University of Surrey

School of Management

An exploration of the implementation of Six Sigma in a battery manufacturing company

by

C. Or

Submitted in part fulfillment of the requirements for the degree of Doctor of Business Administration
October 2008

Abstract

Six Sigma is reported to be playing an increasingly important role in the business world. Henderson et al. claimed (2000) that it has been a main thrust for many organizations seeking to improve their performance effectiveness and in providing increased value to their stakeholders. However, very little research has been conducted in this area. Many companies have invested a huge amount of money on implementing the initiatives of Six Sigma and some received a big return on the investment while some did not. Motivated by the need for more interpretive types of study using the perceptions of objective reality in the field of Six Sigma implementation, this empirical research was conducted to study the impact of Six Sigma methodology and its effects on: organizational performance; customer satisfaction; and, Six Sigma participants' career path and satisfaction. Forty-two Six Sigma Belts were successfully invited to join a questionnaire survey in this present study; and four Six Sigma Belts were subjected to further in-depth study. Detailed data concerning Six Sigma projects were collected from a large international battery manufacturing firm by survey questionnaires, interview and documentation collection.

The present study reviews and examines the current Six Sigma and quality management theories. In addition, Exploratory Factor Analysis (EFA) was used to establish a research instrument. The data allowed an empirical model, showing the relationships between Six Sigma and organizational performance, customer satisfaction and participant satisfaction, to be developed by a path analytic approach. The direct factors to operational performance were examined using Structural Equation Modelling (SEM).

The research results show that Six Sigma management practices are interrelated to form a complicated structure of the Six Sigma management system. However, out of the seven constructs of the present study: Six Sigma Team Management System, Senior Management Commitment and Involvement and Process Control and Improvement were found to be the most influential factors for organizational performance. These findings revealed the possibility of a more successful implementation of Six Sigma methodology by pinpointing three critical areas – leadership, Six Sigma team management, and, process management. The present study suggests that the values of the Six Sigma methodology is largely dependent on the visionary leadership, team and process management, together with a progressive development of Six Sigma cultures.

Content

List of Tables

List of Figures

Chapter 1 Introduction

1.1 Introduction to Six Sigma Research

As a Six Sigma black belt practitioner, the research aims to study the Six Sigma methodology and its association with operational efficiency, customer satisfaction, participant satisfaction, business performance. This work planned initially to provide the insights concerning the implementation of the methodology in order to help improve organizational performance and provide wider stakeholders' benefits.

This research was carried out to examine the critical aspects of a Black Belt Six Sigma operation due to the interests of the author of the work in having been through the process of achieving personal black belt status. As such the research study led to an interest in exploring the possible benefits of Six Sigma application in a case study of a battery company setting. Moreover, the author's interest in Six Sigma is related to Quality management issues whereby they are now the main focus of organisations competing in both domestic and global economies (Anderson, Rungtusanatham, Schroeder and Devaraj 1995). With these issues, Six Sigma is one of the more recent quality improvement methodologies to gain popularity and acceptance in many industries across the globe (Nonthaleerak and Hendry 2008). It has been sweeping the business world including both service and manufacturing sectors, with remarkable results over the last 20 years or so (Antony 2008). Many supporters of the approach now claim that Six Sigma methodology has developed beyond a quality control approach into a broader process improvement concept. However, there are very few studies that have reported about the successful applications of Six Sigma, and Antony (2008) claimed that Six Sigma is still not widely accepted by many academics.

Integrating established theories

The concept of Six Sigma methodology was established by Mikel Harry in the late 1980s at Motorola (Maguire 1999 cite in Antony 2006). Just like those theories developed by renowned quality experts such as Deming, Juran and Crosby, these philosophies and concepts have been proved to be practical in industry, but still have not been systematically organized and methodically investigated and generalized to improve the overall quality management approaches. Dean et al. (1994) argued the failure of quality initiatives are mainly due to the organizationally and politically naïve. They pointed out that management theorists should develop frameworks that incorporate the accumulate knowledge about organizations and, thus, can better guide quality improvement initiatives implementation.

Nonthaleerak et al. (2005) conducted an extensive literature review on Six Sigma and found that many of the papers written on issues such as implementation are descriptive, concentrate on positive attributes and are not well founded using a rigorous research approach (cited in Nonthaleerak et al. 2008). Considering that many organizations are currently investing heavily on the methodology with many key questions remaining unanswered (Fok, Hartman, Patti and Razek. 2000), and that it significantly affects the organizations and their stakeholders. The researcher attempted to fill the knowledge gap by studying Six Sigma at a battery manufacturing firm which has its headquarters in Hong Kong. She begins by suggesting a conceptual framework that synthesized the findings from the literature and discussions with Six Sigma practitioners and professionals about the methodology and their expected relationship to an organization's performance and its stakeholders.

The case company provides an excellent environment for the research. The firm currently employs over 14,600 people worldwide. The firm started introducing Six Sigma since the year of 2004 and has 5 production plants and are implementing Six Sigma methodology currently with a total of 109 persons trained, 100 persons were certified as Green Belts and Black Belts. Garvin (1983) claimed that analyzing the results concluded from the data which collected was from a single industry should be more convincing, therefore, the analysis result drew from the same organization should also be persuasive.

1.2 Defining Six Sigma and its Values

It is not possible to define Six Sigma in some simple terms because it encompasses the methodology of problem solving, and focuses on organization and cultural change (Raisinghani, Ette, Pierce, Cannon and Daripaly 2005). They claimed that the roots of sigma as a measurement standard go back to Carl Fredrick Gauss (1777-1855), who introduced the concept of the normal curve or distribution. Walter Shewart introduced three sigma in 1922. The concept of three sigma is related to a process yield of 99.973 percent or a defect rate should not be more than 2,600 per million opportunities as a measurement standard of output variation in 1922, and stressed that intervention was needed when the output variance went beyond the limit. However, in the early 1980s, an even higher level of quality was required when the lower price but higher quality of the Japanese goods attracted the eyes of the global consumer. Motorola's chairman at the time, Bob Galvin, argued that much more effort was needed to improve their quality. One of his engineers, Bill Smith, found that the quality level associated with a measure of Six Sigma corresponds to a failure rate of two parts per billion and Motorola then adopted this as a standard and then coined this quality improvement program as "Six Sigma", which included many of the systematic and rigorous tools associated with the Six Sigma programs of today.

The value of Six Sigma is the measurement of an organization's success and achievements. Yeung (1999) pointed out that staying in business and making profits is the ultimate goal of all business firms. However, only focusing on measuring of profitability alone is not enough to assess the overall performance of an organization and the contributions of Six Sigma methodology. Other non-financial measurement criteria are also important. Five criteria of organizational performance including Operational Efficiency, Satisfaction with Six Sigma Methodology, Job Satisfaction, Customer Satisfaction and Business Performance are also focused on in this study. Operational Efficiency is used to indicate how close an organization has come to achieving at least cost the maximum revenue that can be earned from a particular market (McLean 2006). The measurement of Satisfaction with Six Sigma Methodology determines the level of the methodology meets or exceeds the users' expectations or requirements. The measurement of Six Sigma practitioners' Job Satisfaction determines the level to which their career path and treatment in the organization meet or exceed their expectation. The measurement of Customer Satisfaction determines the level to which a product and service delivered meet or exceed customers' expectation. Business Performance in this study mainly concerns the successful aspects of sales and profit making. Profitability refers to the overall earnings and return on investment of the organization.

1.3 Research Space in Six Sigma

Nonthaleerak et al. (2008) claimed that many of the academic articles of Six Sigma are skeptical; some researchers such as McManus (1999) believed that Six Sigma is nothing special but just an add-on project management tool. Nonthaleerak et al. (2008) argued that regardless of such skepticism, it is important for the academic community to continue to study the Six Sigma phenomenon given its acceptance in industry. Antony (2006) pointed out that Six sigma today has evolved from merely a measurement of quality to an overall business improvement strategy for a large number of companies around the world. From the surveys, Aviation Week Magazine in 2002 and Quality Digest in 2006 found that very few respondents are satisfied with the results of their Six Sigma projects.

1.4 General Approaches of Study

Kolarik (1995) stressed that a quality system must reflect quality philosophies and shape management practices. However, the current literature journal mainly concentrates on TQM or focusing on emphasizing the effect of Six Sigma methodology on defect eliminating and bottom line improvement in businesses and provides little discussion regarding the impact on the stakeholders of organizations. Given the interest in Six Sigma by this researcher, the research aim of this thesis is

1) To identify the major constructs and latent factors that make up the Six Sigma approach in a specific type of case company. This is to be utilised to create a model for Six Sigma implementation.

2) To utilise the constructs and factors in order to investigate if there is any connection to aspects of satisfaction for those participating in six sigma, as well as the case study customers, and, finally to examine the association if any to that of business performance.

3) Overall to provide added value on the basis of creating insight into the implementation associated with a Six Sigma initiative.

However, due to a lack of information on sales satisfaction (see section 6.4) there were problems in fulfilling all these aims for the thesis. The following would form the general research directions:

Practical nature

Dean and Bowen (1994) claimed that quality management theory development should benefit both researchers and practitioners. Yeung (1999) pointed out that quality management theories should be practical in nature; the knowledge developed must be of considerable value and able to be applied by quality practitioners directly or indirectly. He argued that pure theory is of little use to quality practitioners. Therefore, developing and testing the theories of quality management should require rigorous empirical research carried out in collaboration with quality practitioners in industry.

Developing Measurement

An instrument for objective measurement in both of the practices and performance of Six Sigma methodology will be firstly constructed. Reliability and validity are also important considerations. Therefore, the literature review and consultation with quality managers is to be used to help inform the researcher in order to improve the validity of constructs and the questionnaire.

1.5 The Methodological Consideration

The scientific investigation is empirical, systematic, controlled and ordered (Kerlinger et al. 2000) and the approach of developing and validating the research instrument is an ongoing process (Dwivedi, Choudrie and Brinkman 2006). The present study is an empirical research. Flynn, Sakakibara, Schroeder, Bates and Flynn (1990) pointed out that the term "empirical" means "knowledge based on real world observations or experiment." The term used here is also to describe field-based research, which uses data gathered from naturally occurring situations rather than via laboratory or simulation studies. As all data is from natural settings, the researcher has no control over the events is the case company being studied.

This research is to utilize a case study-based research methodology with mixed data sources and qualitative and quantitative analysis methods. The reason for selecting the case study methodology is that the case study is a research strategy which Yin (2003[1]) described as an all-encompassing method that not only covers the logic of research design, data collection techniques as well as specific approaches to data analysis. Qualitative research methods, including structured interview and documentation review are applied in this study to facilitate the design and development of the research study, verifying the quantitative data and provide further insights for explaining the research results. A quantitative approach is used here for the measurements of Six Sigma management practice and organizational performance which are complicated ideas and very difficult to quantify. However, by collecting more concrete data about organizational practices and performance and applying multivariate statistical methods, an instrument can be developed for measurements and further analysis. Quantitative researcher methodology is employed for hypotheses testing and model development. Statistical methodologies such as canonical correlation analysis and path analysis are applied in theory building and verifications.

1.6 Organizations of the thesis

The present chapter presents an overview of this study and the subsequent chapters provide the details of the entire study. The thesis is organized as below:
Chapter 2 provides a comprehensive review of the current literature of quality management and organizational performance, including empirical research on Six Sigma, its effects on organizational performance and its other values. The instruments developed in the quality management field are also reviewed.

Chapter 3 discusses the research methodology in the present study and the use of various methods in qualitative and quantitative data collections. This chapter provides in-depth discussions on the methods in obtaining more objective and reliable data.

Chapter 4 provides detailed explanations on the process of instrument development and validations and explains the related methodologies employed. The current instrument was built upon the empirical works of various survey instruments but with different focuses on contents, targeted samples and methods in variables condensation.

Exploratory factor analysis (EFA) was the primary methodology which was employed in the current instrument development, assisted with other statistical techniques.

Chapter 5 develops and verifies an integrate model about Six Sigma management practices constructs and organizational performance measures by using path analytic approach. The present model provides more comprehensive and better empirical based explanations on Six Sigma management practices and performance relationships. Canonical Correlation Analysis (CCA) is used to identify the possible sets of relationships between particular categories of constructs and performance measures.

Chapter 6 provides detailed accounts on the qualitative methodologies used. Structured interview assisted with documentation review.

Chapter 7 summarized the research results and findings.

Chapter Two Literature Review

2.1 Introduction

Six Sigma is a quality improvement program that aims to reduce the number of defects in any process. It uses the normal distribution and strong relationship between product nonconformities, or defects, and product yield, reliability, cycle time, inventory, schedule, etc. (Sokovic, Pavletic and Fakin 2005). According to Pyzdek (2003), the story of Six Sigma methodology being a fad in today's business started when a Japanese firm took over a Motorola Quasar television sets factory in the United States in the 1970. The Japanese management promptly changed the way the factory operated. Under Japanese management, the product defects were reduced by 95 percent compared with the plant under Motorola management by using the same workforce, technology and designs. Since then, Motorola management decided to look into quality seriously. Bob Galvin decided to achieve a tenfold improvement in performance over a five-year period when he became the Motorola CEO in 1981 (Pyzdek [no date[1]]). His veteran engineer Bill Smith discovered that there is a correlation between a product's service life and numbers of reworks needed in the manufacturing process. Smith also found that products that were built with lesser nonconformities will have the optimal performances. He, therefore, convinced Galvin to set up a Six Sigma quality goal (Ramberg 2000). On the other hand, he cooperated with his co-worker Mikel Harry to develop a four-stage problem-solving approach: Measure, Analyze, Improve and Control (MAIC). The MAIC methodology became the road map for achieving Six Sigma quality (Pyzdek [no date[1]]).

After implementing Six Sigma, Motorola became the first American firm to be awarded the Malcolm Baldrige National Quality Award in 1988. Since then, Six Sigma has begun to catch the industry's attention. However, the fact that this powerful tool was made even more well-known and wider spread should be credited to Jack Welch, the General Electric's former CEO. Jack Welch made the Six Sigma approach a central focus of his business strategy in 1995. Jack Welch became the strongest advocator for Six Sigma after he learnt the benefit of implementing Six Sigma by Allied Signal's former CEO Lawrence Bossidy (Chowdhury 2001). Today, Six Sigma is the fastest growing business management system in industry.

Schmidt and Finnigan claimed that the quest for quality is a race without a finish line (1992). Yeung (1999) pointed out that quality management theories have been developing rapidly since the 1950s and extensively documented in the literature. In these publications, quality management has been described as an essential source of competitive advantage which improves a company's overall competitive performance. Quality Management (QM) becomes one of the most relevant research topics in the field of operations management (Filippini1997).

This chapter begins by reviewing the empirical evidence in the literature for the impact of quality initiatives on organizational performance. Then, the chapter continues by examining the Total Quality Management (TQM), ISO 9000 and Six Sigma and analyzing the empirical studies which examined their impact on company performance and customers' satisfaction level as well as the career structure of the Six Sigma participants.

2.2 Quality Improvement and Business Performance

2.2.1 Theoretical Foundations on Quality Improvement

Yeung (1999) claimed that the theory developed by Render and Heizer (1995) which stated that quality improvement is strategically important to a company or even to the entire industry of a country is a well-received theory in management studies. In Yeung's study, he cited Dilworth's work (1993) showing that a company cannot only decrease costs just by improving its quality, it also can sell more products at a higher price than its competitors, the company can therefore earn more profits and market share even in the serious price competition environment. Germain et al. (1999) also claimed that the importance of quality continues to be recognized by leading worldwide businesses and the research in quality extends beyond operations and is increasingly cross-disciplinary with studies emerging in marketing, economics, and management. Quality management has long been involved in the entire firm of both industrial and service sectors (Deming 1982; Ishikawa 1985).

Among all the well-received quality management theories developed by the well-known quality gurus, Yeung (1999) believed that Deming's (1982; 1986) works received the most attention. Deming considered that the quality improvement induces a chain effect in that improved quality will reduce the rework, defects and mistakes, the costs will therefore be decreased. The machine-time and materials will be better used and the productivity will be increased. This chain effect will allow business to earn more market shares with higher quality but lower prices. The business will also be able to create more jobs than its competitors.

2.2.2 Empirical Evidence

Although quality management has become very common practice in both of the public and private service sectors (Lagrosen and Lagrosen 2006), every few empirical studies have identified the direct and indirect effects of quality management practices on performance (Tari et al. 2006). Yeung (1999) claimed that most of the empirical evidence of the effects of quality improvement on company performance is concluded from the isolated case histories, anecdotal experiences and small-scale studies. Similarly, Taylor and Wright (2001) commented that too much of the quality management literature consists of anecdotal case reports or before-and-after evaluation studies that may be of more use politically in promoting quality management than they are in building knowledge about quality processes and practices.

2.2.2.1 The Impact of Quality Improvement on Business Performance

Taylor and Wright (2003) conducted a longitudinal research studying the link between TQM implementation and successful outcomes in 113 organizations which practiced TQM. These organizations were surveyed firstly in 1992 and then contacted again 5 years later. After the study, they claimed that there is evidence to show that TQM does deliver improved performance when implemented effectively.

Another empirical research was conducted by Adam et al. (1997), they studied what approaches to quality lead to best quality and financial performance across different regions of the world. The survey involved 977 firms in Asia/South Pacific, Europe, and

North America. From the study, Adam et al. found that although quality improvement approach successfully influences quality, the impact on financial performance is somewhat weak. Adam et al. claimed that the findings are consistent with those previous researchers (Adam 1994; Sluti 1992).

Mann and Kehoe (1994) conducted a research in order to evaluate the effects of quality improvement activities on business performance. They employed questionnaires survey and structured interviews to study more than 200 companies. Mann and Kehoe (1994) provided the quantitative data as empirical evidence for the effects of quality on each company's percentage sales turnover. In their study, quality was measured in terms of annual sales turnover rate. They concluded that the quality activities particularly TQM has beneficial effects on business performance and the TQM can also be used to assess an organization's present strengths and weakness with regard to its targeting of quality activities. They argued that this information can assist in deciding which quality activities to implement.

With the advocacy of the importance of empirical research and more rigorous studies in operations management by previous researchers such as Meredith et al. (1989) and Flynn et al. (1990), Yeung (1999) conducted a larger scale research on the relationships between quality and company performance. Yeung (1999), who conducted his Ph.D. research on quality management system while studying in Hong Kong University, tried to link the quality management system with organizational performance. He studied two hundred and twenty-five medium and large size electronics manufacturing firms in Hong Kong and found, by using sophisticated statistical techniques, a significant linkage between quality measures and overall organizational performance.

