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GORDON INSTITUTE OF BUSINESS SCIENCE

The role of Six Sigma in improving financial performance

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A research project submitted to the Gordon Institute of Business Science, University of Pretoria, in partial fulfilment of the requirements for the degree of Master of Business Administration.

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i. Abstract

As the rise of globalisation continues to pressurise companies to improve performance, there is a lot of hype surrounding Six Sigma's abilities to do so. After all, for managerial techniques to be credible, they need to improve profit. It is therefore concerning that to date only one empirical study examines the role of Six Sigma on performance and it finds mixed empirical results. This study aims to replicate the preceding study over a more recent time period and include the impact of sector on performance.

This study examined 43 Six Sigma firms listed in the United States and their financial results for a four year period from 2004 to 2007, compared to 43 homogenous firms that formed a control group. The results for five operational and five financial measures were tested using analysis of covariance to see whether, given equal initial levels of the measure, the Six Sigma firm would outperform the control firm after four years.

The main contribution of this study is to show how little Six Sigma contributes to financial and operational performance overall. Companies looking to implement a Six Sigma initiative should be cognisant of this before investing in high initial investment costs.

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ii. Declaration

I declare that this research project is my own work. It is submitted in partial fulfilment of the requirements for the degree of Master of Business Administration at the Gordon Institute of Business Science, University of Pretoria. It has not been submitted before for any degree or examination in any other University. I further declare that I have obtained the necessary authorisation and consent to carry out this research.

Bridget Moore

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iii. Acknowledgements

Writing this thesis proved to be challenging and rewarding, and especially tested my ability to keep momentum over a lengthy period of time. I received encouragement and wisdom from numerous sources and would like to thank them for their efforts.

The individuals who contributed in various ideas, discussions and support along the process are too numerous to name, but I would specifically like to make mention of the following people, who I thank dearly for their help:

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- Adrian Saville for his help regarding the selection of comparison companies.
- My colleagues, friends and family for supporting me every step of the way during my MBA, even when my moods and stress levels left much to be desired.
- Everyone I interacted with during my time at GIBS. You encouraged me to push the boundaries while standing close by. Werner Erhard said that “mastering life is the process of moving from where you are to where you want to be” and I would not be where I am today without you.

iv. Dedication

I would like to dedicate this research to my grandparents, the last two of whom past away during the course of my MBA. My boss, Lance Smith, related a story to me of his grandmother warning him to look after his eyes and ears. She went on to tell him that as an old woman, material things were no longer important, but she needed her eyes and ears to keep her close to people and that was the most important thing at that age, and in fact at any age. My grandparents not only imparted great wisdom to me, they set high standards by their principles and by how they modelled their love of life in their everyday activities. I will miss them all dearly.

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1. Chapter 1: Introduction to Research Problem

1.1. Introduction

This chapter introduces the evidence regarding the research problem, defines the constructs contained within the title and discusses what the research will cover in terms of scope. It then describes what the research will aim to accomplish and finally motivates why this research is needed.

The first section describes the research problem that exists by reviewing the main evidence concerning the role of Six Sigma in improving financial performance and highlighting where calls have been made for additional research. The second section then describes the area of research that this problem falls under by dissecting the title to define the constructs that are contained within it, namely performance improvement, financial performance and Six Sigma.

The third section elaborates about the specific areas that the research will and will not cover within these constructs. Since the unit of analysis for the research is a firm, this section describes the location, industry, nature and size of firms that are applicable to the research, before examining the effect of subjectivity on the scope of the research. An outline of what this research aims to achieve within the scope follows in section four, which elaborates on the specific objectives of the research. Finally, motivation is given for the use of the research at the individual, company and national level before concluding this introductory chapter on the research problem.

1.2. Research Problem

The rise of globalisation has meant that companies need to operate with higher costs and lower prices, which in turn has led to managing the cost of quality becoming more critical for them (Feigenbaum, 2008). The proof of validity for a managerial technique is its ability to improve profit (Freiesleben, 2006) and "every quality initiative gained its legitimacy by linking its use to increased profits" (Townsend and Gebhardt, 2005, p. 29).

Despite the above theoretical argument, historically quality management programmes have been accused of focusing too much on operational performance and of ignoring financial performance (Foster, 2007; Gupta, 2004; Pande *et al*. 2000). Due to the size of the financial resources required to implement quality management programmes, more recent initiatives have shifted their focus to ensure sufficient financial returns (Breyfogle, 2003).

Six Sigma is growing rapidly and it is also "probably the most widely used methodology for improving human performance and is increasingly popular as a way of organizing an entire company to become more customer focused and more quality conscious" (Harmon, 2003, p.1). Six Sigma is one of the more recent quality initiatives that incorporate techniques aimed at financial performance (Wiklund and Wiklund, 2002). However, despite this new emphasis, there remains a lack of empirical research supporting the statement that quality management programmes lead to improved financial returns (Foster, 2007; Freiesleben, 2006).

Freiesleben (2006) describes how authors assert that quality results in improved financial performance without appropriate empirical evidence and calls for additional research in this regard. In fact, Foster (2007) finds that prior to his study no empirical research investigated the relationship between Six Sigma implementation and financial results. Foster (2007) in turn calls for industry specific research into the effects of Six Sigma adoption in order to better isolate the effects of Six Sigma. This study will aim to investigate whether research at an industry level provides different results to those of Foster (2007).

1.3. Title and Definitions of Constructs

After having described the need for the research as indicated in the literature, this section will now describe the title and the constructs contained within the title in order to explain the area that the research falls into.

The title of the research project is: “The role of Six Sigma in Improving Financial Performance”.

The above title can be broken into the following terms, each of which forms a topic of this research: **Six Sigma, Performance Improvement** and **Financial Performance**. These main topics are defined below and will be explored in more detail in the literature review presented in Chapter 2.

1.3.1. Performance Improvement

Performance improvement is defined the achievement of accomplishments that are better than historic performance (BusinessDictionary.com, 2008). Quality management is a philosophy and process to improve performance across the organisation (Pycraft *et al*, 2005). In chapter 2, and the rest of this study, quality management will be examined as a form of performance improvement. Chapter 2 will discuss the evolution and expansion of this discipline until the point of being widely known for covering performance improvement.

1.3.2. Financial Performance

Financial performance is defined as maximising the value of the shares in the business or the market value of the existing owners' equity. In order to improve financial performance, decisions need to be weighed up based on the effect they will have on financial performance (Firer *et al*, 2004). Various other definitions and their associated measures of financial performance will be discussed in Chapter 2.

1.3.3. Six Sigma

Six Sigma is the most popular quality improvement methodology in history (Eckes, 2001). Six Sigma Quality is defined as a “well controlled process that is six sigma from the centreline of a control chart; thus, no defects within six standard deviations at the target level of performance. It translates into 0.00034 percent defects (3.4 defects per million) or, in practical terms, zero defects” (BusinessDictionary.com, 2008). Six Sigma is based on the premise that companies require consistently higher quality at lower cost and that a disciplined approach that examines root causes will reduce variance, waste and errors (Hammer 2002).

1.4. Research Scope

The area of research as indicated in the previous section will now be broken down further by drawing the boundaries that determine what this study will include and exclude. The scope of this research and the associated implications for practitioners will be examined under the categories of physical location, industry, nature and size of company and then subjectivity of the research.

1.4.1. Physical location

Although this study is being conducted in South Africa, international companies will be studied due to the relative immaturity of Six Sigma implementations locally. This should not prevent the findings from being applied in a South African context, because Six Sigma is defined above as a disciplined approach to quality.

This definition implies that Six Sigma's implementation and success is not geographically or culturally dependent. The results of this research should therefore be of interest to companies across locations.

The applicability of this research is important for South African firms for the following reasons:

- Although Six Sigma is immature in South Africa compared to elsewhere, it looks set to grow internationally as the growing interest in publishing articles is a reflection of the interest in Six Sigma applications in business (Hoerl *et al*, 2004).
- Due to the newness of the phenomenon, case studies and other comparisons of South African firms cannot be made.
- A greater understanding of which aspects of financial performance Six Sigma improves, will enable firms to target their initiatives towards these areas.

1.4.2. Industry

Six Sigma can be successfully applied across industry sectors and is applicable to both service and manufacturing industries (Jugulum and Samuel, 2008). Foster (2007) calls for industry specific research into the effects of Six Sigma adoption, so this research will examine firms within the health, technology, basic materials and capital goods sectors as many Six Sigma firms were found within these sectors.

1.4.3. Nature and Size of Company

This study requires the measurement of financial results that can be verified and then compared across Six Sigma and non-Six Sigma companies. Due to the availability of this information, the scope of this study is limited to listed companies. Whilst no constraint regarding the size of company has been identified, it is assumed that listed companies will be relatively large in size.

1.4.4. Subjectivity

Whilst every effort has been made to keep this study objective and to examine the theory from a broad base, the scope has been influenced by the subjectivity of the author who works in the field and therefore has certain pre-existing mental models.

The study is therefore limited in some way to the pre-existing mental models of the author and consequently the aspects that appealed to her under each topic. In addition, much of the literature is not in the public domain due to the theoretical competitive benefits of Six Sigma. This restricted the author's access to material. Practitioners should therefore supplement their reading with additional material.

Having described the evidence that a problem exists and the area that this problem falls under in previous sections, followed by the scope of what this particular study will cover in this section, the remainder of this chapter will describe the research aim and objectives and motivate why the research is important.

1.5. Research Aim and Objectives

The purpose of the study is to investigate the role of Six Sigma in improving financial performance. In order to achieve this purpose, the research will aim to answer the following fundamental question:

- **Does Six Sigma improve financial performance?**

This aim will be accomplished by replicating and extending Foster's (2007) study to examine whether, during a more recent timeframe and taking into account the effect of industry on results, firms that have implemented Six Sigma have financial performance superior to firms that have not implemented Six Sigma. Freiesleben (2006) postulates that any managerial technique's proof of validity is its ability to improve profit.

The research question can be broken down into the following research objectives:

- Objective 1: To determine whether there is a positive relationship between Six Sigma adoption and improved financial performance.

Financial performance measures need to be determined in order answer this research question. Although all of these measures are financial and can be determined from the financial statements, they can be subdivided into measures about financing or cash and measures about operations or assets and investment.

- Objective 1 a): To determine whether there is a positive relationship between Six Sigma adoption and improved operating margins in the financial results.

  Six Sigma involves process improvements as well as aggressive cost reduction which will lead to improved operating margins and also free up cash for other uses (Foster, 2007). Improved operating margins can be measured by:

  - Increased free cash flow per share
  - Decreased cost per US dollar of sales
  - Increased EBITDA
  - Increased sales
  - Increased sales per employee

- Objective 1 b): To determine whether there is a positive relationship between Six Sigma adoption and improved operational performance in the financial results. Operational performance can be divided into the use of assets and the use of employees.

Six Sigma involves improving the use of assets and hence it should increase the productivity of those assets (Foster, 2007). In terms of assets, operational performance can be measured by:

- Increased asset turnover
- Increased return on assets
- Increased return on investment
- Increased total assets

Operational performance also includes employees. The second part of this sub-objective is to determine whether Six Sigma has a relationship with the number of employees. This relationship is uncertain because Six Sigma could help to grow the number of employees as profitability improves, but it could also result in downsizing due to the more productive use of employees (Foster, 2007). In terms of employees, operational performance can be measured by:

- Either increased or decreased numbers of employees

1.6. Research Motivation

Now that a clear description of the research has been outlined, the concluding section of this introductory chapter serves to motivate the potential use of this research from an individual, corporate and national perspective.

1.6.1. Use by Individuals

It is hoped that the results of this research will be of interest to individuals and practitioners who are interested in adopting Six Sigma. This research will help them to:

- Understand the Six Sigma methodology
- Successfully implement Six Sigma in areas that are likely to add the most value in terms of performance.
- Maximise return on investment by effectively integrating people, processes and knowledge as outlined by the Six Sigma methodology.
- Be aware of potential pitfalls of Six Sigma implementation.
- Decide on careers in Six Sigma compared to other managerial techniques.

1.6.2. Use by Companies

Investigating the effectiveness of Six Sigma in improving financial performance is more relevant today than ever before due to rapid change. Firms are faced with "a new competitive landscape" (Hitt *et al*, 1998, p. 22) due to globalisation, technological revolution, fewer distinctions between product and service sectors, the elimination of industry boundaries, intense foreign competition and advances in logistics and communication. This results in a highly turbulent environment of uncertainty and hyper-competition which is characterised by a focus on price, quality, customer satisfaction and innovation (Hitt *et al*, 1998). Additional evidence of this is that "product life cycles are getting shorter, customer expectations are changing, and technology and globalisation are rewriting the basis for competition" (Jugulum and Samuel, 2008, p. 15).

In order to continue to grow and develop shareholder value, companies need to ensure that they identify new opportunities, create new customer promises and deliver flawlessly to keep them ahead of the competition (Jugulum and Samuel, 2008). Chang and Kelly (1994) espouse that being competitive, through efficiently and effectively meeting customer demands in a fast changing world, is a moving target. With ongoing and quicker changes in "technology, production techniques, delivery methods and shifts in customer preferences," (Chang and Kelly, 1994, p. 1) the above statement holds even more weight today than when it was written just over a decade ago.

Firms require a future oriented management focus and continuing evaluation and analysis if they are to respond effectively to the changing and intensely competitive global environment. They must position themselves to respond proactively to a future course as well as achieve the necessary ability to survive in their current environment (Coyle, Bardi and Langley, 2003).

In theory, Six Sigma will help to achieve this as it enables companies to strive for perfection and to improve their performance. Six Sigma principles emphasise defining, measuring and analysing the current system to improve or perfect it (Jugulum and Samuel, 2008). However Six Sigma is costly to implement and there is little empirical evidence to show that it improves performance (Foster, 2007). The results of this research will therefore be of use to companies in the process of deciding whether to invest in a quality management programme.

1.6.3. Use by Nations

Management tools that apply to companies are equally applicable to nations (Kelley and Littman, 2008); however their goal changes from financial performance to economic performance. Economic development leads to political development, because as people express a need for products this forces politicians to agree on policies that will encourage further economic development (Hitt *et al*, 1998).

In a free market, customers will reward quality with profit in both the marketplace and the stock market; however international politics and governmental policies, such as subsidies, distort environments. Governments can create greater economic prosperity by encouraging continual improvement instead of interfering in the free market (Townsend and Gebhardt, 2005). This research will therefore be of use to nations investigating how to unlock economic performance.

1.7. Concluding Remarks

As globalisation continues to increase competition, it is important to be able to quantify the role that Six Sigma can play in improving performance at both a micro and macro level. In addition, this research is of personal interest to the author whose company is currently rolling out Six Sigma as a strategic initiative.

The role of Six Sigma in improving financial performance covers the constructs of performance improvement, financial performance and Six Sigma. By combining the definitions of each of these constructs, the research examines the role of a disciplined approach that examines the root causes of defects in achieving better market value of owners' equity than historic performance.

This role is examined through the lens of listed Six Sigma companies that operate within the health, technology, basic materials and capital goods sectors in the United States as they have verifiable results and are seen as a large and mature enough sample to generate significant results. The research is needed because literature states that Six Sigma aims to overcome previous quality programmes that did not focus enough on ensuring financial performance (Breyfogle, 2003; Wiklund and Wiklund, 2002; Foster 2007); however Foster (2007) provides the only empirical evidence that investigates this aim and he finds mixed results. This study extends Foster's (2007) work by examining the same profitability, cost, efficiency and growth measures over a more recent time period.

The results of this research will help practitioners by providing information on how well Six Sigma improves performance and in which sectors and areas. It will also help companies and nations to decide whether to invest in Six Sigma as a competitive weapon that will unlock economic performance.

2. Chapter 2: Literature Review

2.1. Introduction

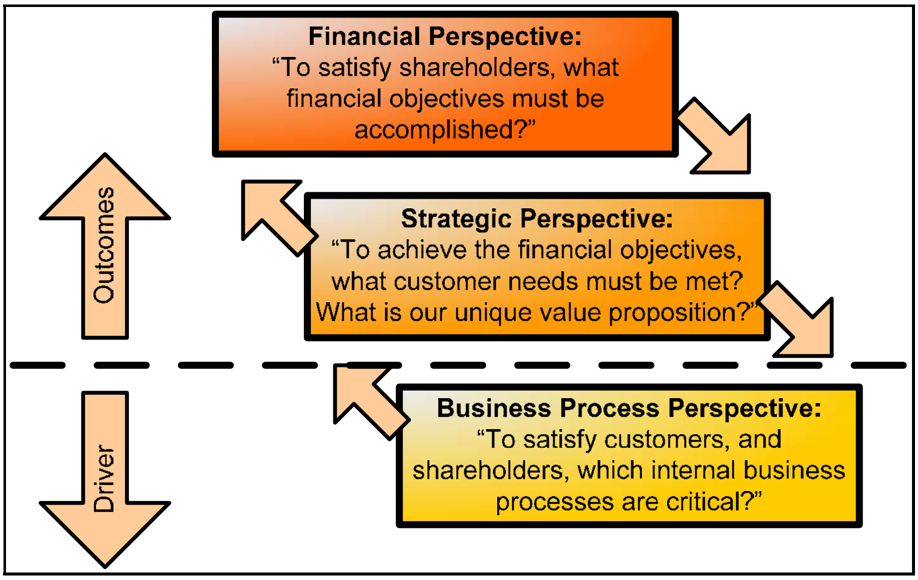
Chapter one provided an introduction to the research problem and the three themes contained within it, as well as some initial evidence of the problem. Following on from those main themes, this section will review the latest literature and the main debates surrounding the research problem.

The literature review is comprised of five main sections. The first three position where the last two main sections fit within management theory. This is based on the value-creation hierarchy of Jugulum and Samuel (2008) as shown in Figure 1.

Firstly, financial performance is described as the goal of an organisation and the goal of management approaches. Companies set financial objectives in order to create wealth for shareholders (Jugulum and Samuel, 2008). Secondly, these objectives are achieved by using strategy to create unique value for customers (Jugulum and Samuel, 2008). Financial performance and strategy are the outcomes of the firm.

The third section describes performance improvement, because this is used to create and sustain critical business processes. A performance process itself is described. Sections four and five form the main area of this research. Section four describes the performance improvement technique of quality management and section five describes Six Sigma as a quality management methodology.

Figure 1: Organisational value-creation hierarchy (Source: Adapted from Jugulum and Samuel, 2008, p. 74).



In summary, Six Sigma forms part of quality management which forms part of improving the performance of business processes. This in turn drives strategy through improving conformance to customers' expectations, which ultimately drives financial performance.

Sections four and five then examine the literature along the following dimensions, which are based on the structure used in Brady and Allen's (2006) review of Six Sigma literature. The discipline is defined, before looking at its evolution. Advantages and limitations are then discussed, before describing the current debates, including whether these disciplines improve performance. Finally, views on what the future holds for these disciplines are described.

Each section aims to leave the researcher with enough background to be able to develop a conceptual model of whether Six Sigma improves performance and, if so, why and how Six Sigma is seen to be able to improve performance. The literature review concludes with a discussion that integrates these sections into a conceptual model of the role of Six Sigma on performance.

2.2. Financial performance as the goal of a company

2.2.1. Definition of financial performance

BusinessDictionary.com (2008) defines financial performance as “measuring the results of a firm's policies and operations in monetary terms”. This definition can be expanded by stating the goal of financial performance, which should encompass risk control and should not be influenced by the trade-off between current and future profits. Finally, a complete definition should also state the recipient of the goal, which is important as agency theory describes how the potential conflict of interest between the firm’s shareholders and its management (Firer *et al*, 2004).

For the purposes of this study, financial performance is defined as:

- Maximising the value of the shares in the business, or
- Maximising the market value of the existing owner’s equity.

The reason for the two definitions is based on whether or not the business is listed (Firer *et al*, 2004). Graves and Waddock (2000) define this distinction as either looking at market or accounting-based measures.

2.2.2. Financial performance measures

Financial management consists of identifying the key growth and value drivers of the business and understanding how a change in any one of them can affect the others (Ward and Price, 2006). In order to improve financial performance, decisions need to be weighed up based on the effect they will have on these important measures of financial performance (Firer *et al*, 2004).

It is therefore necessary to examine the measurements of financial performance in order to be able to determine whether the end goal of financial performance has been achieved. However traditional financial statements are seldom drawn up in a way that aids decision making or that gives a measure of performance that correlates with the value of the business and this can lead to managers setting the wrong goals or performance measures (Ward and Price, 2006). It is therefore important to evaluate financial measures. This is done in Table 1 which describes the definition of various measures of financial performance, together with their most important uses.

Table 1: Financial and operational performance measures.

Measure	Definition	Use
Free Cash Flow per Share (or cash flow from operating activities per share)	Cash flow from profit (sometimes less capital expenditures) divided by the number of issued shares or common stock (Tracy and Barrow, 2004).	Unaffected by the depreciation method, the effects of the sale of assets and the capital structure of the firm (Hendricks and Singhal, 1997). However, because the value of a share fluctuates, cash flow return on investment (CFROI) is sometimes seen as a better measure (Madden, 1999).
Cost per Dollar of Sales	Total costs divided by revenue (Hendricks and Singhal, 1997).	Indicates the efficiency of the sales operation (Hendricks and Singhal, 1997).
EBITDA - Earnings before Interest, Taxes, Depreciation and Amortisation	Sales revenue less cost of goods sold and operating expenses but before deducting interest on debt, tax expenses, depreciation or amortisation expenses (Tracy and Barrow, 2004).	A useful measure of profitability that is unaffected by the particular accounting treatment used when dealing with the depreciation or sale of assets (Hendriks and Singhal, 1997) thus aiding the comparison of figures across a selection of firms.
Total Sales	Revenue for the year. It is strictly what belongs to the business and doesn't include money that anyone else can claim (for example, VAT that the business collects and then remits (Tracy and	The level of sales can act as a proxy for the degree to which the public value a firm's product, with improved sales indicative of a better product (Hendricks and Singhal, 1997).

Measure	Definition	Use
	Barrow, 2004).	
Sales per Employee	Sales revenue divided by the number of employees.	An alternative means of measuring sales that enables comparison across firms of varying size (Hendriks and Singhal, 1997).
Asset Turnover Ratio	Revenue divided by either total assets or net operating assets (total assets less short-term non-interest-bearing liabilities) (Tracy and Barrow, 2004).	A measure of how effectively assets were used during a period. As with sales per employee, this measure allows for the easier comparison of figures across firms of varying size (Hendriks and Singhal, 1997).
Return on Investment (ROI)	ROI is a general term, but one of the most relevant ROI ratios is Return on Equity (ROE), which is net income as a percentage of the total book value of owners' equity (Tracy and Barrow, 2004). For the purposes of this study, return on equity (ROE) will be used as the ROI ratio.	"ROE is the basic measure of how well a business is doing in providing 'compensation' on the owners' capital investment in the business" (Tracy and Barrow, 2004, p. 351).
Return on Assets (ROA)	Earnings before interest and taxes (EBIT) as a percentage of net operating assets (or total	Measures the degree to which a firm has been able to use its assets to create value (Hendriks and Singhal, 1997).

Measure	Definition	Use
	assets, for convenience) (Tracy and Barrow, 2004).	
Total Assets	Fixed or long term assets such as land, buildings, machinery, equipment, tools, and vehicles plus current assets such as cash and cash equivalents (Tracy and Barrow, 2004).	Shows the economic resources being used in business (Tracy and Barrow, 2004).
Number of Employees	The average number of employees in an organisation over the period of study.	

Financial performance has been described in this section as the goal of the firm. This study will now examine strategy, the discipline that leads to financial performance.

2.3. Strategy underpinning financial performance

2.3.1. Definition of strategy

An academic and practical interest in the relationship between quality management and strategy has resulted from quality increasingly being viewed as a strategic source of competitive advantage (Jabnoun *et al*, 2003).

Chandler (1962) defines strategy as “the basic long term goals and objectives of an enterprise, and the adoption of courses of action and the allocation of resources necessary for carrying out these goals”. Mintzberg (1973) adds that strategy should include both the organisation’s goals and an action plan to achieve them.

Porter (1991) views the question of strategy as central to why firms succeed or fail. This question originates from his broader underlying theory of the firm and its associated theory of strategy (Porter, 1991). The foundation for a dynamic theory of strategy must rest on a body of theory that links firm performance to market outcomes, in order to discriminate between good and bad performance. A successful firm attains a competitive position that leads “to superior and sustainable financial performance” (Porter 1991, p. 96).

The definitions of financial performance taken with the above overview of strategy shows how these concepts are conceptually linked. Whilst financial performance is largely post hoc, strategy looks to a firm’s future direction. However both strategy and financial performance are driven by the underlying business processes.

2.3.1.1. Porter’s dynamic theory of strategy

Porter (1991) describes the three conditions of firm success. A company must develop internally consistent and functionally aligned goals and policies that determine that firm’s position in the market.

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Then, these goals and policies must be aligned to internal strengths and weaknesses and to external opportunities and threats. Finally, to be effective, this strategy must create and exploit the firm's distinctive competencies (Porter, 1991).

Porter (1991) breaks a firm's success into the firm's industry attractiveness and the relative position of the firm within that industry using his five forces model. Beard and Dess (1979, 1981) found that industry profitability could predict firm profitability considerably more than relative market share, relative debt/equity ratio and relative capital intensity. Industry profitability has also been found to predict firm profitability more than changes in leadership or general economic factors (Dess *et al*, 1990). However, McGahan and Porter (2002) built on their previous work and found that the business specific effects which arise from competitive positioning are the most significant determinant of profitability, followed by both industry and corporate-parents as well as the interactions between these effects.

