %	Input
CONTR	0.00 %	Output
COST	0.00 %	Output
CUSTO	100.00 %	Output
PROFI	0.00 %	Output
SAFETY	0.00 %	Output
SCHD	0.00 %	Output

Peers

CO32

48.21% **CO33**

Peers: 6
References: 0

Potential Improvements

Variable	Actual	Target	Potential Improvement
BWE	1.60	1.60	0.00 %
CONTR	1.00	2.41	140.70 %
COST	1.00	3.05	204.99 %
CUSTO	1.00	2.41	140.70 %
ITBA	3.84	3.84	0.00 %
ITHS	1.67	1.67	0.00 %
ITSI	1.80	1.80	0.00 %
PROFI	1.00	2.07	107.43 %
SAFETY	1.00	2.07	107.43 %
SCHD	1.00	2.87	187.46 %

Peer Contributions

CO03	BWE	21.45 %
CO03	CONTR	28.52 %
CO03	COST	22.51 %
CO03	CUSTO	28.52 %
CO03	ITBA	38.17 %
CO03	ITHS	30.89 %
CO03	ITSI	38.14 %
CO03	PROFI	16.55 %
CO03	SAFETY	16.55 %
CO03	SCHD	11.94 %
CO10	BWE	32.19 %
CO10	CONTR	16.46 %
CO10	COST	6.50 %
CO10	CUSTO	16.46 %
CO10	ITBA	17.04 %
CO10	ITHS	15.85 %
CO10	ITSI	19.81 %
CO10	PROFI	19.10 %
CO10	SAFETY	38.20 %
CO10	SCHD	13.78 %
CO11	BWE	1.61 %
CO11	CONTR	0.45 %
CO11	COST	0.71 %
CO11	CUSTO	0.45 %
CO11	ITBA	0.72 %
CO11	ITHS	0.97 %
CO11	ITSI	1.55 %
CO11	PROFI	0.52 %
CO11	SAFETY	1.56 %
CO11	SCHD	0.75 %
CO26	BWE	41.25 %
CO26	CONTR	51.41 %
CO26	COST	67.62 %
CO26	CUSTO	51.41 %
CO26	ITBA	39.99 %
CO26	ITHS	49.50 %
CO26	ITSI	36.67 %
CO26	PROFI	59.66 %
CO26	SAFETY	39.77 %

CO26	SCHD	71.75 %
CO34	BWE	2.64 %
CO34	CONTR	2.51 %
CO34	COST	1.98 %
CO34	CUSTO	2.51 %
CO34	ITBA	3.63 %
CO34	ITHS	2.11 %
CO34	ITSI	3.02 %
CO34	PROFI	2.91 %
CO34	SAFETY	2.91 %
CO34	SCHD	1.05 %
CO45	BWE	0.85 %
CO45	CONTR	0.65 %
CO45	COST	0.69 %
CO45	CUSTO	0.65 %
CO45	ITBA	0.44 %
CO45	ITHS	0.68 %
CO45	ITSI	0.82 %
CO45	PROFI	1.27 %
CO45	SAFETY	1.01 %
CO45	SCHD	0.73 %

Input / Output Contributions

BWE	41.25 %	Input
ITBA	42.72 %	Input
ITHS	14.63 %	Input
ITSI	1.40 %	Input
CONTR	0.00 %	Output
COST	0.00 %	Output
CUSTO	0.00 %	Output
PROFI	20.60 %	Output
SAFETY	79.40 %	Output
SCHD	0.00 %	Output

Peers

CO03
CO10
CO11
CO26
CO34
CO45

100.00% **CO_{34}**

Peers: 0
References: 2

Potential Improvements

Variable	Actual	Target	Potential Improvement
BWE	1.40	1.40	0.00 %
CONTR	2.00	2.00	0.00 %
COST	2.00	2.00	0.00 %
CUSTO	2.00	2.00	0.00 %
ITBA	4.63	4.63	0.00 %
ITHS	1.17	1.17	0.00 %
ITSI	1.80	1.80	0.00 %
PROFI	2.00	2.00	0.00 %
SAFETY	2.00	2.00	0.00 %
SCHD	1.00	1.00	0.00 %

Peer Contributions

CO34	BWE	100.00 %
CO34	CONTR	100.00 %
CO34	COST	100.00 %
CO34	CUSTO	100.00 %
CO34	ITBA	100.00 %
CO34	ITHS	100.00 %
CO34	ITSI	100.00 %
CO34	PROFI	100.00 %
CO34	SAFETY	100.00 %
CO34	SCHD	100.00 %

Input / Output Contributions

BWE	100.00 %	Input
ITBA	0.00 %	Input
ITHS	0.00 %	Input
ITSI	0.00 %	Input
CONTR	0.00 %	Output
COST	0.00 %	Output
CUSTO	0.00 %	Output
PROFI	0.00 %	Output
SAFETY	100.00 %	Output
SCHD	0.00 %	Output

Peers

CO34

71.74% **CO35**

Peers: 5
References: 0

Potential Improvements

Variable	Actual	Target	Potential Improvement
BWE	2.00	2.00	0.00 %
CONTR	2.00	2.94	46.97 %
COST	2.00	3.91	95.45 %
CUSTO	2.00	2.79	39.39 %
ITBA	5.00	3.59	-28.23 %
ITHS	2.00	1.93	-3.54 %
ITSI	1.80	1.80	0.00 %
PROFI	2.00	2.79	39.39 %
SAFETY	2.00	2.79	39.39 %
SCHD	2.00	4.12	106.06 %

Peer Contributions

CO10	BWE	27.58 %
CO10	CONTR	14.43 %
CO10	COST	5.43 %
CO10	CUSTO	15.22 %
CO10	ITBA	19.55 %
CO10	ITHS	14.66 %
CO10	ITSI	21.21 %
CO10	PROFI	15.22 %
CO10	SAFETY	30.43 %
CO10	SCHD	10.29 %
CO17	BWE	18.18 %
CO17	CONTR	20.62 %
CO17	COST	15.50 %
CO17	CUSTO	16.30 %
CO17	ITBA	14.87 %
CO17	ITHS	18.32 %
CO17	ITSI	21.89 %
CO17	PROFI	16.30 %
CO17	SAFETY	21.74 %
CO17	SCHD	14.71 %
CO22	BWE	4.55 %
CO22	CONTR	3.09 %
CO22	COST	2.33 %
CO22	CUSTO	3.26 %
CO22	ITBA	2.63 %
CO22	ITHS	3.66 %
CO22	ITSI	2.36 %
CO22	PROFI	2.17 %
CO22	SAFETY	3.26 %
CO22	SCHD	2.21 %
CO26	BWE	46.06 %
CO26	CONTR	58.76 %
CO26	COST	73.64 %
CO26	CUSTO	61.96 %
CO26	ITBA	59.80 %
CO26	ITHS	59.69 %
CO26	ITSI	51.18 %
CO26	PROFI	61.96 %
CO26	SAFETY	41.30 %