His research provides important empirical evidence that quality management system is highly associated with organizational performance. His measures for quality are based on the Time-based Efficiency, Cost-related Efficiency and Customer Satisfaction. The measures of quality in terms of Time-based Efficiency, Cost-related Efficiency and Customer Satisfaction are only a few of many indicators of organizational performance. However, he did not disclose the financial improvement and whether the market share of these companies has been improved.

Lakhal (2006) employed the mail survey method and studied 133 Tunisian companies from the plastic transforming sector to explore the relationship between quality management practices and their impact on performance. In this study we have provided empirical evidence that quality management practices have a positive impact on organizational performance. Moreover, the results also proved the importance of the support of senior management and their commitment. However, his measure for performance is based on managers' perceptions. He contended that it is rather dangerous to readily assume that an individual response is a reliable and valid indicator of an organization-level construct. He also stressed that the study was not able to capture the effects of other mutually supportive process management techniques on the firm's performance.

Madu and Kuei (1995) conducted a comparative analysis of quality practice in manufacturing firms in the U.S. and Taiwan to study whether there is a causal relationship between multivariate constructs for quality such as customer satisfaction, employee satisfaction, and employee service quality and organizational performance. The study found a significant causal relationship between the quality constructs and organizational performance. However, Yeung (1999) argued that the uses of customer satisfaction, product features and company culture as indicators are highly subjective in that these constructs are unobservable variables by themselves. Moreover, these data are unavailable in most organizations and therefore the result could not be objective.

The pursuit of organizational effectiveness and success through higher quality in products and services is a dominant theme for organizations throughout the world. However, many quality initiatives fail to achieve their objectives or only partially succeed, contributing to improvement but not leading to the higher levels of organizational performance expected. (Beckford 1998)

Beckford (1998) claimed that most of the principals of quality are established in the text of field are produced by the 'Quality Gurus' themselves. Each of these takes only the particular author's view of the subject. And it reflects a bias towards one aspect of the subject. Six Sigma methodology is one of the most popular quality improvement initiatives adopted by different sizes of organizations. The time and money investment in implementing the Six Sigma methodology is quite a burden to most organizations. Therefore, the main objective of the study is to study whether it is valuable to employ Six Sigma methodology in the organization. The research will assess through different indicators of operational efficiency, customer satisfaction as a business performance indicator and Six Sigma participants career structure.

2.3 Developing a Quality Management System (QMS)

2.3.1 Principles in QMS Development

Tam (2000) defined quality as the totality of features and characteristics of a product or service that bear on its ability to satisfy stated or implied needs. In relation to the above, the requirement on quality will be changed when needs are changing with time, which implies periodic revision of specifications. She further clarified that needs include aspects of usability, safety, availability, reliability, maintainability, economics and environment. Quality management is that aspect of the overall management function that determines and implements the quality policy. Quality management requires the commitment of top management including strategic planning, allocation of resources and other systematic activities for quality such as quality planning, operations and evaluations.

Deming (1986) summarized his quality management philosophy into 14 principles which include management commitment and leadership, statistical process control, removal of barriers to employee participation and control of their own quality, and continuous improvement of processes, to remain competitive in providing products and services. Rungtusanatham et al. (1998) pointed out that despite the fact that there is no sufficient scientific evidence attesting to the effectiveness of W. Edwards Deming's quality management approach; it has received considerable attention from manufacturing and service organizations around the world. However, Mersha (1997) questions the universal applicability of quality management, he pointed out that developing countries possess a host of sociopolitical and socioeconomic factors that inhibit the transferability of quality management concepts, principles, and techniques to these countries. He advised that further studies should also seek to evaluate the relative strength of the driving and restraining forces in different countries. Yeung (1999 as cited in Taylor 1995; Smith et al. 1994; Reedy 1994) argued that some researches revealed that TQM and ISO 9000 are not well comprehended in industry and their effectiveness is also the subject of controversy.

Wilkinson and Willmott (1996) claimed that there are many books which support the cause of quality management but very few of the studies deal with its meaning, or reflect on its practical implementation or social significance. They argued that the leading quality management advocators are unwilling to refer to previous management literature or, indeed, to reference anything outside the quality management field; nor are they inclined to draw on ideas and literatures which can provide a more rounded evaluation of the claimed benefits of quality initiatives. They further pointed out that the academics sector regard quality initiative as too faddish and superficial, thereby, reluctant to provide a broader assessment and examination on it. Therefore, the quality gurus in the field become dominant at the definition and discussion of the field as a result.

Born (1994), as cited by Yeung (1999) showed that the quality management field simply using TQM programs as the QMS is difficult and often ineffective. Born (1994) argued that TQM programs take a very long time to produce small improvements and are normally very costly in both time and efforts. He stressed that a QMS with effective process management systems is the key to total quality. Lagrosen et al. (2006) and Wiele et al. (2002) pointed out that quality management has grown from some simple control techniques into a system of improvement that involves the entire organization in order to deal with the more complex business environment more effectively. However, Combe and Botschen ((2004) pointed out that the complexity of quality managing will be increased with the continuous changing customer needs and the external environment. Many academics have also urged the development of a more comprehensive QMS which leads to a new management paradigm.

2.4 Quality Management Systems and the Six Sigma Paradigm

2.4.1 The Paradigm of Six Sigma

The Six Sigma approach has set a new paradigm of excellence in any manufacturing ambience (Senapati 2004). Since its inception in 1987, Six Sigma has been gaining more attention and acceptance in industry as a quality improvement framework. Thus performance in both manufacturing and service operations can now be calibrated in terms of "sigma level", and companies eager to impress customers have begun to label themselves "six sigma organizations" (Goh 2004). He also pointed out that Six Sigma is traditionally used to represent the range of values of a population with a normal distribution. However, it has been known as a framework for quality improvement and more broadly, business excellence (Harry 1998). Hatice (2007) claimed that Six sigma can provide leaders with the strategy, methods and tools to change their organization. This is a key leadership skill that has been, until now, missing from leadership development. He also claimed that Six sigma is seen as the basis for a "best-in-class" philosophy and a long-term business strategy that measures quality improvement. Six Sigma is the tool for continuous improvement and variance reduction in every process and transaction within an organization. The waste and cost are driven out as quality improves, and customer satisfaction and loyalty, and thus profits, will be increased through the Six Sigma methodology.

Hatice (2007) claimed that if organizations would like to grow, to prosper and become a national asset to generate wealth, the only way is to continuously improve. Employing Six Sigma methodology is the best way for continuous improvement because Six Sigma is not a simple quality program, it is a set of statistical tools for continuous improvement. He claimed that many world manufacturing firms have adapted Six Sigma as a benchmark standard in that Six Sigma quality is a statistical measure that equates to nearly perfect quality and it has become a recognized quality program based on the goal of virtually perfect quality. Although Hoerl et al. (2004) claimed that Six Sigma is a generic improvement methodology which can be applied anywhere, however, they stressed that Six Sigma is only an improvement methodology, it is not a holistic QMS. Anon[1] (2000) argued that Six Sigma should not be considered just another initiative but should be integrated in other programs and initiatives at a higher level as a part of an overall business strategy. They claimed that Six Sigma emphasizes an intelligent blending of the wisdom of the organization with proven statistical tools to improve both the efficiency and effectiveness of the organization in meeting customer needs. The ultimate goal of Six Sigma is not improvement for improvement's sake, but rather the creation of economic wealth for the customer and provider alike.

Pyzdek [no date[2]] claimed that there are critical differences between TQM and Six Sigma, and these differences explain why the popularity of TQM has waned, while Six Sigma's popularity continues to grow. He stressed that the difference is the management. He further pointed out that unlike TQM, Six Sigma was not developed by techies who only dabbled in management, it was created by some of America's most gifted CEOs.

Despite Six Sigma being a technical term to represent a specific statistical phenomenon, it has been used to describe a whole sphere of statistical, managerial, engineering and other procedures to improve performance profits (Stephens 2001). The definition of Six Sigma has still not been carefully defined by either the practitioner or academic, and like any other initiative, the definition of Six Sigma varies between organizations (James 2003). The difference can be roughly divided into two mainstreams–operating philosophy and management philosophy since some organizations use Six Sigma as a tool for specific problem solving; and the others use it as a management strategy to meet their business goals.

2.4.2 Empirical Research on Six Sigma

2.4.2.1 Surveys on Six Sigma Efforts

The literature suggests Six Sigma is a powerful tool for any size of organization to gain a more competitive advantage in the market. Quality Digest randomly selected and contacted about 4,300 of its 75,000 readers, the participants were nearly all quality professionals, and asked them to share their perceptions of Six Sigma and, if they had experience with it, the results of their experience. Quality Digest also contacted about 200 readers who were directly involved in Six Sigma programs. The result showed that only a small number of companies have implemented a formal Six Sigma program and the vast majority of those were units of large corporations. Of the 280 respondents, only 73 have a Six Sigma program in place. Nearly 90 percent of participants work for divisions of larger organizations, with 60 percent being part of organizations with more than 10,000 employees. This might be attributable to the methodology having started in a giant corporation, Motorola, and then migrating to other giants, such as GE, AlliedSignal and Texas (Dusharme 2001). Dusharme claimed that although the Six Sigma methodology has been around for 15 years or so before the survey, almost two-thirds (62%) of Quality Digest's surveyed companies that have been using Six Sigma have been doing so for less than two years. Dusharme further pointed out that although the survey result seems to complain about the implementation and support of Six Sigma, the respondents do believe that Six Sigma is worth the effort.

Dusharme (2006) reported that Quality Digest conducted its second annual Six Sigma Survey to study who is using Six Sigma and the state of Six Sigma and where it could be headed. Table 2.1 shows the distribution of company size for Sites with Six Sigma

Distribution of Company Size for Sites With Six Sigma

Number of Employees	QD Survey* Percentage
0-500	15.1%
501-1,000	4.3%
1,001-1,500	3.8%
1,501-2,000	4.1%
2,001-5,000	15.8%
5,001-10,000	9.9%
10,001-20,000	7.9%
20,001-50,000	14.9%
50,001-100,000	13.3%
100,001-200,000	6.5%
200,001-300,000	2.7%
> 300,000	2.0%

Number of Employees	QD Survey* Percentage	DynCorp Survey* Percentage
0-1,000	19.4%	32.6%
1,001-5,000	23.7%	20.5%
5,001-10,000	9.9%	6.3%
10,001-20,000	7.9%	7.6%
> 20,000	39.3%	24.1%

* *Quality Digest* percentages total 100; DynCorp percentages do not. This is because *Quality Digest* numbers are percentages of only Six Sigma companies that answered the question and DynCorp's are percentages of total respondents having Six Sigma.
Note: *Quality Digest* asked two questions related to size: "How many employees are on-site?" and "How many employees are in the entire company?" Data shown is for company size. DynCorp didn't distinguish between the two.

Table 2.1 Distribution of Company Size for Sites With Six Sigma
(Source: Dusharme, 2006)
http://www.qualitydigest.com/feb03/articles/01_article.shtml

Quality Digest invited all of its readers and members (75,000 readers plus the 12,500 members) of its InsideQuality Web Site to participate in the survey. However, it received only 2,870 responses. The survey result showed that although there are a lot of papers showing huge Six Sigma successes, only 22% of all companies have a Six Sigma program in place. Ninety percent of the companies that do implement Six Sigma are units, divisions or sites of larger organizations. Of those, three-quarters belong to organizations with more than 2,000 employees.

The result also showed that 53.6% of participants voted that Six Sigma have yielded the greatest results compared with process mapping 35.3%, Root Cause analysis 33.5%, ISO 9000-based standards 21.0% and TQM 10.3%.

iSixSigma conducted a survey in 2007 to study the investment return rate on the Six Sigma investment and found that ROI on Six Sigma Programs Directly Related to Investment Size are directly proportional to the returns for a company. An investment upwards of $2 million is likely to improve returns by 200-500 percent, while a comparatively low investment amount of $500,000 is likely to lead to a break-even situation at best. A third indicator from the survey was the relative advantage of an enterprise-wide deployment of Six Sigma programs. Marx [no date] reported that although only 42 percent of respondents' companies started Six Sigma with a full deployment and generated eight-fold ROI in the first two years compared with the companies which did not start with full deployment. He concluded that a higher level of investment results in a higher return on investment.

2.4.2.2 The Impact of Six Sigma on Business Performance

Ayeni (2004) conducted an empirical study to compare the impact of TQM and the Six Sigma method on the financial performance of organizations. Her study sampled 45 companies from among manufacturing and non-manufacturing firms in the United States. The financial performance was measured as net income, return on assets, and stock price. All of the participant companies had implemented TQM in the past and had then switched to Six Sigma. The financial data were collected for three years of each company's TQM phase and three years of its Six Sigma phase. The results of the study showed that there were significant differences in the net income, return on assets, and stock price between TQM and Six Sigma. She found that implementing Six Sigma method result in better financial performance than TQM. The result suggested that the Six Sigma management philosophy is a more effective agent for financial success than the TQM philosophy.

However, she stressed that all results showed on Six Sigma method might not necessary have come from Six Sigma methodology only in that the companies may have been cutting costs at the time that they switch from TQM to Six Sigma, thereby increasing their income. Alternatively, the changes from TQM to Six Sigma may have had already been accompanied by changes in a top executive, which also may have had an independent effect on financial performance.

2.5 Sources of Improvement in Six Sigma

2.5.1 The Value of Six Sigma to business

Compared with Three or Four Sigma companies, Six Sigma companies spend less than 5 percent of their profit to fix problems. General Electric estimates that the cost of poor quality is about $8 billion and $12 billion per year between the gaps of Three or Four Sigma and Six Sigma (Berdebes 2003). Chen et al. (2005) reported that GE increased annual profit by $750 million in 1998 and Motorola increased its stock price 21 percent in 2000 just by implementing Six Sigma methodology. Before merging with Honeywell, AlliedSignals reported a saving of $175 million in 1995 and the saving goes to double in 1996 (Bendell 2000). In 1999, Honeywell claimed that Six Sigma tools help it improve the safety performance by 33% and increased US$1.4 million in productivity (Chua 2002). Samsung SDI started to launch its Six Sigma program in January of 2000. It tripled its profit to USD$530 million and increased its sales 9% within 24 months. Due to the Samsung SDI achievement it was awarded the South Korean Six Sigma Award in December of 2000 (Antis et al. 2003).

Six Sigma is able to improve the quality of decision which affects every process in a firm to reduce product/service variance and cost of quality. Once the customers are satisfied, they tend to spend more on the supplier (Naumann et al. 2001), the customer loyalty will be established, the profits margin and market share will expand and the stock price will be increased. Pyzdek (1999) stresses that the value of "Six Sigma is not only just about the quality for the sake of quality. It is about providing better value to customers, investors and employees". For Pyzdek, Six Sigma is a new system which could deliver better quality products/services to customers at lower costs simultaneously. However, Six Sigma is not a destination; it is a journey of continuous improvement. Satisfying customers, building up better quality and lowering the costs are just the first step to reach the Six Sigma quality level.

Harry and Schroeder (2000) reported that when Motorola applied Six Sigma to the development of it Bandit Pager, the 23 Bandit engineers designed a pager within 18 months for less than $10 million. The pager could be produced in an automated factory in Florida within 72 minutes from the time an order was placed by computer from any Motorola sales office. And the pager could be ordered with various options and could also be custom built. The life expectancy is up to 150 years. The pager is also very reliable so that the product testing process is finally eliminated.

Moreover, a Motorola facility located in Illinois received outstanding rewards after implementing Six Sigma for ten years, the productivity has been increased by more than 12% each year, and the cost of poor quality is reduced by 80%. The plant is able to get rid of more than 90% in process defects. The Six Sigma program adds more than $11 billion to the bottom line (Baetke et al. 2002).

Before the Six Sigma initiative is implemented, GE Capital which offers mortgages and other financial services handle about 300,000 calls per year, however, about 25% of the calls have to be returned because of the unavailability of the company representatives. However, after the Six Sigma team re-designed the call handling processes, in-person response rate was improved to 99.9% (Smith, Blakeslee and Koonce 2002).

Pande and Holpp et al. (2001) claimed that Six Sigma can make change work for everyone and provides values to every stakeholder of an organization which is implementing it. Six Sigma is not only used by the manufacturing giants, it is also widely used in the service industries like health care, finance, law, engineering, marketing and other fields (Chowdhury 2001; Chua 2002).

The Juran Institute, Inc. and Greenwich Associates (2002) have carried out a joint study to examine the use of Six Sigma at 13 high profile companies in depth and found that each Six Sigma program returned two times on the investment. The average return over 12 months project is about $1,300,000 with the average program cost $609,000. But the return between $100,000 to 250,000 is the most common (The Juran Institute, Inc., 2003).

Reported Benefits of Implementing Six Sigma

Manufacturing Sector

Company/Project	Metric/Measures	Benefit/Savings
Motorola (1992)	In-process defect levels	150 times reduction
Raytheon/Aircraft Integration Systems	Depot maintenance inspection time	Reduced 88% as measured in days
GE/Railcar leasing business	Turnaround time at repair shops	62% reduction
Allied Signal/Laminates plant in South Carolina	Capacity Cycle time Inventory On-time delivery	Up 50% Down 50% Down 50% Increased to near 100%
Allied Signal/Bendix IQ brake pads	Concept-to-shipment cycle time	Reduced from 18 months to 8 months
Hughes Aircraft's Missiles Systems Group/Wave soldering operations	Quality Productivity	Improved 1000% Improved 500%
General Electric	Financial	$2 billion in 1999
Motorola (1999)	Financial	$15 billion over 11 years
Dow Chemical/Rail delivery project	Financial	Savings of $2.45 million in capital expenditures
DuPont/Yerkes Plant in New York (2000)	Financial	Savings of more than $2 million
Telefonica de Espana (2001)	Financial	Savings and increases in revenue 30 million euro in the first 10 months
Texas Instruments	Financial	$ 600 million
Johnson & Johnson	Financial	$ 500 million
Honeywell	Financial	$1.2 billion

Reproduced from (Anbari and Kwak (2004))
http://home.gwu.edu/~kwak/Six_Sigma_PMI_2004.pdf

Financial Sector

Six Sigma projects deployed in the financial sector mainly are for reducing collection cycle time and variation in collection performance (Doran 2004). Doran studied the sources of variation in collection performance and found out that collectors, sale personnel and managers do not perform equally well. And each customer has a different approval process. A company may offer different payment terms to different customers.