2.4. Performance Improvement

2.4.1. Definition of Performance Improvement

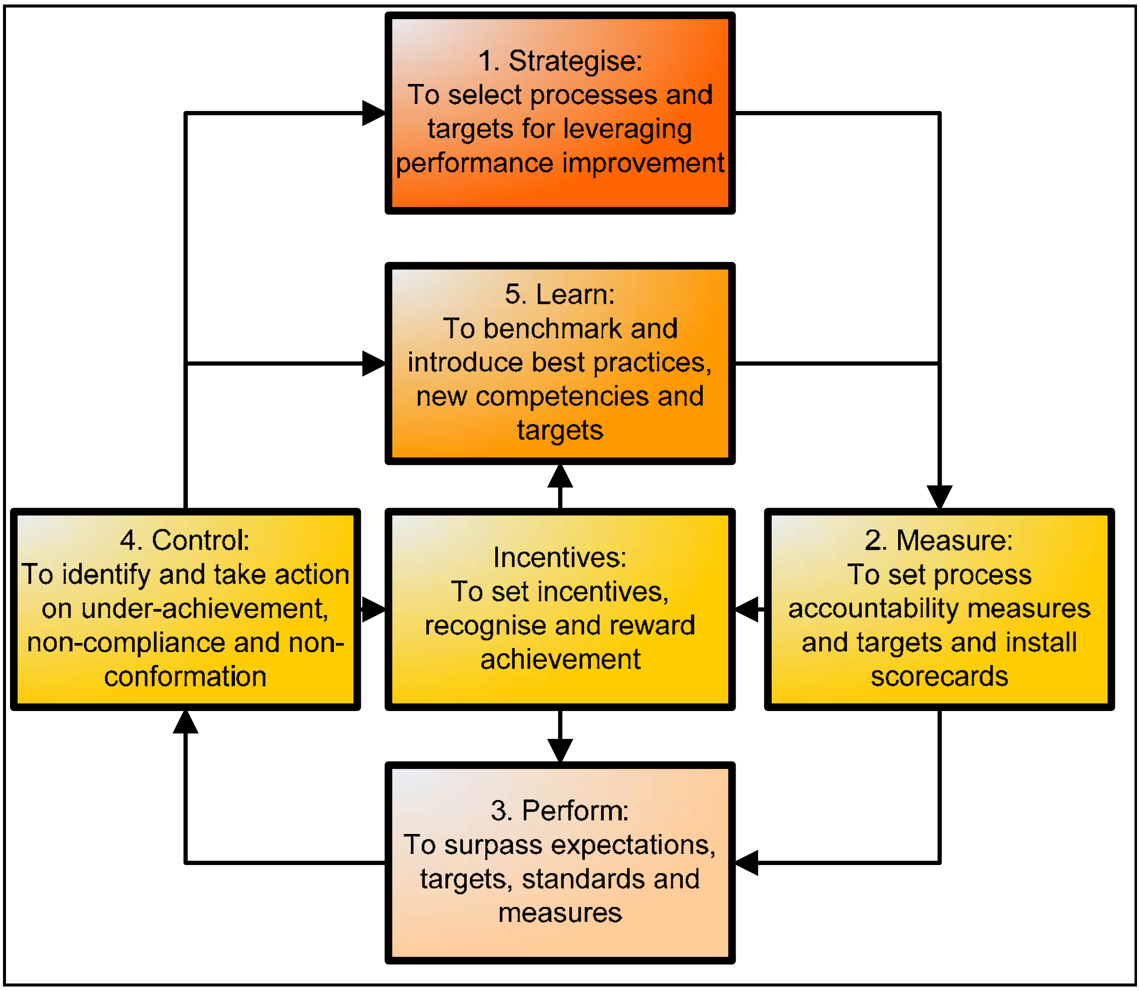
Performance is defined as the "accomplishment of a given task measured against preset standards of accuracy, completeness, cost, and speed" and improvement is defined as "change for the better" (BusinessDictionary.com, 2008). Combining these definitions, performance improvement can be defined as a change in trend for the better or the achievement of accomplishments that are better than historic performance or expectations or standards (BusinessDictionary.com, 2008). .

2.4.2. The Performance Improvement Process

An immediate impact can be made on performance by leveraging intellectual capital using tools such as performance scorecards, accountability and incentives, by training or replacing ineffective people, by eliminating non-essential costs or activities and by streamlining key processes (Joubert, 2002).

The performance process that drives performance improvement is shown in Figure 2 on the next page. Performance is a function of competence, passion, accountability, measurement, regular feedback, reward and gratification but is ultimately a continuous cycle revolving around incentives. It consists of six vital components, namely: an expectation of the outcome, a predetermined standard or target, a period in which to perform, a measured result or outcome, an emotional reaction to the result, and a corrective or incentive response (Joubert, 2002).

Figure 2: The Performance Process (Source: Joubert, 2002, p. 13).



More demanding customers and increased competition have seen companies move relatively quickly from strategically striving for stability to striving for ongoing performance improvement (Hammer, 2002). Hammer (2002) calls for performance improvement initiatives to be positioned under a process management umbrella so that they can be managed and integrated, instead of a confusing proliferation of programmes, harmful competition and cynicism.

2.5. Quality Management driving strategy and financial performance

2.5.1. Definition of quality management

There is no common definition for quality and it can be looked at from a variety of perspectives based on the evolution of the discipline, among these, a customer's perspective and a specification-based perspective (Sower and Fair, 2005). Tamimi and Sebastianelli (1996) find that only a third of managers define quality as "innate excellence", while two thirds take a user based perspective and define it as "maximising customer satisfaction". Pycraft, Singh and Phihlela (2005, p. 613) define the latter perspective as "consistent conformance to customers' expectations".

The lack of a common definition for the term "quality" is not a new state of affairs and debate over the nature of quality, or true excellence, can be traced back all the way to ancient Greece through the writings of Augustine, Aquinas, Adam Smith, and others (Sower and Fair, 2005).

2.5.2. History

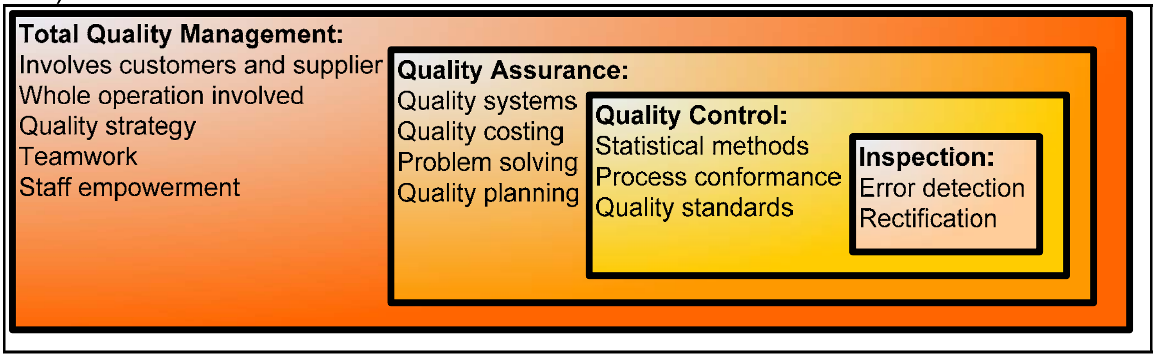
Quality management is a difficult discipline to research from a theoretical perspective, because it originated as a practice-oriented approach to management (Kujala and Lillrank, 2004).

The American Society for Quality (2007) gives an overview of the quality movement wich can be traced back to the guilds in medieval Europe. Product inspection was introduced in British factories in the mid-1750s, ultimately growing into the Industrial Revolution. The advent of World War II, and the subsequent need for bullets and guns manufactured in states across America to work together, introduced sampling and statistical process control. Quality moved from inspection function to a focus across all processes when Deming and Juran introduced the concept of total quality in Japan. In response, the U.S. introduced total quality management (TQM) with a focus on statistics and an organisation-wide view.

Since then, quality initiatives have matured and currently focus on approaches such as ISO 9000, the Malcolm Baldrige National Quality Award and Six Sigma. In addition they have expanded from manufacturing into service, education, healthcare and government sectors (The American Society for Quality, 2007).

This history is summarised in Figure 3 on the next page.

Figure 3: The expansion of quality management. (Source: Pycraft *et al*., 2005, p. 737).



Hill (2005) contrasts the philosophies of Deming, Crosby and Juran who were contributors to the quality movement during the 1980's. Deming sees quality as an organisation-wide challenge requiring a fundamental change over a long time, while Juran focuses on how a product or service is made fit for use as it moves through the supply chain (Hill, 2005). The cost of quality concept translates analytical and statistical measures into monetary terms that are meaningful to management and help to gain organisation-wide commitment to a process of continuous improvement (Hill, 2005).

Finally, Crosby advocates the goal of zero defects to be achieved through prevention instead of inspection. He estimates the cost of quality as 15-20% of sales and believes in creating management action through short term impacts (Hill, 2005).

In addition, Crosby (2005) expresses surprise that people see quality as a silver bullet instead of acknowledging that, in the real world, people reject change. Tacit approval can be achieved, however, by properly explaining the absolutes of quality management though, such as zero defects and the cost of quality. Freiesleben (2006) sees things differently, arguing that Juran and Crosby's focus on the cost aspect of quality results in quality being viewed as a negative unpleasant necessity that needs to be implemented at minimal costs.

More recently Kujala and Lillrank (2004) see quality culture as the theoretical basis for quality management. Quality management therefore requires a change in organisational culture to be compatible with quality culture and success can be predicted by the similarity between the underlying assumptions of the cultures. The basic assumptions of a quality culture are shown in Table 2 below.

Table 2: Assumptions of a quality culture. (Source: Kujala and Lillrank, 2004, p. 48).

1. Organisation's mission and relationship to nature
1.1. Proactive and harmonised relationship to the environment: An organisation should continuously scan its external environment to proactively respond to the needs of external stakeholders, specifically those of the customer. 1.2. Customer dominating in supplier chain relationship: An organisation should respond to the needs of all stakeholders, but the customer has a dominant role and priority when setting organisational objectives. This also applies further down in the supplier chain, where an organisation has a dominant role in relation to its suppliers/partners.

2. The nature of reality and truth
2.1. Objective physical reality dominating: Scanning of internal processes and external environment produces context independent and objective information, which can be used as a basis for decision-making process. Objective physical reality is limited and shaped by quality ideology. 2.2. Continuous improvement by analysing objective facts: It is beneficial for an organisation to continuously improve the organisational processes. This improvement should be based on the analysis of objective information.
3. The nature of human nature and relationship
3.1. The basic nature of human good: All employees, by nature, have an endogenous will and motivation for good work; they are capable of improving themselves, and employees align their personal objectives to comply with those of the organisation. 3.2. Central role of senior management: Senior management has a key role in ensuring organisational effectiveness, and they have the legitimacy to set organisational objectives. 3.3. Teamwork is more valuable than individualism: Teamwork across functional and legal boundaries of the organisation is required to manage and improve organisational processes.
4. The nature of time and space
4.1. Future orientation—time to wait for results: Organisational stakeholders prefer to have long-term relationships and they have the patience (and resources) to wait for results. 4.2. Efficiency through planning and coordination: An organisation is a set of interrelated parts and in order to improve overall effectiveness, activities should be carefully planned for coordination and alignment.

2.5.3. Advantages

Proponents of quality, such as Ravichandran (2006), sing it's praises by stating that quality not only achieves performance improvement, but also plays a part in delivering business excellence well beyond customer's expectations. Whilst companies who have had failed quality efforts might not be optimistic, research shows that quality is becoming more important to CEO's and that they believe it drives profitability (Palmer, 2007; Arthur, 2005); however they have difficulty proving it (Arthur, 2005).

The ultimate proof of validity for a managerial technique is its positive effect on profitability and Freiesleben (2006) argues that better quality results in improved profit in terms of price, unit costs, sales and fixed costs. Many authors have asserted that quality results in improved financial performance, but they have largely been dismissed due to case specific research or a lack of empirical evidence (Freiesleben, 2006).

Townsend and Gebhardt (2005) concur that quality management is implemented for a variety of reasons such as environmental concerns, human dignity issues and national competitiveness, but that the main reason is always the financial bottom line. They suggest using the capacity of work concept to translate hard and soft savings into their effect on the bottom line (Townsend and Gebhardt, 2005).

This concept incorporates measures such as increased productivity, happier customers, fewer returns and whether budget savings are being reinvested. An argument for why incorporating the measures from this concept is useful is given as follows. Staff turnover is a good measure of both current performance and a predictor of future performance, as low turnover shows a productive workforce with high morale and a rising level of experience (Townsend and Gebhardt, 2005).

Townsend and Gebhardt (2005) build on Crosby's (2005) work that shows that the cost of quality should be measured in terms of whether corrective action will result in additional profit for the company, but also heed Freiesleben's (2006) call not to associate quality with cost.

Although it is tempting to try to use complex solutions for complex problems, simple tools such as Pareto analyses and process mapping usually suffice (Thiraviam, 2006). In addition to having simple tools, the abundance of quality techniques rely on the underlying relatively simple concept of increasing profitability (Freiesleben, 2006).

Additional research and the development of a model to communicate the performance benefits of quality to top management are therefore required. In addition, companies should make small investments in quality and then depreciate these over time to correctly evaluate the impact of quality initiatives (Freiesleben, 2006).

2.5.4. Limitations

Harvey (2004) proposes that there are a plethora of quality improvement initiatives, none of which are a panacea. Initiatives fail when they are not suited to solving the specific circumstances present in a firm and firms should take time to understand their circumstances before selecting the appropriate methodology, tools and change vehicle for their purpose.

A failure to do so can be devastating for quality management in the long run because:

- Significant investment in time and resources is required,
- Initiatives require strong top management commitment, so it is then difficult for top management to back down, and
- Failure creates employee cynicism which gets linked to quality management as a whole, not just to the mismatch (Harvey, 2004).

In contrast, Jacobsen (2008) argues that quality management concepts, such as continuous improvement, employee involvement, customer focus and teamwork are sound and their methodologies proven. Failure is instead attributed to a lack of planning for and executing the methodology.

People issues are key and so by “engaging top management’s full support, managing employees’ fear of change, providing the best tools and training, keeping the focus on the customer, selecting the right projects, and communicating your successes, you will greatly improve the likelihood of meeting and even exceeding the expectations for your quality initiative” (Jacobsen, 2008, p. 8).

A third reason for failure is a lack of operating knowledge preventing the empowerment of employees to make decisions as problems arise, even when they have the necessary analytical tools provided by quality management. This problem can be overcome by incorporating the operational knowledge that resides with a few people into knowledge based systems (Miscikowski and Stein, 2006).

2.5.5. The impact of quality management on performance improvement

Numerous studies examine the impact of quality management on both financial and operational performance (Kaynak 2003). Many use a method that compares firms to a control group (Foster, 2007) and they show mixed results both in terms of financial and operational performance.

Easton and Jarrell (1998) find that firms who implemented TQM between 1981 and 1991 saw their stocks outperforming their rivals’ returns.

In similar market return studies, Hendricks and Singhal (1996; 1997; 2001a; 2001b) find strong evidence that quality award winners outperform control firms in terms of operating income. The award is assumed to be a proxy for the effective and mature implementation of TQM. York and Miree (2004) too find that Baldrige Award winners showed better results than a control group within the same SIC group both before and after winning the award.

However, Adams, McQueen, and Seawright (1999) only find limited evidence to support abnormal returns for Baldrige Award winners on the day of the quality award announcement, possibly because analysts may have been forewarned, they may have already factored in the effects of quality improvement efforts and an award may not impact stock as this is not its purpose.

Other studies look at the impact of quality management on operational results. Dow, Samson, and Ford (1999) find positive correlations between improved quality outcomes and employee commitment, shared vision, and customer focus; however no correlation between quality outcomes and benchmarking, work teams, advanced manufacturing technologies, and close supplier relations.

Douglas and Fredendall (2004) find that process management is positively related to continuous improvement and employee fulfillment.

Employee fulfillment is also related to customer satisfaction and business performance, but whilst continuous improvement is positively related to cash flow margin, it is not related to financial performance or customer satisfaction The ability of quality management programmes to improve customer satisfaction is contingent on the degree of international competitive intensity, with increased competition negating returns (Das *et al*., 2000).

A survey amongst government workers shows that the contextual variables of leadership and teamwork, together with imparting appropriate quality knowledge followed by application, are seen to result in process improvement, as well as employee satisfaction (Foster *et al*, 2007).

2.5.6. The future of Quality Management

Table 3, on the next page, lists the future research priorities of academics and practitioners (Latham, 2008). Culture and leadership are the main areas for further research, followed by the Malcolm Baldrige Quality Award criteria, innovation and measurement. Practitioners want to concentrate more on the soft issues of innovation, people and knowledge management where academics would like to research quantitative issues like Malcolm Baldrige Quality Award criteria and measurement.

Table 3: Voting results of research agenda priorities (Source: Latham, 2008, p. 18).

Question category	Practitioners	Researchers	Total
Culture	26	9	35
Leadership	22	12	34
MBNQA Criteria	8	11	19
Innovation	12	6	18
Measurement	4	11	15
Knowledge Management	9	3	12
People	10	0	10
Integration	3	5	8
Processes	6	2	8
Stakeholders	3	1	4
Strategy	3	0	3

The next section delves further into a specific methodology of quality management, namely Six Sigma. Six Sigma is not revolutionary, but an evolutionary step in quality management that incorporates the best of prior tools and philosophies, many of which are well over fifty years old, such as customer focus, data driven decision making and process focus. Understanding these origins will help practitioners to implement successful projects (Folaron, 2003).

2.6. Six Sigma

2.6.1. Definition

Six Sigma is a disciplined, objective and data-centric approach to problem solving that rests on the principle that progress occurs when the right people work on the right problem for the right reason with the right methods and tools (Bailey, 2007).

Minitab, a popular statistical software package often used in Six Sigma initiatives, defines Six Sigma as “an information driven methodology for reducing waste, increasing customer satisfaction and improving processes, with a focus on financially measurable results”. Gupta (2004, p. 21) describes Six Sigma as “a measure of goodness, a methodology for improving performance, a measurement system that drives dramatic results, and a new paradigm that requires a passionate commitment from leadership to set high expectations”.

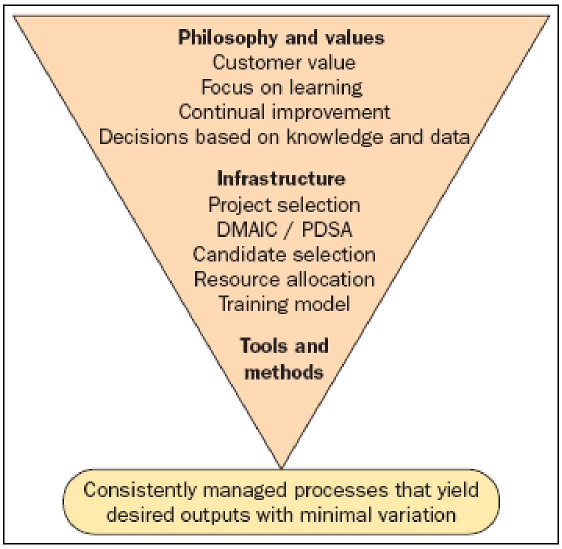
Pande *et al*. (2000) describe the technical definition of Six Sigma. Six Sigma is represented by 3.4 defects per million opportunities (DPMO). In statistical notation, Sigma - σ – is a letter of the Greek alphabet used as a symbol for the standard deviation of a population. The standard deviation indicates the amount of variation in the population or process. The main aim of a Six Sigma programme is to improve quality through variance reduction, because statistical thinking shows how variation exists in every process (Ravichandran, 2006). By examining variation instead of mean performance, management can better understand performance. Six Sigma performance occurs when variation has been reduced to such an extent that there is a buffer of six standard deviations within the limits defined by the customer’s specifications (Pande *et al*., 2000).

Klefsjo, Wiklund and Edgeman (2001) argue that although the content of Six Sigma varies between companies, between authors and between consultants; there are three common features, namely:

1. It is a top-down approach,
2. It is a disciplined approach that usually includes a measure, analyse, improve and control stage, and
3. It is a data oriented approach that uses statistics.

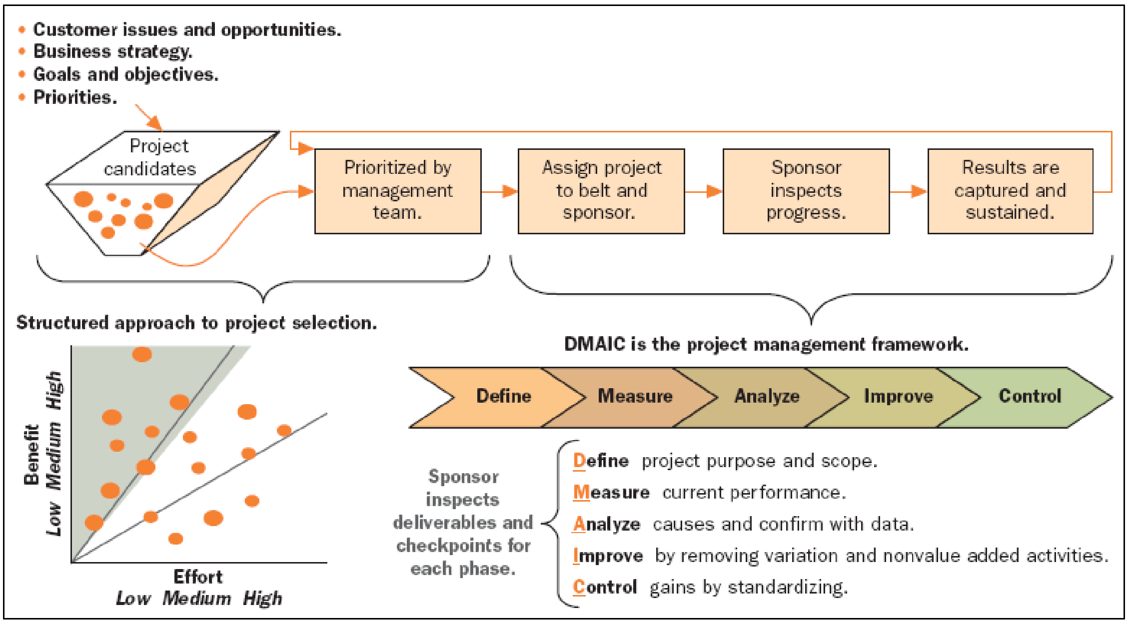
The three most common perspectives of Six Sigma, namely business philosophy, infrastructure and set of methods and tools, all of which are argued to be essential in a successful implementation, are shown below in the Figure 4. It is argued that more flexibility is required at the tool and infrastructure levels to make Six Sigma more applicable to transactional implementations (Hild and Sanders, 2007).

Figure 4: A hierarchical view of Six Sigma (Source: Hild and Sanders, 2007, p. 38).



Projects are undertaken to create this buffer according to the Six Sigma process improvement framework. A systematic approach to define, measure, analyse, improve and control processes (DMAIC) is followed, using a collection of quality management and statistical tools (Goh and Xie, 2004). Fornari and Maszle (2004) illustrate Xerox uses a two stage approach as shown Figure 5.

Figure 5: Lean Six Sigma processes at Xerox (Source: Fornari and Maszle, 2004, p. 12).

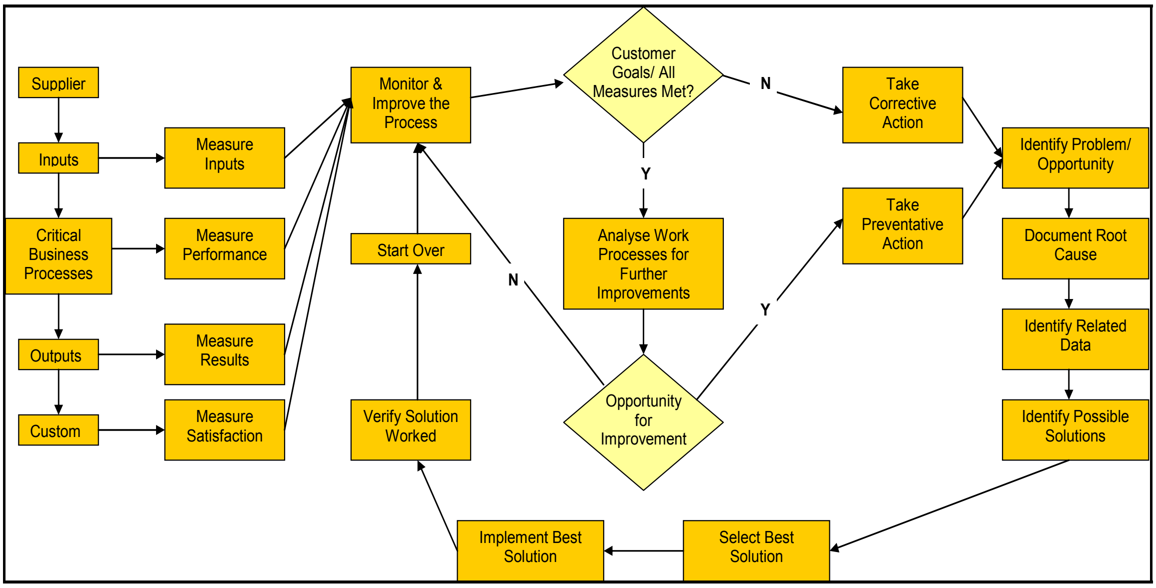


Firstly, projects are identified based on customer issues, business strategy, goals and objectives and priorities and then the projects are prioritised and selected according to business impact and effort.

Once selected, the second stage is to manage them. Resources are assigned and the DMAIC methodology is used to find the best solution for the problem. Progress in each phase is reviewed to ensure sustainable results before a new project is created (Fornari and Maszle, 2004).