CO26	SCHD	69.85 %
CO28	BWE	3.64 %
CO28	CONTR	3.09 %
CO28	COST	3.10 %
CO28	CUSTO	3.26 %
CO28	ITBA	3.16 %
CO28	ITHS	3.66 %
CO28	ITSI	3.37 %
CO28	PROFI	4.35 %
CO28	SAFETY	3.26 %
CO28	SCHD	2.94 %

Input / Output Contributions

BWE	38.83 %	Input
ITBA	0.00 %	Input
ITHS	0.00 %	Input
ITSI	61.17 %	Input
CONTR	0.00 %	Output
COST	0.00 %	Output
CUSTO	39.39 %	Output
PROFI	9.09 %	Output
SAFETY	51.52 %	Output
SCHD	0.00 %	Output

Peers

CO10
CO17
CO22
CO26
CO28

100.00% **CO_{36}**

Peers: 0
References: 1

Potential Improvements

Variable	Actual	Target	Potential Improvement
BWE	1.00	1.00	0.00 %
CONTR	1.00	1.00	0.00 %
COST	1.00	1.00	0.00 %
CUSTO	1.00	1.00	0.00 %
ITBA	4.92	4.92	0.00 %
ITHS	1.00	1.00	0.00 %
ITSI	1.00	1.00	0.00 %
PROFI	1.00	1.00	0.00 %
SAFETY	1.00	1.00	0.00 %
SCHD	1.00	1.00	0.00 %

Peer Contributions

CO36	BWE	100.00 %
CO36	CONTR	100.00 %
CO36	COST	100.00 %
CO36	CUSTO	100.00 %
CO36	ITBA	100.00 %
CO36	ITHS	100.00 %
CO36	ITSI	100.00 %
CO36	PROFI	100.00 %
CO36	SAFETY	100.00 %
CO36	SCHD	100.00 %

Input / Output Contributions

BWE	55.56 %	Input
ITBA	0.00 %	Input
ITHS	44.44 %	Input
ITSI	0.00 %	Input
CONTR	0.00 %	Output
COST	0.00 %	Output
CUSTO	100.00 %	Output
PROFI	0.00 %	Output
SAFETY	0.00 %	Output
SCHD	0.00 %	Output

Peers

CO36

100.00% **CO_{37}**

Peers: 0
References: 4

Potential Improvements

Variable	Actual	Target	Potential Improvement
BWE	1.60	1.60	0.00 %
CONTR	4.00	4.00	0.00 %
COST	2.00	2.00	0.00 %
CUSTO	2.00	2.00	0.00 %
ITBA	4.93	4.93	0.00 %
ITHS	1.00	1.00	0.00 %
ITSI	1.00	1.00	0.00 %
PROFI	1.00	1.00	0.00 %
SAFETY	2.00	2.00	0.00 %
SCHD	2.00	2.00	0.00 %

Peer Contributions

CO37	BWE	100.00 %
CO37	CONTR	100.00 %
CO37	COST	100.00 %
CO37	CUSTO	100.00 %
CO37	ITBA	100.00 %
CO37	ITHS	100.00 %
CO37	ITSI	100.00 %
CO37	PROFI	100.00 %
CO37	SAFETY	100.00 %
CO37	SCHD	100.00 %

Input / Output Contributions

BWE	0.00 %	Input
ITBA	0.00 %	Input
ITHS	0.00 %	Input
ITSI	100.00 %	Input
CONTR	57.14 %	Output
COST	0.00 %	Output
CUSTO	0.00 %	Output
PROFI	42.86 %	Output
SAFETY	0.00 %	Output
SCHD	0.00 %	Output

Peers

CO37

62.75% **CO38**

Peers: 3
References: 0

Potential Improvements

Variable	Actual	Target	Potential Improvement
BWE	2.20	2.10	-4.55 %
CONTR	3.00	4.78	59.38 %
COST	2.00	3.56	78.13 %
CUSTO	1.00	2.78	178.13 %
ITBA	4.26	3.99	-6.40 %
ITHS	2.50	2.05	-17.92 %
ITSI	2.60	2.60	0.00 %
PROFI	2.00	3.34	67.19 %
SAFETY	1.00	1.59	59.38 %
SCHD	2.00	3.47	73.44 %

Peer Contributions

CO05	BWE	65.48 %
CO05	CONTR	71.90 %
CO05	COST	77.19 %
CO05	CUSTO	74.16 %
CO05	ITBA	67.21 %
CO05	ITHS	72.59 %
CO05	ITSI	79.33 %
CO05	PROFI	82.24 %
CO05	SAFETY	43.14 %
CO05	SCHD	79.28 %
CO37	BWE	16.67 %
CO37	CONTR	18.30 %
CO37	COST	12.28 %
CO37	CUSTO	15.73 %
CO37	ITBA	27.03 %
CO37	ITHS	10.66 %
CO37	ITSI	8.41 %
CO37	PROFI	6.54 %
CO37	SAFETY	27.45 %
CO37	SCHD	12.61 %
CO39	BWE	17.86 %
CO39	CONTR	9.80 %
CO39	COST	10.53 %
CO39	CUSTO	10.11 %
CO39	ITBA	5.76 %
CO39	ITHS	16.75 %
CO39	ITSI	12.26 %
CO39	PROFI	11.21 %
CO39	SAFETY	29.41 %
CO39	SCHD	8.11 %

Input / Output Contributions

BWE	0.00 %	Input
ITBA	0.00 %	Input
ITHS	0.00 %	Input
ITSI	100.00 %	Input
CONTR	98.44 %	Output
COST	0.00 %	Output

CUSTO	0.00 %	Output
PROFI	0.00 %	Output
SAFETY	1.56 %	Output
SCHD	0.00 %	Output

Peers

CO05
CO37
CO39

100.00% **CO39**

Peers: 0
References: 4

Potential Improvements

Variable	Actual	Target	Potential Improvement
BWE	4.00	4.00	0.00 %
CONTR	5.00	5.00	0.00 %
COST	4.00	4.00	0.00 %
CUSTO	3.00	3.00	0.00 %
ITBA	2.45	2.45	0.00 %
ITHS	3.67	3.67	0.00 %
ITSI	3.40	3.40	0.00 %
PROFI	4.00	4.00	0.00 %
SAFETY	5.00	5.00	0.00 %
SCHD	3.00	3.00	0.00 %

Peer Contributions

CO39	BWE	100.00 %
CO39	CONTR	100.00 %
CO39	COST	100.00 %
CO39	CUSTO	100.00 %
CO39	ITBA	100.00 %
CO39	ITHS	100.00 %
CO39	ITSI	100.00 %
CO39	PROFI	100.00 %
CO39	SAFETY	100.00 %
CO39	SCHD	100.00 %