The variations may also exist in different branches, sites, divisions and countries. Six Sigma projects are launched to reduce the process variations and improve the performance consideration.

In 2001, the then-new CEO Kenneth D. Lewis of the Bank of America (BOA) realized that the BOA was not as efficient as a world's largest financial services company should be and the error prone processes make customers dissatisfied and costs the BOA money. The new CEO and his top executives decided to implement a rigorous program – Six Sigma to improve the process. In the year of 2003, Jones Jr. (2004) claimed that the BOA was able to handle almost 200 customer transactions per second and the transactions were handled at a faster and more accurate rate than ever. He also stressed that their same day payments are improved by more than 36% and deposit processing is improved by 47%. The Six Sigma programs make a total measurable contribution to $2 billion in 2003.

Healthcare Sector

A health care study conducted by Lazarus and Butler (2001) showed that if the healthcare organization is operating at 99% error free standard, then 5,000 incorrect surgical operations per weeks would happen. Or 200,000 wrong drug prescriptions would happen at each year. However, if the healthcare organization is operating at 99.99966% error free which is the reached 6 sigma level, then only 1.7 incorrect surgical operations per week would happen or 68 wrong prescriptions per year is possible. Of course, healthcare sectors are performing even higher quality level services in most of the treatments but Six Sigma methodology still can be used in a lot of functions of healthcare organizations. According to Lazarus et al. (2001), the president of ISSSP, Roxanne O'Brasky claimed that "the healthcare industry has a tremendous opportunity to gain from the application of Six Sigma principles," in a Six Sigma Leadership Conference. In their study, Lazarus and Butler also found that physicians become the main advocators of Six Sigma methodology when they learnt the benefit of it.

Charleston Area Medical Center (CAMC), one of their study objects has improved its inventory turnover; reduced the bulk purchase and avoided $841,540 unnecessary cost after employing the Six Sigma methodology. Lazarus and Butler also found that Six Sigma methodology helped another object, Scottsdale Healthcare (AZ) to reduce the cycle time for bed control by 10%, and the Emergency Department's throughput is increased by 0.1 patients per hour, and the generate $600,000 profit. Jerry Kolins, the MD of Commonwealth Health Corp. (CHC) claims that Six Sigma methodology helps to dramatically increase Troponin lab test without the need to increase staffing just by simply improving the process itself. The cumulative average of all tests performed in CHC after the Six Sigma project is 45 minutes, which is 15 minutes less than the industry best practice benchmark (Lazarus et al. 2004).

In 2004, Lazarus conducted another study about the Six Sigma methodology in the healthcare sector with Wendy Novicoff. Jerry Kolins, the MD of Palomar Pomerado Health Laboratory Services claimed that the lab throughput could be dramatically increased just by employing the Six Sigma methodology to improve the process; there was no need to increase staffing. Six Sigma methodologies is also used to motivate workforce's morale, reduce medical errors, minimize waste as well as maximize stakeholders' satisfaction in CHC.

Froedtert Hospital in Milwaukee, Wisconsin is another healthcare organization that reported to successfully implement Six Sigma. Froedtert Hospital received an even better result in lab tests. The lab test time decreased from 52 minutes to 23 minutes after using the Six Sigma program. Moreover, there is only one reported case on a wrongly medicated patient after employing Six Sigma (Baetke et al. 2002).

Engineering and Construction Sector

Riley Bechtel, the Chairman and Chief Executive Officer of a well known worldwide engineering and construction company Bechtel Corporation after seeing its success at General Electric and Motorola invested $30 million in a Six Sigma program, to a large extent, the investment goes to customers directly by working to improve customer satisfaction, reduce customer costs. Bechtel completed about 300 Process Improvement Projects in 2002. The investment not only reported that they produced a $200 million saving in one single year just by focusing on preventing rework and defects in every construction process, but also helped Bechtel to win more contracts. Another subsidiary of Bechtel, Bechtel Civil's global business unit also implemented Six Sigma program eagerly. Bechtel Civil's global business unit inputs $2.3 million in training, but reported the $19.8 million on ROI (Eckhouse 2003).

Research and Development Sector

The International Society of Six Sigma Professionals (ISSSP) invited a portion of the 250 conference attendees of a pre-conference discussion session titled "Six Sigma and Innovation" to discuss the issue in response to a Reuters news service article which suggested that Six Sigma could stifle creativity in May 13, 2004. In the conference, the participants generally defended that Design for Six Sigma plays an important role in developing new products and services to meet Six Sigma standards and customers expectations (Lee 2004).

Johnson and Swisher (2003) stressed that R&D is basically a series of problem-defining and problem-solving processes, and the Six Sigma logic provides a measurable and goal-oriented context, it can be broadly applied in a R&D context. They also found that 37% of 140 Six Sigma practitioners and R&D leaders of 49 companies had a formal Six Sigma program in their R&D organization.

Nonthaleerak et al. (2008) argued that even though there are many stories reported that the Six Sigma helps to generate profits in many reputable companies; however, the financial benefits generated could be the outcomes of other factors such as the changes of market, the effective asset management or some other initiatives employed. Unfortunately, it has not been possible to verify the accuracy of the data. Even Nonthaleerak et al. (2008) agreed that the perception of success is very subjective per se. They still proposed that the successful Six Sigma project should be classified by three levels. If there is no financial evidence or the financial evidence is insignificant, the Six Sigma project is grouped to the low success level. If there is no financial evidence or only has a moderate amount of financial savings from the Six Sigma project, it is classified as moderate success. The high success level is the Six Sigma project which generates a significant amount of financial evidence.

2.5.2 The other values of Six Sigma

There are few articles that discuss whether employees will benefit by Six Sigma projects. Pande (2001) claims that Six Sigma is a good media to offer business leaders a way to test the potential of employees at all levels of an organization by doing Six Sigma Projects. Ingle and Roe (2001a) found that Six Sigma Black Belt certification is a must in General Electric for being considered for a promotion. Chau (2002) stresses that a successful Six Sigma implementation will not only produce a significant return on investment for an organization, but also makes employees proud to be a part of the company. In his book, Greg (2002) claims that Six Sigma techniques help employees to build up better critical thinking skills and become more competent in their jobs which not only could help the company to be more competitive but also promotes employees' professional development which will help a company to promote employees' morale and also a sense of self-esteem. Moreover, a study showed that a company will be even more profitable just by keeping customers happy because only a 5 percent increase in customer retention will help business to increase more than 25 percent profit (Pande et al. 2001).

2.5.2.1 The Rewards Associated With Six Sigma

Buch and Tolentino (2006) conducted a survey to examined employee perceptions of the rewards associated with their participation in a six sigma program. They claimed that Organizational rewards are the very reason that most companies implement Six Sigma in the first place in that the organizational outcomes can also be impacted indirectly through increased employee motivation and satisfaction that occurs through the receipt of individual rewards, both intrinsic and extrinsic. They pointed out that there are four categories of rewards that are most frequently used with change programs such as Six Sigma: intrinsic, extrinsic, social, and organizational rewards. According to Buch et al. (2006), the extrinsic rewards are those that employees receive from their organization or management either directly or indirectly at any forms as a result of their performance or participation. The direct rewards may be the recognition from management or a symbol of appreciation and acknowledgement, such as key chains or enhanced job security, new opportunities for promotion, and better performance appraisals. Social rewards such as increased opportunities for employees to interact with coworkers on the job and to work together toward shared goals and outcomes may also be considered as one type of extrinsic rewards. Opposed to the extrinsic, the intrinsic rewards such as being acknowledged for their involvement in activities that enhance feelings of self competence, growth, satisfaction, responsibility and autonomy are considered as the intrinsic rewards.

The survey was completed by 215 employees with 34 percent response rate. The results suggested that employee perceptions reflect these incentive practices, finding that both Green and Black Belts report it likely or near likely that Six Sigma will lead to social rewards and such intrinsic rewards as job satisfaction, the development of new skills, and increased work responsibility. Somewhat surprisingly, these rewards were not significantly higher for Black Belts than for Green Belts, with the exception of job responsibility. Thus, this study provides evidence that the social and intrinsic incentives that six sigma is designed to deliver are in fact perceived as such by participants.

Six Sigma has become one of the most widely employed quality initiatives in worldwide organizations. iSixSigma has conducted a Global Six Sigma Salary Survey, it surveyed more than 2,400 Black Belts, Master Black Belts, Champions and Deployment Leaders who are employed as full time change agents in the Six Sigma work. But it did not disclose the detail of the survey methodology in their report which was published in the March/April 2006. The report showed that the worldwide Black Belts make more than USD75,000 on average, and the rest of the three roles are in the USD101,000-USD106,000 range. The salary for these professionals is only slightly increased compared with 2005, but the difference is insignificant statistically. Also, the survey showed that those professionals who have official certifications are only making very slightly more than their non-certified counterparts. The research manager Marx (2006) stressed that experience is the main factor that caused the difference. But the education level only affects the Black Belts not the Master Black Belts. Black Belts make the highest salary in IT sectors while Master Black Belts earn the most in the healthcare or financial services sectors.

2.5.2.2 What makes Six Sigma so successful?

Six Sigma is acclaimed for providing a complete set of tools for understanding the voice of customers, defining the critical processes and making improvement (Hefner et al. 2006; Richard C H Chua, 2002). DMAIC (Define, Measure, Analyze, Improve and Control) methodology is considered as the most important tool for the success (James, 2003). The DMAIC is a comprehensive guideline to lead the project team to know when and how to use the correct tool and make the hidden process dynamically visible by using the flow diagrams and maps, the real root of the cause could be found and eliminated.

Moreover, implementing a Six Sigma program needs everyone's contribution; it combines the effort and involvement of both leadership and front line staff. People at all levels of the organization have a better understanding of the voice of customers, the process flow and are equipped with knowledge to tackle problems, it makes everyone's work more smooth and effective, less chaotic and more rewarding (Pande et al. 2001). Six Sigma becomes a common language for different business units to talk to one another is another intangible benefit (Hoerl 1998). This common language also creates a closer bond between suppliers and the buyers (Chowdhury 2001; Lee 2004).

2.6 Benchmarking General Electric Company

Motorola is the founder of Six Sigma Methodology while GE is the most famous advocator of it. Henderson et al. (2000) pointed out that the concept of Six Sigma at GE is to deal with measuring and improving on what it planned to do. Six Sigma provides a way for improving processes so that GE can be more efficient and predictable in producing world-class products and services. GE Aircraft Engines was the first one to launch Six Sigma in GE. Henderson et al. (2000) found that the critical step at GE is identifying and bounding Six Sigma projects. The projects are headed up by Customer Business Teams and those projects are managed and worked by all employees. At GE Aircraft Engines, each dashboard is negotiated with individual customers to identify what is most important about GE products and services to the customer. GE selected projects based on their ability to impact either customer satisfaction or business priorities. Projects may also be selected to leverage successfully completed projects to other processes, sites, or product lines. GE applies different approaches to implement Six Sigma which include achieving "entitlement" and implementing "stable operations". Henderson et al. (2000) pointed out that entitlement is the level of performance a business should be able to achieve without substantial investment and/or reengineering.

Ingle et al. (2001) made a judgment that the successfulness of the Six Sigma initiatives deployed in GE and Motorola should be attributed to the Black Belts program. The difference is that GE regards Six Sigma as the corporation's overall quality improvement program; it is driven from the top-level executives to the front-line staff (Ricardo et al. 2002). Jack Welch, the past CEO of General Electric became closely involved in his first Six Sigma initiative. He brought Six Sigma to every area of GE's businesses and declared that the involvement in the Six Sigma initiative is necessary, every manager and everyone in GE should be qualified as a Black Belt before any promotion consideration (Pries 2005; Ingle and Roe 2001). Welch also stressed to his senior executives that 40 percent of their annual bonus is link to their involvement and success in the Six Sigma project. Every executive throughout GE has to participate in the Six Sigma training. The participation of every executive sends the signal to everyone else that the company is serious (Chowdhury 2001).

Moreover, GE has created a unique culture for Six Sigma. In the GE Corporation, only those who are highly regarded people are entitled to hold an important role in the Six Sigma projects. Also, GE uses the project as real case training; candidates must have a project as a prerequisite for attending the Six Sigma training (Hoerl 1998).

2.7 Black Belt Program

Ingle and Roe (2001) declared that the success of the Six Sigma initiatives deployed in GE and Motorola should be attributed to the Black Belts program. Przekop [no date] believed that the key concepts of Six Sigma can be applied to every scope of work without the need of Six Sigma Black Belts. The Six Sigma Black Belts is the backbone of the Six Sigma Projects and a leader of the project team to work on the problem and make the saving (Hoerl 2001). However, Hoerl (2001) also criticized that the terms of Six Sigma Black Belts, Master Black Belts and Green Belts are not clearly classified, and the use of the term as anyone pleases causes confusion to the organization which wants to deploy Six Sigma. Pande et al. (2001) also pointed out that even though there in no formal or official guideline for certification and the criteria are inconsistent; the Six Sigma Black Belt program is still being widely adopted by every company which would like to implement the initiative. Some companies even use the Black Belt program to select and train their future leaders.

Ingle and Roe (2001) conducted a study to compare and contrast the implementation strategies used in both Motorola and General Electric. In their paper, they cited the term which was used by Chase (1999), who pointed out that Six Sigma Black Belt was first introduced by the Motorola Corporation to describe employees who are trained and experienced in applying statistical techniques to business processes and procedures so that they can make major positive contributions to the bottom line. Ingle and Roe (2001) claimed that Six Sigma is viewed as a continuous improvement approach that in several ways replaces the TQM in Motorola. It also appears on scorecards for different sites and can facilitate comparisons between diverse products and services. Motorola regards its Black Belts as the experts and skilled data analysts of the subject matter who play an important role of mentors, team leaders, facilitators and trainers.

The Six Sigma Black Belt program also plays an important role in cost savings and quality improvements in Black Belt projects in GE. It is a major focus of top corporate management. The role of Black Belts in GE is mainly that of project leaders and analyzers of data. They are respected team players and are selected from differing backgrounds including engineering, general management, quality and finance.

In other organizations, the role of the Black Belt is to lead and complete the Six Sigma project, improve business performance by preventing re-works and defects, teach Green Belts in the use of Six Sigma tools. Arthur (2004) estimates that it costs $250,000 to train a Black Belt in the traditional approach but without mentioning whether it is the average cost globally or just the cost in the USA. It is said that selecting and training a Black Belt is the second most critical element in the successful implementation of Six Sigma.

Since the investment and effort input to train a Black Belt is significant, a company will definitely want to have leverage on its investment. According to the reported result, companies could save US$150,000 to US$243,000 per each project on average. However, the cost saved by each project is varied from organization to organization and from Black Belt to Black Belt. The more effective the Black Belt, the better she/he can contribute to the organization (Ingle and Roe 2001). Pyzdek [no date[1]] estimates that "if a company has 1000 employees and trained 1% of its staff to be Black Belts and each Black Belt can handle 5-7 projects per year, the company could save up to 17 million dollars every year".

2.7.1 The levels of Belts

2.7.1.1 Green Belt

Ingle and Roe (2001) pointed out that a Green Belt employee in Motorola is trained and experienced in using Six Sigma tools and techniques. Green Belts are not required to have the same level of experience in the use of statistics or leadership skills. However, a Green Belt has a similar skill set to a Black Belt and assists in the completion of Black Belt projects in GE. They are required to complete two projects to be accredited.

2.7.1.2 Black Belt

Black Belt is a specialist in the use of Six Sigma problem solving and prevention tools and techniques in Motorola. These techniques are usually, but not necessarily, statistical or numerical. These Black Belts should have extensive experience in the use of Six Sigma tools suitable to the area of business in which they are employed. They also have leadership and team-building skills. The number of Black Belts is approximately 120 in a corporate population of about 100,000 employees. The number of candidates is continuously growing. The Belts will be given substantial one-off payments which are percentages of salary based on the particular belt level for the successful Six Sigma project (Ingle and Roe 2001).

The Black Belt employees are well trained in the 12 elements of the measure, analyze, improve and control methodology in GE. They are required to utilize the different parts of this methodology during the design and completion of two major projects. The projects are carried out in parallel with their training. The number of Black Belts is approximately 4,000 in a corporate population of about 340,000 employees. There are no special payments or bonuses following qualification. In some parts of the organization, senior jobs require Black Belt accreditation to qualify for consideration (Ingle and Roe 2001).

2.7.1.3 Master Black Belt

A Black Belt not only has to practice at least five years in order to be eligible to be promoted a Master Black Belt in Motorola. He or she also needs the recommendation of upper management from their own and one other Motorola business unit. Once he/she becomes a Master Black Belt, he or she will be a full-time practitioner in Six Sigma tools and needs to be a mentor to at least five successful Black Belt candidates. In GE a Master Black Belt is a leader in the implementation of Six Sigma methodologies, and is usually trained directly by the Six Sigma Institute. They will have completed a number of projects and are full-time working on Six Sigma and Black Belt cost-saving programs (Ingle and Roe 2001). They claimed that the overall leadership for Six Sigma in GE is provided by Black Belts and Master Black Belts. Ingle et al. (2001) stressed that this means these individuals are being identified as a primary source for future top leaders in GE.

2.7.1.4 Champion

Six Sigma Champions are the highest-level in the Six Sigma Projects. A devoted CEO is inclined to send one of his executives such as an Executive Vice-President or the director of manufacturing to oversee and support the initiative. Sending a high level champion helps to send the signal to the entire company that the organization is serious about the program (Chowdhury 2001). The champion is expected to understand Six Sigma and be committed to its success. Sponsors are also assigned by the CEO to own the processes and systems, and help to initiate and coordinate the Six Sigma project in his area of responsibilities (Pyzdek [no date[1]]).

2.8 The Weakness of Six Sigma

Hammer (2002) claimed that the main weakness of Six Sigma is that Six Sigma is used to discover the variance in an existing process under the premise that the existing process is assumed flawless. Once the existing process is not sound per se, the effort will be a waste. Nonthaleerak et al. (2008) found two areas of weakness in the Define and Control phases in the DMAIC methodology. Generally, the phases are used to pursue the organization's financial goal instead of the organizational improvement goal. On the other hand, they also claimed that the strict use of statistical tools and quality tools creates a fear of Six Sigma. The problem is especially common in the non-manufacturing areas since these areas usually do not have an engineering background and also has a lack of mathematics skills. The other weaknesses found by Recker and Bolstorff (2003) are that they claimed Six Sigma lacks a fundamental methodology for selecting and executing high priority projects. The weakness is more apparent to the companies which are very mature on the Six Sigma application. Moreover, the Six Sigma methodology is less powerful in an environment which is highly disorganized, wasteful or poorly managed.