The process flowchart shown in Figure 6 then explains how process measurement can lead to continuous improvement. Product, service and process measurements are required to understand what value is being acquired, sold or created. After data analysis, corrective – or preventative - action in the form of a Six Sigma project can be taken depending on the measurement results (Scott, 2007).

Figure 6: Process optimisation flowchart (Source: Scott, 2007, p. 72).



Annamalai (2008) extends the two stage model described above to a six stage model:

1. “Creating a Six Sigma focus in the organisation.
2. Selecting key problem areas.
3. Selecting and training the right people.
4. Developing and implementing improvement measures.
5. Managing Six Sigma projects.
6. Sustaining the gains” (Annamalai, 2008, p. 36).

The last step is the most difficult and requires implementing control plans and regularly training staff, reviewing project effectiveness and initiating new projects (Annamalai, 2008).

Reviewing a Six Sigma project should include the following four questions (Hariharan, 2006):

1. Has the project charter been signed off and does it contain a clear problem statement, goal statement and definition of a defect?
2. Does the data and analysis show the top categories that account for 80% of the problem?
3. What root causes did data analysis uncover for these categories?
4. What corrective actions are recommended based on these root causes?

The George Group helped Xerox to implement their initiative with minor adjustments to the plan shown in the Table 4.

Table 4: Steps to implement Six Sigma. (Source: Fornari and Maszle, 2004, p. 16).

The path to transformation
1. Select projects based on value creation opportunity such as return on invested capital and economic profit, with the number of projects in process controlled.
2. Use a consistent financial results tracking approach established by the deployment team and financial organisation.
3. Consistently deploy and train full-time BBs, full-time deployment managers, sponsors and GBs.
4. Assign demonstrated top performers to the full-time roles.
5. Adopt the defined organisational structure to enable success.
6. Engage operations leadership in the process and integrate lean Six Sigma into daily business operations.
7. Achieve critical mass toward the Xerox transformation of at least 0.5% of the employee population as BBs in 2003 and another 0.5% in 2004.

2.6.2. Emergence as a Quality Approach

Six Sigma has undergone a series of evolutions from being created by Motorola, to having dedicated resources and a strong business focus at GE, to being a values based approach at ITT and now to being integrated with other quality tools, as Caterpillar has done with lean (Fornari and Maszle, 2004).

Hammer (2002) describes how Six Sigma was introduced by Motorola in the 1980's as an extension of their TQM initiative. Despite its financial success, few companies followed suit until General Electric Co. (GE) did so in 1996. Its impact on GE is well known, with Jack Welch stating that it is the most important initiative undertaken by the company. This leads to renewed interest to such an extent that, currently, more than 25% of the Fortune 200 have implemented a Six Sigma programme making Six Sigma being the most popular quality improvement methodology in history (Eckes, 2001).

Hammer (2004) believes that the key to Six Sigma is its ability to cope with complex business operations. Rather than applying inappropriate solutions, Six Sigma pinpoints the causes of problems before applying appropriate solutions. Davison and Al-Shaghana (2007) find that Six Sigma organisations display more of a quality culture than non Six Sigma organisations. The organisational factors that facilitate a quality culture are management commitment to quality, employee training and participation, awareness of quality and performance evaluations based on quality-related criteria.

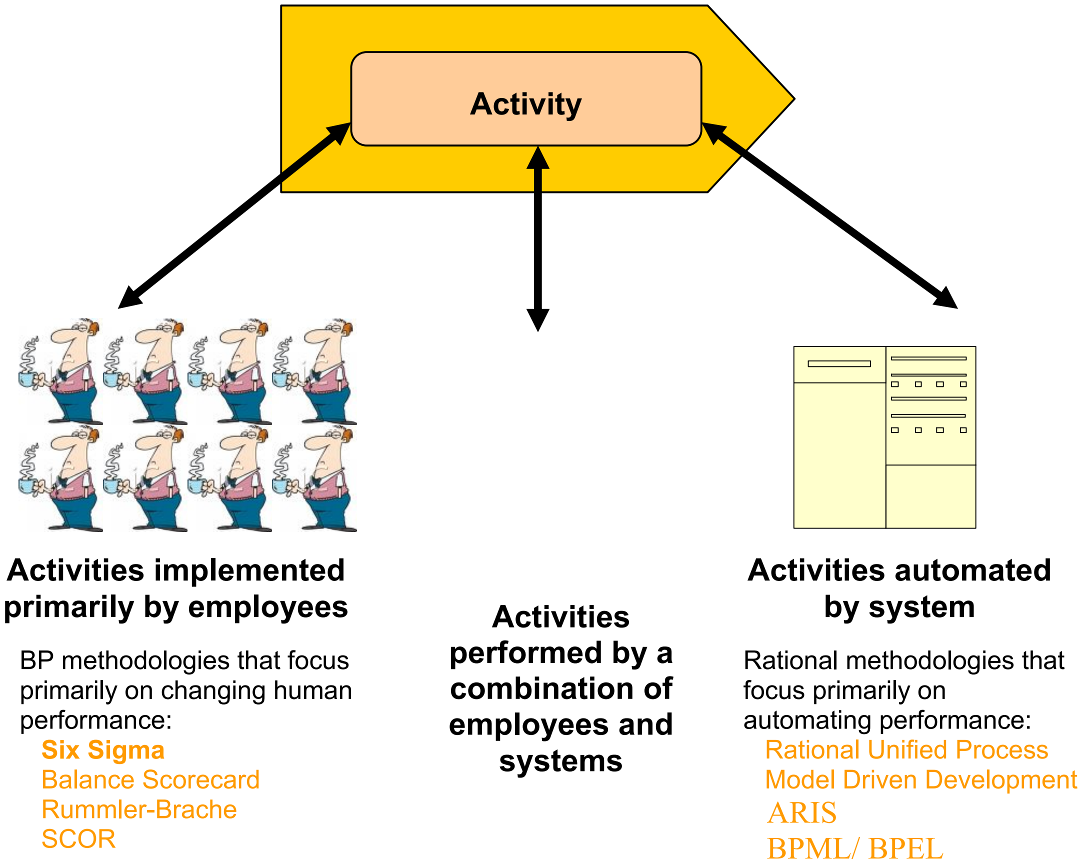
Each era has contributed both quality management tools and philosophies that have been incorporated into the Six Sigma methodology as shown in the Table 5 (Folaron, 2003).

Table 5: Each era's contribution to Six Sigma. (Source: Folaron, 2003, p. 41).

Era	Contribution
1798: Eli Whitney, Mass Production & Interchangeable Parts	Need for consistency
	Identification of defects
1924:Walter Shewhart	Process oriented thinking
	Control charts (assignable and common cause)
1945: The Japanese Quality Movement Begins	Statistical methods and use of statisticians
	Continuous improvement (plan-do-study-act) methodology
	Active engagement of management and staff
	Diagnostic and remedial journeys
1973: The Japanese Make Their Move	Quick response to changing customer needs
1980: Phillip Crosby and Quality is Free	Methodology to achieve companywide quality improvement
	Improve product, process and service. Strive for perfection.
1987: International Organization for Standardization	Widespread sharing of basic elements of sound quality systems
	Organizational rally cry for improvement
1987: Malcolm Baldridge National Quality Award	Sharing best practices
	Strong focus on customers and results
1987: Motorola and Six Sigma	Focus on customer needs and compare process performance them
	Structured methodology with discipline and proven business results
1960-1995: Other Initiatives	Tools to be used by everyone in the organization

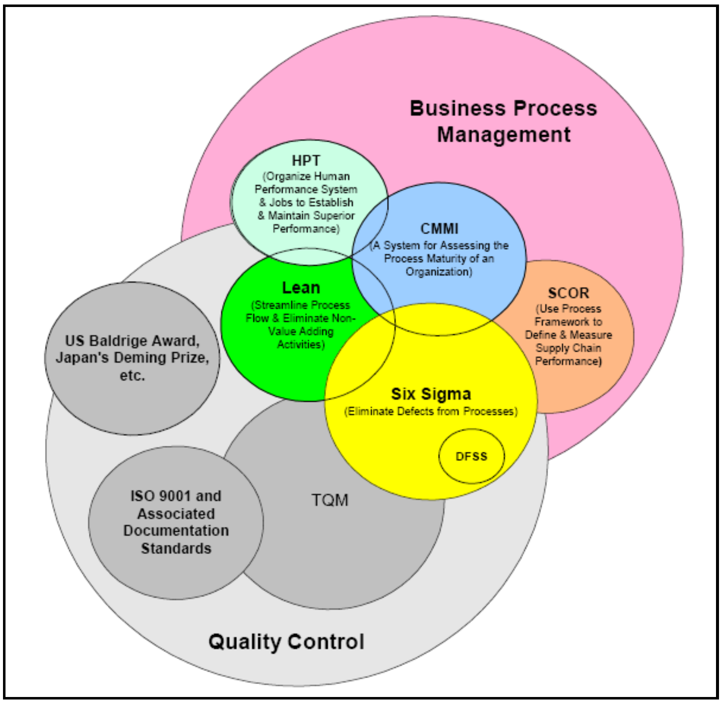
As Figure 7 on the next page shows, business process change methodologies focus on either process automation through IT or improved employee performance. Six Sigma is the dominant methodology for the latter and is "probably the most widely used methodology for improving human performance and is increasingly popular as a way of organising an entire company to become more customer focused and more quality conscious" (Harmon, 2003, p.1).

Figure 7: The focus of business process change methodologies. (Source: Harmon, 2003, p. 2).



Both the disciplines of quality control and business process management and the methodologies within them are merging as shown in Figure 8 on the next page. Whilst the business process management market focused on software vendors, the quality control market has historically focused on training and consulting (Wolf and Harmon, 2005).

Figure 8: The Quality Control tradition together with emerging methodologies. (Source: Wolf and Harmon, 2005, p. 2).



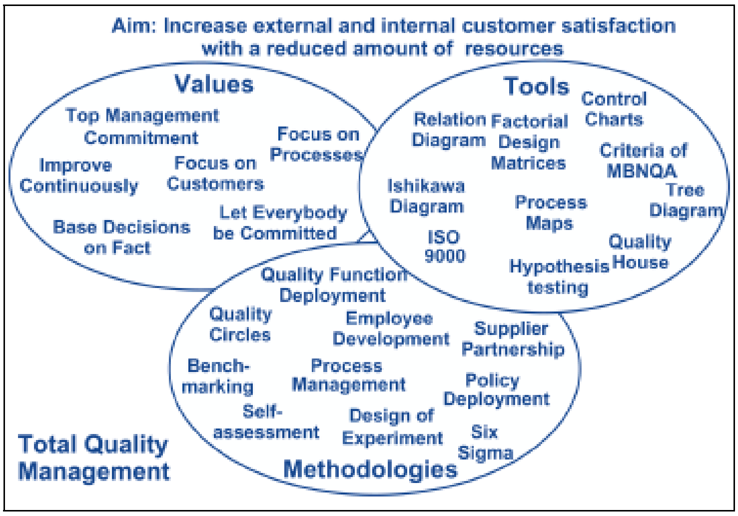
Each of the methodologies will be discussed briefly to highlight their current and potential future linkage to Six Sigma. Whilst Six Sigma reduces the defects within existing processes, Design for Six Sigma (DFSS) designs products and processes in order to minimise defects. Lean focuses on eliminating waste or non-value adding activities (Wolf and Harmon, 2005). Six Sigma and Lean can work effectively together to create ongoing business improvement.

Six Sigma is popular and effective, applies precision by using statistics to uncover root causes and hidden problems, provides metrics to guide projects, but projects take months and are carried out by elite practitioners who spend most of their time removed from the shop floor. Lean encourages productivity, changes cultures by involving shop floor employees and using teamwork, action and results are seen quickly, success is achieved by tackling easy gains by using employee's intuition. It can not, however, fix unidentified quality issues. Due to the different styles and focus, there is friction between these programmes when they are run separately; however when combined they lead to better results (Smith, 2003).

ISO 9000 consists of a standard approach to process documentation (Wolf and Harmon, 2005). ISO 9001 therefore describes processes as they actually are, not as they should be. Changing the way people perform is the role of management and cannot be imposed by documentation. Non-compliance to ISO 9001 is difficult as the system merely describes what people do daily. Thought of in this way, ISO 9001 is similar to a conversation with a customer discussing how the steps pertaining to their business will be fulfilled within the organisation. After finding no catch, people buy into the system and wonder why it hasn't been done before (Wright, 2001).

TQM is seen as part of the older tradition of quality control (Wolf and Harmon, 2005). Klefsjo, Wiklund and Edgeman (2001) argue for Six Sigma to be a methodology within the framework of TQM as shown by Figure 9. TQM starts with the values which make up an organisat's culture. This culture is created through the use of methodologies and tools. Six Sigma is seen as applying old tools in a new methodology that links tactical and strategic initiatives.

Figure 9: Total Quality Management. (Source: Klefsjo, Wiklund and Edgeman, 2001, p. 34).



National awards - such as the Deming Prize in Japan and the Baldrige Award in the U.S. - recognise companies who have achieved quality criteria. The Corporate Maturity Model Integrated (CMMI) expanded from the field of IT into providing analysis on the maturity of any business processes. This is now being used in Lean and Six Sigma implementations to analyse the relative maturity of organisations and therefore to identify suitable interventions (Wolf and Harmon, 2005).

Similarly, the Supply Chain Operations Reference (SCOR) model, which is a common set of supply chain process models, is used to help identify areas for process improvement (Wolf and Harmon, 2005). Both Six Sigma and Lean Six Sigma projects commonly struggle to identify and select projects that align with the strategic business goals and have the most impact on the bottom line. Incorporating the SCOR methodology as a diagnostic tool can aid in this regard as SCOR "benchmarks operational measures to create a prioritised improvement portfolio tied directly to a company's P&L and balance sheet for increasing profitability" (Harelstad *et al.*, 2004, p. 19).

Some of the advantages that SCOR can provide are identifying:

- Common problems across the company's supply chain rather than within one supply chain,
- Strategic process design changes instead of narrow tactical changes, and
- Areas of business excellence that were not shared throughout the business (Harelstad *et al*., 2004).

Finally, human Performance Technology (HPT) helps to analyse human performance problems and thus to better design jobs. This is incorporated into Lean and Six Sigma as it helps managers and employees to act together to jointly sustain improved processes (Wolf and Harmon, 2005).

Today, Six Sigma remains a growing phenomenon, as shown by the results of a recent survey showing that more than 70% of interviewed Six Sigma companies had adopted Six Sigma in the last three years with less than 10% having worked on it for more than three years (Antony and Banuelas, 2002). Having seen a growing interest in publishing articles in this area, Hoerl, Snee, Czarniak and Parr (2004) also infer that Six Sigma is continuing to grow and that there is a significant and growing interest in its many business applications.

Wolf and Harmon (2005) estimate the Six Sigma market in the U. S. to be worth more than $200 million. Around 50% of this market consists of the six leading consultancies, each with 50-100 employees, who together run 250-500 training courses per annum alongside other projects. The remainder consists of smaller consultancies, software vendors and corporations.

2.6.3. Perceived advantages

More important than its limitations is the fact that Six Sigma is rapidly expanding and therefore it shouldn't be ignored by any practitioner involved in business process change (Harmon, 2003). As a technical initiative, the interest shown in Six Sigma by businesses and the public alike is phenomenal - as Harry and Schroeder's 2002 book, Six Sigma: The Breakthrough Strategy Revolutionising the World's Top Corporations showed after making it onto the New York Times best seller list (Hoerl, 2001).

"Six Sigma has a better record than Total Quality Management (TQM) and business process re-engineering (BPR), since its inception in the mid-late 1980s" (Antony, 2004, p. 305).

Antony (2004) lists the following advantages of Six Sigma:

1. Project selection based on the bottom line impact
2. Unprecedented focus on leadership support
3. Integration of human and cultural elements with process elements
4. Disciplined approach to projects and tool usage
5. Creation of a project team infrastructure through the various roles of belts and champions
6. Emphasis on data, measurement and fact-based decision making
7. Utilisation of statistical thinking and statistical tools

The power of Six Sigma stems from its "rigorous, disciplined approach and well-publicised, proven business successes" (Folaron, 2003, p. 38). All processes vary and process variation increases if processes are left unmonitored. Statistical tools are therefore needed to monitor processes so as to identify, categorise, quantify and reduce variation (Snee, 2005). Goh and Xie (2004) assert that Six Sigma is effective due to its application of statistical techniques for information gathering, analysis and interpretation.

An operational problem is translated into a statistical problem that is solved using proven mathematical tools. The results are then translated back into practical actions. The customer focus ensures that improved processes and products bring value to customers and, therefore, also a competitive edge to the organisation.

In summary, Six Sigma is a tool that "brings about improvements based on actual data, proven techniques, and purposeful changes and does not rely on mundane quality management practices such as slogans, pep talks, audit, accreditation or awards". (Goh and Xie, 2004, p. 237)

Snee (2005) states that the DMAIC framework adds repeatability, discipline and predictability to improvement projects. He believes that it can comprise the improvement infrastructure that links and sequences the required tools regardless of their source.

Some projects find organisational culture at fault instead of a process flaw. In these cases a solution cannot just be implemented, even if it is known, as it will not be sustainable. However the rigorous DMAIC process and objective, statistical analysis ensures that data leads to the solution even in the case of a cultural problem. For example, the cultural problem of time wastage will show up on productivity charts. Through the process, Six Sigma enables employees and management to agree on and implement a sustainable solution even when cultural rather than process change is needed (Chauncey and Thornton, 2006).

2.6.4. Perceived limitations

When asked to rate the impact of Six Sigma in their organisations, improved cost of quality, productivity improvement, cost savings, improved work flow, cycle time reduction and process improvement measurable results were all rated highly (Cooper and Noonan, 2003). However improved employee morale and increased customer satisfaction were rated significantly lower. This is concerning especially since improving customer satisfaction via listening to the Voice of the Customer (VOC) is a foundation of Six Sigma. In addition, Cooper and Noonan (2003) found that teams are critical to the success of Six Sigma and it essential to determine the stakeholders and ask their views on how to improve the process.

Catherwood (2005) believes a number of input factors are likely to be responsible for results below expectations, including the role of the Six Sigma champion and a lack of sufficient senior management commitment and involvement. He implores organisations to set clear expectations and to understand how a new initiative fits into their current structure and strategy. In addition, the team, the project manager – known as a black belt in Six Sigma parlance - and the champion need to work for each others' success and the team's success. The selection of black belts is vital as they need to possess both power and analytical competence though Goh and Xie (2004) caution against the common tenet that black belts should be explicitly recognised and rewarded.

They state that this can cause harmful competition and narrow thinking resulting in sub-optimisation instead of taking a larger, longer term perspective. They also believe that some processes are improved when they should rather be phased out due to changing conditions. An example of this is the efforts to improve the Polaroid instant camera in the face of digital photography. Instead Goh and Xie (2004) recommend taking a wider systems perspective and selecting, executing and evaluating projects in the context of the organisation's strategy.

The growth in popularity of Six Sigma has led to conflict between its proponents and the proponents of other quality management frameworks. A holistic performance improvement methodology is needed to overcome this (Snee, 2005). Carnell (2004) warns that a Six Sigma effort is doomed without a new culture, revised reward systems and creating an atmosphere of organisation wide empowerment together with accountability.

Hammer (2004) describes how, despite the success achieved by Bombadier, they recognise several limitations within their implementation. Projects only succeed when they have a limited scope and low-level focus. Secondly, projects seldom contribute to the larger strategy due to a lack of alignment. Finally, the effort has not changed the company's basic assumptions or its structure and so is unable to deliver breakthrough improvements.

Hammer (2004) goes on to refer to other companies, such as IBM and Allmerica Financial Corp., that have managed to significantly reduce costs through concerted transformation programmes and not through DMAIC. He describes how Six Sigma's limitations are inherent in its project oriented problem solving nature. Six Sigma deploys statistics to uncover flaws in the execution of existing processes. It does not question whether there is an entirely different way of performing the process thus limiting dramatic improvement. Hammer (2004) goes on to explain that waste comes from variation in existing processes and that DMAIC is effective at eliminating this. However, non-value-adding work holds a process together and so cannot be readily eliminated.

Six Sigma success requires an appropriate mix of process, people and statistics from the start of an implementation until its completion. However this is context specific and requires an innovative approach, without which the implementation is likely to fail. It is this - and not deficiencies in the methodology - which leads to failure (Annamalai, 2008).

Well known Six Sigma companies such as Dell, Honeywell, Credit Suisse and SKF are questioning the assertion that quality improvement and cost reduction lead to growth, which is essential for survival. Instead these companies are moving towards creating value and revenue opportunities through rethinking a customer's purchasing experience and how they use a product rather than merely focusing on the product itself (Abramowich, 2008).

Knowledge is considered the fourth factor of production and should receive as much focus as the tangible results of processes. Instead of a focus on financial performance, organisational performance can be assessed by the effectiveness of knowledge management and learning, because this is the only way an organisation can move from a reactive state to a procative one (Okes, 2005).

Kubiak (2007) highlights the limitations for Six Sigma implementations across seven elements:

1. Management: Delegates, lacks commitment and knowledge and makes an outside person responsible.
2. Projects: Quick hits instead of strategic projects, only focus on big savings, are badly scoped, lack a powerful champion, lack goals, certification of resources becomes more important than financial benefits, bad projects are terminated quickly, Six Sigma methods are applied inappropriately, control and replication are not achieved and work consists mainly of administration.
3. Financial savings: Any project savings are attributed to Six Sigma and saving calculations are not clear.
4. Training: Is based on headcount instead of skills, is open to anyone, has bad instructors, is of a low standard, lacks refresher training, is customised for management.
5. Communications: lacks a communication plan and communication is not frequent or consistent.

6. Champions: Are absent from a support role, change the project scope and do not terminate a failed project.
7. Green Belts: Stop implementing Six Sigma after certification and little infrastructure is in place to support green belts.

Antony (2004) mentions many of these same limitations while also including:

- Availability of quality data and the amount of time taken to generate data when none exists
- The need for expensive solutions can exclude smaller companies
- The lack of a framework to objectively select and prioritise projects
- Defects are all treated equally from a statistical perspective, but vary greatly in terms of their importance
- The lack of a standard certification procedure.
- Without a focus on savings, Six Sigma can become a bureaucratic task.
- Consultancies selling Six Sigma without the necessary skills.
- The linkage between a process sigma quality level and the cost of poor quality is justified enough.

Six Sigma projects should be conducted by the people who run the process because it is they who will be impacted by the results and they who can ease communication and data collection and integrity. A project can easily move forward once people know how they and the business will be impacted.

If needed, team representatives can be chosen to become members of the project team provided they are respected and experienced (Finn and Reynard, 2005).

Long term change and success can only be achieved by focussing on soft issues as people cannot operate effectively without a defined process. Without one a host of unrelated issues tend to enter into daily operations. Instead, programmes should create a culture of continuous improvement, by involving teams from all levels of the organisation. As well as leading to effective results, there is a direct correlation between employee satisfaction and participating in these initiatives as workers are proud of their contribution and of their company (Smith, 2003).

Hoerl (2001) clarifies the roles within a Six Sigma environment to help address the confusion amongst these roles brought about by the hype surrounding Six Sigma and the lack of standardised criteria for certification. A quality champion or leader leads the initiative and therefore is involved in strategic work such as monitoring, allocating resources and setting objectives. Master Black Belts have a managerial role that includes selecting and training resources and selecting and reviewing projects and they require a deep understanding of statistics and soft skills to fulfill this role. The Black Belt role is usually developmental and works well when linked to leadership development over a two year period.

The Black Belt has the operational role of leading a team to make improvements happen. Whilst needing to lead several projects at once, they require the ability to apply statistical tools to real problems, manage projects and meetings, multi-task, present clearly and train fellow team members.

Juran sees Six Sigma as a fad that has given a new name to existing quality approaches. The flaws of Six Sigma include a lot of hype, a lack of standardised certification and a lack of research into its benefits (Phillips-Donaldson, 2004).

Kelly (2007) describes seven limitations of implementing Six Sigma within a service setting and ways of overcoming these with common sense as well as "organisational support, good data, effective communication, listening to the customer, deployment wins, standardisation and patience" (Kelly, 2007, p. 21). Kelly implores leaders to understand these common problems and amass enough resources and commitment to be able to overcome them.

The limitations and advice for overcoming them are described below:

1. Support can wane as operational problems and resource constraints become apparent, but they can be overcome by fast tracking a project so it finishes quickly.

2. Service companies often lack the integrated, validated data necessary for projects and this can lead to wrong solutions. However, understanding the common measurement system upfront and confirming that it is repeatable and reproducible helps to prevent this. Automating the measurements at the outset is also cost effective in the long term.
3. After initial Six Sigma success, resources can be spread too thin and focus can dwindle when everyone starts to call for projects. Leadership then needs to provide support and guidance.
4. Service companies often mistake the need for communication for the need for lots of meetings. Meetings can be kept to a minimum and can be kept productive by using techniques such as imposing strict time limits on agenda items, addressing only open actions and allowing someone to talk only when they have the talking token.
5. Improvement is important for all customers, but individually customised solutions are not always in the interests of all customers. Assessing comments from multiple customers through multiple channels will help to ensure fair representation and prioritise projects. Once started, the project can immediately make customer feedback part of the operational measures, so staff become aware of what customers are feeling.
6. Commonsense solutions that can sometimes present themselves, but these can take more time to implement than expected.

This can be overcome by a blitz project to implement solutions that the team has brainstormed; however change has to be balanced with stability to allow time for changes to become entrenched and accountability to be transferred in a controlled manner.

7. People can interpret a standard operating procedure in numerous ways depending on how it relates to their tasks and how resistant they are to change. Audits help to ensure that behavioural change endures.