Input / Output Contributions

BWE	0.00 %	Input
ITBA	82.54 %	Input
ITHS	17.46 %	Input
ITSI	0.00 %	Input
CONTR	0.00 %	Output
COST	0.00 %	Output
CUSTO	0.00 %	Output
PROFI	0.00 %	Output
SAFETY	100.00 %	Output
SCHD	0.00 %	Output

Peers

CO39

100.00% **CO40**

Peers: 0
References: 2

Potential Improvements

Variable	Actual	Target	Potential Improvement
BWE	2.40	2.40	0.00 %
CONTR	3.00	3.00	0.00 %
COST	5.00	5.00	0.00 %
CUSTO	2.00	2.00	0.00 %
ITBA	3.51	3.51	0.00 %
ITHS	1.67	1.67	0.00 %
ITSI	2.40	2.40	0.00 %
PROFI	4.00	4.00	0.00 %
SAFETY	3.00	3.00	0.00 %
SCHD	4.00	4.00	0.00 %

Peer Contributions

CO40	BWE	100.00 %
CO40	CONTR	100.00 %
CO40	COST	100.00 %
CO40	CUSTO	100.00 %
CO40	ITBA	100.00 %
CO40	ITHS	100.00 %
CO40	ITSI	100.00 %
CO40	PROFI	100.00 %
CO40	SAFETY	100.00 %
CO40	SCHD	100.00 %

Input / Output Contributions

BWE	100.00 %	Input
ITBA	0.00 %	Input
ITHS	0.00 %	Input
ITSI	0.00 %	Input
CONTR	0.00 %	Output
COST	62.50 %	Output
CUSTO	0.00 %	Output
PROFI	0.00 %	Output
SAFETY	37.50 %	Output
SCHD	0.00 %	Output

Peers

CO40

100.00% **CO_{41}**

Peers: 2
References: 0

Potential Improvements

Variable	Actual	Target	Potential Improvement
BWE	2.00	2.00	0.00 %
CONTR	3.00	3.50	16.67 %
COST	3.00	4.50	50.00 %
CUSTO	3.00	3.00	0.00 %
ITBA	4.52	3.62	-19.75 %
ITHS	2.83	2.17	-23.53 %
ITSI	2.20	2.10	-4.55 %
PROFI	3.00	3.00	0.00 %
SAFETY	3.00	3.00	0.00 %
SCHD	3.00	4.50	50.00 %

Peer Contributions

CO17	BWE	60.00 %
CO17	CONTR	57.14 %
CO17	COST	44.44 %
CO17	CUSTO	50.00 %
CO17	ITBA	48.58 %
CO17	ITHS	53.85 %
CO17	ITSI	61.90 %
CO17	PROFI	50.00 %
CO17	SAFETY	66.67 %
CO17	SCHD	44.44 %
CO26	BWE	40.00 %
CO26	CONTR	42.86 %
CO26	COST	55.56 %
CO26	CUSTO	50.00 %
CO26	ITBA	51.42 %
CO26	ITHS	46.15 %
CO26	ITSI	38.10 %
CO26	PROFI	50.00 %
CO26	SAFETY	33.33 %
CO26	SCHD	55.56 %

Input / Output Contributions

BWE	100.00 %	Input
ITBA	0.00 %	Input
ITHS	0.00 %	Input
ITSI	0.00 %	Input
CONTR	0.00 %	Output
COST	0.00 %	Output
CUSTO	33.33 %	Output
PROFI	0.00 %	Output
SAFETY	66.67 %	Output
SCHD	0.00 %	Output

Peers

CO17
CO26

64.65% **CO42** Peers: 5
References: 0

Potential Improvements

Variable	Actual	Target	Potential Improvement
BWE	2.00	2.00	0.00 %
CONTR	1.00	3.21	220.99 %
COST	2.00	3.21	60.55 %
CUSTO	1.00	2.54	154.20 %
ITBA	3.72	3.72	0.00 %
ITHS	2.00	2.00	0.00 %
ITSI	2.40	2.32	-3.23 %
PROFI	1.00	2.30	129.98 %
SAFETY	2.00	3.09	54.69 %
SCHD	2.00	3.09	54.69 %

Peer Contributions

CO03	BWE	12.11 %
CO03	CONTR	15.09 %
CO03	COST	15.09 %
CO03	CUSTO	19.06 %
CO03	ITBA	27.85 %
CO03	ITHS	18.16 %
CO03	ITSI	20.86 %
CO03	PROFI	10.53 %
CO03	SAFETY	7.83 %
CO03	SCHD	7.83 %
CO10	BWE	9.26 %
CO10	CONTR	4.44 %
CO10	COST	2.22 %
CO10	CUSTO	5.61 %
CO10	ITBA	6.34 %
CO10	ITHS	4.75 %
CO10	ITSI	5.52 %
CO10	PROFI	6.20 %
CO10	SAFETY	9.21 %
CO10	SCHD	4.61 %
CO11	BWE	2.23 %
CO11	CONTR	0.58 %
CO11	COST	1.16 %
CO11	CUSTO	0.73 %
CO11	ITBA	1.29 %
CO11	ITHS	1.39 %
CO11	ITSI	2.08 %
CO11	PROFI	0.81 %
CO11	SAFETY	1.80 %
CO11	SCHD	1.20 %
CO15	BWE	2.69 %
CO15	CONTR	3.35 %
CO15	COST	5.02 %
CO15	CUSTO	2.11 %
CO15	ITBA	6.34 %
CO15	ITHS	4.03 %
CO15	ITSI	2.77 %
CO15	PROFI	2.34 %
CO15	SAFETY	1.74 %

CO15	SCHD	6.94 %
CO17	BWE	73.71 %
CO17	CONTR	76.54 %
CO17	COST	76.52 %
CO17	CUSTO	72.49 %
CO17	ITBA	58.18 %
CO17	ITHS	71.66 %
CO17	ITSI	68.77 %
CO17	PROFI	80.13 %
CO17	SAFETY	79.42 %
CO17	SCHD	79.42 %

Input / Output Contributions

BWE	56.58 %	Input
ITBA	34.68 %	Input
ITHS	8.73 %	Input
ITSI	0.00 %	Input
CONTR	0.00 %	Output
COST	0.00 %	Output
CUSTO	0.00 %	Output
PROFI	0.00 %	Output
SAFETY	97.07 %	Output
SCHD	2.93 %	Output