2.8.1 Factors weakening the Six Sigma projects performance

The success of Six Sigma implementation at GE and Motorola are widely reported and fanned up by millions of books and articles that encourage numerous companies to follow, however, not all the Six Sigma companies can benefit in the same way. According to David Fitzpatrick, the worldwide leader of Deloitte Consultant's Lean Enterprise practice, "fewer than 10 per cent of the companies are doing it to the point where it is going to significantly affect the balance sheet and the share price in any meaningful period of time" (Coronado and Antony 2002). Lee (2001) attributed the failure to the low commitment of the CEO of companies. The main reason for the low commitment is that the senior executives' performances are linked to the companies revenues, they are unwilling to take any risk to implement any new program which they have no confidence in, unless they could see the return on investment is attractive enough (Naumann and Hoisington 2000)

Quality Digest in 2006 conducted a survey with the help of some notable Six Sigma experts to study the state and the future of Six Sigma. Quality Digest invited about 75,000 readers and 12,500 members of their InsideQuality Web site (www.insidequality.com) to participate in the survey. Total 2,870 responses are received.

From the survey, Quality Digest found that less than 22 percent of the companies which participated in the survey have implemented a Six Sigma program. 90 percent of the 22 percent which deployed Six Sigma initiative are units, divisions or sites of larger organizations. About three-quarters of those companies have more than 2,000 employees. Another finding is that those companies who were using Six Sigma ceased the program after three or four years, as explained below.

Dusharme (2006) concluded that there are a few possible explanations to the dropping usage rate in Six Sigma. A company that uses Six Sigma is stirred up by successful cases reported. The companies who drop out of the Six Sigma program are where the project does not link to the corporate goals or the initiative is not driven by top management. The other issue is that the Six Sigma is being misused to solve a particular problem. Furthermore, companies do not commit to continuous improvement; some three sigma companies are satisfied when they reached the five sigma level and stop the program. The last explanation given by Dusharme is that both consultants and companies do not do well and pay no attention to the design for Six Sigma. Another reason that contributed to the failure of Six Sigma is because Six Sigma initiative is always abandoned after two or three years. Arthur (2004) argued that it is because the average life-span of a CEO is only two to three years when the leadership is changed, Six Sigma will vanish.

Apart from the Six Sigma survey conducted by Quality Digest in the early 2006, Aviation Week Magazine conducted a survey for Aviation Week & Space Technology in 2002 by Pittiglio Rabin Todd & McGrath (PRTM). The survey found that less than 50% of the respondents are satisfied with the results of their Six Sigma projects; about 30% are dissatisfied and another 20% or so were only somewhat satisfied (Zimmerman and

Weiss 2005). Zimmerman et al. (2005) concluded that Six Sigma companies committed "seven sins" which made Six Sigma fail. These seven sins are 1) Inadequate Information — organizations often succumb to the tendency to gather and analyze all of the information they collected. Successful Six Sigma initiatives include streamlined information-gathering and retrieval systems that avoid information overload and limit analysis to relevant, accurate data., 2) Selecting the Wrong Projects for Six Sigma — over 60 percent of companies' existing Six Sigma projects had no impact on high-priority product or market segments. They were doing things right, but they were doing the wrong things, 3) Creating Solution-Caused Problems — forget to ask "what could go wrong" when implementing a solution or making an improvement, the companies bound to run into difficulties. Every implementation plan should include an analysis of potential problems, their likely causes, and preventive and contingent actions, 4) Serving the Wrong Customer — A basic element of all Six Sigma projects involves listening to the "voice of the customer." Yet, in practice this focus is often perverted or diluted, 5) Leaping to the Fix — far too many Six Sigma teams end up brainstorming improvement ideas prior to fully understanding the cause of poor process or product performance. When attempting to correct problems within a work process, most teams immediately leap into action. While this is understandable, given the pressure to get things up and running, in the long run it's a tremendous time waster. Without identifying, verifying, and removing the root cause of the problem, teams almost always fall short of reducing variation, 6) Faulty Implementation — such as Unclear project objectives, Shoddy sequencing, Ineffective resource planning, Under-involvement, Over-involvement, Ineffective or delayed monitoring mechanisms, Lack of formal project evaluation and closeout, and 7) Failing to Consider the "Human Side" of Change — when designing the system the improvement team had never stopped to consider the consequences.

2.8.1.1 Six Sigma for Small and Medium-sized Enterprises

"Six Sigma is the only program I have ever seen where customers win employees are engaged in and satisfied by, shareholders are rewarded – everybody who touches it wins", the past-Chairman of General Electric Jack Welch said (Kullmann 2005).

Kullmann (2005) and Bhote (2003) believed that Six Sigma should work well for a company of any size as long as the Six Sigma initiative is properly implemented; despite the fact that it is commonly perceived that it is only available to the industry giants. Kullmann stressed that Six Sigma is a business management system; it is not only a quality program. Small and Medium size businesses could benefit as much as giant corporations and not a lot of resources input are needed if it is properly implemented. For making the initiative easier to deploy, Kullmann suggested that a company has to integrate the Finance and Human Resource departments in the initiative. Arthur (2004), Burton and Sams (2004) even believed that the small business can get an even bigger benefit from the Six Sigma program than big corporations with less investment because a small business is more flexible for changes.

Antony et al. (2005) claimed that many academics and Six Sigma practitioners are showing more interest in finding the value of Six Sigma for small- and medium-sized enterprises (SMEs) over the last two to three years. However, very few studies have been reported about the successful applications of Six Sigma in SMEs. Antony et al. (2005) based on the experiences of both academics and practitioners on Six Sigma within an SME environment investigated the strengths and weaknesses associated with SMEs. They mailed out 400 questionnaires to SMEs in the UK which were randomly selected from the Glasgow Caledonian University's FAME database. The response rate was 16.5 percents. About 15 percents of the companies had less than 50 employees and 75 percents of the companies had between 50 to 150 employees. Only 27 percent of those companies have been using Six Sigma for more than one year on average. There are about 35 percent of the companies which did not know about Six Sigma. The study also showed that there are more than 35 percent of the responded companies which were using Six Sigma that did not have Six Sigma project champions.

The result also showed that about 69 percent of the responded companies had completed about one to five Six Sigma projects. About 25 percent of the companies had completed between five to ten Six Sigma projects, but only one of the respondent companies had completed more than 20 projects. About 62 percent of the companies improved bottom-line up to £250,000 per annum. 13 percent of the companies experienced financial benefits of between £250,000 and £500,000 per annum in total. However, about 25 percent of the participated companies never quantified the financial bottom-line impact from six sigma projects.

2.8.1.2 Critical Success Factors for the Successful Implementation of Six Sigma Projects in Organizations

Coronado and Antony (2002) and Antony and Banuelas (2002) pointed out that although many organizations have reported significant benefits today as a result of Six Sigma implementation, not all companies can claim to have had the same benefits. This was based on reviewing the related literature of the critical success factors for the effective implementation of six sigma projects in organizations. They identified 11 critical successful factors in the following order

(1) Management involvement and commitment; (2) Cultural change; (3) Organization infrastructure; (4) Training; (5) Project management skills; (6) Project prioritization and selection, reviews and tracking; (7) Understanding the Six Sigma methodology, tools and techniques; (8) Linking Six Sigma to business strategy; (9) Linking Six Sigma to the customer; (10) Linking Six Sigma to human resources; (11) Linking Six Sigma to suppliers.

Antony et al. (2002) sent out 300 questionnaires to large organizations with over 1,000 employees and higher turnover. The response rate was about 15 percent. However, only 37 percent of these companies were applying Six Sigma methodology. Antony et al. (2002) used Cronbach's alpha test to analyse the internal reliability for the set of questions. All the factors in the survey instrument have a Cronbach alpha coefficient of above 0.6. The results of each test were satisfactory. And the "management commitment and involvement" is the most important ingredient and "linking Six Sigma to employees (human resources)" is the least important ingredient for the Six Sigma program. The results of the key ingredients in descending order of importance are arranged in the following manner:

1. Management commitment and involvement.
2. Understanding of Six Sigma methodology, tools and techniques.
3. Linking Six Sigma to business strategy.

4. Linking Six Sigma to customers.
5. Project selection, reviews and tracking.
6. Organizational infrastructure.
7. Cultural change.
8. Project management skills.
9. Linking Six Sigma to suppliers.
10. Training.
11. Linking Six Sigma to employees (human resources).

2.9 Compared Six Sigma with Other Quality Approaches

Goffnett (2004) claimed that the growth of Six Sigma in both industry and academia has created some confusion and a consequential need for a greater understanding on the subject. Stamatis (2000) criticized that Six Sigma is only a repackaging of old concepts. Andersson et al. (2006) based on a literature review as well as employing a case study investigated the similarities and differences between the concepts, including an evaluation and criticism of TQM, Six Sigma and Lean concept. The study showed that there are many similarities between Six Sigma and TQM in concepts. However, they agreed with Klefsjö et al's. (2001) viewpoint that Six Sigma should be regarded as a methodology with the larger framework of TQM in that Six Sigma supports all the six values in TQM. Andersson et al. (2006) quoted from Dahlgaard and Dahlgaard's (2001) argued that "Six Sigma and Lean should rather been seen as a collection of concepts and tools, which support the overall principles and aims of TQM". Dahlgaard et al. (2001) consented that Six Sigma and Lean have clear road-maps in order to achieve business excellence. They concluded that TQM and Six Sigma have many similarities, but the Lean concept is slightly different compared to the previous two. Andersson et al. (2006) suggested that organizations will be able to gain more by combining these three concepts. They stressed that these three concepts are complementary; especially Six Sigma and Lean are excellent road-maps, which could be used one by one or combined together to strengthen the values of TQM within an organization.

By reviewing both the practitioner and academic literatures, Zu (2005) found that Six Sigma shares TQM's principles, such as customer focus, continuous improvement, and teamwork. He pointed out that Six Sigma is also a management program that involves organizational wide employees in continuous improvement activities to pursue better customer satisfaction. He also found that there are some principles which do not include traditional TQM principles; these principles are a bottom line benefit focus, a structured approach, and goal setting. With these differences, Six Sigma principles are better to reflect the essence of using the Six Sigma philosophy to design and manage the organization's quality improvement activities. However, TQM's main efforts are targeting more on improving work processes rather than directly increasing the financial returns for the organization. He further suggested that Six Sigma generally stresses on the use of a structured approach more than TQM.

Platt (2005) conducted a study to examine the ISO 9001:2000, CMMI, and Six Sigma's application on a non-manufacturing environment. The result showed that there are many commonalities between these approaches. Platt (2005) pointed out that the strengths of one model or methodology often offset the weaknesses of another. She found that Six Sigma fits well with CMMI's measurement and analysis process area. Six Sigma is especially good for using on the time tracking and analysis of accuracy of estimates required by engineers using the PSP process. Her study also confirmed that Six Sigma can provide a mechanism for linking business goals to process performance and identifying process areas with high-improvement leverage when using CMMI's continuous representation.

2.10 The Effects of Six Sigma

2.10.1 Will Six Sigma shorten the product life cycle?

Jay Desai who used to help GE implement Six Sigma said that "when companies must demonstrate change through new products every couple of quarters; companies need to move beyond the 20-year-old method in order to compete" in a Reuters story (Taub 2004 cited Desai). Desai believed that "Six Sigma does not create innovation". Desai's speech had drawn attention to the Six Sigma circle. Michael Cyger, the founder and managing director of iSixSigma.com invited some 50 company deployment leaders, vice presidents and directors to attend a pre-conference discussion session titled "Six Sigma and Innovation." The 250 conference attendees were invited to discuss whether Six Sigma does not allow for innovation.

Participants claimed that Design for Six Sigma played a key role in developing new products and services to satisfy customer expectations. STEMCO, a manufacturer of sealing products, metal polymer bearings and compressor systems located in Longview, Texas, claimed that the company used Six Sigma to develop a new maintenance tool for heavy duty trucks, the new maintenance tool allows equipment to be "smart serviced" based on usage and not on mileage. STEMCO also used Six Sigma to establish an intensive quality program by combining with a Lean manufacturing philosophy, STEMCO has developed a company-wide cooperative effort to improve its products and launch new, innovative products and services.

One of the participants made a statement that "Six Sigma is all about improving process," the results of Six Sigma is irrefutable. "Its use eliminates the use of pre-conceived ideas that could cloud the creative process and the ability to bring a product or service to market", he said.

During the discussion, a 3M employee expressed that he noted that his company's introduction of a new sandpaper line designed for builders used the extensive voice of the customer. Their Design for Six Sigma techniques do delight customers with its intended use, quality and price (Lee 2004).

Jim McNerney, the chairman and chief executive officer of 3M said that "3M has a company-wide new product introduction process, the process helps derive innovative ideas, and Six Sigma provides the rigorous methodology to ensure that development does not flag. The result is a product or service developed with less waste and frustration and on the market sooner with less development cost" (Lee 2004).

2.10.2 How Long does It Take for Six Sigma to generate benefit?

Base on the articles studied, no one has ever promise how fast a Six Sigma company can expect the benefits. Bendell (2000) is the only author who declared that if companies properly introduced the Six Sigma initiative, they should experience financial benefits shortly after they begin, but he did not mention how long exactly it will take to see the result. The time that it takes Six Sigma to generate benefits most properly varies from organization to organization. Some companies benefit just after a few days of implementation, like Bechtel, the company that received the fastest benefit, Nasser Al-Tell claims that with the help of Six Sigma analysis methodology, they need only 3 percent of their effort to solve a problem compared with before employing Six Sigma, they had been putting 99 percent effort to solve the bottleneck at the maintenance facility. And the problem disappeared within a few days. And Bechtel receive a huge amount of return within one year of implementing the Six Sigma program (Eckhouse 2003). Baetke et al. (2002) claimed that it usually takes four to five years for companies to see the benefits of Six Sigma. Baetke et al. (2002) even claimed that the Six Sigma took General Electric more than five years to see the significant result. However, Boyer (1998) reported that GE Aircraft Engines invested $37 million in Six Sigma training in 1996 and 1997 and generated $79 million in saving in 1998. The return on the investment is 113%.

However, the study carried out by Juran Institute, Inc. and Greenwich Associates (2002) reveals that companies with longer term programs have a better success rate than the companies which have a shorter term in implementing the Six Sigma projects. The causation of difference is because the veterans have more experience in deploying Six Sigma and they also have better knowledge of how to transfer the program better. On the other hand, Caponecchi claimed that General Electric Appliances (GEA) added Six Sigma to the design and development of its latest dishwasher, within six months or less after using Six Sigma tools, factory yields were significantly improved and the scrap rates were reduced very quickly (Fellenstein [no date]).

Wipro Corporation, a diversified conglomerate company eliminated unnecessary steps and decreased rework and leading to an eightfold gain in 15 months over the investment made (Erwine 1998). Citibank, the international financial division of Citicorp, undertook the Six Sigma method in the spring of 1997 has reduced the defects from five to ten times within three years (Erwine 1998). However, it took Motorola five years to achieve a tenfold improvement in performance (Harry 1998).

General Domestic Appliances' (GDA) Refrigeration Factory in Peterborough introduced Six Sigma in 1996. The company found it was able to solve problems that had been long running issues, and were able to get into sub-1,000 parts per million problems and tackle them effectively. Financially, the Six Sigma project saved the operation £47,000 and more importantly reduced the potential for customer dissatisfaction. The Six Sigma project also helped GDA to reduce the service call rate for poor sealing doors from 1.13 per cent to 0.6 per cent within four months, the project generated a cost saving of £15,000 per annum, and immeasurable benefits in improved customer satisfaction (Bendell 2000).

General Electric Company spent over half a billion in Six Sigma programs and received over two billion in benefits for the fiscal year. The return on investment is about 400% in one year (Linderman et al. 2002). Honeywell used Six Sigma to improve global site safety. The reportable cases were reduced 43% and lost work-day cases by 50% in 1999 compared to the previous year (Chua 2002). Caterpillar, based in Peoria, Illinois state of USA implemented Six Sigma worldwide in January 2001. Caterpillar received the benefit which exceeded the cost to implement the program in the first year (Rozgus 2003).

2.10.3 Six Sigma and Downsizing

Gluckman (2003) noted that Circuit City lay off 3,900 high performing salespeople in February 2002 despite that it may have had nothing to do with Six Sigma. The unions around the country or the world are afraid that implementing Six Sigma is just an excuse for downsizing; the workers will be laid off when the company becomes more efficient. However, Pande et al. (2000) asserted that between the 1980s and 2000, Motorola's employment rose from 71,000 to over 130,000. Except that, there are only a few articles that discuss whether Six Sigma will affect the employment rate when the company becomes more efficient.

Gluckman (2003) claimed that the Six Sigma consultants will say that if "the company can use Six Sigma methods to cut costs or meet customers' needs better, the business will grow and jobs will be created." However, "many analysts predict that Six Sigma will fit right into the downsizing trend that many workers know well after years of corporate restructuring". Air Canada has carried out a downsize-speedup cycle. The number of flight attendants on the plane has been reduced after using the Six Sigma, the head of the flight attendants union Pamela Sachs said (Gluckman 2003).

Keller [no date] believes that after the chaos of misuse downsizing in the 70s and 80s. "A proper Six Sigma deployment will recognize this potential misuse, and educate the organizational leaders on the dangers of this approach. Realizing the benefits of Six Sigma requires commitment and cooperation from both leadership and its organizational ranks. Leadership commitment includes resource allocation, data driven decision making, and strategic direction. Its practices, particularly the selection and deployment of Six Sigma projects, should be based on their contribution to the three main stakeholder groups: customers, shareholders and employees. Six Sigma efforts will focus on reduction in the time and cost related to key processes, freeing up valuable resources. The committed organization will redirect those available resources to increase market share, with a positive impact on all three stakeholder groups".

2.10.4 The future of Six Sigma

The future of Six Sigma seems to be bright and full of challenges. Antony (2004) commented that Six Sigma will be around as long as the projects yield measurable or quantifiable bottom-line results in monetary or financial terms. It will disappear when it no longer can yield bottom-line results. He believed that Six Sigma will evolve in the forthcoming years; however pointing out there are some core elements or principles within Six Sigma that will be maintained, irrespective of the "next big thing". He pointed out that there only two dangers of Six Sigma is the capability of black belts (the so-called technical experts) who tackle challenging projects in organizations. The first of the danger is that we cannot simply assume that all black belts are equally good and their capabilities vary enormously across industries (manufacturing or service), depending a great deal on the certifying body. Another danger is the attitude of many senior managers in organizations that six sigma is "an instant pudding" solving all their ever-lasting problems.