Ensuring that Six Sigma aligns with a company's strategy is difficult because there are usually three levels of strategy, namely corporate, strategic business unit and competitive strategy. The competitive level has an overall view of the company's current offerings and markets, unlike the strategic business unit level, and is able to understand the voice of the market in terms of which of the current offerings customers are reacting to, unlike the corporate level with its future orientation. The competitive strategy focuses on how an organisation competes by identifying value gaps and creating value within their chosen product offerings and markets. Six Sigma should align with strategy at this competitive level as initiatives are most useful here. (Reidenbach and Goeke, 2007).

To overcome these hurdles, management need a convincing argument about why Six Sigma should become the way the business is run in future in order to sustain the implementation when difficulties arise such as the following experienced by Xerox (Fornari and Maszle, 2004) or recommended by Hariharan (2006):

Managers need to assign their best people to the Six Sigma initiative (Hariharan, 2006) and, ideally, black belts need to be allocated to Six Sigma full time (Fornari and Maszle, 2004). Moving them back to an operational role during a crisis perpetuates a cycle of fire fighting instead of fixing root causes and shows a lack of commitment to Six Sigma. People should also be enthusiastic about taking on a black belt role instead of being forced into it (Fornari and Maszle, 2004).

Projects must be prioritised according to value and must be scoped and broken into manageable sizes (Fornari and Maszle, 2004). If a project has too broad a scope, it can be divided into parallel projects and if it has too aggressive a scope, it can be divided into sequential projects. The results of these projects must be carefully tracked (Fornari and Maszle, 2004). Because Six Sigma projects should be linked to strategic business objectives, they need to be reviewed by the CEO at least once a month and should stay at the top of their agenda (Hariharan, 2006).

Six Sigma results are directly proportional to the weight given to Six Sigma in appraisal systems (Hariharan, 2006). A set percentage of financial savings should be set aside as an investment into rewards and recognition systems. Whilst this cost may look excessive on its own, it should not seem excessive when compared to the breakthrough financial benefits that Six Sigma achieves Making Six Sigma responsibilities part of the appraisal system for all levels in the company is therefore essential (Hariharan, 2006).

Instead of setting a large target number of projects to implement, companies should rather identify a manageable amount of critical projects that can be completed successfully. Although people tend to jump to solutions, sufficient time needs to be allowed for the data collection and analysis upon which solutions are based (Hariharan, 2006).

Companies may argue that they aren't mature enough to implement Six Sigma either culturally or from disciplined process point of view, but these are the companies who have the most to gain by realigning their organisation at the same time as they implement Six Sigma (Fornari and Maszle, 2004). Culture and leadership behaviour need to be changed, so that Six Sigma can be integrated into the culture of how employees work (Hariharan, 2006).

Jamie Houghton retired from Corning a year after winning the Malcolm Baldrige National Quality Award, but he was brought out of retirement when the company was in dire straits just six years later. With a focus on quality and by implementing Six Sigma, he manages to turn the company around with savings from projects increasing eightfold in four years. Lessons from Corning are that the top leader needs to visibly enable and support quality management, by preaching it everywhere for at least five years until it becomes part of the culture. A strong quality culture with reinforcing communication and metrics allows organisation's to respond quickly to difficult times. Future leaders need to be trained to ensure continuity during structure changes (Daniels, 2007).

Innovation is as important as quality and instead of spending money to drive quality; companies should engage their employees as these are the people who find simple solutions to problems they know well. Whilst financial analysts may only focus on short term performance, quality and people help a company achieve long term success. But quality has to show financial results along with customer satisfaction and reduced cycle times (Daniels, 2007).

Companies often fail in implementing management approaches because they do not assure organisation-wide implementation. Instead of fundamentally changing the organisation by developing organisational capabilities to implement their vision, companies often add new methods onto existing ones (Graves and Waddock, 2000). Poor implementation is the cause of more than half of Six Sigma initiatives failing, but this can be mitigated by an incremental implementation with a few people that develops support from informal leaders rather than top management. Whilst consulting firms benefit from emphasising top management commitment, high CEO turnover means that support from informal leaders would result in a more sustainable initiative (Arthur, 2005).

Arthur (2005) proposes that the following variables can be used to increase the adoption rate of Six Sigma:

1. Increase the perceived relative advantage
2. Increase the compatibility to current initiatives
3. Decrease the complexity
4. Increase the ease of trying it
5. Increase the visibility of results

In addition, Arthur (2005) advocates starting a Six Sigma epidemic in order to convert a culture by starting small and growing exponentially through combining the concepts of contagiousness, the butterfly effect and the tipping point.

2.6.5. Debates regarding Six Sigma

Breyfogle (2005) advocates systems thinking to prevent losing sight of the big picture and optimising subsystems at the expense of the overall system. Instead, a proper implementation can create a roadmap for changing data into knowledge and creating a learning organisation. In contrast, Arthur (2005) describes a similar phenomenon of the results of highly successful projects being offset by projects that add little or no value, but proposes that the solution is to divide the organisation into subsystems as the joint effect of each subsystem achieves optimal results for the whole, but this is created in a more controlled environment.

Moving from 3 to 6 sigma quality is the result of a 20,000 times improvement which highlights the need for both dramatic and quick improvement associated with Six Sigma. This can only be achieved through innovation, which is only implicit in Six Sigma methodology and therefore often ignored. Similarly, Six Sigma also doesn't contain methods that deliver breakthrough project solutions. Those companies looking to significantly improve performance must incorporate innovative thinking into their Six Sigma initiative (Gupta, 2005).

Gack and Robison (2003) see an application for Six Sigma in system development, but caution that it needs to be integrated with other improvement initiatives. One of the benefits Six Sigma will bring to system development is a focus on the customer's and not the engineer's requirements.

Folaron (2003) answers the debate as to how long Six Sigma will endure by stating that it is not suitable for all situations and changes over time will lead to significant changes in the methodology, such as the removal as belts as descriptors for practitioner grading, the elimination of the root causes of problems becoming part of generally accepted management practice and the move towards designing processes correctly rather than fixing them. Despite these changes, the focus on continuous improvement will ensure that Six Sigma endures in the future.

In addition, Folaron (2003) sees an economic limit to improvement and therefore views the debate as to whether the goal of Six Sigma should be achieving 3.4 defects per million opportunities or zero defects as meaningless for most companies.

Successful Six Sigma implementation is more of a change management programme than either a quality improvement programme or a systematic innovation management programme. Over time, it always changes cultures, but rather than do this directly which usually results in failure, Six Sigma focuses on changing behaviour indirectly through examining what people do and how they do it instead of how they feel. Through the DMAIC framework, Six Sigma teaches a better way of thinking based on a disciplined, analytic, deliberate method. Feelings and culture change will eventually result from achieving short term results and role modelling how to solve problems through deliberate decision-making rather than fire fighting and by not attributing blame (Bisgaard, 2007).

Data collection enables analysis, which creates information and so each step limits what can occur at the next step. This highlights why the initial step in a project is critical and cannot rely solely on data that currently exists. Instead, the design of experiments (DOE) should take more of a central role in Six Sigma as it enables cause and effect relationships to be established based on solid evidence (Bailey, 2007).

Fundin and Cronemyr (2003) call for customer feedback to be incorporated as a mechanism to select projects. They describe how Alstom Power Industrial Turbines in Sweden channels feedback from customer complaints through to process improvement as a mechanism to identify and prioritise Six Sigma projects. Codifying customer feedback as process faults can provide a powerful input to process improvement (Fundin and Cronemyr, 2003). Companies spend only 5% of their resources analysing how to solve root causes and 95% on solving individual customer complaints (Adamson, 1993). Goldstein (2001) recommends incorporating a customer's ability to notice improvement, the ease of measurement and a high probability of success into project selection criteria.

Whilst some view the fundamental principle of Six Sigma as solving "the right problem the right way" (Lim, 2003, p. 17) through choosing the right problems and then choosing an appropriate solution strategy, others see the lack of a structured process to identify projects as a flaw in the Six Sigma methodology (Antony, 2004). Lim's (2003) method for prioritising problems centres around identifying processes that require the most stabilising in terms of controllability and that also have the most process capability problems, however these factors still need to be linked to financial returns based on an estimate of how much the project will improve the process and an estimate of the impact that this will have financially (Lim, 2003).

2.6.6. The future of Six Sigma

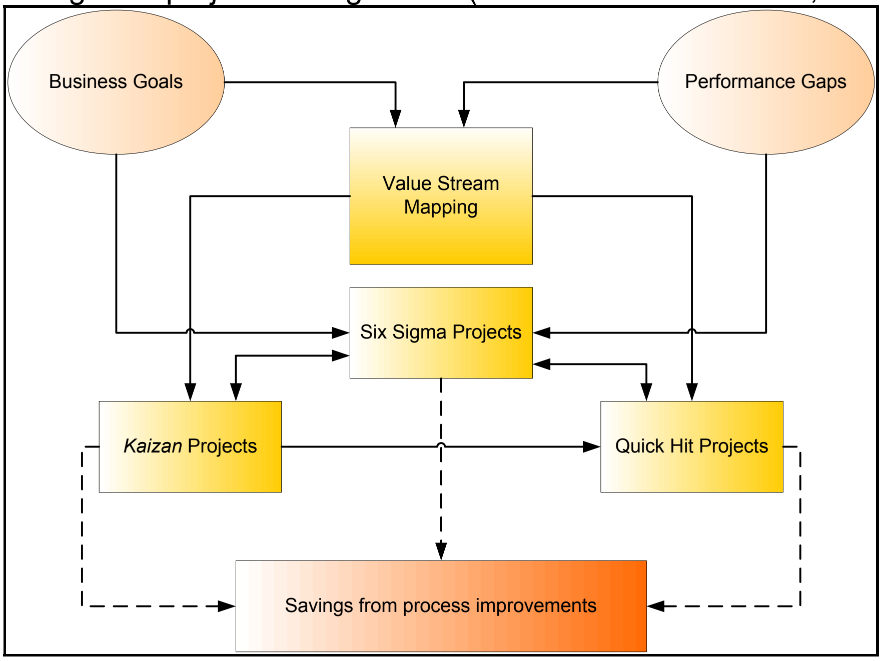
Sower and Fair (2005) argue that although continuous improvement is necessary for an organisation's survival, it is not sufficient as breakthrough improvement is also required, especially in today's environment of shorter product life cycles and increased technology usage. Transcendent quality is the most important perspective from which to view quality as it leads to breakthrough improvement and shifting paradigms, but it requires a higher level of awareness than understanding, namely insight.

Without insight, creativity and innovation, quality programmes such as Six Sigma can only lead to the continuous incremental improvement of customer-based quality. In addition, these programmes can stifle creativity and innovation as their focus is on discipline and quantitative measurement. Transcendent quality can be achieved through creativity which needs to be measured by recognising, prioritising and celebrating it (Sower and Fair, 2005).

Even if some companies have managed to overcome the debate as to which method is better and the hurdle of seeing lean and Six Sigma as being mutually exclusive, few have merged them into a holistic improvement programme, where lean helps to achieve simplicity and Six Sigma manages complexity. Instead companies are still using lean to improve process flow by reducing cycle time and waste and Six Sigma to improve quality. In order to compete successfully into the future it is necessary to integrate the approaches and makes use of their mutually reinforcing power (Snee and Hoerl, 2007).

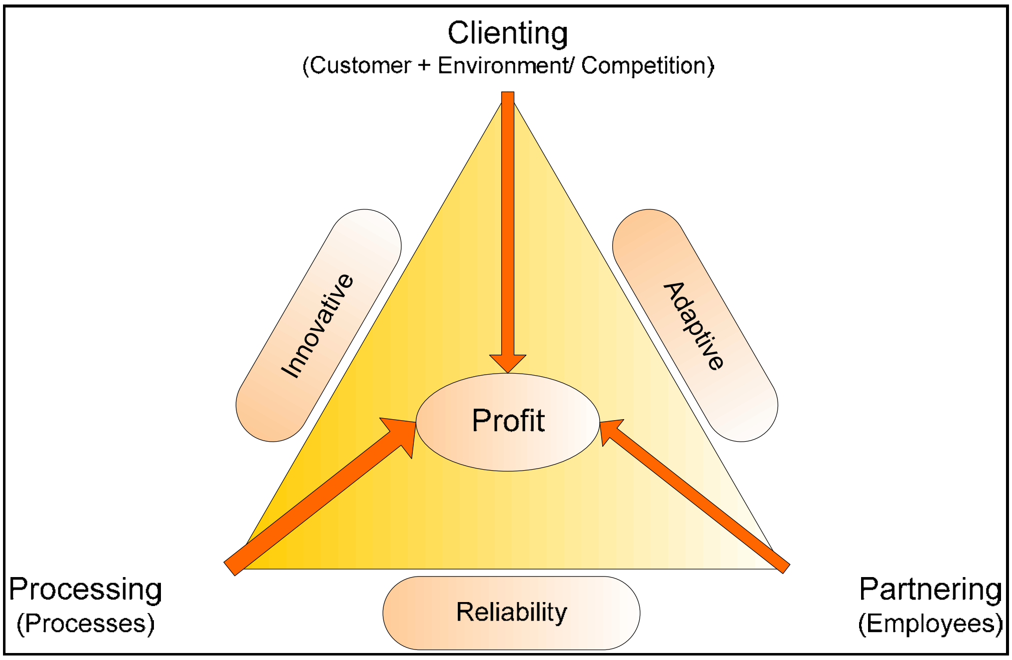
Figure 10 shows how this works. Potential projects are generated top-down through business goals or bottom-up through performance gaps identified by employees. These can create Six Sigma projects directly or serve as input into the lean technique of value stream mapping that can also be used to generate projects. In addition, a Six Sigma project may discover smaller, immediate quick hit projects or 30 day kaizen event projects (Snee and Hoerl, 2007).

Figure 10: Integrated project management. (Source: Snee and Hoerl, 2007, p.17).



Weigang (2005) illustrates how well known companies who were pioneers of Six Sigma, such as Motorola and Bombadier, had problems in declining markets which led to factory closures and retrenchments. The value of Six Sigma is still felt through the numerous success stories; however what has worked in the past may not work for tomorrow. In a typical implementation of Six Sigma, only 5-10% of staff become black or green belts. People are the organisation's most critical success factor and so the other 90-95% also need to be engaged. An integrated profit management concept can be used to achieve this aim as shown in Figure 11.

Figure 11: Integrated profit management. (Source: Weigang, 2005, p. 19).



This concept combines the following:

- “Clienting: customer orientation with concentration on the most important bottleneck in the organisation.
- Partnering: People orientation.
- Processing: Improving product and processes” (Weigang, 2005, p. 19).

This concept helps to change the culture of top management who tend to focus on short term shareholder benefit through Six Sigma at the expense of organisational culture, employee job satisfaction and long term success. Whilst competitors can quickly emulate strategic, high level activities, they cannot imitate the processes involved in day to day work, which tend to contain numerous opportunities to reduce waste and small mistakes (Weigang, 2005).

"The long-term success of Six Sigma lies in the adoption of a business philosophy that encourages acquisition of knowledge over meeting arbitrarily assigned targets; developing an infrastructure that encourages critical thinking and rewards learning and personal development; and continually developing a diverse set of tools and methods that support the variety of needs across different areas of the organisation" (Hild and Sanders, 2007, p. 39).

Because Six Sigma originated in industry, it lacks a theoretical underpinning and further research is required to bridge the gap between Six Sigma theory and practice (Antony, 2004).

2.6.7. The impact of Six Sigma on performance

Six Sigma "has been so successful in many organisations where performance is significantly improved beyond that which can be obtained through other means" (Antony and Banuelas, 2002, p. 92). Since the organisation's goal is to be profitable, the goal of Six Sigma projects is to make business processes profitable by reducing variability. This is done through the Six Sigma methodology which states that every project objectives should clearly link to the organisation's strategy (Antony and Banuelas, 2002).

The preceding view is in sharp contrast to Catherwood (2005) who asserts that for many companies without significant resources and mature strategies Six Sigma does not deliver on expected performance. Both Motorola and GE have had to modify their programmes to changing business conditions. However, part of the Six Sigma methodology involves ensuring projects drive financial benefits and therefore nearly all Six Sigma research states that Six Sigma drives operational performance in such a way that it is then translated into financial performance (Pande *et al*., 2000; Eckes, 2001; Gupta, 2004).

Although studying a large sample of firms provides a better indication of whether a quality management methodology improves financial performance overall (Foster, 2007), the reported results of companies that have implemented Six Sigma are also an indication of its ability to improve financial performance. Motorola, General Electric (GE), and Cummins have reported more than $15 billion, $12 billion and $1.4 billion in savings respectively (Foster, 2007). A survey found that while 17% of companies didn't measure their savings, 75% reported financial benefits of more than £100,000 per annum (Antony and Banuelas, 2002).

Given the popularity of Six Sigma adoption, Foster (2007) calls for more research into the costs and benefits of Six Sigma implementation.

Foster (2007) empirically tests 138 American organisations to determine whether Six Sigma improves their performance compared to non-Six Sigma organisations. He finds a significant effect on free cash flow across all Six Sigma firms and limited effects on asset turnover. In addition, he finds that while Six Sigma companies did not outperform firms with no quality management programme in terms of earnings before interest, taxes, depreciation and amortisation (EBITDA), they did outperform their counterparts using other quality management techniques.

Companies with low asset turnover seem to benefit more than companies with high asset turnover and Six Sigma did not appear to affect sales, return on assets, return on investment and firm growth. In addition, Six Sigma seems to be a drain on the resources of cash-poor firms which did not perform well (Foster, 2007).

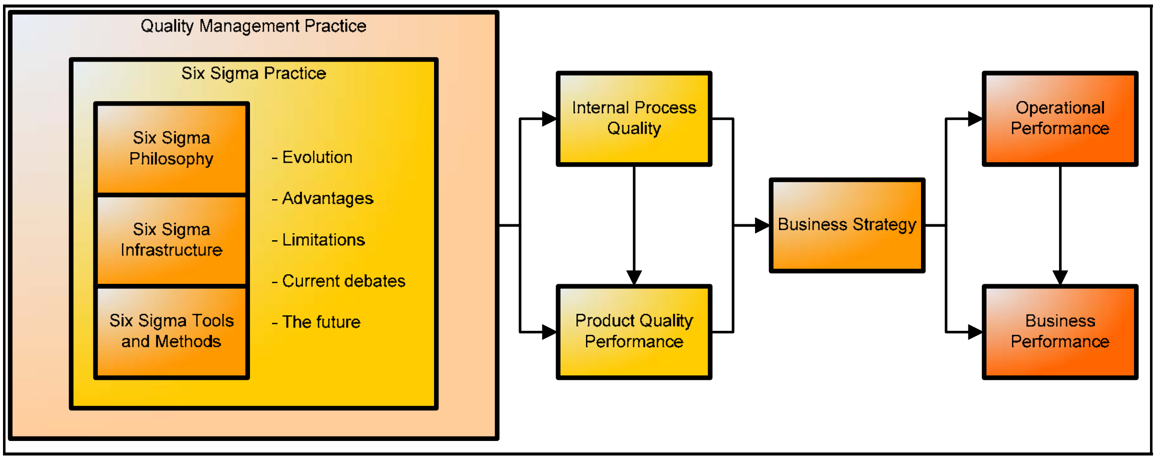
In summary, Foster (2007) discovers mixed results in his four year longitudinal study. His sample consists of companies whose annual reports mention a quality initiative between 1996 and 1998 as well as a control group from the 1998 Fortune 500 list. Of the 138 firms, his final sample consists of 24 Six Sigma firms, 26 TQM firms, 24 Baldrige firms and 23 ISO 9000 firms as well as a control group of 41 firms. He classifies financial and operational performance into measuring profitability, cost, efficiency and growth.

2.7. Conclusion to the literature review

This chapter set out to explore the research problem of whether Six Sigma improves performance based on the body of knowledge that already exists. The chapter delves into the constructs within the literature to find that, whilst it is almost taken for granted that Six Sigma improves performance due to this being stated as part of the methodology, Foster (2007) is the only one to test empirically whether this is true and he finds mixed results. Since the proof of validity for a managerial technique is to improve profit (Freiesleben, 2006), it is concerning that more research hasn't been done in this area and supports Foster's (2007) call for additional research.

The chapter gives tentative indications that Six Sigma should improve both financial and operational performance, but that it is also highly dependent on the team responsible for the implementation of the initiative. Figure 12 below serves to pull together a model of where Six Sigma fits into the body of knowledge and illustrate the main themes of interest that fall within this topic and that were covered within this chapter.

Figure 12: Model of Six Sigma's position within the performance process.



3. Chapter 3: Research Hypotheses

3.1. Introduction

This chapter gives a rationale for following Foster's methodology before describing the two propositions of the study. These propositions are each translated into five hypotheses that are used to test the relationship between Six Sigma and financial results.

3.2. Propositions and Hypotheses

The research will apply Foster's methodology (2007) to more recent data from American firms. Foster (2007) used a modified version of the performance measures suggested by Hendriks and Singhal (1997). Because Foster (2007) had a comprehensive measurement that included profitability, cost, efficiency and growth, a similar scale will be used. The research hypotheses are described below:

Proposition 1: There is a positive relationship between Six Sigma adoption and improved financial results. This proposition is translated into five hypotheses based on the following logic. Cost reduction and process improvement associated with Six Sigma should free up cash for other uses and result in improved operating margins.

- Hypothesis 1a: Six Sigma adoption is positively associated with higher free cash flow per share.

- Hypothesis 1b: Six Sigma adoption is positively associated with lower cost per US dollar of sales.
- Hypothesis 1c: Six Sigma adoption is positively associated with higher EBITDA.
- Hypothesis 1d: Six Sigma adoption is positively associated with higher sales.
- Hypothesis 1e: Six Sigma adoption is positively associated with higher sales per employee.

Proposition 2: There is a positive relationship between Six Sigma adoption and improved operational performance. This proposition is translated into five hypotheses based on the following logic. Part of the Six Sigma process is an improvement in the use of assets and implicitly a more productive use of assets. Secondly, it is uncertain whether or not Six Sigma results in more employees, because it could help growth as profitability improves, but increased employee productivity could also lead to downsizing.

- Hypothesis 2a: Six Sigma adoption is positively associated with higher asset turnover.
- Hypothesis 2b: Six Sigma adoption is positively associated with higher return on assets.
- Hypothesis 2c: Six Sigma adoption is positively associated with higher return on investment.

- Hypothesis 2d: Six Sigma adoption is positively associated with higher total assets.
- Hypothesis 2e: Six Sigma adoption is not related to number of employees.

3.3. Concluding Remarks

Foster's methodology (2007) is used in this study to determine the relationship between Six Sigma adoption and financial and operational results, which are measured in terms of profitability, cost, efficiency and growth. In order to measure these areas, ten hypotheses are posed in order to compare Six Sigma to the following measures: free cash flow per share, cost per US dollar of sales, EBITDA, sales, sales per employee, asset turnover, return on assets, return on investment, total assets and number of employees.

4. Chapter 4: Research Methodology

4.1. Introduction

This chapter will outline the methodology that was used in this study. The chapter is divided into sections outlining the research design, unit of analysis, population, sampling method and sample size, as well as the research instrument. The process used to collect and analyse the data is then described. Finally the assumptions and limitations of the study are discussed.

Each section starts with a section definition. Next, details of the methodology chosen for each section are described. Finally, a defence is given as to why the chosen methodology was deemed appropriate.

4.2. Research design

4.2.1. Definition

Business research is defined as “the systematic and objective process of gathering, recording, and analysing data for aid in making business decisions” (Zikmund, 2003, p. 6). Applied research is defined as “research undertaken to answer questions about specific problems or to make decisions about a particular course of action” (Zikmund, 2003, p. 7). Inductive reasoning is defined as “the logical process of establishing a general proposition on the basis of observation of particular facts” (Zikmund, 2003, p. 47).

Business research may be classified into exploratory research that is "conducted to clarify and define the nature of a problem" (Zikmund, 2003, p. 54), descriptive research that is conducted "to describe characteristics of a population or phenomenon" (Zikmund, 2003, p. 55) or causal research that is "conducted to identify cause-and-effect relationships among variables when the research problem has already been narrowly defined" (Zikmund, 2003, p. 56). Descriptive research is either longitudinal or cross-sectional in design. A longitudinal study is a "survey of respondents at different points in time, thus allowing analysis of response continuity and changes over time" (Zikmund, 2003, p.187).

Replication is defined as "the duplication of a previously published empirical study to determine whether the findings of that study are repeatable" (Singh *et al*., 2003, p. 534) and a replication with extension is a study that "departs from the original study in some respect or employs different data while largely repeating the original study to evaluate the generalisability of earlier results" (Singh *et al*., 2003, p. 534).

Secondary data are "data that have been previously collected for some project other than the one at hand (Zikmund, 2003, p. 63)".

4.2.2. Details

This study took the form of applied research and was descriptive in nature. The study used inductive reasoning to test the theory that Six Sigma improves performance by examining the results of firms empirically. A longitudinal design that spanned a four year period from 2004 to 2007 was chosen. The study was a replication with extension of Foster's (2007) work and secondary data was used as the research method.

4.2.3. Defence of method

4.2.3.1. Use of descriptive research

Descriptive research was chosen as the research methodology because the problem was fairly well defined and much theory has been written about how Six Sigma improves performance. So much so, that this is attributed to being what differentiates Six Sigma from other quality programmes.

Exploratory research was not required as the problem was already fairly well defined. Similarly causal research could not be used, because a study inferring causality is required to establish the sequence of events, measure concomitant variation and recognise the presence of other factors (Zikmund, 2003). This study is post hoc, so the sequence of events cannot be determined. In addition, there are many factors that cannot be ruled out of influencing the profitability of a firm.