Peers

CO03
CO10
CO11
CO15
CO17

90.60% **CO43**

Peers: 4
References: 0

Potential Improvements

Variable	Actual	Target	Potential Improvement
BWE	2.40	2.40	0.00 %
CONTR	3.00	3.31	10.38 %
COST	1.00	4.12	311.69 %
CUSTO	2.00	2.95	47.49 %
ITBA	3.35	3.35	0.00 %
ITHS	2.83	2.33	-17.89 %
ITSI	1.80	1.80	0.00 %
PROFI	1.00	2.85	185.48 %
SAFETY	1.00	2.77	176.80 %
SCHD	2.00	3.99	99.31 %

Peer Contributions

CO14	BWE	4.61 %
CO14	CONTR	6.07 %
CO14	COST	3.66 %
CO14	CUSTO	3.41 %
CO14	ITBA	5.40 %
CO14	ITHS	4.32 %
CO14	ITSI	6.14 %
CO14	PROFI	7.04 %
CO14	SAFETY	5.44 %
CO14	SCHD	3.78 %
CO22	BWE	40.75 %
CO22	CONTR	29.54 %
CO22	COST	23.76 %
CO22	CUSTO	33.16 %
CO22	ITBA	30.27 %
CO22	ITHS	32.70 %
CO22	ITSI	25.36 %
CO22	PROFI	22.84 %
CO22	SAFETY	35.33 %
CO22	SCHD	24.54 %
CO26	BWE	32.88 %
CO26	CONTR	44.68 %
CO26	COST	59.89 %
CO26	CUSTO	50.15 %
CO26	ITBA	54.79 %
CO26	ITHS	42.40 %
CO26	ITSI	43.84 %
CO26	PROFI	51.82 %
CO26	SAFETY	35.63 %
CO26	SCHD	61.86 %
CO39	BWE	21.77 %
CO39	CONTR	19.72 %
CO39	COST	12.69 %
CO39	CUSTO	13.28 %
CO39	ITBA	9.54 %
CO39	ITHS	20.58 %
CO39	ITSI	24.67 %
CO39	PROFI	18.30 %
CO39	SAFETY	23.59 %

CO39	SCHD	9.83 %

Input / Output Contributions

BWE	21.96 %	Input
ITBA	57.79 %	Input
ITHS	0.00 %	Input
ITSI	20.26 %	Input
CONTR	100.00 %	Output
COST	0.00 %	Output
CUSTO	0.00 %	Output
PROFI	0.00 %	Output
SAFETY	0.00 %	Output
SCHD	0.00 %	Output

Peers

CO14
CO22
CO26
CO39

99.16% **CO44**

Peers: 4
References: 0

Potential Improvements

Variable	Actual	Target	Potential Improvement
BWE	2.20	1.68	-23.61 %
CONTR	3.00	3.03	0.84 %
COST	3.00	3.87	29.14 %
CUSTO	2.00	2.50	24.79 %
ITBA	3.98	3.98	0.00 %
ITHS	1.83	1.78	-3.06 %
ITSI	1.40	1.40	0.00 %
PROFI	2.00	2.18	9.25 %
SAFETY	1.00	1.97	96.63 %
SCHD	4.00	4.03	0.84 %

Peer Contributions

CO15	BWE	9.50 %
CO15	CONTR	10.55 %
CO15	COST	12.36 %
CO15	CUSTO	6.40 %
CO15	ITBA	17.61 %
CO15	ITHS	13.47 %
CO15	ITSI	13.68 %
CO15	PROFI	7.31 %
CO15	SAFETY	8.12 %
CO15	SCHD	15.83 %
CO22	BWE	22.48 %
CO22	CONTR	12.49 %
CO22	COST	9.75 %
CO22	CUSTO	15.14 %
CO22	ITBA	9.86 %
CO22	ITHS	16.53 %
CO22	ITSI	12.59 %
CO22	PROFI	11.53 %
CO22	SAFETY	19.21 %
CO22	SCHD	9.37 %
CO26	BWE	50.41 %
CO26	CONTR	52.51 %
CO26	COST	68.34 %
CO26	CUSTO	63.65 %
CO26	ITBA	49.61 %
CO26	ITHS	59.59 %
CO26	ITSI	60.51 %
CO26	PROFI	72.70 %
CO26	SAFETY	53.86 %
CO26	SCHD	65.63 %
CO37	BWE	17.61 %
CO37	CONTR	24.45 %
CO37	COST	9.55 %
CO37	CUSTO	14.82 %
CO37	ITBA	22.92 %
CO37	ITHS	10.41 %
CO37	ITSI	13.21 %
CO37	PROFI	8.46 %
CO37	SAFETY	18.81 %

CO37	SCHD	9.17 %

Input / Output Contributions

BWE	0.00 %	Input
ITBA	35.55 %	Input
ITHS	0.00 %	Input
ITSI	64.45 %	Input
CONTR	34.50 %	Output
COST	0.00 %	Output
CUSTO	0.00 %	Output
PROFI	0.00 %	Output
SAFETY	0.00 %	Output
SCHD	65.50 %	Output

Peers

CO15
CO22
CO26
CO37

100.00% **CO45**

Peers: 0
References: 6

Potential Improvements

Variable	Actual	Target	Potential Improvement
BWE	2.60	2.60	0.00 %
CONTR	3.00	3.00	0.00 %
COST	4.00	4.00	0.00 %
CUSTO	3.00	3.00	0.00 %
ITBA	3.20	3.20	0.00 %
ITHS	2.17	2.17	0.00 %
ITSI	2.80	2.80	0.00 %
PROFI	5.00	5.00	0.00 %
SAFETY	4.00	4.00	0.00 %
SCHD	4.00	4.00	0.00 %

Peer Contributions

CO45	BWE	100.00 %
CO45	CONTR	100.00 %
CO45	COST	100.00 %
CO45	CUSTO	100.00 %
CO45	ITBA	100.00 %
CO45	ITHS	100.00 %
CO45	ITSI	100.00 %
CO45	PROFI	100.00 %
CO45	SAFETY	100.00 %
CO45	SCHD	100.00 %

Input / Output Contributions

BWE	42.87 %	Input
ITBA	57.13 %	Input
ITHS	0.00 %	Input
ITSI	0.00 %	Input
CONTR	30.14 %	Output
COST	0.00 %	Output
CUSTO	0.00 %	Output
PROFI	69.86 %	Output
SAFETY	0.00 %	Output
SCHD	0.00 %	Output

Peers

CO45

80.00% **CO46**

Peers: 3
References: 0

Potential Improvements

Variable	Actual	Target	Potential Improvement
BWE	4.60	3.80	-17.39 %
CONTR	3.00	4.00	33.33 %
COST	3.00	4.13	37.50 %
CUSTO	2.00	2.50	25.00 %
ITBA	4.02	3.50	-13.04 %
ITHS	4.33	2.37	-45.19 %
ITSI	4.20	2.95	-29.76 %
PROFI	3.00	3.75	25.00 %
SAFETY	3.00	3.75	25.00 %
SCHD	4.00	5.00	25.00 %