Six Sigma is the mean for GE to train its future leaders. Jack Welch, the former CEO of GE declared that the successor of Jeffrey Immelt "will be someone with Six Sigma in his or her blood". Six Sigma becomes a common language not only in GE but also in the global business (Chua 2002). Chairman and Chief Executive Officer of Bechtel, Riley Bechtel believes that Six Sigma will be important for the next 30 years (Eckhouse 2003). Ingle et al. (2001) believed that to be a qualified Six Sigma Black Belt will be a prerequisite for promotion in his/her career path. And Arthur (2004) even predicted that Black Belts certification will be as common as a high school diploma; everyone should have such a certificate for his/her career.

It is also expected that the Six Sigma method will still remain as one of the key initiatives to improve the management process (Johnson et al. 2003). However, Six Sigma should be used on the organization's overall improvement in the future instead of just focusing on solving defect or reducing scrap. It is also necessary to integrate some more advanced tools into the Six Sigma methodology to make Six Sigma a more comprehensive business methodology (Anbari et al. 2004).

2.11 Instruments for Quality Management Systems

2.11.1 Introduction to Measurement Research

Performance measurement is a topic which is often discussed but rarely defined. Literally, it is the process of quantifying the performance. In business, organizations reaching their goals by satisfying their customers with greater efficiency and effectiveness than their competitors are regarded as achieving better performance (Neely, Gregory and Platts 2005 cited Kotler 1984). Neely et al. (2005) quoted the terms effectiveness and efficiency from Slack 1991 in their study that effectiveness referred to the extent to which customer requirements are met, while efficiency is a measure of how economically the firm could satisfy its customers by the resources used. They claimed that it is an important point because it not only identifies two fundamental dimensions of performance, but also highlights the importance for the firm internally and externally to pursue the specific courses of action. Yeung (1999) pointed out that the purpose of research in measurement is to seek to establish the 'size' of a phenomenon on one or more of its dimensions and assess them systematically and in relatively great detail. He argued that it is a process of linking the crucial relationship between the empirically grounded indicators such as the observable response and the underlying unobservable concepts. However, the scales and levels of measurement in management and behavioral research are often complex and even controversial (Kerlinger 2000; Neely 2005). Kerlinger (2000) claimed that the difficulties are mainly from disagreement over the statistics that can be used reasonable and acceptable at the different levels of measurement.

2.11.2 Conceptual Framework of Quality Management Instruments

Yeung (1999) claimed that although there are very limited studies conducted for developing operational measures for evaluating the critical factors in quality management, the major constructs are widely discussed in the literature. He claimed that these constructs are the elements for developing conceptual frameworks in quality management. However, Wan and Chen (2004) claimed that not all items are useful or eligible to every individual in the system. Based on the European Foundation for Quality Management (EFQM) excellence model (European Foundation for Quality Management, 1999), and the International Standards Organization norms (ISO 9001), Eggli and Halfon (2003) concluded that there are only two concepts that are entirely specific to the EFQM model: these are "leadership" and "policy and strategy". They claimed that although the EFQM model is based on nine components including leadership, policy and strategy, people, partnerships and resources, processes (enablers criteria), customer results, people results, society results; and key performance results (results criteria), only leadership and "policy and strategy" are entirely specific to the EFQM model.

Van Der Wiele et al. (1996) according to the framework of European Quality Award, MBNQA and Deming Application Prize identify seven major quality management activities which included process control, process improvement, quality planning, employee involvement and participation, customer and supplier involvement, policy deployment and self-assessment. They invited companies in the six European countries to participate a questionnaire survey. From the 402 respondents of the six European countries, they found that the process control and process improvement are the most common quality management activities adopted in the participated companies (cited at Yeung's work 1999).

2.11.3 Measurement of Quality Management

Yeung (1999) stressed that the quality management is complicated systems, activities and ideas. He commented that the purpose of management research in this area is to identify and define the underlying and unobservable management constructs and subsequently develop a reliable and valid instrument for assessing quality management practices. Schalkwyk (1998) claimed that although performance measurement systems are only a means of gathering data to support decisions making throughout the organization, he agreed that appropriate measurement systems are crucial to ensure the successful implementation and execution of strategies in that it provides the link between strategy and action. Yeung's study (1999 as cited in Flynn et al. 1990; Flynn et al. 1994) showed that unless the data collected by surveys and other empirical designs can demonstrate its reliability and validity otherwise, the data are of little use. However, the theory development and measurement related to reliability and validity are particularly weak in quality management (Badri, Davis and Davis 1995).

Badri et al. also pointed out that the measurement of the critical factors in quality management is very important because Specification and measurement of the critical factors of quality management permit managers to obtain a better understanding of quality management practices and allow researchers to proceed with the task of developing and testing theories of quality management. When it is used periodically, the instrument will help the decision makers to evaluate the perception of quality management in their organizations. Moreover, the periodic use of the instrument will help the organization to identify the weakness of the processes and the priority of the quality management efforts needed. Measurement researches are important in disseminating reliable and valid instruments for use by other research (Flynn et al. 1990).

Ahire et al. (1996) pointed out that the quality management theory is far from being fully developed. They argued that researchers like Anderson, Rungtunsanatham and Schroeder only make the effort on synthesizing a theory of quality management. These researchers assess the impact of Deming's management method on a firm's organizational behaviour and practice of quality management. They stressed that this work suffers from a lack of systematic scale development, content validity, and empirical validation. Hence, it falls short on overall generalisability of results.

2.11.4 Conceptually Developed Instruments

Black et al. (1996) claimed that although current concepts in the area of quality management are largely based upon case studies, anecdotal evidence and the prescriptions of leading "gurus," there is little consensus on which factors are critical to the success of the approach. They argued that only a few attempts have been made to scientifically synthesize frameworks for measuring quality management practices, and a methodology for examining the issue has yet to be established. This has meant that current TQM models, such as the Malcolm Baldrige Award, have not been constructed or validated by empirical means.

Hensley and Dobie (2005) studied the readiness for organizations to adopt Six Sigma. Based on extensive review of the literature from leading quality experts, their study identify that there are a number of quality improvement programs available for uses, including total quality management (TQM), Six Sigma, reengineering, benchmarking and quality function deployment. Some of these programs are used for specific purposes, not for general purpose; they pointed out that quality function deployment is a methodology used to clearly define design qualities based on customer expectations. Cross-functional teams are more appropriate for addressing the issues related to providing products, processes, services, and strategies to improve customer satisfaction. Reengineering and benchmarking also have a rather narrow focus that was not considered adequate for the needs of the particular service organization.

Hensley and Dobie (2005) agreed that TQM has been used for a number of years and results show that it can help to improve teamwork, enhance personal responsibility feeling, increase customer loyalty and improve organizational efficiency. Part of the benefits of TQM is the improvement of "human outcomes". TQM programs range from a managerial orientation to a process control orientation depending on the particular organization. They pointed out that Six sigma is particularly attractive to the services sector due to its customer-driven methodology. Hensley et al. claimed that Six sigma programs stem from the Deming philosophy of management, which is based on statistical thinking and statistical process control (SPC), TQM and continuous quality improvement. The SPC tools are applied to process improvement with the goal of lowering the costs of poor product quality.

2.11.5 The Quality Management Instruments

Saraph et al. (1989) conducted one of the first empirical efforts to validate an instrument for integrated quality management. They developed and tested 78 operational measures of quality activities or practices to which some technical aspects of a quality system have been implemented in a plant or company (Motwani 2001). Badri et al. (1995) pointed out that Saraph et al. developed the comprehensive set of requirements of quality management that spans the literature for assessing quality management practices in both manufacturing and service organizations. They provided a synthesis of the quality literature by identifying eight critical factors of quality management in a business unit. They stated that the measures were both valid and reliable by using data collected from 424 general managers and quality managers in the United Arab Emirates. Badri et al. (1994) conducted a replication study on a more broadly based sample to examine the level of practice of factors of quality management in the UAE. The result suggested that better use of the instrument is accomplished when it is used jointly with other instruments that measure customer satisfaction.

Ahire et al. (1996) pointed out that although the instrument developed by Saraph et al. (1989) has a high level of external validity by including both manufacturing and service industries in the sample, the research is still subject to some limitation because it excluded at least two important constructs: customer focus and use of SPC. They also argued that the single instrument measuring could not function equally well in all kinds of industries. Moreover, they further claimed that an impact of the prescribed QM strategies on a firm's product quality has not been analyzed; therefore, they identified 12 constructs of integrated QM strategies through a detailed analysis of the literature, and employed a more sophisticated technique, Confirmatory Factor Analysis, for scale refinement and validation based on a survey of 371 manufacturing firms, the constructs were then empirically tested and validated.

However, Black et al. (1996) argued that the empirical framework developed by Saraph et al. (1989) which was based on eight critical factors of quality management were defined by only a small number of assessors, and based largely on knowledge of the literature. They stressed that it can be argued that the weakness in their approach was that the factors were preconceived on the basis of literature, which could not provide a comprehensive understanding of the subject. They suggested that factor extracted based upon the perceptions of actual industrial practitioners might be more valid. Black et al. (1996) employed a different approach and generated an instrument with ten critical elements which exhibit an acceptable degree of reliability in terms of internal consistency and split-halves test results of Total Quality Management. Their questionnaire was developed by a series of key TQM variables based largely on the Baldrige Award model. Respondents were required to rate the relative importance of the TQM variables. Black et al. (1996) claimed that 204 correctly completed questionnaires were returned in total. The response rate was 442.2%. The factor analysis on the responses was analyzed by using the statistical software package, SPSS-X.

However, Ahire et al. (1996) argued that although this approach has been traditionally used in organizational behaviour and marketing research, it has its own limits such as if items are assigned to factors that were not correctly loaded, it may affect measurement of the factors simultaneously. Or, the correlation cannot be theoretically explained if a factor consist of items that only statistically correlated with one another.

Ahire et al. (1996 cited Mulaik 1972) showed that the major weakness of pure exploratory factor analysis lies in the difficulty involved in interpreting the factors. Mulaik claimed that the difficulty most often comes about because the researcher lacks even tentative prior knowledge about the processes which produce covariation among the variables studied.

2.12 Management Practices and Business Performance Improvement

Yeung (1999) pointed out that quality and management researchers have been attracted to find out the relationship between management practices and performance results long ago. Understanding these relationships helps the managers formulate management strategies better. Yeung claimed that empirical study on the relations in operations management has grown rapidly in the past decade and a series of researches has been conducted to study this relationship. Ahire et al. (1996) attempted to identify the key factors contributing to the success of quality management. Cua et al. (2001), Sousa and Voss (2002) and Kaynak (2003) emphasized the importance of studying the causal relationships between quality management practices and consented that there is a positive relationship between quality practices and organizational performance.

2.12.1 The Impact of Quality Management on Business Performance

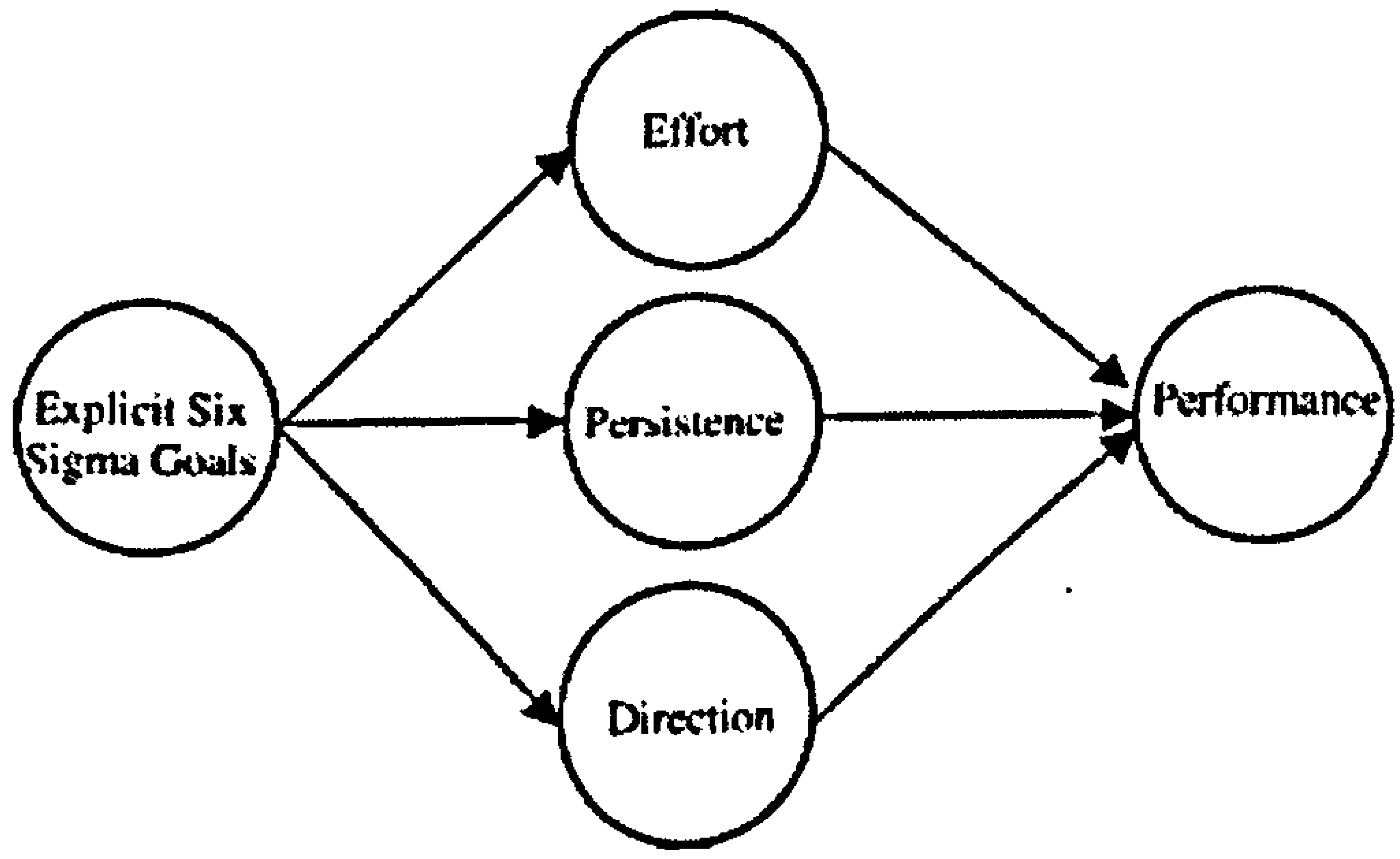
Kaynak (2003) pointed out that recent research on total quality management has examined the relationships between the practices of quality management and various levels of organizational performance; however, these studies have produced mixed results. His opinion of reason is probably because of the nature of the research designs used such as measuring TQM or performance as a single construct. For that reason, he based the work on a comprehensive literature review to study the relationships among TQM practices and investigate the direct and indirect effects of these practices on various performance levels. He also conducted a cross-sectional mail survey in the US. The findings as a whole showed that there is a positive relationship between the extent to which companies implement TQM and firm performance. The result also explained why TQM has not produced maximum benefits for every company that has implemented it. The findings highlighted the importance of top management's attitude on the quality improvement program. The study showed that the more aggressive top management is in the implementation of TQM, the more training employees at all levels get. Moreover, empowerment is another critical factor for the success because it makes the employees more conscious of the organization's goals.

Adam (1994) conducted a study that attempted to relate the quality improvement approaches to actual operating and financial performance. He also studied the productivity improvement approaches and its relation to performance in order to define linkage between quality and productivity. The study showed that the multiple quality and productivity approaches are correlated to eight quality, three operating, and three financial performance measures for 187 US business firms. The results indicated a strong linkage between a quality improvement approach and performance quality. Although the relationship between a quality improvement approach and operating or financial performance is weaker, the relationship is still significant. Eriksson (2003) also studied the impact of TQM on financial performance and received similar results. The study showed that organizations which successfully implement the quality management approach perform better than their rivals and they also have higher return on assets than their competitors. Adam's (1994) study also showed that productivity improvement approaches also help predict quality, operating, and financial performance. His study suggested that the profile of quality and productivity improvement approach should vary, depending upon whether the organization is focusing on improving the performance quality, operating or financial performance.

2.12.2 Research Models on Quality Management

Anderson et al. (1995) and Forza and Filippini (1998) pointed out that quality management has increasingly become the focus of organizations competing in global markets. Six Sigma is one of the phenomenons that is gaining wide acceptance in industry, however, there is not enough of adequate theoretical formulation suitable for empirical research (Linderman et al. 2002). They proposed and elaborated a model to examine the Six Sigma goals and performance. Figure 3 shows the Mediating variables between Six Sigma goals and performance.

Figure 3. Mediating variables between Six Sigma goals and performance



Source from: Linderman et al. (2002)

The result suggested that effort and persistence must be directed toward some work. Linderman et al. (2002) claimed that goals have two relatively automatic directional effects. "First, goals may orient the individual toward goal-relevant activities or away from goal-irrelevant ones. Second, they will activate the stored knowledge and skills that the individual possesses that are perceived relevant to the task. They concluded that Organizational leaders must be aware that successful deployment of Six Sigma requires not only technical understanding, but also behavioural insight.

Anderson et al. (1995) pointed out that models have limited capability in explaining quality conformance and, with the present operationalisation of the considered dimensions, unluckily, it seems impossible to improve it because the modification indices did not suggest alternative paths in order to improve the overall fit. They claimed that the result may be due to missed constructs (for example, design for manufacturing and quality checkpoint criteria and location) or to inadequate operationalisation of the construct, in particular, the human resource one and the conformance one.

Anderson et al. (1995) claimed that structural equation modeling (SEM) is the most appropriate statistical technique in testing models in management research. They suggested that the best use of this technique, the sample size should be between 100 and 200 observations, but samples with a number of observations between 50 and 400 are also acceptable. Anderson et al. (1995) stressed that, there are some cases that only obtained 22 observations that also generated very good results. They argued that the reason for the existence of such different limit values lies is strictly dependent on the type of model hypothesized and on the quality of the incoming data. However, Yeung (1999) argued that using SME to test models might result in the neglect of the importance of theories in guiding the development of models. He pointed out that some research just simply fits the model to the data instead of testing the model in accordance with theories.