4.2.3.2. Use of a longitudinal design

The problem required examining whether Six Sigma improved performance. This problem meant that the change in performance over time needed to be measured. In order to do this, it was necessary to allow enough time to see the effects of an implementation. This study used the same methodology as Foster (2007) who in turn used a four-year interval based on four previous studies. Ozan (1992) recommended gradual implementation, the United States General Accounting Office (1991) recommended 3.5 years to see TQM results, Narasimhan, Ghosh, and Mendez (1993) recommended 2.26 years to see sales improvements from quality efforts and finally Foster (1996) recommended that slower improvement lead to better results in quality efforts.

4.2.3.3. Use of a replication with extension study

Singh, Ang and Leong (2003) call for a greater emphasis on replication as it helps to ensure that research is valid and reliable and leads to rigorous theory development. The critical evaluation of empirical results through replication is therefore as important as peer review and research publication (Singh *et al.*, 2003). The advantages are protection against Type 1 errors and enhanced generalisability of empirical findings due to different contexts. Foster (2007) conducted the first study into the relationship between Six Sigma and improved financial performance. Replication will therefore help to promote rigorous theory development and generalisability.

4.2.3.4. Use of secondary data

Using secondary data is cheaper and it is quicker to obtain than primary data that may not be accessible to the researcher; however the data was not designed for the researcher's needs and therefore may not be accurate, sound and free from bias (Zikmund, 2003). With tight deadlines, access to cheap and easily accessible data is important. I would rather reduce this comment. The study will follow previous methods that have shown that the methodology and data obtained is sound. In addition, the data is assumed to be accurate and free from bias, since the financial statements are audited by independent third parties.

4.3. Unit of analysis

4.3.1. Definition

The unit of analysis specifies "whether the level of investigation will focus on the collection of data about the entire organisation, departments, work groups, individuals, or objects" (Zikmund, 2003, p. 96).

4.3.2. Details

The unit of analysis is a listed firm.

4.3.3. Defence of method

Balnaves and Caputi (2001) note the importance of the unit of analysis as research findings can be generalised across a unit of analysis. A problem can usually be examined at many units of analysis, but the choice is "a crucial aspect of problem definition" (Zikmund, 2003, p. 96). The firm was chosen as the unit of analysis in order to replicate Foster's (2007) study and in order to obtain data from a large number of organisations.

Another possible study could have looked at whether Six Sigma practitioners and recipients felt that Six Sigma had a role in improving performance. Although this option would have possibly been more relevant to the South African context, it was decided against because attitudes are hypothetical constructs and would have been less capable of measuring the direct role of Six Sigma on performance. It is envisaged that later studies into this area will examine why certain implementations are successful and others aren't and that this will include research at the individual level of analysis.

4.4. Population of relevance

4.4.1. Definition

A population is "a complete group of entities sharing some common set of characteristics" (Zikmund, 2003, p. 369) and the population of relevance or target population is "the specific, complete group relevant to the research project" (Zikmund, 2003, p. 373).

4.4.2. Details

The population of relevance comprised companies listed in the United States of America from 2004 to 2007. This population was divided into Six Sigma firms and a control group of non Six Sigma firms.

4.4.3. Defence of method

This research was initially aimed at a population of South African firms, but not enough companies were identified and so the population was extended to firms worldwide. However the only available sampling frames obtained were largely for American firms and so the population was ultimately limited to the United States.

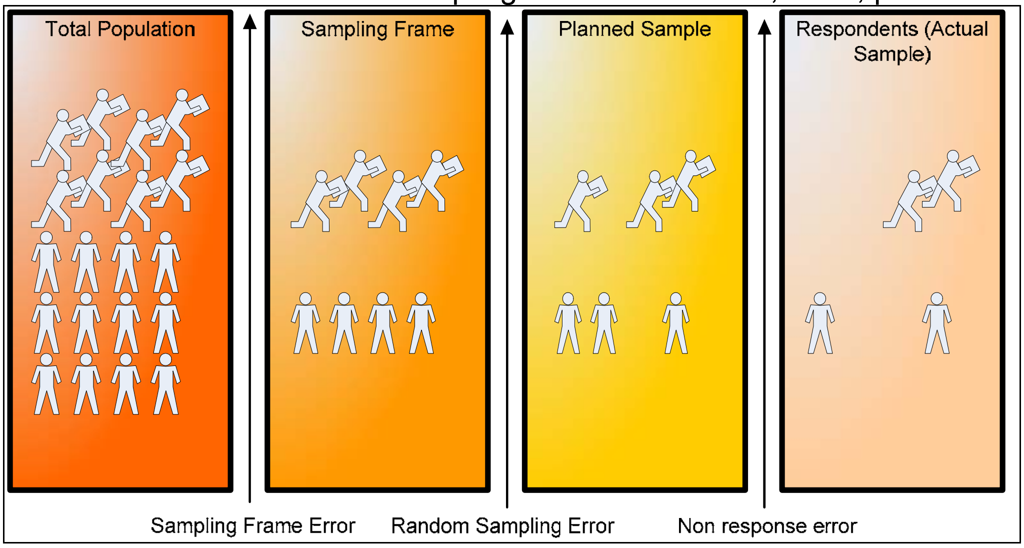
When looking at the results of firms in an earlier study, Foster (2007) looked at financial results from 1996 to 1998 to amass a large enough population of firms. However Six Sigma continues to be a growing phenomenon and so firms were included in the population if they were using Six Sigma in 2003. In addition, a later time period than Foster (2007) was chosen in order for the study to be more relevant to firm's today.

4.5. Sampling method, sampling frame and sample size

4.5.1. Definition

Before looking at the definitions of each of the elements associated with sampling, it is useful to examine how they fit together. Figure 13 below shows the various elements of sampling and how errors arise at the different steps of the sampling process.

Figure13: Errors associated with sampling. Source: Zikmund, 2003, p. 380



The sampling frame is “the list of elements from which a sample may be drawn; also called a working population” (Zikmund, 2003, p. 373). A sample is “a subset, or some part, of a larger population” (Zikmund, 2003, p. 369).

Sampling is “the process of using a small number of items or parts of a larger population to make conclusions about the whole population” (Zikmund, 2003, p. 369). Probability sampling is “a sampling technique in which every member of the population has a known, nonzero probability of selection” (Zikmund, 2003, p. 379). Nonprobability sampling is “a sampling technique in which units of the sample are selected on the basis of personal judgement or convenience” (Zikmund, 2003, p. 380) and judgement sampling is “a nonprobability sampling technique in which an experienced individual selects the sample based upon some appropriate characteristic of the sample members” (Zikmund, 2003, p. 382).

Finally the sample size is "the size of a sample; the number of observations or cases specified by (1) the estimated variance of the population, (2) the magnitude of acceptable error, and (3) the confidence level" (Zikmund, 2003, p. 425) and is calculated according to the following formula.

"$n = (ZS/E)^2$

where Z = standard value corresponding to a confidence level

S = sample standard deviation or an estimate of the population standard deviation

E = acceptable magnitude of error, plus or minus and error factor" (Zikmund, 2003, p. 426).

4.5.2. Details

Two samples needed to be obtained for this study, namely a sample of Six Sigma firms and a sample of non Six Sigma firms. This section will firstly describe the process followed to obtain the sample of Six Sigma firms and then the non Six Sigma firms.

4.5.2.1. Details for Six Sigma firms

The sampling frame was made up of combined lists of Six Sigma companies that were obtained from scouring the internet.

In order to find a sampling frame, lists of Six Sigma companies were searched for on the internet. Reference to three lists was found, namely:

- A list of 440 companies that the George Group were said to have as clients. Unfortunately the George Group has since merged with Accenture and so the original list was no longer available on their website. However a partial list of these companies was posted on www.iSixSigma.com in August 2005. It is assumed that these companies would have started beforehand or would have seen an impact, if not in 2004, then from 2005 to 2007 and so they were included.

- A list of 115 companies was posted on a blog on the www.iSixSigma.com website in April 2003. One company on the list was later cited as not being a Six Sigma company and many companies were added to the list. In order to be prudent, both the single company and the other companies were excluded, the latter because the credibility of their sources could not be determined.

- A list of 69 companies was posted on Wikipedia. This list dovetailed with the other lists to some extent, but Wikipedia was not deemed to be a credible source from which to obtain a list and so this list was ignored, except for where Wikipedia cited references for the companies. In these 22 cases, the reference was found and the company was added to the sampling frame where appropriate.

Members from the three lists were combined where appropriate and duplications were eliminated, resulting in a list of 72 firms. In order to account for sector, convenience sampling was then used to limit the study to the four sectors that had the most Six Sigma firms, namely health, technology, capital goods and basic materials. Each company in the sampling frame that fell within one of these sectors was selected to be in the sample. Because each firm had the same probability of being chosen, a probability sampling method was followed.

Since access to Reuter's knowledge database gave easy access to the population of firms listed in the United States, this was used to determine the sample size. The required sample size was calculated using the standard deviation for the last financial year's normalised EBITDA for all companies listed in the United States, which was USD (m) 4,096. A 95% confidence level and an acceptable magnitude of error of USD (m) 1,000 were chosen. These assumptions resulted in a required sample size of 64 firms when using the calculation in section 4.5.1. As half the sample would be made up of Six Sigma firms and half of non-Six Sigma firms, this resulted in a required sample size of 32 companies per group.

4.5.2.2. Details for non Six Sigma firms

The sampling frame was made up of a list of listed companies in the United States obtained from Reuter's knowledge database. This list contained the last five years results for all of the companies, even companies that no longer existed. A judgemental sampling method was used to choose a control group of companies. The criteria for choosing a comparison company were that the company was still in business and in the same sector and industry as the Six Sigma company. Within this group, the company with the closest return on equity (ROE) in the first year was chosen as the comparison company. Initially the market capitalisation was used, but this could only be obtained for the last year, so a comparison of ROE in the first year was chosen instead as it was believed to be more reliable. As stated in section 4.5.2.1 above, the required sample size of non Six Sigma firms is also 32 firms.

4.5.3. Defence of method

4.5.3.1. Defence for Six Sigma firms

Foster (2007) used a sampling frame made up of results from searching for the keyword Six Sigma in annual reports in the LexisONE database. This was done based on the assumption that annual reports communicate commitment to shareholders (Foster, 2007) and so, if an annual report stated that a firm was implementing Six Sigma, the implementation would be both strategic enough and broad enough to influence financial results.

This study differs from Foster (2007) in that lists of Six Sigma companies were used to determine a sampling frame. The reason is that a keyword search did not generate results in the 2004 reports of Motorola, General Electric and 3M, all of which are well known Six Sigma companies. It is assumed that Six Sigma has become part of the culture of these companies and is therefore no longer explicitly stated.

Despite viewing lists as a more effective sampling frame than a keyword search, the lists do not cover the entire population of Six Sigma firms in the United States. In addition, they may contain companies that haven't implemented Six Sigma at a strategic level. There is much debate about the level of Six Sigma implementation that is required for a firm to be classified as a Six Sigma firm. Sampling frame error is therefore introduced into the sample.

The lists obtained from www.isixsigma.com were deemed to be credible for the following three reasons. Firstly, the website was seen as credible, because "since 2000, iSixSigma.com has provided the most comprehensive and essential resources available anywhere to businesses at every stage of their Six Sigma maturity and professionals at every skill level". Secondly, many people had commented on and critically analysed the list of 115 companies including people looking to use the list in research and academics. Thirdly, it was felt that previously the George Group and currently Accenture would not allow a false list of their previous clients to be published on the website.

After obtaining a list of Six Sigma companies, the list was reduced to the sectors with the most firms. This was done in order to improve the accuracy of the results by having a larger sample of a smaller population (Zikmund, 2003). The reason that every company within these sectors was then selected was also to gain as big a sample as possible.

Normalised EBITDA was selected as the profitability measure with which to determine the ideal sample size. This measure is easy to calculate. It was also accessible as it could be read off the income statement. Secondly a 95% confidence interval was selected as this is typical in statistical studies (Zikmund, 2003). Finally USD (m) 1,000 was seen as an acceptable magnitude of error as this was around 25% of the standard deviation of the population.

4.5.3.2. Defence for non Six Sigma firms

In order to compare the sample companies with non Six Sigma companies, Foster (2007) selected 50 companies randomly from the 2002 Fortune 500 list. After removing firms that were no longer in business and firms that were in the list of Six Sigma companies, the control group was reduced to 41 firms. This study will again differ from Foster (2007) as an effort has been made to control for company sector and size when selecting a comparison group of companies. Comparative companies were therefore not selected randomly, but rather with the goal of creating a homogenous group of companies. Unless there is a reason to be concerned that the financial results of the sample firms differ in a relevant way from the entire population, it is deemed safe to treat them as a random sample (Zikmund, 2003).

4.6. Measurement instrument

4.6.1. Definition

The measurement instrument is the instrument used to collect the data, such as a questionnaire or interview guide.

4.6.2. Details

Secondary data was used for this study and so a measurement instrument was not required. However the secondary data still needed to be collected and this was done by running a report in Reuter's knowledge database that included the fields necessary for the study as shown in Table 6 below.

Table 6: Fields used in study

Static Fields	
Company name	Reuter's Sector Code
Ticker	Reuter's Industry Code
RIC	Fiscal period date, last financial year
Fields collected per annum from the current financial year to five years ago	
1c. Normalised EBITDA	Cash from operating activities
1d. Total revenue	Total equity
2d. Total assets	Common stock
2e. Number of employees	
Calculated measurements per annum	
1a. Free cash flow per share: Cash from operating activities / Common stock	
1b. Cost per $ of sales: (Total revenue - Normalised EBITDA) / Total revenue	
1e. Sales per employee: Total revenue / Number of employees	
2a. Asset turnover: Total revenue / Total assets	
2b. Return on assets: Normalised EBITDA / Total assets	
2c. Return on investment: Normalised EBITDA / Total equity	

4.6.3. Defence of method

The measurements were based on the issues identified in the literature review and in keeping with previous studies. The performance measures were the same ones used in Foster's (2007) study, who in turn modified those used in Hendricks and Singhal's (1997) study. Reuter's was used to collect the data as it was quick and seen as a credible source.

4.7. Process of data collection

4.7.1. Definition

Data collection is usually defined as "the process of gathering information from respondents" (Zikmund, 2003, p. 72). Secondary data was used in this study, but the data still needed to be collected from those sources. The following sections will describe the process followed and defend the choices made.

4.7.2. Details

Data was collected to determine the profitability of both Six Sigma and non Six Sigma firms. The data collected was secondary data obtained from Reuter's knowledge database. This database contains audited annual financial statements of listed companies around the globe. After seeing that most of the identified Six Sigma companies were listed in the United States, the study was restricted to looking at American companies. A report was created from the database to generate the required data.

The report was then exported to a Windows Excel Spreadsheet for the period last financial year to fifth last financial year in order to analyse the data. Section 4.6.2 shows the measures that were downloaded as well as the calculations used to derive profitability measures that were then performed in Excel where appropriate. The measure number of employees could only be obtained for the final year on the report and not per annum, so this information was recorded manually per firm from Reuter's once the final list of firms was obtained.

4.7.2.1. Excluded data

After downloading the data, firms that had ceased operations were deleted from the dataset. Results for financial year 2008 were also deleted and the other results for these firms were moved backward a year. In other words, a firm that was initially downloaded as having results from three years ago (2005) to current financial year (2008) had all its results moved backwards one year, so that they became results from three years ago (2004) to current financial year (2007).

The list of data was then eyeballed to identify any missing data and companies that had missing data were removed from the study. Where these companies were comparison companies, they were replaced with another comparison company. Two comparison companies and one Six Sigma company were removed as they had no common stock. This process also identified that the initial measure downloaded as cost per $ of sales, namely cost of revenue, was not actually cost per $ of sales. The measure was therefore calculated from Normalised EBITDA and Total Revenue instead.

4.7.2.2. Editing and coding data

The data was coded by calculating the ten measures necessary for the study. In addition, a series of three successive pivot tables were created to get the data into the right format to be imported into the statistical programme, Minitab. The first pivot table was created in order to be able to choose the closest comparison company. Once identified here, the information was fed back to the original dataset. A second pivot table then stacked the yearly data in order to create Year as a variable. However this could not be done without also stacking all of the measure variables. The final pivot table therefore unstacked the measures again.

4.7.3. Defence of method

Reuter's knowledge database was seen as a credible source of financial statements and it provided easy access to the data. A report with the necessary data could be run quickly and easily and eliminated the possibility of data capturing errors. The study was restricted to looking at American companies in order to obtain a larger sample for a smaller population and Excel was used as it is an easy programme in which to manipulate data.

Data was excluded and manipulated where necessary according to the principles of maximising the sample size, whilst at the same time having accurate and complete data that was relevant to the research problem. Pivot tables were used to transform the data into a format that was easy to use in Minitab, so that once the data was in the statistical programme the focus could be on statistics instead of on data manipulation.

4.8. Process of data analysis

4.8.1. Definition

"Analysis is the application of reasoning to understand and interpret the data that have been collected." Descriptive statistics is "statistics used to describe or summarise information about a population or sample" (Zikmund, 2003, p. 402). Inferential statistics is "statistics used to make inferences or judgements about a population on the basis of a sample" (Zikmund, 2003, p. 402).

4.8.2. Details

Descriptive and inferential statistics were used to analyse the data.

4.8.3. Descriptive statistics

Descriptive statistics were calculated as shown in Table 7 below for each of the profitability measures in the first and final year and per sector.

Table 7: Elements of Descriptive Statistics

Statistical element	**Description**
Number of observations (n)	The number of observations in the sample.
Mean	"The mean is the average of all values of a variable" (Albright, Winston and Zappe, 2006, p. 82).
Median	The median is the "middle" observation when the data are arranged from smallest to largest" (Albright, Winston and Zappe, 2006, p. 83).
Minimum	"The smallest value" (Albright, Winston and Zappe, 2006, p. 85).
Maximum	"The largest value" (Albright, Winston and Zappe, 2006, p. 85).
Interquartile range	"The difference between the first and third quartiles." "It measures the spread between the largest and smallest of the middle half of the data" (Albright, Winston and Zappe, 2006, p. 85).
Standard deviation	"The square root of the variance" (Albright, Winston and Zappe, 2006, p. 87). This is easy to interpret as it is a measure of spread in the same units as the data (Albright, Winston and Zappe, 2006).

4.8.4. Inferential statistics

Inferential statistics was chosen in order to fulfil the research problem by being able to test the sample collected to see whether Six Sigma firms outperformed non Six Sigma firms and infer the results to the population.

4.8.4.1. Hypothesis testing

Hypothesis testing was used to test the ten hypotheses outlined in section 3. After describing hypothesis testing in this section, the following section will describe the analysis of covariance, which is the specific test that was used to carry out the hypothesis testing.

Albright, Winston and Zappe (2006) state that hypothesis testing is possible due to the central limit theorem, which implies normality. The process that was followed to conduct the hypothesis tests is as follows (Albright, Winston and Zappe, 2006):

1. The null hypothesis (H_0) about a population mean that reflected the "status quo" was stated.
2. The alternative hypothesis (H_a) that was trying to be proved was stated.
3. The significance level (α) was chosen to determine the size of the rejection region.
4. The p-value was calculated. "The p-value is the probability of seeing a random sample at least as extreme as the observed sample, given that the null hypothesis is true." "The smaller the p-value, the more evidence there is in favour of the alternative hypothesis" (Albright, Winston and Zappe, 2006, p. 493).
5. The p-value was compared to the significance level.
6. The null hypothesis was rejected if the p-value was smaller than the significance level and could not be rejected if the p-value was greater than or equal to the significance level.

4.8.4.2. Analysis of covariance (ANCOVA)

Analysis of covariance (ANCOVA) was chosen as an appropriate test to analyse whether significant differences existed between the means of Six Sigma and non-Six Sigma firms. A significance level of 5% was chosen as an acceptable probability level above which to fail to reject the null hypothesis. ANCOVA was conducted by using an analysis of variance (ANOVA) method with general linear model together with covariates.

ANCOVA tests were run to see which terms were significant. A full regression model was also run to see how well the model was suited to explain the dependent variable. Another and sometimes two more regression models were then run with the reduced number of significant terms to see how well the new model fit and to get the coefficient for the significant terms in order to see what effect they have on the model. ANCOVA tests were also run for the reduced models to test which terms were significant.

4.8.4.3. ANCOVA Assumptions

According to Lowry (1999, Ch 17, Part 1), “ANCOVA is the result of a felicitous marriage between the analysis of variance and the concepts & procedures of linear correlation & regression. It is, in fact, a veritable powerhouse of a statistical procedure.” ANCOVA’s assumptions therefore come from these two parent procedures.

Velleman (2004) states that the analysis of variance (ANOVA) requires three conditions about the response variable, namely:

1. The observations must be mutually independent as can be assumed based on the design of the experiment and its measurements.
2. The residuals must be normally distributed as can be verified with a normal probability plot of the residuals which allows outliers to be omitted or corrected.
3. The groups must have approximately equal variability as can be checked using boxplots which again allow outliers to be dealt with or tested using an equal variance statistical test. Point 2 and 3 can also be dealt with by re-expressing the data.

Lowry (1999) states that, similarly to ANOVA, ANCOVA is also robust enough to handle the non-satisfaction of the above assumptions, providing the groups have the same number of subjects. Lowry (1999) also explains the additional ANCOVA assumption that descends from correlation and regression, namely that:

4. The slopes of the regression lines for each of the separate groups are roughly the same.

Because these are both rough and robust enough to withstand non-satisfaction, outliers were not removed from the sample due to the limited sample size.

4.8.5. Defence of methods

"The appropriate analytical technique for data analysis will be determined by management's information requirements, the characteristics of the research design, and the nature of the data collected" (Zikmund, 2003, p. 73). The chosen analytical techniques are consistent with the information requirements, which were to determine whether Six Sigma improves performance, the research design, which was a longitudinal descriptive design, and the nature of the data collected, which was profitability measures per firm.

Descriptive statistics were used to gain a good understanding and interpretation of the sample that had been collected and to examine the presence of outliers and differences between means.

ANCOVA was used to test whether these differences were significant. ANCOVA was deemed to be an appropriate test as it firstly allows conditions to be examined independently (Lowry, 1999). This was important in this study, because a repeated measures design would not have been suitable. It would have made no sense to compare half the number of firms that first implemented Six Sigma and then stopped with the other half that first didn't implement Six Sigma and then did.

Secondly, ANCOVA allows one to measure and remove systematic biases between samples (Lowry, 1999). This was important in this study as it was believed that a firm's profitability in one year is correlated with its profitability in another year. So a substantial portion of the variability within firm's profitability in 2007 is actually covariance with their corresponding profitability in 2004. By removing this covariance a substantial portion of the extraneous variability of individual differences is removed. ANCOVA allows a what-if scenario that answers what would have happened if the Six Sigma and non Six Sigma firms had started out with equivalent mean levels of profitability in 2004.

4.9. Assumptions and research limitations

4.9.1. Definition

The assumptions below describe areas that were interpreted or where a decision was made based on what was believed to be the best alternative after taking into account trade-offs between the benefits and costs of the step of the methodology. The assumptions are closely linked to the limitations or shortcomings of the study, many of which arose through the assumptions made.

4.9.2. Details

The following list aims to include the major assumptions and limitations of this study.

Sampling frame error is one of the largest limitations of the study, due to the difficulty of gaining access to a list of Six Sigma companies. A related limitation is that their level of Six Sigma implementation was not analysed. The assumptions made in this regard were that the lists obtained were accurate and that they only contained the names of companies who had implemented Six Sigma to the level and scope that it would impact their financial results. A further related limitation is the use of statistics on a relatively small population size. Future research should incorporate a survey with companies to gauge their level of Six Sigma maturity before including them or by researching the benefits of different levels of implementation. Fortunately the sectors were then limited to try to get results that would be more reliable for their populations.

Another limitation of the study is that it is not directly applicable to the South African context. Whilst this is not necessarily a big limitation of the study, the original intention of the study was to investigate something that would be useful in South Africa. However, it is assumed that South Africa lags the United States in terms of Six Sigma

Even if Six Sigma did impact the financial results, it was not the only impact. A major limitation of the study is that it assumes that the impact from Six Sigma will be reflected in the financial results when it is possible that results showing this will be obtained but that they could have been caused by other factors. It is assumed that even if this is the case in a few companies, the sample is large enough for the mean results to be accurate.

The study is also limited by the profitability measures that were chosen. Accounting measures may not provide an accurate picture of a company's profitability. For example, they may exclude intangible assets and so understate assets. However these measures have been used in previous studies and are therefore judged as being fairly reliable.

4.9.3. Defence of methods

The major defence of the assumptions and limitations is that a process was followed to try to minimise the limitations and to try to verify assumptions and check that they were logical inferences whilst working with the timeframe and resources available. Sampling frame error within Six Sigma research has been cited by numerous people (www.isixsigma.com, 2008) and is difficult to overcome without conducting in depth research into each company studied. This is in turn difficult because many companies view their implementation as strategic and therefore are reluctant to discuss it. However a study of this nature would also be able to examine various ways of measuring financial performance and qualitative performance indicators.

4.10. Concluding Remarks

After having looked at the need for research in the first chapter and then setting out the relationship between constructs and showing the tentative indications of them in the second and third chapters, this chapter describes how this study went about heeding Foster's (2007) call for more empirical testing by describing the methodology that was followed in the design of the study.

This study is a replication of Foster's (2007) study. Secondary data was collected from the 2004 to 2007 financial statements of a Six Sigma group and a homogenous non Six Sigma control group of firms listed on major stock exchanges in the United States. These firms operated within the health, basic materials, capital goods and technology sectors.

Reuter's Knowledge Database was used to collect the annual results of the ten profitability measurements that were used in Foster's (2007) study. The data was cleaned and then analysed by means of analysis of covariance in order to make inferences about whether Six Sigma firms outperform non Six Sigma firms. The main assumptions and limitations of the study are that the list of Six Sigma companies is valid and that the Six Sigma implementation within these firms was both strategic and broad enough to influence financial results.