Peer Contributions

CO02	BWE	19.74 %
CO02	CONTR	25.00 %
CO02	COST	24.24 %
CO02	CUSTO	30.00 %
CO02	ITBA	23.52 %
CO02	ITHS	26.32 %
CO02	ITSI	20.34 %
CO02	PROFI	20.00 %
CO02	SAFETY	20.00 %
CO02	SCHD	25.00 %
CO24	BWE	69.08 %
CO24	CONTR	62.50 %
CO24	COST	60.61 %
CO24	CUSTO	50.00 %
CO24	ITBA	64.13 %
CO24	ITHS	61.40 %
CO24	ITSI	63.56 %
CO24	PROFI	66.67 %
CO24	SAFETY	66.67 %
CO24	SCHD	62.50 %
CO47	BWE	11.18 %
CO47	CONTR	12.50 %
CO47	COST	15.15 %
CO47	CUSTO	20.00 %
CO47	ITBA	12.34 %
CO47	ITHS	12.28 %
CO47	ITSI	16.10 %
CO47	PROFI	13.33 %
CO47	SAFETY	13.33 %
CO47	SCHD	12.50 %

Input / Output Contributions

BWE	28.48 %	Input
ITBA	22.92 %	Input
ITHS	24.68 %	Input
ITSI	23.92 %	Input
CONTR	0.00 %	Output
COST	0.00 %	Output

CUSTO	0.00 %	Output
PROFI	0.00 %	Output
SAFETY	0.00 %	Output
SCHD	100.00 %	Output

Peers

CO02
CO24
CO47

100.00% **CO47**

Peers: 0
References: 2

Potential Improvements

Variable	Actual	Target	Potential Improvement
BWE	3.40	3.40	0.00 %
CONTR	4.00	4.00	0.00 %
COST	5.00	5.00	0.00 %
CUSTO	4.00	4.00	0.00 %
ITBA	3.45	3.45	0.00 %
ITHS	2.33	2.33	0.00 %
ITSI	3.80	3.80	0.00 %
PROFI	4.00	4.00	0.00 %
SAFETY	4.00	4.00	0.00 %
SCHD	5.00	5.00	0.00 %

Peer Contributions

CO47	BWE	100.00 %
CO47	CONTR	100.00 %
CO47	COST	100.00 %
CO47	CUSTO	100.00 %
CO47	ITBA	100.00 %
CO47	ITHS	100.00 %
CO47	ITSI	100.00 %
CO47	PROFI	100.00 %
CO47	SAFETY	100.00 %
CO47	SCHD	100.00 %

Input / Output Contributions

BWE	100.00 %	Input
ITBA	0.00 %	Input
ITHS	0.00 %	Input
ITSI	0.00 %	Input
CONTR	0.00 %	Output
COST	0.00 %	Output
CUSTO	50.70 %	Output
PROFI	0.00 %	Output
SAFETY	0.00 %	Output
SCHD	49.30 %	Output

Peers

CO47

100.00% **CO_{48}**

Peers: 0
References: 4

Potential Improvements

Variable	Actual	Target	Potential Improvement
BWE	1.80	1.80	0.00 %
CONTR	4.00	4.00	0.00 %
COST	3.00	3.00	0.00 %
CUSTO	2.00	2.00	0.00 %
ITBA	4.17	4.17	0.00 %
ITHS	2.00	2.00	0.00 %
ITSI	2.00	2.00	0.00 %
PROFI	4.00	4.00	0.00 %
SAFETY	1.00	1.00	0.00 %
SCHD	3.00	3.00	0.00 %

Peer Contributions

CO48	BWE	100.00 %
CO48	CONTR	100.00 %
CO48	COST	100.00 %
CO48	CUSTO	100.00 %
CO48	ITBA	100.00 %
CO48	ITHS	100.00 %
CO48	ITSI	100.00 %
CO48	PROFI	100.00 %
CO48	SAFETY	100.00 %
CO48	SCHD	100.00 %

Input / Output Contributions

BWE	0.00 %	Input
ITBA	10.35 %	Input
ITHS	0.00 %	Input
ITSI	89.65 %	Input
CONTR	24.77 %	Output
COST	0.00 %	Output
CUSTO	0.00 %	Output
PROFI	75.23 %	Output
SAFETY	0.00 %	Output
SCHD	0.00 %	Output

Peers

CO48

40.91% **CO49**

Peers: 3
References: 0

Potential Improvements

Variable	Actual	Target	Potential Improvement
BWE	2.40	2.22	-7.41 %
CONTR	1.00	3.11	211.11 %
COST	1.00	4.67	366.67 %
CUSTO	1.00	2.78	177.78 %
ITBA	4.02	3.78	-6.14 %
ITHS	2.00	2.00	0.00 %
ITSI	3.00	1.93	-35.56 %
PROFI	1.00	3.11	211.11 %
SAFETY	1.00	2.44	144.44 %
SCHD	2.00	4.89	144.44 %

Peer Contributions

CO04	BWE	10.00 %
CO04	CONTR	7.14 %
CO04	COST	9.52 %
CO04	CUSTO	12.00 %
CO04	ITBA	13.10 %
CO04	ITHS	7.41 %
CO04	ITSI	10.34 %
CO04	PROFI	7.14 %
CO04	SAFETY	9.09 %
CO04	SCHD	9.09 %
CO24	BWE	42.00 %
CO24	CONTR	28.57 %
CO24	COST	19.05 %
CO24	CUSTO	16.00 %
CO24	ITBA	21.12 %
CO24	ITHS	25.93 %
CO24	ITSI	34.48 %
CO24	PROFI	28.57 %
CO24	SAFETY	36.36 %
CO24	SCHD	22.73 %
CO26	BWE	48.00 %
CO26	CONTR	64.29 %
CO26	COST	71.43 %
CO26	CUSTO	72.00 %
CO26	ITBA	65.78 %
CO26	ITHS	66.67 %
CO26	ITSI	55.17 %
CO26	PROFI	64.29 %
CO26	SAFETY	54.55 %
CO26	SCHD	68.18 %

Input / Output Contributions

BWE	0.00 %	Input
ITBA	0.00 %	Input
ITHS	100.00 %	Input
ITSI	0.00 %	Input
CONTR	0.00 %	Output
COST	0.00 %	Output

CUSTO	0.00 %	Output
PROFI	0.00 %	Output
SAFETY	11.11 %	Output
SCHD	88.89 %	Output

Peers

CO04
CO24
CO26

UNIVERSITY OF SALFORD

Research Governance and Ethics Committee

Ethical Approval Form for Post-Graduates

Ethical approval must be obtained by all postgraduate research students (PGR) prior to starting research with human subjects, animals or human tissue. A PGR is defined as anyone undertaking a Research rather than a Taught masters degree, and includes for example MSc by Research, MRes, MPhil and PhD. The student must discuss the content of the form with their dissertation supervisor who will advise them about revisions. A final copy of the summary will then be agreed and the student and supervisor will 'sign it off'.