By adapting a survey approach using the data from 339 manufacturing companies, Choi and Eboch (1998) proposed a simple model to study the quality management practices, plant performance, and customer satisfaction. They found that although the correlations among the three constructs in the model are positive, the quality practices have a much stronger impact on customer satisfaction than they do on plant performance. They explained that it is because the manufacturing plants are driven by customers demand instead of the goals of making any improvement.

2.13 Selection of Research Variables

Five major components of the values of Six Sigma are identified in the construction of the present research instrument. Four of these key components are Top Management Commitment and Involvement, Customer Focus, Supplier Management and Team Management and Deployment. Only Saraph et al. (1989) did not measure the customer focus in their study, and none of them measure the team management and deployment but the other three components were identified in those renowned researchers' instruments such as Flynn et al. (1994), Ahire et al. (1996), Black et al. (1996) and Antony et al. (2005). The last major components of the present study are inconsistently identified in the literature, which is Internal Quality System. Internal Quality Systems refer to the operational environment, processes and procedures within an organization for quality improvement but the constructs identified for internal quality systems varied across different instruments (Yeung 1999), which will be discussed later.

2.13.1 Indicators for Six Sigma

Top Management Commitment and Involvement

Henderson et al. (2000) argued that of those who have implemented and practice Six Sigma there is agreement that the most critical success factor is top management support. They claimed that: "The top executive must be part of Six Sigma. [He or she] must change the agenda of upper management meetings so the quality initiative is right near the top". In six sigma success stories such as Motorola, GE, and AlliedSignal, the CEOs are identified as the ones who have made it possible. Coronado et al. (2002) identify this whereby with success there is overall support, participate and are actively involved and dedicated in company-wide six sigma initiatives. However, instead of focusing on the short-term financial benefits, top management should consider quality performance and customer satisfaction as the main driving force in the organization growth (Deming 1986; Bounds et al. 1994; Anderson et al. 1995; Cenek 1995; Flynn et al. 1995).

Customer focus

Xie, Tan, Puay and Goh (1998) in a comparative study of nine different national quality awards indicated that, "Customer management and satisfaction", is one of the most emphasized criterion in many national quality awards. However, Behara, Fontenot and Gresham (1995) argued that it is very difficult to reach the Six Sigma level in the customer satisfaction arena because customer satisfaction is rarely based on contact with only one person, or one aspect of a company due to the fact there are many facets of the business such as customer service, product or service delivery, product quality etc. that will impact the customers' satisfaction. (Henderson et al. 2000). It is argued that in order to satisfy customers organizations need to involve every department and to have a close cooperation with customers in every stage of operations (Anderson et al. 1995; Deming 1986; Flynn et al. 1995; Juran 1986). A study by Henderson et al. (2000 cited by Bolze 1998) showed that GE Harris Energy Control Systems LLC was devoted to increase the customer satisfaction and customer perception of the company. It set an aggressive objective to improve the poor on-time delivering of the XA/21 Energy Management Systems record in 1997. It finally delivered all 20 systems 100 percent on the targeted date.

Supplier Management

Antony et al. (2002) found that many organizations that implement Six Sigma find it beneficial to extend the application of Six Sigma principles to management of their supply chain. Hendricks and Kelbaugh (1998) claimed that under the concept of "Everybody Plays", many product lines are characterized by a high level of outsourced parts that comprise the final assembly. Thus, no one can be a Six Sigma company without 'his' suppliers participating in the culture change. Hendricks et al. (1998) suggested companies should train their suppliers' Green Belts in the same classroom as their own employees and obtain support up front from the highest levels of management in the supplier firm. Pande et al. (2000) suggested using a few suppliers with high sigma performance capability levels in order to reduce variability.

Employees Involvement and Training

An employee does not just refer to workers or operators; it also includes managers (Bounds et al., 1994). Yeh (2003) stressed that a successful quality improvement implementation requires employees' engagement in extra-role behaviors. He pointed out that these factors includes individual training and project involvement, job characteristics, organizational structure, social support and employees' self-efficacy. Employee involvement is an essential element of the emerging paradigm; it is a process of empowering employees to be involved in decision making and improvement activities appropriate to their levels in the organization (Bounds et al., 1994). Deming (1986) believed that training is one of the best means to empower employees. Yeung argued that if the relationship between employees and organizations are poor, the morale will suffer. He claimed that in order to have an effective quality system, employee involvement and empowerment are required. He also suggested that it is necessary to establish a participation and suggestion system.

In his study, Eighteen (1999) concluded that businesses will go on incurring the cost of implementation without exploiting the benefits of the initiative if the businesses do not appropriately educate their staff. Training is especially important when introducing Six Sigma into organizations. Very similar to introducing TQM into organizations as Brown (1994) suggested, it also requires an increased training effort to maximize the benefits of implementing Six Sigma for several reasons. First, it is necessary to make the employees aware of the programs and simply to inform them of what Six Sigma is, how it can be introduced and what it can do. Second, it is important to develop appropriate attitudes and values relating to the approach to quality. Third, people should be well equipped with the tools and techniques of Six Sigma tools and techniques before it is implemented. A fourth reason may be to provide training in job roles, equipment use, and so on, so that employees can identify improvement opportunities.

Internal Quality Systems

To a large extent the successfulness of improvement initiatives depend on how well the organization is managed. Yeung (1999 cited Deming 1994; Hillmer and Karney 1997) contended that to effectively manage an organization, the organization should be viewed as a part of a large system or even as a whole system. In order to survive in the global economy, organizations should establish a well-designed and implemented internal management system (Karapetrovic and Willborn 1998). Yeung (1999 cited Bounds et al., 1995) showed that a Quality Management System should not only just focus on the systems of managing suppliers and acquiring customer requirements, it should also include the essential internal operational components in the organization such as policies, plans, procedures, processes, responsibilities, structures, regulations, information, employees and other resources. Quality participant training and deployment, attitude of Top Management are of equivalent importance (Antony et al. 2005). However, the identification of the internal operational constructs in quality management has been inconsistent among many instruments (Yeung 1999). The employees involvement and training, organizational structures and teamwork, use of quality techniques, quality system procedures and continuous process improvement are among the central ideas of the internal quality systems (Juran 1979; Bounds et al., 1994; Yeung 1999, Antony et al., 2005).

1. Organizational Structures and Teamwork

Ingram, Teare, Scheuing and Armistead (1997) believed that putting people together as a team is the best solution for companies to cope with the more complex and more competitive business environment. Keen (1990) also argued that businesses in order to be more effectively managed should pursue a structure becoming flatter and more team centered. Companies are seen to be emphasizing more on the co-ordination, sharing of responsibilities and the participation of the employees in the decision process (cited by Costa 2003). The Six Sigma team should have all kinds of talents including a person who has strong leadership quality, someone who is good at defining problems and analyzing - but all of them should have good knowledge of the company and the process (Pande et al. 2001). Each project team is supposed to be grouped by a group of belts to be Six Sigma Master Black Belt, Black Belts and Green Belts. Each Six Sigma project is to be led by a Master Black Belt and Black Belts. A Master Black Belt and Black Belts are employed as full-time change agents and project leaders. A Master Black Belt and Black Belts are directly responsible to the project team's owner, who are titled as Champion or Sponsor; and get support from the Green Belt. The project owner is served by senior management to oversee the project. The Green Belt is the part-time project leader (Gluckman 2003; Chowdhury 2001; Pyzdek [no date[1]]). Interestingly, as part of the Six Sigma implementing companies, the quality department is not found to be necessary to participate in the Six Sigma project (Pries 2005).

2. Use of Quality Information

Decision making is based on information (Beckford 1998). It then follows that quality information interlinks the quality efforts to quality performance and which is also the key element of operational efficiency improvement program (Yeung 1999 cited National Institute of Standards and Technology 1997). The quality performance information such as the defect rates and quality costs helps organizations to quantify the size of the quality problem and reveals the opportunities for quality improvement, cost reductions and efficiency enhancement (Yeung 1999 cited Juran and Gryna 1986; Dean et al. 1994). However, Beckford (1998) pointed out that employees very often exist in what might be considered an information vacuum. They are unaware of performance standards or even do not know that the standards exist. Yeung (1999) suggested that organizations should record the quality information by product line for section of process flow and make the quality performance information available and ready to be retrieved by all employees because this information can serve as a tool to reveal the main problem areas and help organizations to reduce the overall production costs. Therefore, he concluded that quality records such as the service reports, customer complaints, and work instructions should be analyzed and reviewed regularly in order to detect and get rid of the potential causes for non-conforming products.

3. Quality System Procedures

The creation of quality is through the process development and maintenance (Kolarik 1995, p. 7). Kolarik also stressed the need of paying attention to each process in that the failure in an earlier process will finally influence the success in subsequent processes. He pointed out that the effectiveness of a quality system largely depends on the commitment and management of an organization. The hierarchy of commitments to action is supported by goals, objectives, targets and specifications of the organization. Kolarik also claimed that Motorola uses the Six Sigma theme as well as the clearly laid out systematic action-oriented strategy backed up with a stated commitment to the theme and to leadership and management efforts to achieve their goals (p. 46).

However, Beckford (1998) argued that an organization is organized through a formal hierarchical system which is not a bad thing in itself, but problems can arise with such system when systems and procedures can become 'frozen into the organization and any pressure for changes and adaptation to will encounter high level of resistance' (p. 21). The resistance to adapt to any required changes will be a barrier to the achievement of quality.

4. Continuous Process Improvement

Although the importance of continuous improvement is increasing in the keen competitive globalised market, it is difficult to establish and maintain (Labib and Shah (2001). The previous authors explained that organizations should keep continuous improvement in order to respond to the changing demands of the market. Organizations should also regularly evaluate the improvement process itself in order to identify what next steps need to be carried out and to highlight the problems and the areas of weakness as well as the improvement opportunities (Dale 1996).

Six Sigma is a well-structured continuous improvement methodology used by organizations to reduce process variability and drive out waste within the production or services processes (Coronado and Antony 2002). Bañuelas and Antony (2003) claimed that the potential of Six Sigma to reduce the variability from processes and products is by using either a continuous improvement methodology or a design/redesign approach that is widely known as Design for Six Sigma (DFSS). Antony and Bañuelas (2001) believed that the continuous improvements will not only help organizations to drive out waste and improve profitability but will also help businesses to meet or even exceed their customers' needs and expectations by the improving effectiveness and efficiency of all operations processes.

Six Sigma Methodologies and Tools

Bounds et al. (1994) claimed that the power of knowledge cannot be harnessed without the Tools. According to their definition, "tools include the instruments, machines, algorithms, or programs that are used to execute the work to provide valued goods and services". Raisinghani et al. (2005) claimed that Six Sigma is only a toolset, not a management system which could be used with other more comprehensive quality standards such as the Baldrige Criteria for Performance Excellence or the European Quality Award. Based on the literature, articles and books a survey of major Six Sigma methodology and tools, indicates twenty sets of them were identified. These methodologies and tools can be used in various stages of business processes from product development and process control. **Supplier-input-process-output-customer (SIPOC)** (Pfeifer, Reissiger and Canales 2004; Nellis and Harrington 2003; Senapati 2004; Antony, Kumar and Madu 2005). **Failure Modes and Effects Analysis (FMEA)** (Chang, Wei and Lee 1999; Lunde 2003; Dhillon 2003; Braglia, Fantoni and Frosolini 2007; Teng and Ho 1996; Teng and Liu 2006; Devadasan, Muthu, Samson and Sankaran 2003; Daya and Raouf 1996; Ginn, Jones, Rahnejat and Zairi 1998; Sankar and Prabhu 2001). **Root Cause Analysis** (Tan and Raghavan 2007; Dorsch, Yasin and Czuchry 1997; Finlow-Bates 1998; Dhillon 2003; Yavas and Yasin 2001; Finlow-Bates, Visser and Finlow-Bates 2000). **Brainstorming & Affinity Group Tool** (Babbar, Behara and White 2002; Villarreal and Kleiner 1997; Smart and Dudas 2007; Anjard 1995; Tan 2003; He, Staples, Ross and Court 1996; Lyons 2005; Antony 2004). **Thought Map Relations Diagram** (Babbar et al. 2002; Tague 2004; Hild, Sanders and Ross 1999; McQuater, Scurr, Dale and Hillman 1995; Brassard 1989; Mizuno 1995).

Customer Segmentation Worksheet (DiGiacomo, King and Nordquist 2003; Muir [no date]; Case, Cardella and Toomey [no date]). **Voice of the Customer Data Collection Worksheet** (Tague 2004; Bailey Jr. [no date]; Waxer [no date]; Buthmann [no date]; Duffuaa and Ben-Daya 1995). **Voice of the Customer Requirements Translation and Kano Analysis** (Tontini and Silveira 2007; Witell and Löfgren 2007; Shahin 2004; Tan and Pawitra 2001; Shen, Tan and Xie 2000; Bhattacharyya and Rahman 2004; Nilsson-Witell 2005). **House of Quality – Quality Functional Deployment Matrix** (Tan and Pawitra 2001; Shen, Tan and Xie 2000; Bhattacharyya and Rahman 2004; Ginn and Zairi 2005; Jiang, Shiu and Tu 2007; Pun, Chin and Lau 2000; Mill 1994; Carpinetti, Gerólamo and Dorta 2000). **Cause and Effect Matrix** (Beckfor 1998; Pyzdek 2003; Banuelas, Tennant, Tuersley and Tang 2006; Grover, Agrawal and Khan 2006; Dhillon 2003; Lynch and Cloutier 2003; Breyfogle 2003; McQuater et al. 1995; Duffuaa et al. 1995; Koning and Mast 2006).

Critical to Quality CTQ Tree Diagram (Nellis and Harrington 2003; Mast 2004; Yang, Choi, Park, Suh and Chae 2007; Berryman 2002; Brown 2002; Mizuno 1995). **DMAIC methodology Measurement Selection Matrix** (Bañuelas et al. 2004; Thomas and Barton 2006). **Design for Six Sigma (DFSS)** (Kim, Yoon and Zeon 2004; Bañuelas and Antony 2003; Bañuelas et al. 2004; Antony 2002; Antony et al. 2005). **Measurement Assessment Tree Diagram** (Mizuno 1995; Ahmad, Kamaruddin, Khan, Mokthar and Almanar 2006; Daniels 1997). **Quality Data Checklist & Scorecard** (Ishikawa 1986; Duffuaa 1995; Ahmed, Kayis and Amornsawadwatana 2007; Jones 2004). **Production Schedule to Actual Scorecard** (García-Cebrián and López-Viñegla 2002). **Pareto Chart** (Kim et al. 2004; Burr 1990; Ishikawa 1986; McQuater et al. 1995; Duffuaa 1995; Juran 1979; Omar and Kleiner 1997; Anjard 1995; Watson 1998). **Six Sigma Team Roles** (Ingle et al. 2001; Antony et al. 2002; Henderson 2000). **Team Empowerment Boundaries** (Nykodym, Simonetti, Nielsen and Welling 1994; Collins 1995; Collins 1996; Smith 1997; Wickisier 1997; Pastor 1996; Born and Molleman 1996; Cook 1994; Geroy, Wright and Anderson 1998; Honold 1997; Swenson 1997). **Six Sigma Project Charter** (Swinney [no date]; Antony 2006; Antony et al. 2005; Leung, Liao and Qu 2007).

2.13.2 Organizational Performance Indicators

Curtis and Dean (2004) indicated performance measurement has become a major factor in the services improvement auditing. However, Marr and Schiuma (2003) argued that there is a lack of a cohesive body of knowledge in the field of business performance measurement. Franco-Santos, Kennerley, Micheli, Martinez, Mason, Marr, Gray and Neely (2007) believed that the lack of agreement on the definition of the performance measurement not only created the confusion but also limited the potential for generalizability and comparability of it. Neely, Gregory and Platts (2005) defined the business performance measurement (BPM) as a process of quantification and action leads to performance. When it is applied in the marketing perspective, organizations achieved their goals when they satisfy their customers better than their competitors do in terms of efficiency and effectiveness. Bittici, Carrie and McDevitt (1997) pointed out that in order to improve the BMP system, businesses "should take account of the strategic and environmental factors relating to the business as well as considering the structure of the organization, its processes, functions and their relationships".

Yeung (1999) stressed the importance of the need of building an effective instrument for an objective measurement of corporate success related to quality management and the employment of some concrete and simple indicators. By studying the literature, Adam, Corbett and Flores et al. (1997) employed only two constructs "performance quality" and "financial performance" to measure an organization's performance, however, the stakeholders aspects were not mentioned in their paper. Small and Yasin (1997) evaluate the organization performance by using the firms' self-assessment of changes. They used an exploratory factor analytic approach to determine the minimum number of underlying factors to represent the nine performance variables. The factors they used are "time-based competitive factors", "organizational effectiveness factors", and "operational efficiency factors". The quality, worker productivity and sales/marketing performance are considered in measuring the organizational effectiveness factor. Ahmed et al. (1997) identified 39 quality improvement indicators from 52 factor analyzed items, 13 productivity improvement indicators which influence quality indirectly. However, Yeung (1999) argued that some of the selected indicators used by Ahmed et al. (1997) such as "ability to improve", "employee flexibility" and "returns from manufacturing operations" are quite subjective and difficult to quantify and are disputable. He also pointed out that some indicators such as "product quality" used by Ahmed, Montagno and Firenze (1996) and Small et al. (1997) are multi-dimensional by themselves which need a further development of application.

This study

In the present study, this researcher aims to investigate four general quality performance aspects. Operational efficiency is a general measure in most of empirical studies in the operations management field (Yeung 1999). "Defect and rework rate" is a common indictor of the capability in process management and "engineering change rate" is a manifest variable of engineering design inefficiency. The "total quality cost" and the unit cost of manufacturing" are used to measure the cost effectiveness. The other variables such as 'Inventory turnover rate' and 'Manufacturing lead time' indicate part of the overall manufacturing competence. Customer satisfaction is also an important business characteristic that should be included in the performance measurement if businesses want to remain competitive in the long term (Love and Holt 2000; Ross, Fernström and Pike 2004). However, Yeung (1999) argued that customer satisfaction is an abstract concept related to various measures from product reliability to customer relations. Therefore, some researchers tend to use it as an indicator of operational performance instead of a latent variable of organizational performance by itself. Business performance is a relatively objective measure as numerical data can be revealed by marketing and financial performance, as well as the data which is available from senior management. Return on investment, sales volume and profit margin are among the most commonly used criteria for marketing and financial measures (Robinson, Anumba, Carrillo, Loughborough and Al-Ghassani 2005; Franco-Santos et al. 2007; Marr et al. 2003; Kuwaiti and Kay 2000). Six Sigma participant satisfaction or employee satisfaction is another important measure of performance in many studies (Love and Holt 2000; Ross, Fernström and Pike 2004; McAdam and Bannister 2001).