5. Chapter 5: Results

5.1. Introduction

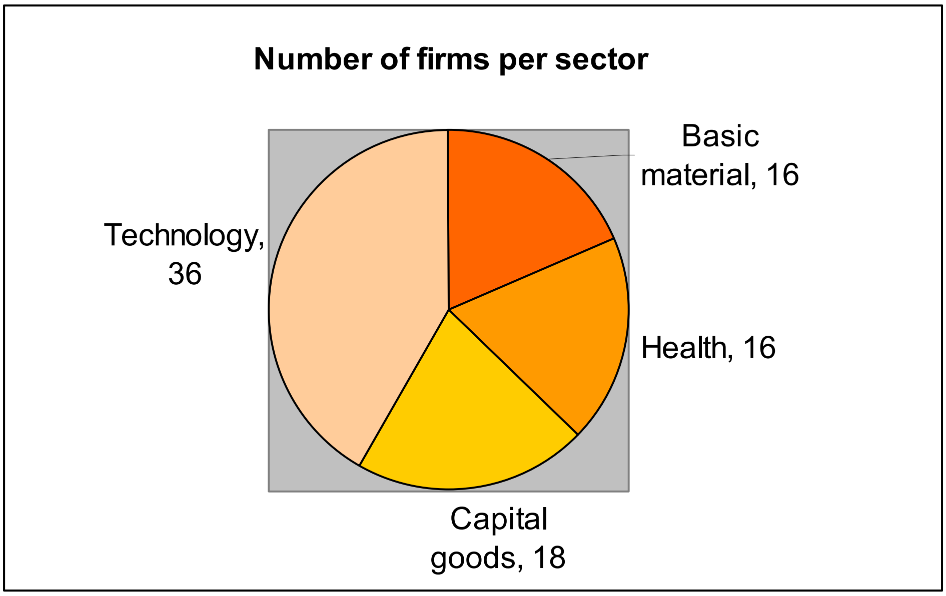
This chapter firstly describes the sample. Secondly, descriptive statistics are presented to give an initial indication of possible differences between means. The final section is broken down into ten sub-sections, each of which maps directly back to the propositions and hypotheses set out in chapter 3. This section presents the results of the ANCOVA tests together with the p-values for the various F-statistics to show whether or not each of the hypotheses is supported.

It must be noted that Foster (2007) presents his results per method split into percentiles to give an indication of different effects based on company size. Because some of these percentile subgroups only contain zero or 1 firm and Zikmund (2003) suggests that an adequate number of respondents should be in each subgroup, this study does not break the sample into subgroups based on size.

5.2. Description of sample

A list of all the matched pairs of Six Sigma firms and comparison firms are shown in Appendix A. The firms are grouped per sector and each pair comes from the same industry to prevent any bias from entering the sample through events that might have impacted on an industry during the period. A summary of the number of firms per sector is shown in Figure 14 below. Half of these are Six Sigma firms and the other half are control firms which results in a total sample of 86 firms. Although a relatively small sample, this sample of 43 Six Sigma firms is more than Foster's (2007) study which consisted of 24 Six Sigma firms.

Figure 14: Description of sample: number of firms per sector.



5.3. Descriptive statistics

The descriptive statistics for each method (Six Sigma or non Six Sigma) are shown in Table 8 below for each of the ten measures, namely free cash flow per share, cost of sales, EBITDA (millions), revenue (millions), revenue per employee (millions), asset turnover, return on assets, return on investment, assets (millions) and number of employees. The descriptive statistics for each of these broken down by sector are shown in Appendix B.

Table 8: Descriptive Statistics per method for all sectors combined.

Variable	Method	Total Count	Mean	StDev	Minimum	Median	Maximum	IQR
2004 FCFPS	Non Six Sigma	43	71.8	236.4	-17.2	4.19	1524	34.8
	Six Sigma	43	91.7	191.1	-47.5	3.23	852	73.3
2007 FCFPS	Non Six Sigma	43	89.6	196.5	0.07	14.8	1109	72.3
	Six Sigma	43	137.2	279.9	-51.7	3.37	1177	157.1
2004 COS	Non Six Sigma	43	0.7907	0.1348	0.38	0.82	0.96	0.15
	Six Sigma	43	0.8323	0.1093	0.56	0.86	1.01	0.2
2007 COS	Non Six Sigma	43	0.906	0.767	0.41	0.81	5.75	0.18
	Six Sigma	43	0.8305	0.1032	0.6	0.86	1.06	0.14
2004 E(M)	Non Six Sigma	43	1195	2061	0.3	319	8166	695
	Six Sigma	43	3059	3516	-72	2054	15019	3519
2007 E(M)	Non Six Sigma	43	1779	3236	-9.5	625	15361	1337
	Six Sigma	43	4087	4762	-99.8	2321	20441	5199
2004 R(M)	Non Six Sigma	43	5359	7376	8	2206	26670	6401
	Six Sigma	43	20639	21186	710	13858	79905	29223
2007 R(M)	Non Six Sigma	43	7545	10171	2	2643	41676	9379
	Six Sigma	43	26429	27841	1042	17228	104286	36324
2004 RPE(M)	Non Six Sigma	43	0.3214	0.2275	0	0.26	1.13	0.23
	Six Sigma	43	0.3886	0.4015	0.14	0.31	2.81	0.18
2007 RPE(M)	Non Six Sigma	43	0.4328	0.5249	0	0.3	3.47	0.23
	Six Sigma	43	0.434	0.4115	0.16	0.35	2.92	0.21

Variable	Method	Total Count	Mean	StDev	Minimum	Median	Maximum	IQR
2004 AT	Non Six Sigma	43	0.8263	0.4981	0.01	0.68	2.63	0.33
	Six Sigma	43	0.9295	0.579	0.39	0.82	4.26	0.38
2007 AT	Non Six Sigma	43	0.8347	0.4656	0	0.77	2.4	0.4
	Six Sigma	43	0.9788	0.5228	0.44	0.88	3.88	0.36
2004 ROA	Non Six Sigma	43	0.1458	0.0755	0	0.13	0.35	0.11
	Six Sigma	43	0.1333	0.074	0	0.11	0.31	0.1
2007 ROA	Non Six Sigma	43	0.1447	0.0743	0	0.12	0.33	0.1
	Six Sigma	43	0.1488	0.0817	-0.03	0.14	0.36	0.1
2004 ROI	Non Six Sigma	43	0.3058	0.1394	0	0.29	0.61	0.19
	Six Sigma	43	0.3135	0.2046	-0.17	0.3	1.13	0.2
2007 ROI	Non Six Sigma	43	0.304	0.1559	-0.01	0.28	0.66	0.21
	Six Sigma	43	0.3579	0.201	-0.05	0.33	0.88	0.26
2004 A(M)	Non Six Sigma	43	7944	12309	28.1	1944	52799	9449
	Six Sigma	43	23204	22971	654	16240	94368	29602
2007 A(M)	Non Six Sigma	43	10783	16326	76.1	2901	70629	10437
	Six Sigma	43	26401	24401	830	23543	98081	33580
2004 EMP	Non Six Sigma	43	17044	21637	75	8260	79400	19100
	Six Sigma	43	58909	60827	2260	43000	306876	75000
2007 EMP	Non Six Sigma	43	20078	22718	92	11823	81939	29800
	Six Sigma	43	67003	72333	2600	42000	384444	97700

The above means give an indication of the possible influence of Six Sigma on each of the measures. The next section shows the results of the statistical tests, which state whether the differences between means are significant.

5.4. Inferential statistics

Detailed results of all the statistical tests are shown in Appendix C with only the main results being summarised here. The R-squared and F-statistic for the reduced regression models are shown in Table 9 below. Where the model has not been reduced, the values are from the full regression model. The next two columns show the ANCOVA level of significance for the main factor effects. These effects come from the reduced model if they were included in the reduced model; otherwise they come from the full model. Similarly, the final two columns show the ANCOVA level of significance for the interaction effects between the covariate and either sector or method. These effects come from the reduced model if they were included in the reduced model; otherwise they come from the full model. The reduced regression model together with the estimate showing the direction of the effect is shown in Appendix C.

Table 9: Summarised statistical results.

Measure	R-squared	F statistic P-value	P-value for sector main effect	P-value for method main effect	P-value for sector interaction effect	P-value for method interaction effect
Free cash flow per share	0.7454	< 2.2e-16	0.159	0.278935	0.015556	0.000382
Cost of sales	0.1904	0.05249	0.2849	0.2377	0.2689	0.2377
EBITDA	0.9061	< 2.2e-16	0.7606	0.5578	0.9258	0.02614
Revenue	0.9824	< 2.2e-16	0.5599	0.17209	0.09255	0.51196
Revenue per employee	0.8038	< 2.2e-16	0.2143	0.0778	0.000102	3.86e-7
Asset turnover	0.8449	< 2.2e-16	5.91e-2	0.1963	0.5422	0.454
ROA	0.3842	4.92e-08	3.45e-1	0.39298	0.03778	0.83343
ROI	0.4488	6.37e-10	1.67e-1	0.1	0.0204	1.13e-1
Assets	0.9244	< 2.2e-16	0.0571	0.6744	0.0084	0.0103
Number of employees	0.9726	< 2.2e-16	0.0444	0.6372	0.0006	0.1308

5.5. Results for proposition 1

The results will now be presented for all the hypotheses that fall under proposition 1, as outlined in Chapter 3, namely that there is a positive relationship between Six Sigma adoption and improved financial results.

5.5.1.1. Results for hypothesis 1a

Hypothesis 1a postulates that Six Sigma adoption is positively associated with higher free cash flow per share. Table 9 above shows that the model explains 75% of the free cash flow per share in 2007. The ANCOVA results and the coefficients of the reduced model show there is evidence that free cash flow in 2007 varies positively with the interaction of free cash flow in 2004 and Six Sigma method (p-value: 0.000382). The latter can be interpreted as had two firms had the same amount of cash flow in 2004, the Six Sigma firm would have had more free cash flow in 2007. The results also show evidence that free cash flow in 2007 varies depending on the interaction of free cash flow in 2004 and sector (p-value: 0.015556).

5.5.1.2. Results for hypothesis 1b

Hypothesis 1b postulates that Six Sigma adoption is positively associated with lower cost of sales. The full regression model only explains 19% of the variation in 2007 cost of sales and the results show that the null hypothesis that none of the terms are significant cannot be rejected.

5.5.1.3. Results for hypothesis 1c

Hypothesis 1c postulates that Six Sigma adoption is positively associated with higher EBITDA. Table 9 above shows that the model explains 91% of the EBITDA in 2007. The ANCOVA results and the coefficients of the reduced model show there is evidence that EBITDA in 2007 varies negatively with the interaction of EBITDA in 2004 and Six Sigma method (p-value: 0.02614). The latter can be interpreted as had two firms had the same amount of EBITDA in 2004, the Six Sigma firm would have had less EBITDA in 2007.

5.5.1.4. Results for hypothesis 1d

Hypothesis 1d postulates that Six Sigma adoption is positively associated with higher sales or revenue. Table 9 above shows that the model explains 98% of revenue in 2007. The ANCOVA results and the coefficients of the reduced model show no evidence of significant terms besides 2004 revenue.

5.5.1.5. Results for hypothesis 1e

Hypothesis 1e postulates that Six Sigma adoption is positively associated with higher sales or revenue per employee. Table 9 above shows that the model explains 80% of the revenue per employee in 2007. The ANCOVA results and the coefficients of the reduced model show there is evidence that revenue per employee in 2007 varies negatively with the interaction of revenue per employee in 2004 and Six Sigma method (p-value: 3.86e-7). The latter can be interpreted as had two firms had the same amount of revenue per employee in 2004, the Six Sigma firm would have had less revenue per employee in 2007. The results also show evidence that revenue per employee in 2007 varies depending on the interaction of revenue per employee in 2004 and sector (p-value: 0.000102).

5.6. Results for proposition 2

The results will now be presented for all the hypotheses results that fall under proposition 2, as outlined in Chapter 3, namely that there is a positive relationship between Six Sigma adoption and improved operational results.

5.6.1.1. Results for hypothesis 2a

Hypothesis 2a postulates that Six Sigma adoption is positively associated with higher asset turnover. Table 9 above shows that the model explains 84% of the asset turnover in 2007. The ANCOVA results and the coefficients of the reduced model show no evidence of significant terms besides 2004 asset turnover.

5.6.1.2. Results for hypothesis 2b

Hypothesis 2b postulates that Six Sigma adoption is positively associated with higher return on assets. Table 9 above shows that the model only explains 38% of the return on assets in 2007. The ANCOVA results and the coefficients of the reduced model show evidence that return on assets in 2007 varies with the interaction of return on assets in 2004 and sector (p-value: 0.03778). This can be interpreted as had two firms had the same return on assets in 2004, the return on assets in 2007 would differ depending on the sectors they were from.

5.6.1.3. Results for hypothesis 2c

Hypothesis 2c postulates that Six Sigma adoption is positively associated with higher return on investment. Table 9 above shows that the model only explains 45% of the return on investment in 2007. The ANCOVA results and the coefficients of the reduced model show evidence that return on investment in 2007 varies with the interaction of return on investment in 2004 and sector (p-value: 0.0204). This can be interpreted as had two firms had the same return on investment in 2004, the return on investment in 2007 would differ depending on the sectors they were from.

5.6.1.4. Results for hypothesis 2d

Hypothesis 2d postulates that Six Sigma adoption is positively associated with higher total assets. Table 9 above shows that the model explains 92% of the total assets in 2007. The ANCOVA results and the coefficients of the reduced model show there is evidence that total assets in 2007 varies negatively with the interaction of total assets in 2004 and Six Sigma method (p-value: 0.0103). The latter can be interpreted as had two firms had the same amount of assets in 2004, the Six Sigma firm would have had fewer assets in 2007. The results also show evidence that total assets in 2007 varies depending on the interaction of total assets in 2004 and sector (p-value: 0.0084).

5.6.1.5. Results for hypothesis 2e

Hypothesis 2e postulates that Six Sigma adoption is not related to the number of employees. Table 9 above shows that the model explains 97% of the number of employees in 2007. The ANCOVA results and the coefficients of the reduced model show there is evidence that the number of employees in 2007 varies with the sector of the firm (p-value: 0.0444) and stronger evidence that it varies with the interaction of number of employees in 2004 and sector (p-value: 0.0006). The latter can be interpreted as had two firms had the same number of employees in 2004, the number of employees in 2007 would have differed depending on the sector of the firms.

5.7. Summary of results

No main effects for Six Sigma and only one main effect for sector are found to be significant. This indicates that covariance is a good statistical method to use for this study as it allows the effects to be determined based on the starting point of the measures in a previous period. Six sector and four method interaction terms prove to be significant.

The next chapter discusses these results and gives commentary regarding the findings in light of the literature presented in chapter 2.

6. Chapter 6: Discussion of results

6.1. Introduction

This chapter discusses the results from chapter 5 for each hypothesis that is set out in chapter 3, in light of the literature that is described in chapter 2. This chapter aims to answer the research problem that is described in chapter 1. Over a more recent timeframe than Foster (2007) and taking into account the effect of industry on results, have firms that have implemented Six Sigma experienced superior financial performance over their counterparts? Since the only main effect for sector occurs for the number of employee's measure and this measure does not have any Six Sigma method effects, the effect of sector is not discussed in this section. The lack of main sector effects is surprising given previous studies in this area (Foster, 2007; Porter, 1991).

A discussion of the overall results for the two propositions is included in the conclusion to this chapter, as it is difficult to discuss them before having discussed the detail per hypothesis.

6.2. Hypothesis 1a

Foster (2007) finds that Six Sigma increases cash flow per share for companies overall and for companies that initially have high cash flow per share, but may have a negative effect for companies with low cash flow per share. Quality initiatives (Hendricks and Singhal, 1997) and Six Sigma in particular (Foster, 2007; Hariharan, 2006) are costly to implement and so they may initially reduce cash flow. Some companies with poor initial free cash flow may not have the cash necessary to sustain Six Sigma properly. The results in this study concur with Foster (2007) that, based on a company's free cash flow per share in 2004, Six Sigma firms will have more free cash flow per share in 2007, therefore supporting that Six Sigma aids free cash flow per share. This finding is significant, because even though Six Sigma is initially costly to implement and so will reduce free cash flow, this initial cost is outweighed by the benefits to free cash flow that Six Sigma brings. This finding suggests that criticisms of the cost of implementing Six Sigma are misplaced, at least for companies with enough initial cash flow to sustain the implementation and supports the notion that a high level of investment is necessary to achieve breakthrough improvement (Hariharan, 2006). This finding is also important because Dechow *et al.* (1998) state that cash flow is a better predictor of the future value or performance of a company than accounting earnings or profit.

6.3. Hypothesis 1b

Although Foster's (2007) summarised results show that a quality management programme impacts the cost of sales, Foster (2007) finds no significance in the influence of Six Sigma on cost of sales, neither as a main method, nor as an interaction term. This study supports Foster's (2007) finding on both counts that Six Sigma does not help firms to control costs. A possible reason for this could be the distinction between lean and Six Sigma, with lean focussing on eliminating waste or non-value adding activities, which would reduce costs (Wolf and Harmon, 2005).

6.4. Hypothesis 1c

Foster (2007) finds that Six Sigma has no impact on EBITDA compared to non Six Sigma firms, but drives higher EBITDA for firms with high initial EBITDA when compared to firms using other quality management techniques. This study contradicts Foster (2007) by finding that Six Sigma has a negative effect on EBITDA given initial levels of EBITDA. A reason for the contradiction could be that companies have still not matured in terms of Six Sigma and are not yet heeding the call of numerous authors to ensure that project selection is linked to the firm's strategy, which drives profitability (Fornari and Maszle, 2004; Catherwood, 2005; Goh and Xie, 2004; Hammer, 2004; Reidenbach and Goeke, 2007; Antony and Banuelas, 2002). In addition, companies may wrongly be trying to link to strategy at the corporate or business unit level instead of at the competitive level (Reidenbach and Goeke, 2007).

6.5. Hypothesis 1d

This study finds no evidence to suggest that Six Sigma improves revenue. It supports Foster's (2007) findings in this regard. This could possibly contradict Hariharan (2006) and suggest that critics are correct in their concern that Six Sigma is limited to continuous improvement, when innovative breakthrough improvement is necessary for survival, especially to overcome shorter product life cycles (Hammer, 2004; Gupta, 2005; Sower and Fair, 2005).

6.6. Hypothesis 1e

This study contradicts Foster (2007), who finds no impact, by finding evidence that Six Sigma decreases the revenue per employee based on revenue per employee in the initial period. This can be interpreted as Six Sigma decreasing employee productivity, which directly contradicts Cooper and Noonan's (2003) findings and Foster's (2007) expectations. If this lack of employee productivity is accompanied by low employee morale, high staff turnover and therefore a decreasing level of experience, this could be an indication of low performance both currently and in the future (Townsend and Gebhardt, 2005). A possible reason for this surprising result could be that companies implementing Six Sigma move from being capital intensive to labour intensive, especially in light of the finding that Six Sigma decreases total assets; however no evidence is found to suggest that Six Sigma increases the number of employees and so this hypothesis is not supported.

This finding also supports the literature that does not see Six Sigma providing a value-based or cultural side and therefore remaining as a methodology within TQM (Klefsjo, Wiklund and Edgeman, 2001) and contradicts those who see Six Sigma and quality management as a mechanism to improve organisational culture (Arthur, 2005; Bisgaard, 2007; Carnell, 2004; Chauncey and Thornton, 2006; Daniels, 2007; Davison and Al-Shaghana, 2007; Fornari and Maszle, 2004; Kujala and Lillrank, 2004; Weigang, 2005). It could also suggest that companies are experiencing clashes between different quality initiatives and that they aren't incorporating the cultural change brought about by the Lean technique (Smith, 2003).

6.7. Hypothesis 2a

Foster (2007) finds evidence to support that Six Sigma improves the asset turnover of companies with low initial asset turnover, but not high initial turnover. It is unclear whether Six Sigma improves asset turnover overall. This study finds no influence of Six Sigma on asset turnover and so it does not seem as if Six Sigma results in the more productive use of assets to generate revenue. A possible reason is that Six Sigma is found to have no impact on revenue as discussed above.

6.8. Hypothesis 2b

This study supports Foster's (2007) by finding no evidence to suggest that Six Sigma improves the return on assets. A possible reason for this is that it is comprised of the asset turnover ratio, which is also not significant.

6.9. Hypothesis 2c

This study supports Foster's (2007) by finding no evidence to suggest that Six Sigma affects ROI. This is possibly due to the factors making up the ratio ROI.

6.10. Hypothesis 2d

This study finds evidence to suggest that, given an initial level of assets, a firm running Six Sigma will have lower total assets after four years than one that isn't. This finding contradicts both Foster's (2007) study where no effect is found and the initial hypothesis that Six Sigma leads to increased total assets; however both studies mention an increased use of assets, which this finding supports (Foster, 2007). In addition, Hendricks and Singhal (1997), whose measurements Foster's (2007) study is based on, give no specific hypotheses for the direction of change, as programmes can require additional investment or they can increase the effective productive capacity and therefore results in decreased investment. This study therefore provides evidence to support the view that implementing Six Sigma increases productive capacity and leads to a reduction in assets.

6.11. Hypothesis 2e

This study supports Foster's (2007) by finding no evidence that Six Sigma affects the number of employees in a firm. As with the section above that discusses total assets, there are also mixed views within the literature on the possible influence of Six Sigma on the number of employees (Hendricks and Singhal, 1997).

6.12. Conclusion to the discussion of results

The overall conclusion for the two propositions is mixed. The first proposition that Six Sigma improves financial performance is supported by the finding for free cash flow and not supported by the findings for cost of sales and revenue. In addition, it is contradicted by the findings for EBITDA and revenue per employee. This suggests that the proposition that Six Sigma improves financial performance is not supported.

The second proposition that Six Sigma improves operational performance is not supported for any of the hypotheses initially set; however the finding that Six Sigma decreases total assets could be due to better productive capacity and could therefore help to support the proposition. No evidence of an effect is found for the other four measures.

Overall these findings should be of concern to managers looking to implement Six Sigma as while there is much hype over the benefits of Six Sigma, this study has found little evidence of its use.

7. Conclusion

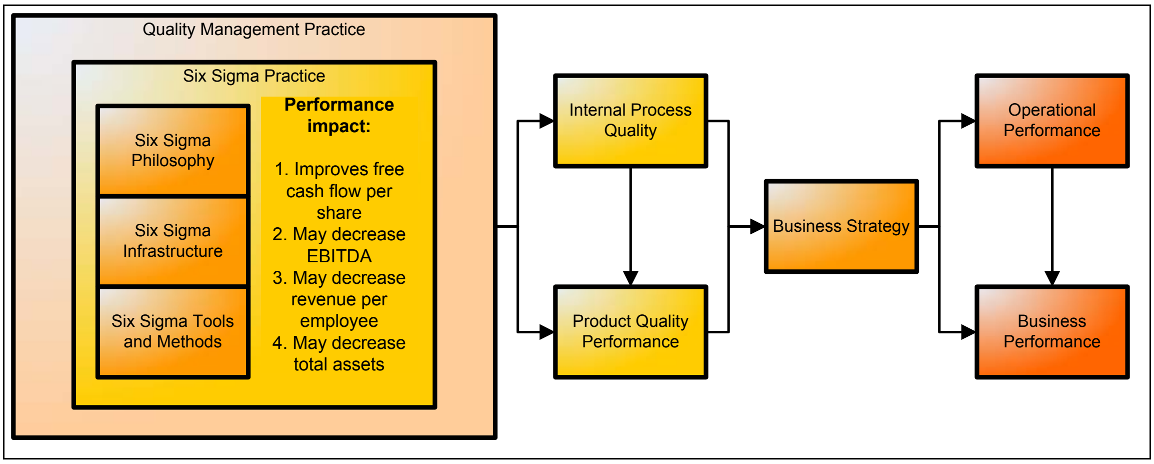
This study presents data on the actual performance of 43 Six Sigma companies compared to 43 non-Six Sigma companies between 2004 and 2007 that were listed in the United States.

The main contribution of this study is that Foster's (2007) study is the only previous study to investigate Six Sigma empirically and this study uses a much larger sample and also uses matched pairs to create as homogenous a group of firms as possible. In addition, this study covers a later period than Foster (2007) and includes the impact of sector. This study therefore fills a gap that exists in the literature on Six Sigma and the results can be used to benchmark what one can expect to accomplish from implementing a Six Sigma programme. In addition, this study provides rigorous empirical data to help stem the flow of unsubstantiated comments regarding the impact of Six Sigma on performance.

The research report finds that Six Sigma has very little positive influence on both financial and operational performance. The only evidence to support the numerous claims that Six Sigma improves performance is an increase in free cash flow per share and a decrease in assets when compared to non-Six Sigma firms at the same level in 2004. In contrast, evidence is also found to show that Six Sigma firms have lower profit (EBITDA) and generate lower revenue per employee.

These findings strengthen Foster's (2007) findings because they are very similar. The only significant evidence that Foster (2007) finds that doesn't depend on the size of the Six Sigma firm is an increase in free cash flow per share. The findings have been incorporated into the model shown at the end of Chapter 2. The model shown in Figure 15 reiterates Sis Sigma's position within management theory and it also summarises the results of this study together with those of Foster (2007). All results show what impact Six Sigma "may" have except result 1. (Improves free cash flow per share) as this was the only significant finding where the two studies concur.

Figure 15: Combined model showing Six Sigma's role in improving performance and its place with management theory.