The applicant must forward a hard copy of the Form to the Contracts Office once it is has been signed by their Supervisor and an electronic copy emailed to the Research Governance and Ethics Committee through Max Pilotti m.u.pilotti@salford.ac.uk.

(The form can be completed electronically; the sections can be expanded to the size required)

Name of student: Yahuza Hassan Kassim

Course of study: PhD in Construction Management

School: School of the Built and Human Environment

Supervisor: Dr. Jason Underwood

Research Institute: Institute for the Built and Human Environment

Name of Research Council or other funding organisation (if applicable):

1. **Title of proposed research project**

   I.T SoCA - Information Technology as Source of Competitive Advantage in Construction Industry

1b. Is this Project Purely literature based?

   YES

2. **Project focus**

   The project will focus on an investigation into IT as a source of competitive advantage within the UK construction industry.

3. **Project objectives** (maximum of three)

(b) To develop a comprehensive process oriented model to measure 'IT business value' for Construction organizations.

(c) To use the model to investigate IT as a source of competitive advantage in the construction organizations proving a basis to benchmark the IT-induced performance in construction organizations

(d) To provide a platform for investigating organisations' IT readiness and tools for monitoring continuous improvement in the deployment of IT resources in construction organisation

4. Research strategy
(For example, where will you recruit participants? What information/data collection strategies will you use? What approach do you intend to take to the analysis of information / data generated?)

The research involves a three-phase methodologically triangulated process:

The first phase involves the development of a conceptual model using hybrid of Porter's (1980; 1985) competitive advantage and competitive strategy models with organisation resource-based view and core competence approach (Barney, 1991). Using non parametric approach of Data Envelopment Analysis (DEA), the model will be used to measure the performance of the construction organization based on the identified and operationalized IT resources as inputs. The outputs will use construction performance metrics. This phase will be complemented by a comprehensive literature review in the field of IT business value, construction management and strategic management; identification and operationalization of IT resources on the construction project value chain; establishing and defining project performance metrics.

The second phase involves the validation of the model will through expert interviews as case studies to establish the details of the work activities within each main activity of the constructed value chain.

The third phase will involve empirically testing the model by collating data from sample organisations within a strategic grouping of the industry. The data collection instrument will be a 5-point likert scale questionnaire. The input variable of IT resources inform of IT investment will be measured on the basis of usage rather than the dollar value, since value depends on usage of IT and not on investment alone.

Participants will be sought from approximately 150 (working on approximately a 30% success return) large UK construction organisations which will be identified through established industry contacts/experts that are currently engaged in the area of construction IT and also have an interested in the focus of this study. Prior to their involvement, each of the identified organisations will be briefed on the overall nature and focus of the study.

5. What is the rationale which led to this project
(for example, previous work – give references where appropriate)

Despite multitude of studies on IT business value and the concept of an organisation's competitive advantage using IT-enabled strategies; there is no known model measuring the IT business value in the literature addressing the unique nature of the construction industry. Most concepts of CA in strategic management are derived with particular reference to manufacturing industries and few applied to services industry such as banks and retails. Therefore the overall aim of this research is to fill in this vacuum and contribute to literature on evaluation of IT investment in construction industry and construction management.

6. **If you are going to work within a particular organisation do they have their own procedures for gaining ethical approval**

YES

If YES – what are these and how will you ensure you meet their requirements?

Each of the construction organisations and their 'recommended' participants will be approached via the established industry contacts/experts. It is through these industry contacts/experts that ethical approval will be discussed and sought (where required) prior to their engagement.

7. **Are you going to approach individuals to be involved in your research?**

YES

If YES – please think about key issues – for example, how you will recruit people?

How you will deal with issues of confidentiality / anonymity? Then make notes that

cover the key issues linked to your study

8. **More specifically, how will you ensure you gain informed consent from anyone involved in the study?**

9. **Are there any data protection issues that you need to address?**

If YES what are these and how will you address them?

YES

It is believed that no data protection issues need to be addressed as the focus of the study is at the organisational level and complete anonymity of individuals will remain. However, along with ethical approval, this will be further discussed with each organisation to ensure that the issue of data protection is in no way contravened.

10. **Are there any other ethical issues that need to be considered? For example - research on animals or research involving people under the age of 18.**

NO

11. **(a) Does the project involve the use of ionising or other type of "radiation"**

NO

(b) Is the use of radiation in this project over and above what would <u>normally</u> be expected (for example) in diagnostic imaging?

NO

(c) Does the project require the use of hazardous substances?

NO

(d) Does the project carry any risk of injury to the participants?

NO

(e) ***Does the project require participants to answer questions that may cause disquiet / or upset to them?***

NO

If the answer to any of the questions 11(a)-(e) is** YES**, a risk assessment of the project is required.

12. How many subjects will be recruited / involved in the study/research? What is the rationale behind this number?

Based on the Data envelopment literature and the number of variables and estimated 50 construction organisations will be expected to be used as sample. Thus up to 150 may be target with questionnaires to mitigate the possible low responses.

Please attach:

- A summary in clear / plain English (or whatever media/language is appropriate) of the material you will use with participants explaining the study / consent issues etc.

  The focus of the research is to investigate the impact of IT as a source of competitive advantage within the UK construction industry. A comprehensive conceptual model to measure IT business value for construction organisations has been developed. Your participation in testing and validating the model through empirical data will provide tools:

  - to benchmark the construction organizations IT-induced performance
  - for continuous improvement in the deployment of IT resources in Construction Organisation
  - to provide a platform for investigating construction organisation IT readiness

  To this end please find enclosed ten research questionnaires for your kind response. Any personally identifiable information will be kept strictly confidential and all the data will be used only for research purposes. The outcome of the research will form part of partial fulfilment of requirements for degree of PhD. Your cooperation is highly important to the success of the project. A consent form is also attached explaining our undertaking to protecting your confidentiality and confirming your consent to participate.

- A draft consent form – again in whatever media is suitable for your research purposes / population.
- A copy of any posters to be used to recruit participants

Remember that informed consent from research participants is crucial, therefore your information sheet must use language that is readily understood by the general public.

Projects that involve NHS patients, patients' records or NHS staff, will require ethical approval by the appropriate NHS Research Ethics Committee. The University Research Governance and Ethics Committee will require written confirmation that such approval has been granted. Where a project *forms part of a larger, already approved, project, the approving REC should be informed about, and approve, the use of an additional co-researcher.*

I certify that the above information is, to the best of my knowledge, accurate and correct. I understand the need to ensure I undertake my research in a manner that reflects good principles of ethical research practice.

Signed by Student …………………………Date April 04, 2009.