2.13.3 Attitudes and Commitment to Six Sigma

Antony, Antony, Kumar and Cho (2007) and Antony et al. (2002) pointed out that top management commitment and involvement is one of the most critical factors for the successful introduction, development and deployment of Six Sigma. They pointed out that organizations use Six Sigma as a business strategy and a systematic methodology in order to achieve a breakthrough in profitability by improving product and service quality, customer satisfaction as well as productivity. Goh et al. (2004) claimed that companies are eager to introduce Six Sigma methodology into their companies because of the intention to impress their customers by labeling themselves as "Six Sigma Organizations". Antony et al. (2002), Bañuelas et al. (2002) and Antony (2005) pointed out that the successfulness of Six Sigma initiatives requires the right mindset and attitude of people working within the organization at all levels. However, no empirical study has been conducted and no comprehensive instrument has been developed with an attempt to measure these mindsets and behaviour. Antony (2004) concluded from his personal experience that many organizations only see Six Sigma as a 'flavour of the month'; whereby it is not different from the other quality improvement initiatives. Three constructs about attitude and commitment to Six Sigma methodology will be measured in the present study. "Objective of labeling Six Sigma Organization" to assess whether senior management uses it as a marketing tool or for operational improvement prospects. *"Attitude" is a psychological tendency that is expressed by evaluating a particular entity with some degree of favor or disfavor* (Eagly and Chaiken 1993, p. 1) which is used to assess whether the management uses Six Sigma for continuous process improvement in the present study. "Understanding" evaluates the management's confidence in understanding the objectives and contents of Six Sigma methodology (Antony et al. 2002; Bañuelas et al. 2002). However, management knowledge on TQM ensures a thorough understanding of the Six Sigma standard, including its roles and limitations in quality improvement (Black and Revere 2006; Anderson, Eriksson and Torstensson 2006; Dahlgaard and Dahlgaard-Park 2006; Mast 2004).

2.14 Proposed Model

The proposed model, as described in detail in the above, identifies factors which affect the organizational performance. The researcher developed an integrated quality management model in the context of Six Sigma Methodology management activities based on prior research and some of Six Sigma Master Black Belt and Black Belts' suggestions. The model posits that intention to improve organisational performance is jointly determined by the Senior Management Commitment and Involvement, Striving for Higher Quality Performance, Six Sigma Team Management System, Customer Focus, and Internal Quality System.

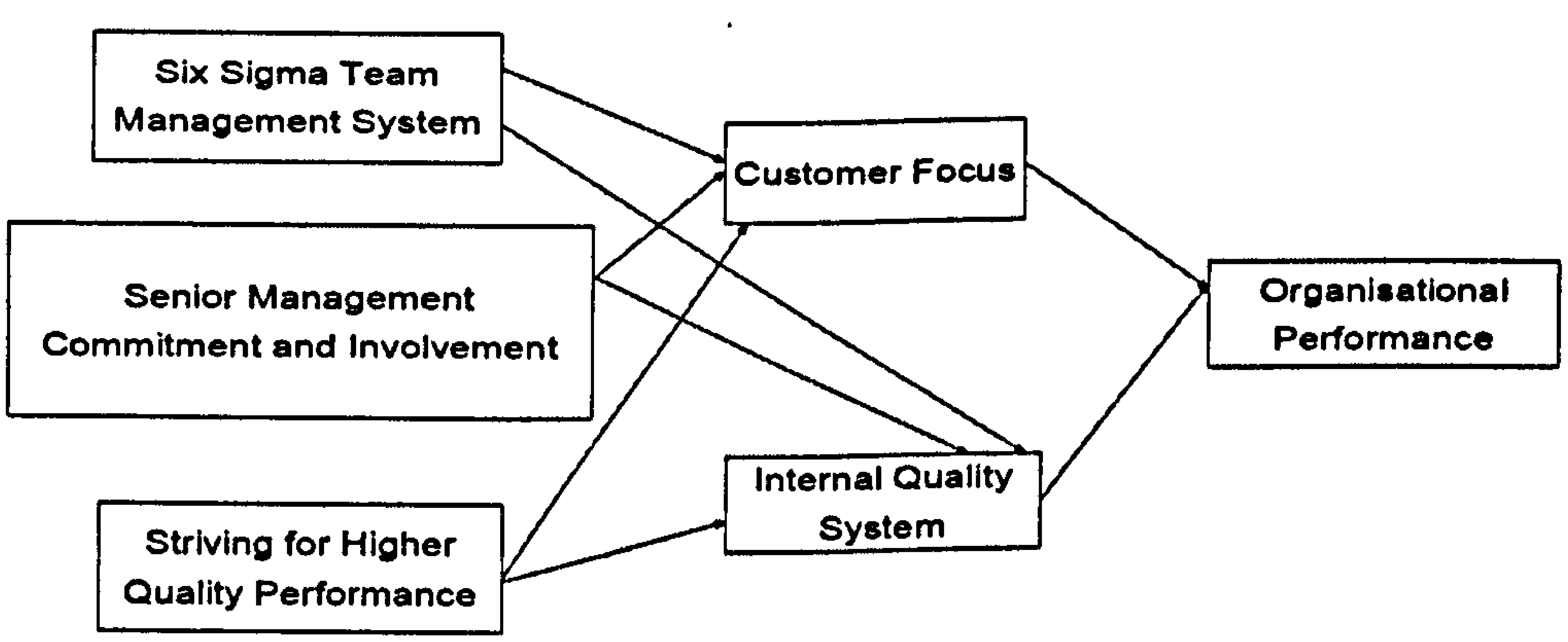


Figure 2.1 Integrated Quality Management Model for Six Sigma Methodology Management Activities
Source: this study

2.15 Conclusion

Six Sigma is a useful management tool which is proved that it could be used in the improvement of product and service quality to satisfy customers, it could also be used to promote employees' morale and enhance employees' competence in their works. However, Six Sigma is not a panacea and free; it could not solve every business problem. It could help to reduce defect in product or service, however, it could not make an unwanted product sell like hot cakes even it is defect free. Six Sigma has its own strengths and weaknesses. Companies not only have to have a comprehensive understanding on its nature, long term commitments, competent project leaders to lead the project through, but also have to understand the customers and the markets' needs and employ the Six Sigma program according to its own ability. If companies employ Six Sigma for the intention to save their own costs instead of bringing any goods to customers, they will certainly lose their share to their competitors. The Six Sigma projects will never succeed.

Chapter 3 Research Methodology

3.1 Introduction

Melnyk and Handfield (1998) identified that the fundamental goal of research is to create simple, concise and useful knowledge which enable the researcher to explain the complex phenomenon. In addition "any research should be objective and scientific", Judd et al. (1991, p. 5) stressed. Kerlinger et al. (2000) pointed out that "the scientific approach is a special systematized form of all-reflective thinking and inquiry". Scientific research is guided by theory and hypotheses about the presumed relations among the studied phenomena. The scientific investigation is empirical, systematic, controlled and ordered; researchers therefore can have critical confidence in the research results.

The primary aim of this chapter is to introduce the research design and methodology and the limitations in a mobile manufacturing firm as well as summarize the methods and procedures for data collections suggested in the literature. This chapter also provides an overview of the research data and describes some implications from the pilot study. Detailed discussions of research methodology related to research instrument development and theory testing and building will be presented in the following chapters.

Although it is claimed that Six Sigma has been implemented with success in many organizations, there is still less documented evidence of its impact on its stakeholders. And, it is also said that even though the result of Six Sigma implementation is promising and rewarding and its concept makes a change in the quality profession, but "it is an expensive and multi-year undertaking" (Henderson and Evans 2000 cited Paul 1999).

3.2 Research objectives and methodology

The researcher decided to utilize a case study-based research methodology with mixed data sources and qualitative and quantitative analysis methods. Amaratunga, Baldry, Sarshar and Newton (2002) claimed that "there is a strong suggestion within the research community that research, both quantitative and qualitative, is best thought of as complementary and should therefore be mixed in research of many kinds." Amaratunga et al. (2002 cited Fellows and Liu 1997) showed that:

> *... a combination of quantitative and qualitative research methods is very powerful for gaining insights and results, and for assisting in making inferences and in drawing conclusions.*

Data will be collected primarily through interviews, documentation, and questionnaire survey. Interviews will be conducted with executives and quality professionals who are familiar with the Six Sigma implementation progress. In addition questionnaire survey will be the second major source of data in the present study. The randomly selected Six Sigma participants will be invited to participate in the survey. The third major source of data is documentation. Motwani, Kumar and Antony (2004) suggested that any of the feasibility studies, reports, memo's, minutes of meetings, proposals, newspaper articles, and books etc. can be reviewed and the contents can be analyzed. Any of the documents available will be collected and analyzed to identify and/or validate data. They also reminded that researchers should pay more attention during the data collection to ensure that the evidence collected from different sources will converge on a similar set of facts. The factual portion of the present case study will be reviewed by the major informants in the company to ascertain the accurateness of the evidence and also as a purpose of validating the data collection process.

The primary goal of this research is to study the extent to which the implementation of Six Sigma contributes beneficially to an organization's major stakeholders. In order to do this effectively, the general objective is further divided into a number of specific research questions as follows:

1. To what extent is this organization implementing Six Sigma?
2. To what extent does Six Sigma methodology impact the organizational performance?
3. To what extent does this organization improve the customer satisfaction level after implementing the Six Sigma methodology?
4. To what extent does this organization actually use the tools and techniques of Six Sigma and how is it familiar with the tools and techniques?
5. To what extend the Six Sigma participants will be promoted to the managerial level

in this organization?

This non-experimental case study used interviews of key informants and review of the documents as qualitative data resources. The case study has been continually used in social science research such as sociology, psychology, anthropology, economics and management science etc., as a research strategy, it is used in many situations to contribute to our knowledge of these fields and disciplines (Yin 2003[1]). The qualitative-based case study methodology chosen will include a mixed-method design because it is desirable to determine the success of implementing Six Sigma, and then to understand the organizational context of how a Six Sigma project and strategies impact organization's bottom line. Yin (2003[1]) agreed that it is appropriate to use the case study method if the researcher intentionally wants to cover contextual conditions especially if 'she' believes that the conditions might be highly related to understanding the phenomenon.

Another reason for selecting the case study methodology is that the case study is a research strategy which Yin (2003[1]) described as an all-encompassing method that not only covers the logic of research design, data collection techniques as well as specific approaches to data analysis; it can be either single or multiple-case designs. If a multiple design is used, it must follow a replication instead of using sampling logic. When no other cases are available for replication, the researcher is limited to single-case designs. Yin (2003[1]) stressed that generalization of results, from either single or multiple designs, is made to theory and not to populations. Yin also pointed out that case studies do not need to have a minimum number of cases, or to randomly select cases like the general practice as in the survey method. The researcher is called upon to work with the situation that presents itself in each case. The researcher will remain neutral and should not attempt to manipulate the condition. The researcher will also employ several methods of data collection to collect information from various sources to prove the same fact or phenomenon. Since the case study database will increase the reliability of the entire case study, therefore, the case study database will be established in terms of four components suggested by Yin (2003[1]). The four components are (1) Case study notes such as the result of interview or observation, (2) Case study documents where the documents relevant to the case study will be collected, (3) Tabular materials such as the qualitative data, and (4) Narratives which may be produced by the researcher during the fieldwork may also be considered as a part of the database.

3.3 An Overview of Case Study Methodology

The United States General Accounting Office (GAO) Program Evaluation and Methodology Division (1990) defines case studies as:-

> "A case study is a method for learning about a complex instance, based on a comprehensive understanding of that instance obtained by extensive description and analysis of that instance taken as a whole and in its context." (p. 17)

The GAO identified the following six types of applications for case study methods in their publication Case Study Evaluations (1990) as: (1) Illustrative, which is a descriptive case study that adds in-depth examples to other information about a program or policy; (2) exploratory, which is also descriptive but aims at generating hypotheses for later study; (3) critical instance, which examines a single instance of unique interest or serves as a critical test of an assertion about a program, problem or strategy; (4) program implementation, which is usually a normative investigation of operations at several sites; (5) program effects, which identifies causality and multi-site, multi-method assessments; and (6) cumulative, which brings together the findings from case studies done at different times.

3.3.1 Strengths of the Case Study Methodology

Yin (2003[1]) stressed that case study allows researchers to keep the complete and meaningful characteristics of real life events of organizational and managerial processes. Compared with other research methodology, it has a unique strength in dealing with a full variety of evidence such as documents, artifacts, interviews, and observation. The case study is the most appropriate methodology for this inquiry since the researcher has very little control over events and is focusing on an existing phenomenon within some real life context. Yin (2003[1]) pointed out that a single case may represent a typical "project" among many different projects; a manufacturing company could be typical of the other manufacturing companies in the same industry.

3.3.2 Weaknesses of the Case Study Methodology

Despite its advantages, the case study method is traditionally considered to be a less desirable form of inquiry than the other methodologies. The major concerns of researcher investigators can be grouped as four main categories: (a) the lack of scientific generalization, (b) time consuming and complex, (c) the lack of objective evidence, (d) the concern of the case identities: Real or Anonymous and are discussed in the following paragraphs.

3.3.2.1 The lack of scientific generalization

Patton (2002) explained that scientific generalization is not the intent of case study research. He explains that in a case study, sampling is aimed at insight about the phenomenon, not empirical generalization from a sample to a population. Yin (2003[1]) explained that "case studies are generalisable to theoretical propositions and not to populations or universes — the investigator's goal is to expand and generalize theories (analytic generalization) and not to enumerate frequencies (statistical generalization)." He further explained that the sampling logic is commonly used to assess the prevalence or frequency of a particular phenomenon. He also substantiated that case studies are not the most appropriate method for judging the prevalence of phenomena because the sampling size will be too large for any statistical consideration of the relevant variables.

3.3.2.2 Time consuming and complex

Yin (2003[1]) claimed that case study research is the most difficult type of research to do because there is not a routine formula which case study investigators could follow. Additionally data analysis is difficult and time consuming because case studies are always making use of qualitative data in combination with quantitative data (Darke et al. 1998; Miles & Huberman 1994). Moreover, most researchers complain that case study takes too long to conduct and ends up in a lot of unreadable documents. Yin (2003[1]) explained that it is not necessarily the way to do the case study, Yin pointed out that it is because most researchers confuse the case study method with ethnography which usually requires a long time in the field work. Yin (2003[1]) further articulated that case studies researchers could do a valid and high-quality case study by using library information and the telephone or even via the internet. This weakness will be partially overcome by studying the results of the company's Six Sigma Projects.

3.3.2.3 The lack of objective evidence

The lack of objective evidence is another main concern of many researchers. Patton (2002) pointed out that the lack of objective evidence in case studies is because there is nothing equivalent to a statistical significance test or factor score to tell the analyst when results are important or what quotations fit together under the same theme (p. 57-58). Patton (2002) and Yin (2003[1]) suggested that using mixed-method data collection and analysis will help to mitigate this accusation.

3.3.2.4 Case identities: Real or Anonymous

Most case study researchers encounter the question of whether the names of the whole case and its participants should be disclosed or disguised. Yin (2003[1]) suggested that to disclose the identities of both the case and the participants is the most desirable option. The researcher will ask for the permission from the organization. If the organization or individual participant is not willing to be disclosed, the researcher will employ an alpha identifier to protect the organization and the participants in the case study.

3.4 Research Paradigm in Quality Management

Meredith, Raturi, Amoako-Gyampah and Kaplan (1989) expressed their concerns on the research methodologies in the operations field. They claimed that although the research paradigms in operations are useful, it limits the kinds of questions researchers can address. They conducted a literature survey and found that some of the previous researchers suggested a new research agenda to benefit the operations managers while some of the alternative research methodologies suggested the traditional research methods such as longitudinal studies, field experiments, action research, and field studies. Meredith (1998) also found that there is relative insufficient use of case and field research in operations management. He claimed that the empirical methods of case and field research are preferred to the more traditional rationalist methods of optimization, simulation, and statistical modeling for building new operations management theories. He also pointed out that the objectivity provided by quantification in the rationalist methods could be an obstacle in the attempt to build theory because a qualitative understanding of the quantified factors is still required for theories to be accepted by others inside and outside of the field (p. 442). He further pointed out that the rationalism is an epistemological paradigm which includes both the beliefs of positivism and empiricism which generally uses quantitative methodologies to explain what happens and how to achieve some goal or end such as the effect of some change in managerial policy on plant measures. However, case/field study is another research paradigm known as interpretivism is more process- or means-oriented which employs both quantitative and qualitative methodologies to help researchers to understand the phenomena and why certain characteristics or effects occur or do not occur.

Meredith et al. (1989) presented a generic research framework for a classification of paradigms based on the framework generated by Mitroff and Mason (1984). As shown in the diagram below (Figure 3.1), the operations research paradigms were based on two key dimensions of research methodologies, from Existential to Rational which concerns the nature of truth and whether it is purely logical and independent of individual experience, and the second dimension is from Natural to Artificial which concerns the source and kind of information used in the research. In their study, Meredith et al. (1989) concluded that the operations research was still overwhelmingly artificial in nature even the operations researchers are allowed to move toward more existential paradigms and to move away from the more rationalistic and scientific paradigm. They also pointed out that methods such as survey and structured interviews provide an empirical approach to studying quality.