The results of these findings indicate that Six Sigma could even have a negative impact on financial performance and has very little impact on operational performance. It is therefore recommended that firms looking to undertake a Six Sigma initiative ensure they have conducted the necessary analysis before going ahead, because they could experience varying results from their efforts depending on their implementation plan. This is especially important for firms short of cash flow, since there are indications that firms can't sustain their initiative long enough to recoup their cash.

A measure to address potential failure would be to determine the exact requirements of the firm and their level of organisational maturity in order to ensure that the solution addresses the needs of the organisation. Managers should also then measure the bottom line savings during their initiative to ensure that it is producing benefits. The more managers understand the potential benefits and limitations, the better they can equip themselves to ensure that their implementation is structured in such a way to reap the benefits. Without this analysis and effort, this study shows that managers are likely to end up breaking even at best and even decreasing their performance.

Foster (2007) seems to find more significant effects due to size than this study finds with respect to sector. Future research could examine the role of the size of a firm on Six Sigma adoption in more detail, as Six Sigma has been criticised for excluding smaller firms due to high implementation costs.

Whilst this study only looks at a four year period, in their study of TQM firms, Hendricks and Singhal (1997) look at the initial implementation phase for five years and the post implementation phase for another five years. In addition, they track changes year on year to identify changes in the economy. It would be interesting to compare results for Six Sigma firms with the results of Hendricks and Singhal's (1997) findings around TQM firms. Other methodologies and measures of performance could also be incorporated into the study. It would be interesting to see if companies using a combination of methodologies outperformed those only using one methodology or if using a combination created confusion and politics and so resulted in underperformance.

In addition, it is difficult to isolate effects due to Six Sigma at such a macro level. Additional research that looks in detail at a firm's implementation on a micro level will aid in determining whether there are contextual factors that influence the impact of Six Sigma on performance. A study could benchmark best practice for Six Sigma implementation in order to achieve large improvements in performance.

Looking at it from another perspective, another study could look at the characteristics of firms, training and consulting companies, or leaders that have implemented successful programmes. Research into whether high performing managers incorporate aspects of Six Sigma into their processes would also be interesting, as would investigating whether small firms can increase their performance using a limited number of Six Sigma techniques, but without the high initial costs of a Six Sigma implementation.

Building on from the areas of future research in performance excellence outlined in chapter 2, it would be interesting to understand how firms and leaders are managing to incorporate culture, leadership and innovation into their implementation of Six Sigma. A study into which of these factors produce the most performance improvement could provide useful guidelines to practitioners.

Finally, now that South Africa is starting to see more and more firms implement Six Sigma, there is scope to research whether there are any factors in South Africa which make implementation different to overseas. This research is in addition to all the previous research ideas stated above, as they would all be relevant to South Africa as well.

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9. Appendices

9.1. Appendix A: List of Companies

Table 10: List of matched pair companies in the sample by sector, including listing, industry and financial year end.

Industry code for both companies	Six Sigma Company	Listing	Financial Year End	Comparison Company	Listing	Financial Year End
			Basic Material Sector			
METALS	Alcoa Inc.	NYSE	12/31/07	The Furukawa Electric Co., Ltd. (ADR)	OTC	03/31/08
CHMMFG	H.B. Fuller Company	NYSE	12/01/07	Central Garden & Pet Co.	NASD	09/29/07
METALS	Kaiser Aluminum Corp.	NASD	12/31/07	Alumina Limited (ADR)	NYSE	12/31/07
LUMBER	Louisiana-Pacific Corporation	NYSE	12/31/07	Rayonier Inc.	NYSE	12/31/07
METALS	Olin Corporation	NYSE	12/31/07	Commercial Metals Company	NYSE	08/31/07
CONTNR	Owens Corning	NYSE	12/31/07	Myers Industries, Inc.	NYSE	12/31/07
PAPERP	Rock-Tenn Company	NYSE	09/30/07	International Paper Company	NYSE	12/31/07
CHMRUB	Rohm and Haas Company	NYSE	12/31/07	PolyOne Corporation	NYSE	12/31/07
			Health Sector			
MAJRRX	Abbott Laboratories	NYSE	12/31/07	Roche Holding Ltd. (ADR)	OTC	12/31/07
BIOTRX	Allergan, Inc.	NYSE	12/31/07	Hospira, Inc.	NYSE	12/31/07
HTHEQP	Baxter International Inc.	NYSE	12/31/07	China Medical Technologies, Inc. (ADR)	NASD	03/31/08
MAJRRX	Bristol Myers Squibb Co.	NYSE	12/31/07	Wyeth	NYSE	12/31/07
MAJRRX	Eli Lilly & Co.	NYSE	12/31/07	AstraZeneca plc (ADR)	NYSE	12/31/07
MAJRRX	GlaxoSmithKline plc (ADR)	NYSE	12/31/07	Alcon, Inc.	NYSE	12/31/07
BIOTRX	McKesson Corporation	NYSE	03/31/08	Shire Ltd. (ADR)	NASD	12/31/07
MAJRRX	Schering-Plough Corporation	NYSE	12/31/07	Prestige Brands Holdings, Inc.	NYSE	03/31/08

Industry code for both companies	Six Sigma Company	Listing	Financial Year End	Comparison Company	Listing	Financial Year End
Technology Sector						
SEMICO	Advanced Micro Devices, Inc.	NYSE	12/29/07	ASM International N.V. (USA)	NASD	12/31/07
SEMICO	Applied Materials, Inc.	NASD	10/28/07	Cree, Inc.	NASD	06/29/08
SEMICO	Atmel Corporation	NASD	12/31/07	Siliconware Precision Industries (ADR)	NASD	12/31/07
CMPEQP	Canon Inc. (ADR)	NYSE	12/31/07	Cisco Systems, Inc.	NASD	07/26/08
ELECTR	Cooper Industries, Ltd.	NYSE	12/31/07	Baldor Electric Company	NYSE	12/29/07
SEMICO	Flextronics International Ltd.	NASD	03/31/08	Standard Microsystems Corporation	NASD	02/29/08
CMPEQP	Hewlett-Packard Company	NYSE	10/31/07	Sigma Designs, Inc.	NASD	02/02/08
SEMICO	Intel Corporation	NASD	12/29/07	Taiwan Semiconductor Mfg. Co. Ltd. (ADR)	NYSE	12/31/07
SOFTWR	Microsoft Corporation	NASD	06/30/08	CA, Inc.	NASD	03/31/08
COMEQP	Motorola, Inc.	NYSE	12/31/07	Comtech Telecomm. Corp.	NASD	07/31/07
SEMICO	National Semiconductor Corporation	NYSE	05/25/08	ASML Holding N.V. (ADR)	NASD	12/31/07
COMEQP	Nokia Corporation (ADR)	NYSE	12/31/07	Plantronics, Inc.	NYSE	03/31/08
SCIINS	PerkinElmer, Inc.	NYSE	12/30/07	Thermo Fisher Scientific Inc.	NYSE	12/31/07
CMPSTR	Seagate Technology	NYSE	06/27/08	Micron Technology, Inc.	NYSE	08/30/07
CMPTRS	Sun Microsystems, Inc.	NASD	06/30/08	Electronics For Imaging, Inc.	NASD	12/31/07
SEMICO	Texas Instruments Incorporated	NYSE	12/31/07	Infineon Technologies AG (ADR)	NYSE	09/30/07
CMPSTR	Toshiba Corporation (USA)	OTC	03/31/08	Western Digital Corp.	NYSE	06/27/08
ELECTR	Woodward Governor Company	NASD	09/30/07	Arrow Electronics, Inc.	NYSE	12/31/07
OFFEQP	Xerox Corporation	NYSE	12/31/07	Ricoh Company Ltd. (ADR)	OTC	03/31/08

9.2. Appendix B: Descriptive statistics per method and sector

Table 11: Descriptive Statistics per method and sector.

Results for Sector = BASICM								
Variable	Method	Total Count	Mean	StDev	Minimum	Median	Maximum	IQR
2004 FCFPS	Non Six Sigma	8	25.8	76.6	-17.2	0.56	214.7	3.96
	Six Sigma	8	33.4	85.5	-47.5	3.34	228.5	58.5
2007 FCFPS	Non Six Sigma	8	59.6	121.7	0.66	4.18	354.9	54.9
	Six Sigma	8	179.4	280.4	-0.08	3.05	648	490.6
2004 COS	Non Six Sigma	8	0.8975	0.0734	0.73	0.925	0.96	0.06
	Six Sigma	8	0.8713	0.0975	0.67	0.895	1	0.0925
2007 COS	Non Six Sigma	8	1.493	1.723	0.67	0.92	5.75	0.085
	Six Sigma	8	0.8888	0.0726	0.83	0.87	1.06	0.05
2004 E(M)	Non Six Sigma	8	481	826	0.3	223	2495	311
	Six Sigma	8	842	1130	3.7	425	3391	1101
2007 E(M)	Non Six Sigma	8	624	931	-9.5	265	2796	735
	Six Sigma	8	949	1643	-99.8	242	4831	1100
2004 R(M)	Non Six Sigma	8	4706	6865	8	1768	20721	5537
	Six Sigma	8	5507	7261	942	2364	22609	5415
2007 R(M)	Non Six Sigma	8	5857	7463	2	2157	21890	8721
	Six Sigma	8	6603	10104	1277	2011	30748	6491
2004 RPE(M)	Non Six Sigma	8	0.3063	0.1903	0	0.28	0.53	0.355
	Six Sigma	8	0.3238	0.0978	0.19	0.32	0.43	0.2025
2007 RPE(M)	Non Six Sigma	8	0.3863	0.2211	0	0.395	0.65	0.3725
	Six Sigma	8	0.3825	0.1336	0.25	0.34	0.58	0.2775
2004 AT	Non Six Sigma	8	0.965	0.715	0.01	0.74	2.4	0.713
	Six Sigma	8	0.883	0.284	0.5	0.765	1.23	0.52

Results for Sector = BASICM

2007 AT	Non Six Sigma	8	1.114	0.716	0	1.01	2.4	0.913
	Six Sigma	8	0.898	0.284	0.53	0.83	1.29	0.565
2004 ROA	Non Six Sigma	8	0.0875	0.0547	0	0.085	0.16	0.0975
	Six Sigma	8	0.1113	0.0714	0	0.1	0.26	0.0325
2007 ROA	Non Six Sigma	8	0.1038	0.0689	0	0.1	0.2	0.1225
	Six Sigma	8	0.1075	0.0632	-0.03	0.13	0.16	0.0725
2004 ROI	Non Six Sigma	8	0.28	0.147	0	0.285	0.48	0.1825
	Six Sigma	8	0.2425	0.2303	-0.17	0.29	0.51	0.385
2007 ROI	Non Six Sigma	8	0.2575	0.1591	-0.01	0.29	0.44	0.2825
	Six Sigma	8	0.2525	0.1777	-0.05	0.24	0.49	0.29
2004 A(M)	Non Six Sigma	8	6681	11547	786	1845	34217	7060
	Six Sigma	8	7464	10683	1135	2667	32609	8114
2007 A(M)	Non Six Sigma	8	5757	8000	698	2197	24159	6848
	Six Sigma	8	8268	12788	1165	2515	38803	8175
2004 EMP	Non Six Sigma	8	17368	26165	2200	6176	79400	17835
	Six Sigma	8	22752	39332	2260	7383	119000	13598
2007 EMP	Non Six Sigma	8	15302	18065	2000	6015	51500	24815
	Six Sigma	8	20814	35401	2600	7200	107000	15628

Results for Sector = CAPGDS

Variable	Method	Total Count	Mean	StDev	Minimum	Median	Maximum	IQR
2004 FCFPS	Non Six Sigma	9	64.1	91	0.24	4.19	220.5	163.2
	Six Sigma	9	61.5	177	-3.24	2.35	533.6	4.75
2007 FCFPS	Non Six Sigma	9	106.7	176.1	0.63	4.33	512	207.9
	Six Sigma	9	114	328	1.89	4.08	989	6.93
2004 COS	Non Six Sigma	9	0.82	0.0529	0.73	0.83	0.88	0.1
	Six Sigma	9	0.8878	0.0441	0.79	0.91	0.93	0.055
2007 COS	Non Six Sigma	9	0.8089	0.0599	0.67	0.81	0.87	0.065

Results for Sector = CAPGDS								
	Six Sigma	9	0.8633	0.0507	0.74	0.87	0.92	0.035
2004 E(M)	Non Six Sigma	9	638	1039	39.4	181	3314	610
	Six Sigma	9	2863	1836	363	2629	6805	2018
2007 E(M)	Non Six Sigma	9	958	1422	98.2	248	4571	988
	Six Sigma	9	4387	2406	583	4538	7413	4350
2004 R(M)	Non Six Sigma	9	3903	6103	216	955	19204	4918
	Six Sigma	9	31261	23177	1720	29000	79543	29332
2007 R(M)	Non Six Sigma	9	5346	7613	508	1592	24082	6885
	Six Sigma	9	39161	28152	2207	34589	94429	37671
2004 RPE(M)	Non Six Sigma	9	0.2089	0.0992	0.1	0.17	0.43	0.11
	Six Sigma	9	0.2811	0.0501	0.23	0.27	0.39	0.065
2007 RPE(M)	Non Six Sigma	9	0.2622	0.087	0.14	0.25	0.46	0.065
	Six Sigma	9	0.3278	0.0785	0.25	0.3	0.44	0.165
2004 AT	Non Six Sigma	9	0.7011	0.0779	0.59	0.68	0.82	0.13
	Six Sigma	9	0.9133	0.2102	0.7	0.87	1.39	0.22
2007 AT	Non Six Sigma	9	0.7611	0.1311	0.57	0.8	0.97	0.225
	Six Sigma	9	0.9789	0.2364	0.61	0.96	1.45	0.285
2004 ROA	Non Six Sigma	9	0.1267	0.0377	0.09	0.12	0.21	0.045
	Six Sigma	9	0.09778	0.02949	0.06	0.09	0.15	0.045
2007 ROA	Non Six Sigma	9	0.15	0.0691	0.08	0.13	0.32	0.05
	Six Sigma	9	0.13	0.0456	0.08	0.12	0.22	0.065
2004 ROI	Non Six Sigma	9	0.3089	0.1186	0.16	0.29	0.52	0.2
	Six Sigma	9	0.31	0.1173	0.16	0.31	0.55	0.16
2007 ROI	Non Six Sigma	9	0.3189	0.154	0.15	0.26	0.64	0.225
	Six Sigma	9	0.4578	0.2234	0.15	0.49	0.75	0.43
2004 A(M)	Non Six Sigma	9	5581	9079	316	1278	28754	6137
	Six Sigma	9	34325	25967	2356	31062	88370	35180
2007 A(M)	Non Six Sigma	9	7836	12127	631	2050	38576	8635
	Six	9	39122	28383	2684	33373	98081	37504

Results for Sector = CAPGDS								
	Sigma							
2004 EMP	Non Six Sigma	9	15462	17636	1263	6100	45000	30779
	Six Sigma	9	113219	87134	5778	109000	306876	91500
2007 EMP	Non Six Sigma	9	17182	17869	2185	9361	52000	28695
	Six Sigma	9	128221	107967	5255	122000	384444	90120

Results for Sector = HEALTH								
Variable	Method	Total Count	Mean	StDev	Minimum	Median	Maximum	IQR
2004 FCFPS	Non Six Sigma	8	41.8	82.3	1.01	9.1	241.9	39.2
	Six Sigma	8	80.7	153.8	-0.15	3.69	421.9	150.6
2007 FCFPS	Non Six Sigma	8	77.1	110.5	1.6	27.4	324.2	118.6
	Six Sigma	8	100.1	188.5	0.85	5.68	513	192.6
2004 COS	Non Six Sigma	8	0.6638	0.1283	0.38	0.7	0.81	0.105
	Six Sigma	8	0.78	0.1282	0.68	0.715	0.98	0.2475
2007 COS	Non Six Sigma	8	0.66	0.1194	0.42	0.67	0.81	0.1375
	Six Sigma	8	0.785	0.1258	0.63	0.75	0.98	0.2225
2004 E(M)	Non Six Sigma	8	2681	3182	9.9	931	8166	5461
	Six Sigma	8	3851	3751	138	3194	11466	4755
2007 E(M)	Non Six Sigma	8	4473	5715	46.5	1372	15361	8907
	Six Sigma	8	4651	4695	370	3531	14926	5070
2004 R(M)	Non Six Sigma	8	9185	10830	16	3280	26670	20004
	Six Sigma	8	22174	21479	2059	16619	69210	22907
2007 R(M)	Non Six Sigma	8	13188	15902	80	4518	41676	26921
	Six Sigma	8	28129	28367	3939	18991	92977	25056
2004 RPE(M)	Non Six Sigma	8	0.455	0.323	0.18	0.335	1.13	0.435
	Six Sigma	8	0.64	0.88	0.2	0.335	2.81	0.16
2007 RPE(M)	Non Six Sigma	8	0.809	1.086	0.24	0.44	3.47	0.38
	Six Sigma	8	0.698	0.904	0.23	0.425	2.92	0.215
2004 AT	Non Six	8	0.6513	0.2769	0.26	0.545	1.13	0.3675

Results for Sector = HEALTH								
	Sigma							
	Six Sigma	8	1.139	1.268	0.52	0.675	4.26	0.32
2007 AT	Non Six Sigma	8	0.53	0.2038	0.17	0.575	0.8	0.31
	Six Sigma	8	1.06	1.144	0.44	0.715	3.88	0.128
2004 ROA	Non Six Sigma	8	0.2088	0.0887	0.07	0.21	0.35	0.1325
	Six Sigma	8	0.165	0.0918	0.01	0.18	0.28	0.1625
2007 ROA	Non Six Sigma	8	0.1675	0.0698	0.1	0.15	0.3	0.11
	Six Sigma	8	0.1525	0.0829	0.01	0.16	0.27	0.125
2004 ROI	Non Six Sigma	8	0.4125	0.1501	0.19	0.45	0.61	0.26
	Six Sigma	8	0.473	0.322	0.02	0.465	1.13	0.28
2007 ROI	Non Six Sigma	8	0.4163	0.1532	0.24	0.385	0.66	0.29
	Six Sigma	8	0.38	0.2371	0.04	0.38	0.88	0.155
2004 A(M)	Non Six Sigma	8	15245	19822	28.1	3592	52799	30806
	Six Sigma	8	21661	11919	2257	20554	40667	15430
2007 A(M)	Non Six Sigma	8	22408	27233	467	6050	70629	44767
	Six Sigma	8	27825	14669	6579	26480	54951	19618
2004 EMP	Non Six Sigma	8	26062	28944	75	13100	64703	60477
	Six Sigma	8	44508	27994	5030	43750	99837	31375
2007 EMP	Non Six Sigma	8	28674	32032	92	14250	78604	62447
	Six Sigma	8	49346	27978	7886	44000	103483	30750

Results for Sector = TECHNO								
Variable	Method	Total Count	Mean	StDev	Minimum	Median	Maximum	IQR
2004 FCFPS	Non Six Sigma	18	109.3	355.1	0.01	9.74	1524	48.3
	Six Sigma	18	137.6	241.6	0.26	2.95	852	200.2
2007 FCFPS	Non Six Sigma	18	100.1	262.5	0.07	16	1109	60.6
	Six Sigma	18	146.5	306.8	-51.7	2.29	1177	211.4
2004 COS	Non Six Sigma	18	0.785	0.1454	0.38	0.82	0.95	0.1275
	Six Sigma	18	0.8106	0.1175	0.56	0.84	1.01	0.1775

Results for Sector = TECHNO								
2007 COS	Non Six Sigma	18	0.8033	0.1288	0.41	0.82	0.95	0.145
	Six Sigma	18	0.8083	0.1128	0.6	0.84	0.97	0.1875
2004 E(M)	Non Six Sigma	18	1131	2021	2.1	287	7494	1008
	Six Sigma	18	3791	4408	-72	2184	15019	6359
2007 E(M)	Non Six Sigma	18	1505	2575	8.2	695	10115	1428
	Six Sigma	18	5081	6101	166	1989	20441	9909
2004 R(M)	Non Six Sigma	18	4676	6363	31	1662	22045	8299
	Six Sigma	18	21371	21802	710	13016	79905	31023
2007 R(M)	Non Six Sigma	18	6886	9050	91	3021	34922	9819
	Six Sigma	18	28120	29892	1042	15551	104286	38841
2004 RPE(M)	Non Six Sigma	18	0.325	0.2236	0.11	0.25	0.93	0.1925
	Six Sigma	18	0.3594	0.188	0.14	0.32	0.78	0.2675
2007 RPE(M)	Non Six Sigma	18	0.3717	0.2909	0.12	0.285	1.27	0.2775
	Six Sigma	18	0.3928	0.1742	0.16	0.36	0.67	0.3225
2004 AT	Non Six Sigma	18	0.905	0.574	0.31	0.715	2.63	0.483
	Six Sigma	18	0.8656	0.2924	0.39	0.795	1.51	0.405
2007 AT	Non Six Sigma	18	0.883	0.462	0.34	0.76	1.98	0.593
	Six Sigma	18	0.9789	0.2656	0.52	0.96	1.53	0.4025
2004 ROA	Non Six Sigma	18	0.1533	0.0724	0.05	0.145	0.32	0.1225
	Six Sigma	18	0.1467	0.0775	0	0.13	0.31	0.125
2007 ROA	Non Six Sigma	18	0.15	0.0798	0.04	0.12	0.33	0.13
	Six Sigma	18	0.175	0.0965	0.03	0.15	0.36	0.155
2004 ROI	Non Six Sigma	18	0.2683	0.1266	0.07	0.275	0.52	0.165
	Six Sigma	18	0.2761	0.1295	-0.01	0.28	0.55	0.1675
2007 ROI	Non Six Sigma	18	0.2672	0.1426	0.06	0.245	0.57	0.2225
	Six Sigma	18	0.345	0.1712	0.06	0.33	0.66	0.27
2004 A(M)	Non Six Sigma	18	6441	9363	29.8	1541	35594	11438
	Six Sigma	18	25326	26322	654	15552	94368	30610
2007 A(M)	Non Six Sigma	18	9323	13236	76.1	2861	53340	14941
	Six Sigma	18	27466	26334	830	14253	88699	49496
2004 EMP	Non Six Sigma	18	13683	18216	133	9080	73137	15209
	Six Sigma	18	54224	48071	3384	44053	161286	71107
2007 EMP	Non Six Sigma	18	19828	22759	180	12212	81939	27991

Results for Sector = TECHNO								
	Six Sigma	18	64769	58840	4248	45810	190708	100109

9.3. Appendix C: Detailed statistical results

9.3.1. Free cash flow per share

FULL MODEL
2007FCF = 2004FCF + Method + Sector + 2004FCF*Method + 2004FCF*Sector

Residuals:

Min	1Q	Median	3Q	Max
-371.452	-31.549	-6.094	-2.075	598.808

Coefficients:

	Estimate	Std Error	t-value	Pr(>|t|)
(Intercept)	96.96335	36.29426	2.672	0.00923
X2004.FCFPS	0.57037	0.41549	1.373	0.17386
Method[T.SS]	-1.8906	29.15825	-0.065	0.94847
Sector[T.CAPGDS]	-90.47712	46.60492	-1.941	0.05592
Sector[T.HEALTH]	-61.43957	48.43894	-1.268	0.20853
Sector[T.TECHNO]	-90.89011	40.40561	-2.249	0.02738
X2004.FCFPS:Method[T.SS]	0.39553	0.13679	2.892	0.005
X2004.FCFPS:Sector[T.CAPGDS]	0.9058	0.46608	1.943	0.05567
X2004.FCFPS:Sector[T.HEALTH]	0.05084	0.48865	0.104	0.91741
X2004.FCFPS:Sector[T.TECHNO]	0.16642	0.41593	0.4	0.6902

Residual standard error: 124.4 on 76 degrees of freedom
Multiple R-Squared: 0.7631, Adjusted R-squared: 0.7351
F-statistic: 27.21 on 9 and 76 DF, p-value: < 2.2e-16

	Df	Sum sq	Mean sq	F-value	Pr(>F)
X2004.FCFPS	1	3307075	3307075	213.8483	< 2.2e-16
Method	1	18391	18391	1.1892	0.278935
Sector	3	82271	27424	1.7733	1.59E-01
X2004.FCFPS:Method	1	217346	217346	14.0544	0.000344
X2004.FCFPS:Sector	3	161348	53783	3.4778	0.019977
Residuals	76	1175309	15465		

REDUCED MODEL
2007FCF = 2004FCF + 2004FCF*Method + 2004FCF*Sector

Residuals:

Min	1Q	Median	3Q	Max
-384.45	-28.62	-27.45	-10.85	679.73

Coefficients:

	Estimate	Std Error	t-value	Pr(>|t|)
(Intercept)	28.0934	14.8534	1.891	0.06219
X2004.FCFPS	0.8818	0.3964	2.225	0.02892
X2004.FCFPS:Method[T.SS]	0.3777	0.1258	3.003	0.00356
X2004.FCFPS:Sector[T.CAPGDS]	0.5418	0.4358	1.243	0.21746
X2004.FCFPS:Sector[T.HEALTH]	-0.225	0.4537	-0.496	0.62135
X2004.FCFPS:Sector[T.TECHNO]	-0.1664	0.3941	-0.422	0.67411

Residual standard error: 125.7 on 80 degrees of freedom
Multiple R-Squared: 0.7454, Adjusted R-squared: 0.7295
F-statistic: 46.84 on 5 and 80 DF, p-value: < 2.2e-16

	Df	Sum sq	Mean sq	F-value	Pr(>F)
X2004.FCFPS	1	3307075	3307075	209.4124	2.20E-16
X2004.FCFPS:Method	1	217295	217295	13.7597	0.000382
X2004.FCFPS:Sector	3	173995	57998	3.6726	0.015556
Residuals	80	1263373	15792		