In signing this form I confirm that I have read and agreed the contents with the student.

Signed by Supervisor …………………………Date …………………….

Adopted from (http://www.banxia.com/frontier/glossary.html)

Aggregate efficiency	A term used to describe the measure of efficiency from the CCR model.
Allocative efficiency	The efficiency of a production process in converting inputs to outputs, where the cost of production is minimized for a given set of input prices. Allocative efficiency can be calculated by the ratio of cost efficiency to technical efficiency.
BCC	The BCC model is the DEA model used in Frontier Analyst when a variable returns to scale relationship is assumed between inputs and outputs. It is named BCC after Banker, Charnes and Cooper who first introduced it in Charnes *et al.,* (1984). The BCC model measures technical efficiency.
Benchmarking	The process of comparing the performance of an individual organisation against a benchmark, or ideal, level of performance. Benchmarks can be set on the basis of performance over time or across a sample of similar organisations, or against some externally set standard.
Categorical variable	Categorical variables are generally used to indicate the presence or lack of a particular attribute. The use of categorical variables requires modifications to the DEA models.
CCR	The CCR (ratio) model is probably the most widely used and best known DEA model. It is the DEA model used in Frontier Analyst when a constant return to scale relationship is assumed between inputs and outputs. This model calculates the overall efficiency for each unit, where both pure technical efficiency and scale efficiency are aggregated into one value.
Composite unit	The attributes of a composite unit (which is a hypothetical efficient unit) are determined by the projection of an inefficient unit, through the origin, to the efficiency frontier. The attributes are formed from the DMU's (units) reference units, in the proportions indicated by the dual weights.
Constant returns to scale	Constant returns to scale (CRS) may be assumed if an increase in a unit's inputs leads to a proportionate increase in its outputs i.e. there is a one-to-one, linear relationship between inputs and outputs.

Controlled (discretionary) inputs	A controlled input is one over which the management of the unit has control and, as a result, can alter the amount of it used. (Controlled inputs are also sometimes referred to as discretionary inputs).
Convexity constraint	The convexity constraint, which forms part of the formulation of the BCC model, ensures that each composite unit is a convex combination of its reference units.
Correlation coefficient	A measure of the strength of the relationship between two variables. A relationship exists between two variables when as the value of one variable changes the other variable changes, in a related manner..
Cost efficiency	Cost efficiency (economic efficiency) is the ratio of the minimum cost to the actual (observed) cost
Cross efficiency matrix	A tool used to help with the identification of efficient operating practices. A unit with a high average efficiency, from a cross efficiency matrix, offers a good comparator for inefficient units to work towards.
Data Envelopment Analysis. (DEA).	Data envelopment analysis is a non-parametric technique, used for performance measurement and benchmarking. It uses linear programming to determine the relative efficiencies of a set of homogeneous units. It is a "process based" analysis, in other words, it can be applied to any unit based enterprise, regardless of whether or not a "profit" figure is involved in the evaluation.
Data set	The data set is the group of DMU's and the values of their inputs and outputs to be included in the analysis.
Decision making unit. (DMU).	Decision making unit was the name used by Charnes et al (1978) to describe the units being analyzed in DEA. The use of this term is intended to redirect the emphasis of the analysis from profit making businesses to decision making entities. In other words, the analysis which is performed can be applied to any unit based enterprise and need have nothing to do with profit.
Decreasing returns to scale. (DRS).	Decreasing returns to scale. (DRS). Decreasing returns to scale are operating when an increase in a unit's inputs result in a less than proportionate increase in its outputs.
Dual model	The dual model and the primal model provide two ways of looking at the same problem and the efficiency scores calculated are the same with both. Mathematically, the dual model is much faster to solve.
Dual weights (l)	The dual weights (l) - so called because they are calculated using the dual model and sometimes also called dual multipliers - give an indication of the importance given to a particular unit in determining the input/output mix of the

	composite unit.
Effectiveness	Degree to which the outputs of a service provider achieve the stated objectives of that service — for example, the extent to which hospitals are meeting the demand for non-elective surgery. In the case of government service providers, the government normally sets such objectives.
Efficiency	Degree to which the observed use of resources to produce outputs of a given quality matches the optimal use of resources to produce outputs of a given quality. This can be assessed in terms of *technical efficiency* and *allocative efficiency*.
Efficient/ efficiency frontier	The efficiency frontier is the frontier (envelope) representing "best performance" and is made up of the units in the data set which are most efficient in transforming their inputs into outputs. The units that determine the frontier are those classified as being 100% efficient.
Efficiency score	DEA results in each unit being allocated an efficiency score. This score is between zero (or 0%) and 1 (100%). A unit with a score of 100% is relatively efficient. Any unit with a score of less than 100% is relatively inefficient.
Efficiency study	The process of studying efficiency within an organisation.
Envelopment form	This term is used to describe the formulation of a DEA model which involves the concept of composite units.
Epsilon (ε)	Epsilon is a very small positive constant (circa 10^{-6}) which is a non-Archimedean variable. Epsilon is a theoretical-mathematical device to allow driving slack variable values to zero, without adding or subtracting any "real" amount to the objective function.
Environmental factor	An environmental factor is neither an economic resource nor a product but rather an attribute of the environment in which the units operate.
Facet	Each of the segments which make up the efficient frontier is known as a facet. Generally, where efficient units make a reference set, they are located on the same facet. Facet and reference set refer to the same concept.
Global leader	A global leader will act as a model of good operating practice for inefficient units. Oral and Yolalan (1990) define a global leader as an efficient unit which appears most frequently in the reference set for inefficient units.
Homogeneous	A DEA study requires a set of homogeneous units. Homogeneity refers to the degree of similarity between units. The operational goals of the units should be similar, as should their operational characteristics.

Increasing returns to scale	Increasing returns to scale exist when an increase in a unit's inputs yields a greater than proportionate increase in its outputs.
Inefficient unit	An inefficient unit is one which, when compared with the actual performance achieved by other units in the analysis, should be able to produce its current level of outputs with fewer inputs or generate a higher level of outputs given the same inputs.
Inputs	An input is any resource used by a unit to produce its outputs (products or services). This can include resources which are not a product but are an attribute of the environment in which the units operate. They can be controlled or uncontrolled.
Input minimization	Input minimization is the DEA mode adopted when the analysis tries to minimize the amount of inputs used to produce the specified outputs.
Input orientated	Input orientated is a term used in conjunction with the BCC and CCR ratio models, to indicate that an inefficient unit may be made efficient by reducing the proportions of its inputs but keeping the output proportions constant. (Note: the CCR model will yield the same efficiency score regardless of whether it is input or output orientated. This is not the case with the BCC model).
Input/output mix	The term "input/ output mix" refers to the relative proportions of a unit's inputs and outputs.
Intensity factor. (Z).	In the dual model the scalar, Z, is the intensity factor. The intensity factor indicates the proportional reduction in inputs (when using input minimization) or the increase in outputs (if using output maximization) to achieve efficiency.
Linear program	A set of linear mathematical equations for which a solution can be obtained subject to an upper bound (maximization) or a lower bound (minimization).
Local returns to scale	Local return to scale describes what happens to units outputs when the input levels are changed.
Most productive scale size. (MPSS).	The most productive scale size of an efficient unit refers to the point (on the efficient frontier) at which maximum average productivity is achieved for a given input/ output mix. At MPSS constant returns to scale are operating. After reaching MPSS, decreasing returns to scale set in.
Multiplier form	Associated with both the BCC and CCR models the multiplier form is both a primal and a dual formulation. The multiplier form of DEA model formulation involves virtual multipliers (see Ali and Seiford 1993).

Ordinal variable	A special type of categorical variable where the factor takes on a predefined set of values ranked in a specific order.
Outlier	An outlier (some times in statistics referred to as an "obscene outlier") is a unit whose input/output mix differs significantly from the other units in the data set. Where an outlier is found to be efficient, it may introduce bias into the results.
Output	Outputs are the products (goods, services or other outcome) which result from the processing and consumption of inputs (resources). An output may be physical goods or services or a measure of how effectively a unit has achieved its goals.
Output maximization	Output maximization is the DEA mode adopted when the analysis tries to maximize the outputs produced for a fixed amount of inputs. (The opposite of output maximization is input minimization).
Output orientated	Output orientated is a term used in conjunction with the BCC and CCR ratio models, to indicate that an inefficient unit may be made efficient by increasing the proportions of its outputs while keeping the input proportions constant.
Peer group	Another name for a Reference Set
Primal (CCR) model	The primal model is that referred to by Charnes et al 1978. The primal model allows a set of optimal weights to be calculated for each variable (input and output) to maximize a unit's efficiency score. The weights are such that were these weights applied to any other unit in the data set the efficiency score would not exceed 1 (or 100%).
Production function	The production function describes the optimal relationship between inputs and outputs with the aim of maximising output for the given inputs. In DEA the equivalent of the production function is the efficiency frontier.
Productive efficiency. (Efficiency).	Productive efficiency is a measure of a unit's ability to produce outputs from a given set of inputs (Norman and Stoker. 1991). The efficiency of a DMU is always relative to the other units in the set being analysed, so the efficiency score is always a relative measure. A unit's efficiency is related to its radial distance from the efficient or efficiency frontier.
Productivity	In the case of a process with a single input and a single output, productivity is the ratio of the unit's outputs to its inputs. DEA does not measure productivity; it measures the efficiency of the production process. Productivity is a function of production technology, the efficiency of the production process and the production environment.
Radial measure	Both the BCC and CCR ratio models use a radial or

	proportional measure to determine a unit's efficiency score. A unit's efficiency is defined by the ratio of the distance from the origin to the inefficient unit, divided by the distance from the origin to the composite unit on the efficient frontier.
Ratio models	Both the BCC and CCR models are called ratio models because they define efficiency as the ratio of weighted outputs divided by weighted inputs.
Reference contribution	Reference contribution indicates the degree to which a reference unit contributes to the calculation of the efficiency score for a unit.
Reference set	The reference set of an inefficient unit is the set of efficient units to which the inefficient unit has been most directly compared when calculating its efficiency rating. It contains the efficient units which have the most similar input/output orientation to the inefficient unit and should therefore provide examples of good operating practice for the inefficient unit to emulate.
Results	Having conducted an analysis, the DEA model will produce, for each unit, an efficiency score, virtual multipliers, intensity factors, the dual weights and the slacks. From these are calculated the virtual inputs and virtual outputs, the reference sets and improvement targets for each unit.
Scale efficiency	Scale efficiency A unit is "scale efficient" when its size of operation is optimal. If its size of operation is either reduced or increased its efficiency will drop. A scale efficient unit is operating at optimal returns to scale.
Slack(s)	Slack represents the under production of output or the over use of input. It represents the improvements needed to make an inefficient unit become efficient. These improvements are in the form of an increase/decrease in inputs or outputs.
Surrogate measures	Surrogate measures are used to represent factors such as environment factors, for example a "score" for the type of neighbourhood in which a unit operates, or the achievement of an organizational goal (which does not have a statistically quantifiable outcome) and so on.
Targets	The values of the inputs and outputs which would result in an inefficient unit becoming efficient.
Technical efficiency	A unit is said to be technically efficient if it maximizes output per unit of input used. Technical efficiency is the efficiency of the production or conversion process and is calculated independently of prices and costs. Technical efficiency is calculated using the BCC model. The impact of

	scale size is ignored as DMU's are compared only with units of similar scale sizes.
Total factor productivity (TFP)	Ratio of the quantity of all outputs to the quantity of all inputs. TFP can be measured by an index of the ratio of all outputs (weighted by revenue shares) to all inputs (weighted by cost shares).
Uncontrolled (exogenously fixed) inputs/ outputs	An uncontrolled or uncontrollable variable (input or output) is one over which the unit's management does not have control and hence cannot alter its level of use or production. An example of an uncontrolled input for a retail outlet would be the number of competitors it had in its area. Uncontrollable variables are also referred to as exogenously fixed and non-discretionary variables.
Unit	A "unit" is a short form for "decision making unit" or "DMU". Units may refer to construction organisations. DEA can be applied to any unit based process.
Variable	Variables are the input and output factors identified as being of particular importance to the operation of the units under consideration.
Variable returns to scale	If an increase in a unit's inputs does not produce a proportional change in its outputs then the unit exhibits variable returns to scale (VRS). This means that as the unit changes its scale of operations its efficiency will either increase or decrease.
Virtual input/output	Virtual inputs are calculated by multiplying the value of the input with the corresponding optimal weight for the unit as given by the solution to the primal model. Similarly for virtual outputs. Virtual inputs/ outputs define the level of importance attached to each factor. The sum of the virtual inputs for each unit always equals 1. The sum of the virtual outputs is equal to the unit's efficiency score.
Virtual multipliers	Another term used to describe weights.
Weight flexibility. (Weighting/ User defined weights).	The CCR (primal) model does not place any restrictions on the weights in the model, other than a minimum (lower bound) on epsilon, as a result it is possible for units to be rated as efficient through a very uneven distribution of weights.
Weights	Within DEA models weights are the 'unknowns' which are calculated to determine the efficiency of the units. The weights are calculated to solve the linear program, in such a way that each unit is shown in the best possible light.
Window analysis	Window analysis is a tabular method which allows an analysis of efficiency changes over time. The user chooses a set of time periods and then calculates the efficiency of each

unit for each time period. The efficiency of a given unit over each of the time periods is treated as a new unit.

Not Used