9.3.2. Cost of sales

FULL MODEL
2007COS = 2004COS + Method + Sector + 2004COS*Method + 2004COS*Sector

Residuals:

Min	1Q	Median	3Q	Max
-0.59086	-0.10862	-0.04249	0.06665	4.15685

	Estimate	Std Error	t-value	Pr(>|t|)
(Intercept)	-2.357	1.4892	-1.583	0.1176
X2004.COS	4.1148	1.6813	2.447	0.0167
Method[T.SS]	0.9073	0.7942	1.142	0.2569
Sector[T.CAPGDS]	1.367	2.3977	0.57	0.5703
Sector[T.HEALTH]	2.0332	1.6101	1.263	0.2105
Sector[T.TECHNO]	2.1634	1.5233	1.42	0.1596
X2004.COS:Method[T.SS]	-1.2511	0.9644	-1.297	0.1985
X2004.COS:Sector[T.CAPGDS]	-1.8571	2.7669	-0.671	0.5042
X2004.COS:Sector[T.HEALTH]	-2.6179	1.8983	-1.379	0.1719
X2004.COS:Sector[T.TECHNO]	-2.7951	1.7377	-1.609	0.1119

Residual standard error: 0.5188 on 76 degrees of freedom
Multiple R-Squared: 0.1904, Adjusted R-squared: 0.09449
F-statistic: 1.986 on 9 and 76 DF, p-value: 0.05249

	Df	Sum sq	Mean sq	F-value	Pr(>F)
X2004.COS	1	2	2	8.6529	0.0043
Method	1	0	0	1.4164	0.2377
Sector	3	1	0	1.2873	0.2849
X2004.COS:Method	1	0	0	1.2403	0.2689
X2004.COS:Sector	3	1	0	0.8995	0.4455
Residuals	76	20	0		

REDUCED MODEL
2007COS = 2004COS + Method + Sector + 2004COS*Method + 2004COS*Sector

Residuals:

Min	1Q	Median	3Q	Max
-0.2403	-0.1092	-0.0763	-0.0335	4.6832

Coefficients:

	Estimate	Std Error	t-value	Pr(>|t|)
(Intercept)	-0.2169	0.3758	-0.577	5.65E-01
X2004.COS	1.3372	0.4579	2.92	0.00449

Residual standard error: 0.5226 on 84 degrees of freedom
Multiple R-Squared: 0.09218, Adjusted R-squared: 0.08137
F-statistic: 8.529 on 1 and 84 DF, p-value: 0.004486

	Df	Sum sq	Mean sq	F-value	Pr(>F)
X2004.COS	1	2.3291	2.3291	8.5293	4.49E-03
Residuals	84	22.9376	0.2731		

9.3.3. EBITDA (millions)

FULL MODEL
2007EM = 2004EM + Method + Sector + 2004EM*Method + 2004EM*Sector

Residuals:

Min	1Q	Median	3Q	Max
-5393.71	-279.39	-16.69	255.54	4672.11

Coefficients:

	Estimate	Std Error	t-value	Pr(>|t|)
(Intercept)	-181.3834	442.5964	-0.41	0.68309
X2004.E.M.	1.4269	0.3639	3.921	0.00019
Method[T.SS]	261.6441	373.7349	0.7	0.48602
Sector[T.CAPGDS]	405.4108	608.8802	0.666	0.50754
Sector[T.HEALTH]	-47.4535	626.3723	-0.076	0.93981
Sector[T.TECHNO]	132.5363	493.2813	0.269	0.7889
X2004.E.M.:Method[T.SS]	-0.2536	0.1217	-2.084	0.04053
X2004.E.M.:Sector[T.CAPGDS]	0.1048	0.3987	0.263	0.79331
X2004.E.M.:Sector[T.HEALTH]	0.1494	0.3715	0.402	0.68863
X2004.E.M.:Sector[T.TECHNO]	0.0732	0.3637	0.201	0.84104

Residual standard error: 1345 on 76 degrees of freedom
Multiple R-Squared: 0.9088, Adjusted R-squared: 0.898
F-statistic: 84.13 on 9 and 76 DF, p-value: < 2.2e-16

	Df	Sum sq	Mean sq	F-value	Pr(>F)
X2004.E.M	1	1356403784	1356403784	750	< 2e-16
Method	1	626669	626669	0	0.5578
Sector	3	2115073	705024	0	0.76058
X2004.E.M.:Method	1	9145445	9145445	5	0.02741
X2004.E.M.:Sector	3	843813	281271	0	0.9258
Residuals	76	137417463	1808125		

REDUCED MODEL
2007EM = 2004EM + 2004EM*Method

Residuals:

Min	1Q	Median	3Q	Max
-5880.17	-239.99	-51.62	154.62	4293.38

Coefficients:

	Estimate	Std Error	t-value	Pr(>|t|)
(Intercept)	61.97847	174.1071	0.356	0.7228
X2004.E.M.	1.50507	0.09219	16.326	<2e-16
X2004.E.M.:MethodSS	-0.21616	0.09545	-2.265	0.0261

Residual standard error: 1305 on 83 degrees of freedom
Multiple R-Squared: 0.9061, Adjusted R-squared: 0.9039
F-statistic: 400.6 on 2 and 83 DF, p-value: < 2.2e-16

	Df	Sum sq	Mean sq	F-value	Pr(>F)
X2004.E.M.	1	1356403784	1.36E+09	796.135	2.00E-16
X2004.E.M.:Method	1	8738388	8738388	5.129	0.02614
Residuals	83	141410074	1703736		

9.3.4. Revenue (millions)

FULL MODEL
2007.R.M.~X2004.R.M. + Method + Sector + X2004.R.M.*Method + X2004.R.M.*Sector

Residuals:

Min	1Q	Median	3Q	Max
-7214.0	-876.5	-144.5	576.5	17477.8

Coefficients:

	Estimate	Std Error	t-value	Pr(>|t|)
(Intercept)	221.72721	1108.953	0.2	0.842
X2004.R.M.	1.26687	0.12744	9.941	2.15E-15
Method[T.SS]	-615.6164	934.5222	-0.659	0.512
Sector[T.CAPGDS]	619.87018	1429.252	0.434	0.666
Sector[T.HEALTH]	-159.0349	1502.048	-0.106	0.916
Sector[T.TECHNO]	-49.54589	1222.147	-0.041	0.968
X2004.R.M.:Method[T.SS]	-0.05545	0.07476	-0.742	0.461
X2004.R.M.:Sector[T.CAPGDS]	0.01779	0.13025	0.137	0.892
X2004.R.M.:Sector[T.HEALTH]	0.10552	0.13245	0.797	0.428
X2004.R.M.:Sector[T.TECHNO]	0.133	0.12856	1.035	0.304

Residual standard error: 3213 on 76 degrees of freedom
Multiple R-Squared: 0.9824, Adjusted R-squared: 0.9803
F-statistic: 471.2 on 9 and 76 DF, p-value: < 2.2e-16

	Df	Sum sq	Mean sq	F-value	Pr(>F)
X2004.R.M.	1	4.37E+10	43668000000	4230	< 2e-16
Method	1	1.96E+07	19620000	2	0.17209
Sector	3	2.14E+07	7142100	1	0.55989
X2004.R.M.:Method	1	4.48E+06	4482200	0	0.51196
X2004.R.M.:Sector	3	6.88E+07	22929000	2	0.09255
Residuals	76	7.85E+08	10325000		

Residuals:

Min	1Q	Median	3Q	Max
-8538.3	-738.2	-116.3	523.1	19106.3

Coefficients:

	Estimate	Std Error	t-value	Pr(>|t|)
(Intercept)	191.9029	439.9741	0.436	0.664
X2004.R.M.	1.29207	0.02023	63.877	<2e-16

Residual standard error: 3271 on 84 degrees of freedom
Multiple R-Squared: 0.9798, Adjusted R-squared: 0.9796
F-statistic: 4080 on 1 and 84 DF, p-value: < 2.2e-16

	Df	Sum sq	Mean sq	F-value	Pr(>F)
X2004.R.M.	1	4.37E+10	4.37E+10	4080.3	2.20E-16
Residuals	84	8.99E+08	1.07E+07		

9.3.5. Revenue per employee (millions)

FULL MODEL
2007RPE = 2004RPE + Method + Sector + 2004RPE*Method + 2004RPE*Sector

Residuals:

Min	1Q	Median	3Q	Max
-0.75174	-0.08907	-0.01495	0.07216	1.05003

Coefficients:

	Estimate	Std Error	t-value	Pr(>|t|)
(Intercept)	-0.02604	0.11655	-0.223	8.24E-01
X2004.RPE.M.	1.36542	0.33305	4.1	0.000103
Method[T.SS]	0.40276	0.07407	5.438	6.31E-07
Sector[T.CAPGDS]	0.04976	0.18169	0.274	0.784909
Sector[T.HEALTH]	-0.3304	0.13843	-2.387	0.019482
Sector[T.TECHNO]	-0.11605	0.13036	-0.89	0.376167
X2004.RPE.M.:Method[T.SS]	-1.36569	0.17452	-7.826	2.37E-11
X2004.RPE.M.:Sector[T.CAPGDS]	-0.29663	0.64024	-0.463	0.644461
X2004.RPE.M.:Sector[T.HEALTH]	1.09159	0.36039	3.029	0.003352
X2004.RPE.M.:Sector[T.TECHNO]	0.29541	0.36753	0.804	0.42403

Residual standard error: 0.1878 on 76 degrees of freedom
Multiple R-Squared: 0.8565, Adjusted R-squared: 0.8396
F-statistic: 50.42 on 9 and 76 DF, p-value: < 2.2e-16

	Df	Sum sq	Mean sq	F-value	Pr(>F)
X2004.RPE.M.	1	13.51	14	383	< 2.2e-16
Method	1	0.14	0	4	0.047881
Sector	3	0.16	0	2	0.214245
X2004.RPE.M.:Method	1	1.34	1	38	3.22E-08
X2004.RPE.M.:Sector	3	0.85	0	8	0.000102
Residuals	76	2.68	0		

Reduced MODEL
2007RPE = 2004RPE + Method + 2004RPE*Method

Residuals:

Min	1Q	Median	3Q	Max
-0.528486	-0.047638	-0.002465	0.061159	1.480875

Coefficients:

	Estimate	Std Error	t-value	Pr(>|t|)
(Intercept)	-0.1858	0.05626	-3.303	0.00142
X2004.RPE.M.	1.92472	0.14344	13.418	2.00E-16
Method[T.SS]	0.22551	0.07213	3.127	2.45E-03
X2004.RPE.M.:Method[T.SS]	-0.91019	0.16486	-5.521	3.86E-07

Residual standard error: 0.2115 on 82 degrees of freedom
Multiple R-Squared: 0.8038,   Adjusted R-squared: 0.7966
F-statistic: 112 on 3 and 82 DF, p-value: < 2.2e-16

	Df	Sum sq	Mean sq	F-value	Pr(>F)
X2004.RPE.M.	1	13.51	14	302	< 2.2e-16
Method	1	0.14	0	3	0.0778
X2004.RPE.M.:Method	1	1.36	1	30	3.86E-07
Residuals	82	3.67	0		

9.3.6. Asset turnover

FULL MODEL
2007AT = 2004AT + Method + Sector + 2004AT*Method + 2004AT*Sector

Residuals:

Min	1Q	Median	3Q	Max
-0.556764	-0.095678	0.007697	0.136488	0.596595

	Estimate	Std Error	t-value	Pr(>|t|)
(Intercept)	0.20568	0.11098	1.853	6.77E-02
X2004.AT	0.84095	0.103	8.165	5.33E-12
MethodSS	0.09472	0.11995	0.79	4.32E-01
SectorCAPGDS	-0.09885	0.26054	-0.379	0.7054
SectorHEALTH	-0.26434	0.15231	-1.736	0.0867
SectorTECHNO	0.04641	0.13226	0.351	0.7267
X2004.AT:MethodSS	-0.05492	0.13511	-0.406	6.86E-01
X2004.AT:SectorCAPGDS	0.07689	0.3065	0.251	0.8026
X2004.AT:SectorHEALTH	0.0949	0.15971	0.594	0.5541
X2004.AT:SectorTECHNO	-0.10088	0.12826	-0.787	0.434

Residual standard error: 0.2072 on 76 degrees of freedom
Multiple R-Squared: 0.8449,   Adjusted R-squared: 0.8265
F-statistic: 46 on 9 and 76 DF, p-value: < 2.2e-16

	Df	Sum sq	Mean sq	F-value	Pr(>F)
X2004.AT	1	1.72E+01	1.72E+01	401.7744	<2e-16
Method	1	7.29E-02	7.29E-02	1.6991	0.1963
Sector	3	0.3332	0.1111	2.5881	5.91E-02
X2004.AT:Method	1	0.0243	0.0243	0.5665	0.454
X2004.AT:Sector	3	0.0929	0.031	0.7216	0.5422
Residuals	76	3.2617	0.0429		

9.3.7. Return on assets

FULL MODEL
2007ROA = 2004ROA + Method + Sector + 2004ROA*Method + 2004ROA*Sector

Residuals:

Min	1Q	Median	3Q	Max
-0.140439	-0.034108	-0.005471	0.033548	0.165255

Coefficients:

	Estimate	Std Error	t-value	Pr(>|t|)
(Intercept)	0.10306	0.03301	3.122	2.54E-03
X2004.ROA	-0.05414	0.27879	-0.194	8.47E-01
MethodSS	0.01173	0.0293	0.4	6.90E-01
SectorCAPGDS	-0.08515	0.05901	-1.443	0.15313
SectorHEALTH	-0.04215	0.04799	-0.878	0.38249
SectorTECHNO	-0.06721	0.03845	-1.748	0.08455
X2004.ROA:MethodSS	0.03742	0.18527	0.202	8.40E-01
X2004.ROA:SectorCAPGDS	1.07352	0.50416	2.129	0.03647
X2004.ROA:SectorHEALTH	0.5365	0.31748	1.69	0.09515
X2004.ROA:SectorTECHNO	0.84106	0.296	2.841	0.00576

Residual standard error: 0.06255 on 76 degrees of freedom
Multiple R-Squared: 0.4203, Adjusted R-squared: 0.3516
F-statistic: 6.122 on 9 and 76 DF, p-value: 1.950e-06

	Df	Sum sq	Mean sq	F-value	Pr(>F)
X2004.ROA	1	1.63E-01	1.63E-01	41.5593	9.49E-09
Method	1	2.89E-03	2.89E-03	0.7381	0.39298
Sector	3	0.013198	0.004399	1.1245	3.45E-01
X2004.ROA:Method	1	0.000174	0.000174	0.0445	0.83343
X2004.ROA:Sector	3	0.036712	0.012237	3.128	0.03057
Residuals	76	0.297328	0.003912		

Reduced MODEL
2007ROA = 2004ROA + Sector + 2004ROA*Sector

Residuals:

Min	1Q	Median	3Q	Max
-1.725e-01	-4.060e-02	-8.029e-05	4.424e-02	1.669e-01

Coefficients:

	Estimate	Std Error	t-value	Pr(>|t|)
(Intercept)	0.06447	0.01577	4.089	1.01E-04
X2004.ROA	0.30007	0.17702	1.695	9.39E-02
X2004.ROA:SectorCAPGDS	0.39672	0.18386	2.158	3.39E-02
X2004.ROA:SectorHEALTH	0.20459	0.16078	1.272	0.206855
X2004.ROA:SectorTECHNO	0.38171	0.15101	2.528	0.013427

Residual standard error: 0.06244 on 81 degrees of freedom
Multiple R-Squared: 0.3842, Adjusted R-squared: 0.3538
F-statistic: 12.63 on 4 and 81 DF, p-value: 4.918e-08

	Df	Sum sq	Mean sq	F-value	Pr(>F)
X2004.ROA	1	1.63E-01	1.63E-01	41.6967	7.36E-09
X2004.ROA:Sector	3	3.45E-02	1.15E-02	2.9453	0.03778
Residuals	81	0.315845	0.003899		

9.3.8. Return on investment

FULL MODEL
2007ROI = 2004ROI + Method + Sector + 2004ROI*Method + 2004ROI*Sector

Residuals:

Min	1Q	Median	3Q	Max
-0.39066	-0.08468	-0.01274	0.07472	0.39437

Coefficients:

	Estimate	Std Error	t-value	Pr(>|t|)
(Intercept)	0.10186	0.07538	1.351	0.1806
X2004.ROI	0.46878	0.23406	2.003	0.0488
MethodSS	0.11721	0.06622	1.77	0.0807
SectorCAPGDS	-0.13432	0.11328	-1.186	0.2394
SectorHEALTH	-0.06527	0.09519	-0.686	0.4950
SectorTECHNO	-0.06682	0.08219	-0.813	0.4188
X2004.ROI:MethodSS	-0.23037	0.19289	-1.194	0.2361
X2004.ROI:SectorCAPGDS	0.81707	0.3482	2.347	0.0216
X2004.ROI:SectorHEALTH	0.33881	0.23894	1.418	0.1603
X2004.ROI:SectorTECHNO	0.42854	0.26582	1.612	0.1111

Residual standard error: 0.1366 on 76 degrees of freedom
Multiple R-Squared: 0.4899, Adjusted R-squared: 0.4295
F-statistic: 8.111 on 9 and 76 DF, p-value: 2.495e-08

	Df	Sum sq	Mean sq	F-value	Pr(>F)
X2004.ROI	1	1.05	1	56	9.52E-11
Method	1	0.05	0	3	0.1
Sector	3	0.10	0	2	1.67E-01
X2004.ROI:Method	1	0.05	0	3	1.13E-01
X2004.ROI:Sector	3	0.11	0	2	0.1177
Residuals	76	1.42	0		

REDUCED MODEL
2007ROI = 2004ROI + 2004ROI*Sector

Residuals:

Min	1Q	Median	3Q	Max
-0.396709	-0.092585	-0.002878	0.069779	0.422218

Coefficients:

	Estimate	Std Error	t-value	Pr(>|t|)
(Intercept)	0.11698	0.03331	3.512	0.0007
X2004.ROI	0.45046	0.13808	3.262	0.0016
X2004.ROI:SectorCAPGDS	0.46031	0.14661	3.14	0.0024
X2004.ROI:SectorHEALTH	0.18232	0.13088	1.393	0.1674
X2004.ROI:SectorTECHNO	0.26017	0.13334	1.951	0.0545

Residual standard error: 0.1376 on 81 degrees of freedom
Multiple R-Squared: 0.4488, Adjusted R-squared: 0.4216
F-statistic: 16.49 on 4 and 81 DF, p-value: 6.372e-10

	Df	Sum sq	Mean sq	F-value	Pr(>F)
X2004.ROI	1	1.05E+00	1.05E+00	55.6198	0.0000
X2004.ROI:Sector	3	1.96E-01	6.53E-02	3.4484	0.0204
Residuals	81	1.53282	0.01892		

9.3.9. Total assets (millions)

FULL MODEL
2007AM = 2004AM + Method + Sector + 2004AM*Method + 2004AM*Sector

Residuals:

Min	1Q	Median	3Q	Max
-29187.5	-1963.7	-759.2	548.7	20246.7

Coefficients:

	Estimate	Std Error	t-value	Pr(>|t|)
(Intercept)	-423.9647	2113.119	-0.201	0.8415
X2004.A.M.	1.0254	0.1597	6.421	0.0000
MethodSS	2007.9381	1886.969	1.064	0.2906
SectorCAPGDS	805.4893	2769.962	0.291	0.7720
SectorHEALTH	2141.8391	3146.856	0.681	0.4982
SectorTECHNO	2198.314	2339.413	0.94	0.3504
X2004.A.M.:MethodSS	-0.2196	0.1071	-2.05	0.0438
X2004.A.M.:SectorCAPGDS	0.2707	0.1716	1.578	0.1188
X2004.A.M.:SectorHEALTH	0.317	0.1834	1.729	0.0879
X2004.A.M.:SectorTECHNO	0.1328	0.1663	0.799	0.4270

Residual standard error: 6334 on 76 degrees of freedom
Multiple R-Squared: 0.9264, Adjusted R-squared: 0.9177
F-statistic: 106.4 on 9 and 76 DF, p-value: < 2.2e-16

	Df	Sum sq	Mean sq	F-value	Pr(>F)
X2004.A.M.	1	37549000000	37549000000	936.0749	< 2.2e-16
Method	1	7132700	7132700	0.1778	0.6744
Sector	3	314840000	104950000	2.6163	0.0571
X2004.A.M.:Method	1	287890000	287890000	7.1769	0.0090
X2004.A.M.:Sector	3	238860000	79619000	1.9848	0.1234
Residuals	76	3048600000	40113000		

REDUCED MODEL
2007AM = 2004AM + 2004AM*Method + 2004AM*Sector

Residuals:

Min	1Q	Median	3Q	Max
-31051.3	-1805.7	-1226.1	455.2	20861.4

Coefficients:

	Estimate	Std Error	t-value	Pr(>|t|)
(Intercept)	1811.4494	881.548	2.055	0.0432
X2004.A.M.	0.94124	0.13795	6.823	0.0000
X2004.A.M.:MethodSS	-0.15503	0.08213	-1.888	0.0627
X2004.A.M.:SectorCAPGDS	0.30024	0.13927	2.156	0.0341
X2004.A.M.:SectorHEALTH	0.40271	0.14064	2.863	0.0054
X2004.A.M.:SectorTECHNO	0.19306	0.13567	1.423	0.1586

Residual standard error: 6260 on 80 degrees of freedom
Multiple R-Squared: 0.9244, Adjusted R-squared: 0.9196
F-statistic: 195.5 on 5 and 80 DF, p-value: < 2.2e-16

	Df	Sum sq	Mean sq	F-value	Pr(>F)
X2004.A.M.	1	37549000000	37549000000	958.1258	< 2.2e-16
X2004.A.M.:Method	1	270960000	270960000	6.9139	0.0103
X2004.A.M.:Sector	3	491160000	163720000	4.1776	0.0084
Residuals	80	3135200000	39190000		

9.3.10. Number of employees

FULL MODEL
2007EMP = 2004EMP + Method + Sector + 2004EMP*Method + 2004EMP*Sector

Residuals:

Min	1Q	Median	3Q	Max
-25423	-3984	-1663	2501	45601

Coefficients:

	Estimate	Std Error	t-value	Pr(>|t|)
(Intercept)	3577.00	3415	1.047	0.2982
X2004.EMP	0.77	0	7.732	0.0000
MethodSS	-3815.00	3100	-1.231	0.2222
SectorCAPGDS	-5301.00	4359	-1.216	0.2277
SectorHEALTH	178.40	5071	0.035	0.9720
SectorTECHNO	741.70	3740	0.198	0.8433
X2004.EMP:MethodSS	0.09	0	1.006	0.3175
X2004.EMP:SectorCAPGDS	0.34	0	3.84	0.0003
X2004.EMP:SectorHEALTH	0.23	0	1.901	0.0611
X2004.EMP:SectorTECHNO	0.34	0	3.663	0.0005

Residual standard error: 10100 on 76 degrees of freedom
Multiple R-Squared: 0.9732, Adjusted R-squared: 0.97
F-statistic: 306.1 on 9 and 76 DF, p-value: < 2.2e-16

	Df	Sum sq	Mean sq	F-value	Pr(>F)
X2004.EMP	1	278030000000	278030000000	2725.412	< 2.2e-16
Method	1	22870000	22870000	0.2242	0.6372
Sector	3	853320000	284440000	2.7882	0.0463
X2004.EMP:Method	1	490250000	490250000	4.8057	0.0314
X2004.EMP:Sector	3	1612200000	537410000	5.268	0.0024
Residuals	76	7753100000	102010000		

REDUCED MODEL
2007EMP = 2004EMP + Sector + 2004EMP*Method + 2004EMP*Sector

	Df	Sum sq	Mean sq	F-value	Pr(>F)
X2004.EMP	1	278030000000	278030000000	2707.309	< 2.2e-16
Sector	3	858340000	286110000	2.786	0.0463
X2004.EMP:Method	1	239480000	239480000	2.332	0.1308
X2004.EMP:Sector	3	1726300000	575440000	5.6033	0.0016
Residuals	77	7907600000	102700000		

REDUCED MODEL
2007EMP = 2004EMP + Sector + 2004EMP*Sector

Residuals:

Min	1Q	Median	3Q	Max
-25505	-3588	-1186	2689	44798

Coefficients:

	Estimate	Std Error	t-value	Pr(>|t|)
(Intercept)	1.51E+03	2.99E+03	0.506	0.614013
X2004.EMP	8.25E-01	8.03E-02	10.269	3.85E-16
SectorCAPGDS	-5.01E+03	4.31E+03	-1.164	0.248169
SectorHEALTH	9.37E+02	5.02E+03	0.187	0.852506
SectorTECHNO	1.14E+03	3.70E+03	0.307	0.759614
X2004.EMP:SectorCAPGDS	3.60E-01	8.61E-02	4.178	7.61E-05
X2004.EMP:SectorHEALTH	2.11E-01	1.20E-01	1.759	8.25E-02
X2004.EMP:SectorTECHNO	3.43E-01	9.03E-02	3.799	0.000286

Residual standard error: 10080 on 78 degrees of freedom
Multiple R-Squared: 0.9726, Adjusted R-squared: 0.9701
F-statistic: 395.2 on 7 and 78 DF, p-value: < 2.2e-16

	Df	Sum sq	Mean sq	F-value	Pr(>F)
X2004.EMP	1	278030000000	278030000000	2738.87	< 2.2e-16
Sector	3	858340000	286110000	2.8185	0.0444
X2004.EMP:Sector	3	1955400000	651800000	6.4209	0.0006
Residuals	78	7918000000	101510000		

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