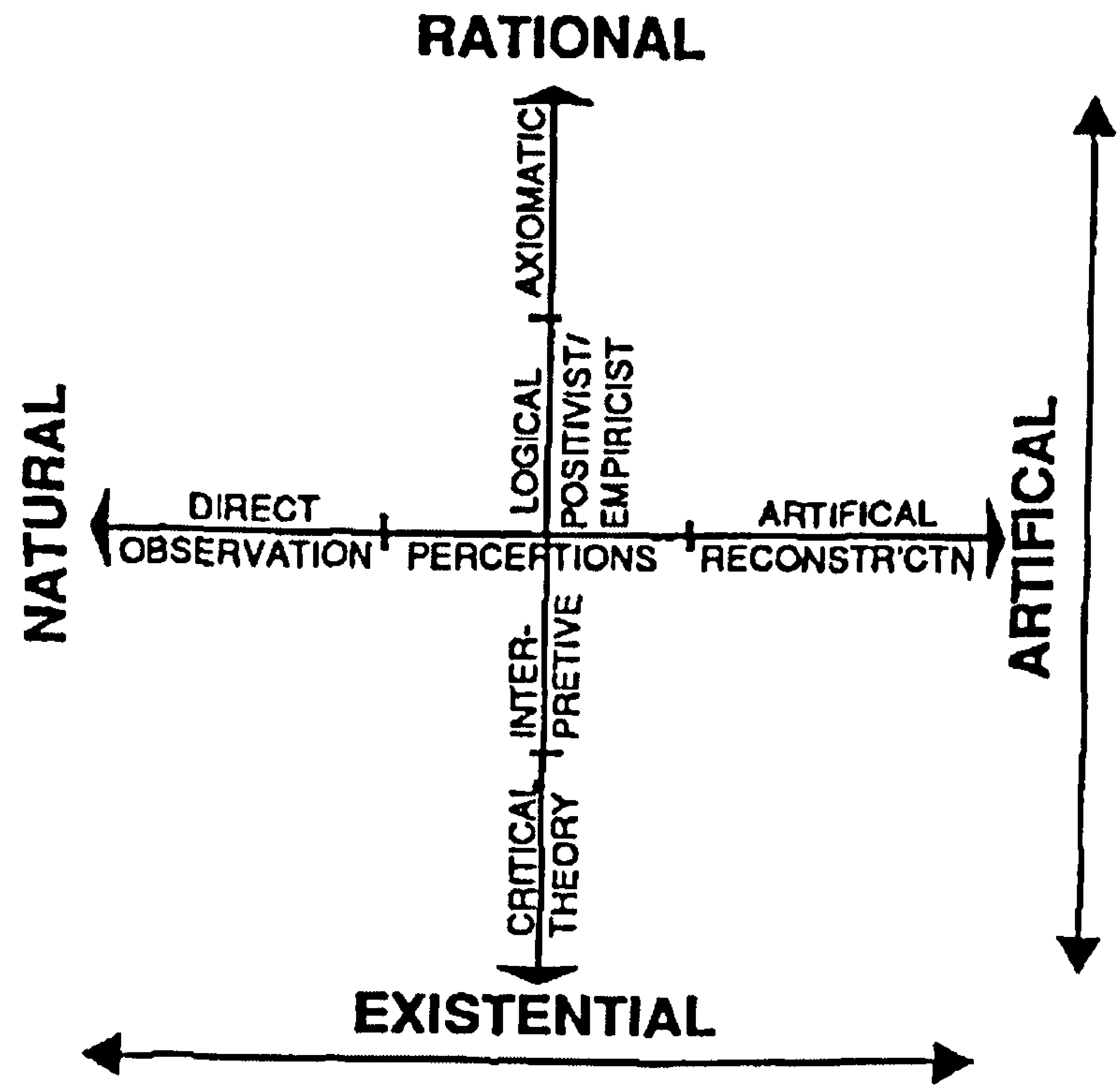


Figure 3.1 A Generic Research Framework (Reproduced from Meredith et al. (1989, p. 306)

3.5 Limitations in Quality Management Research

Gattiker and Parente (2006) claimed that in 1990s, there were a number of leaders in the Operation Management (OM) field who proposed that researches in the OM field should be based on observations made from the "real world". A large volume of more empirical and better empirical OM research expanded greatly after that call. Gattiker et al. consented that the empirical research is a critical component of the theory building process in operations management. The survey and the case study are the two dominant empirical methodologies in the operations management field. They argued that no research method is perfect, the reliance on a limited number of methodologies can influence the body of knowledge that a field generates. They claimed that surveys and case studies which rely on one key informant per unit of analysis (e.g. one survey respondent per plant in a plant level study) run the risk that the measures will be biased by the perceptions of the individual respondent. They also claimed that the willingness of practitioners to participate in surveys and case studies is declining for the reason that the greater workloads on practitioners will make them less able to spare extra time for research to benefit the academy directly with less obvious benefits to their particular firms. Moreover, they pointed out that some companies do not permit their employees to complete surveys; all of the surveys have to be forwarded to a public relations function. They argued that such factors often make obtaining adequate, valid responses more difficult and costly.

3.6 Theoretical Foundation

Melnyk and Handfield (1998) pointed out that researchers may start with a theory. They claimed that theory-driven empirical research is an approach which will provide better insight and understanding into operation management by using empirical data to build and develop better theories. The theory can be either well defined and explicit or implicit and more of an idea, as compared to a formal statement or structure. Quite the opposite, the grounded theory is the discovery of theory from data becomes one of the major research methods in the sociology field because the grounded theory fits empirical situations; and it is not only understandable to both the sociologists and layman, it also provides the user with relevant predictions, explanations, interpretations and applications (Glaser and Strauss 1967).

However, Yeung (1999) argued that without the need for connecting an established theory to prior knowledge, researchers would be in danger of "over-fitting a theory into data" or slipping into "data fishing". He also claimed that the theories in quality management are relatively more well-established than the other areas in operations management. With the increasing number of empirical studies (Anderson et al. 1995; Flynn et al. 1995; Yeung 1999; Ayeni 2003; Olson 2005; Zu 2005), some of them have also consolidated some theoretical foundation of quality management. All of these are important references in the analysis of research results and have formed the foundation for testing, modifying and extending current theories.

3.7 Design of the Research

Yin (2003[1]) pointed out that every empirical study should have an either explicit or implicit research design, he stressed that a research design is the logic which links the empirical data to the research questions. An articulating theory about what is going to be studied will help the case design to become more explicit (Yin 2003[1]). He also described that a research design "is as a "blueprint" of research, that "blueprint" helps researchers to avoid the situation in which the evidence does not address the initial research question." But developing sharp and insightful research questions depends on reviewing previous literature. Darke et al. (1998) also stressed the importance of linking the study design with the existing literature and focusing on the gaps in that literature.

> 'The design and scoping of a case study research project requires a comprehensive literature analysis to be undertaken in order to understand the existing body of research literature within the research area and to position the research question(s) within the context of that literature.' (p. 280)

Chadwick et al. (1984) also claimed that the research design is one of the most important parts in the whole research process because it involves the main investigation processes, procedures and the research approach issues such as data collection to data analysis. A study by Yeung (1999 cited Kerlinger 1986) showed that researchers should set up a research framework to study the relationship variables. However, Kerlinger warned that it is not realistic to draw a precise research plan in the research studies; he suggested that the research design only needs to show the major direction in the observation-making and analysis. The researcher modified Yeung's (1999) research framework in this study as below:

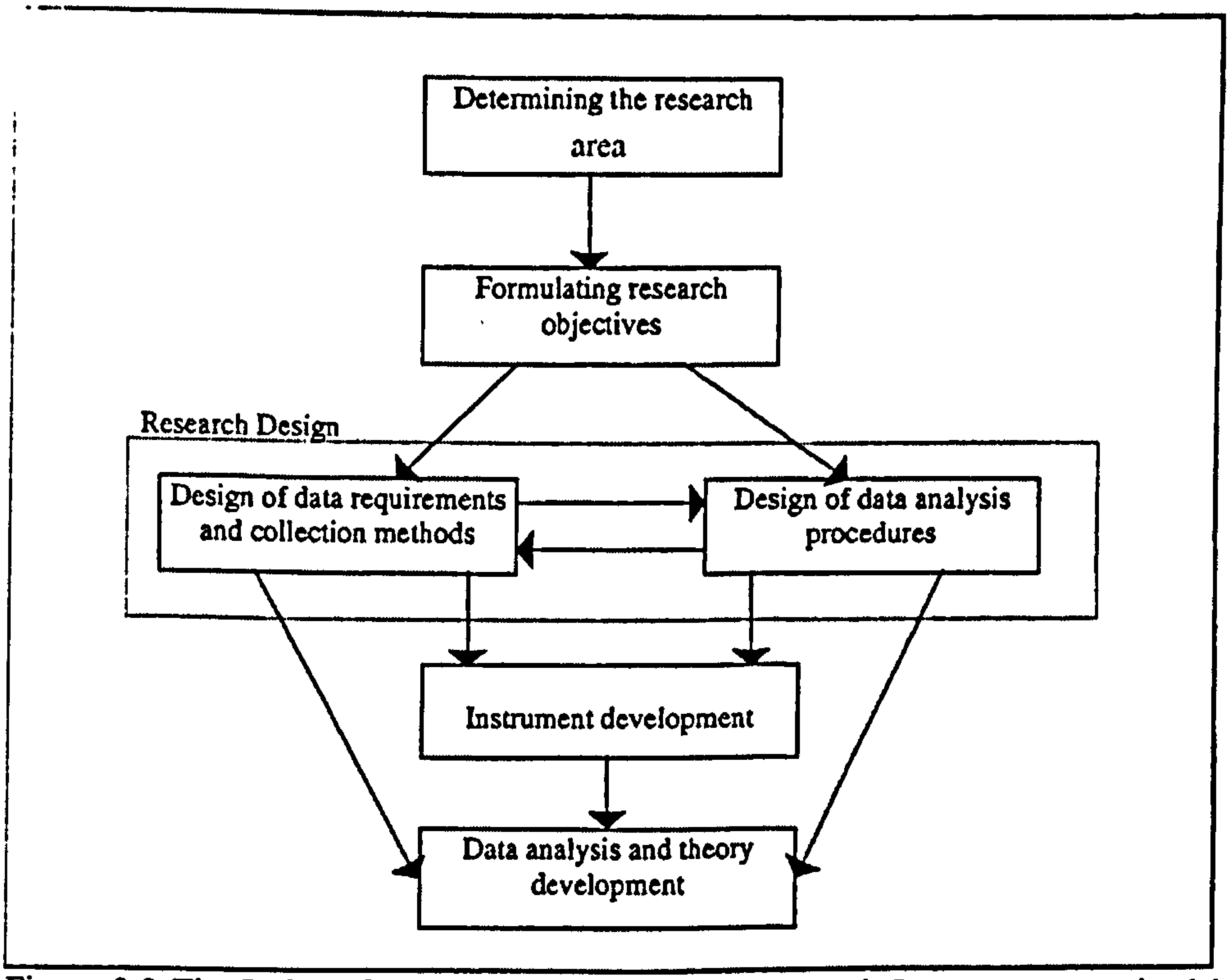


Figure 3.2 The Roles of Research Design in the Research Process summarized in this study

Yeung (1999) suggested that research design should be carried out after the research objectives are determined and the research design should also clearly target to achieve the targeted objectives.

The design of data requirement, collection methods and analysis procedures are interactive and concurrent processes. The flow chart of the present research procedure is shown as below (Figure 3.3). This chapter introduces only the research design of the data requirements and collection methods. The methodology in data analysis will be presented in the next chapters.

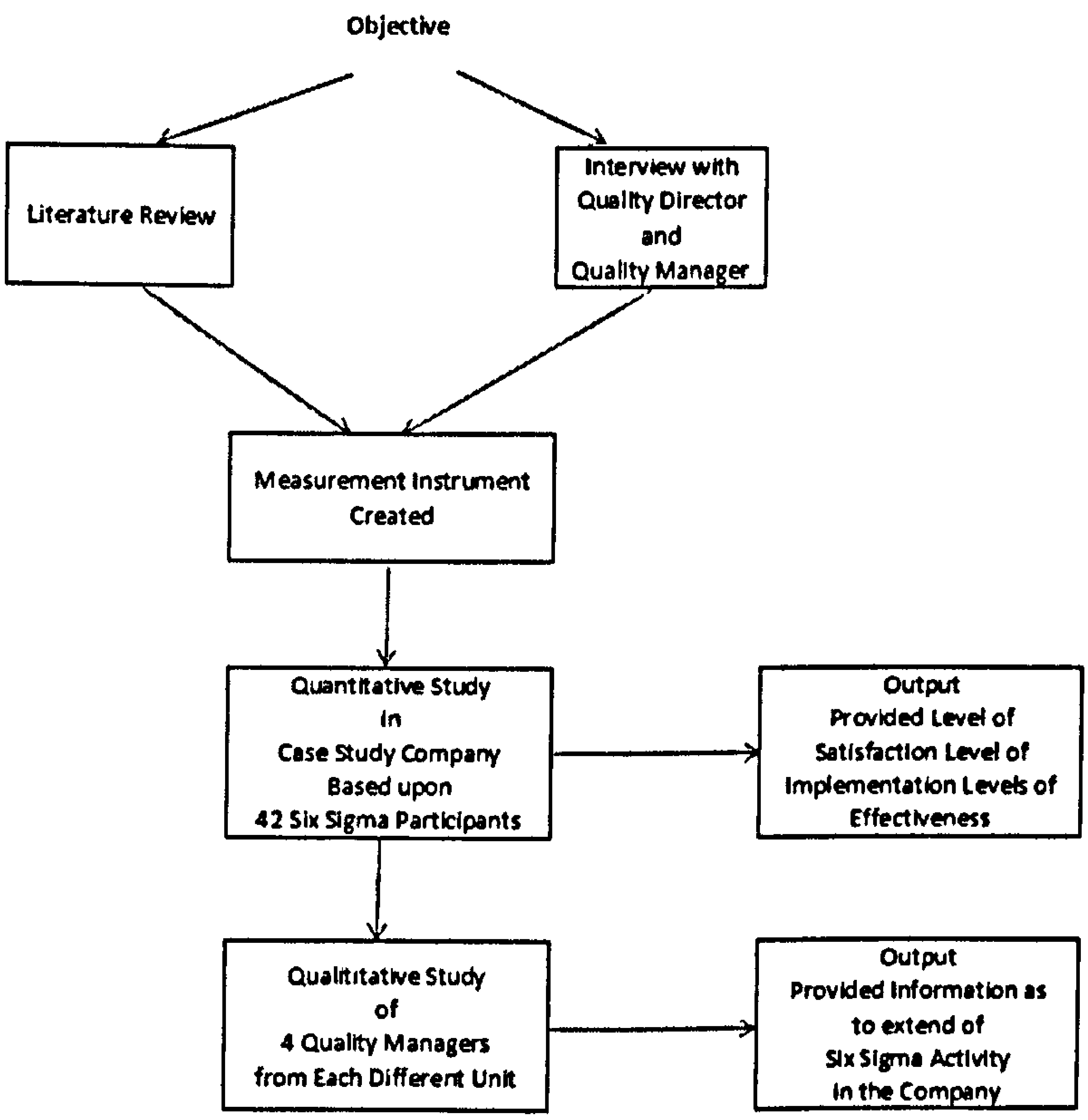


Figure 3.3 Flow Chart of the Present Research Activity
Source: this study

Isolating Six Sigma Methodology from Other Improvement Initiatives.

The researcher aims to find out how valuable Six Sigma methodology is in the business environment, therefore, this study will investigate the implementation of Six Sigma in a natural setting of a real business environment. Although the researcher will not be able to exert any influence which might influence the organizational performance. Yeung (1999) asserted the need of isolating the quality initiative which he studied in his doctorate dissertation from the other improvement initiatives. Multi-evidences will be collected in this study to isolate the effect of Six Sigma methodology from other improvement initiatives such as conducting in-depth interviews with key informants and review of documentation to help the researcher to determine the extent to which Six Sigma Projects are implemented together with other improvement initiatives in order to confirm whether some other improvement initiatives may introduce biased effects.

3.7.1 Data Requirements Design in This Research Study

Thietart et al. (2001) pointed out that 'data' has been conventionally seen as forming the premises of theories. It is one of the fundamental choices which researchers have to determine what type of data is most suitable to their research question. They claimed that the compilation of data is a task which involves evaluation, selection and choices for the outcome of the research. Additionally, it is a process that will signify the epistemological position of research. Yeung (1999) claimed that the data requirement design helps to determine what research variables are to be collected for carrying out the predetermined data analysis methods so as to achieve the stated research objectives. The primary goal of this research is to explore the implementation of Six Sigma in a battery manufacturing company. Therefore, the data about Six Sigma methodology management activities will be the primary information to be collected. Interview, review of documentation and questionnaire survey will be used primarily to collect the data and both quantitative and qualitative analysis methodologies will be employed. The data will be analyzed by multivariate statistical techniques, these indicators or variables will be used to reflect some underlying and unobservable constructs of the Six Sigma implementations.

The strategy for collecting and analyzing data will be based on the advice of Patton (2002) to form a comparative analysis by triangulation of quantitative and qualitative data (p. 558). He pointed out that areas of convergence increase confidence in the findings and the areas of divergence provide the researchers an opportunity to better understand the complexity of the phenomenon. He also explained that the important point is that focusing on the degree of convergence will yield a more balanced overall result. The research processes is discussed in the next section.

3.7.2 Questionnaire Development

3.7.2.1 Suggestions in the Literature

A study by Singleton et al. (1999 cited Payne 1951) showed that survey instrument design is a creative process, which is partly art as well as partly science. Yeung (1999) pointed out that data collection by survey questionnaires is not only playing an important role in social and behavioural research, it also plays an increasingly important role in the field of operations management. However, he claimed that the main objective in the design of a questionnaire in the field of operation management is only to collect objective data based on the facts because for some abstract but essential variables concrete data with exact numbers are not possible to collect. He suggested using the respondent's beliefs and interpretations of their operational environment instead.

Data collection by survey questionnaires has several advantages. Judd et al. (1991) indicated that the primary advantage of written questionnaires is low cost; it also helps to avoid the potential interviewer bias and place less pressure for immediate response on the subject as well as giving respondents a greater feeling of anonymity and therefore encouraging open responses to sensitive questions. However, they also warned that the written questionnaire also has its own disadvantages, particularly in the quality of data that can be obtained.

3.7.2.2 Developing the Questionnaire in This Research Study

The questionnaire attached in Appendix 2 of this thesis is designed to collect concrete information needed for this study about Six Sigma practices and the organizational performance. Part A of the survey questionnaire is to collect the general information of the organization and the Six Sigma participants. Part B of the survey questionnaire consists of two sections. Section 1 contains 45 questions in order to explore the company's quality management system and philosophy. These questions cover an extensive area of quality management practices in the company, including the internal operational systems, the supplier management and the customer information acquisition. Section 2 seeks for the information about the level of use of Six Sigma methodology and tools, including both basic Six Sigma tools and more specialized methodology such as Design for Six Sigma (DFSS). Part C asks for the impacts of Six Sigma methodology on the company performance data. It contains four short sections including Operational Efficiency, Customer Satisfaction, Business Performance and Six Sigma Participants' comments. Part D asks for the information about the Attitude and Commitment to Six Sigma. This part includes three short sections asking about the main objectives of implementing Six Sigma, the management's attitudes and understanding towards the Six

Sigma methodology.

3.7.2.3 Length of Questionnaire and Assignment of Questions in This Study

In order not to affect the quality of data collected, the researcher reviewed the survey questions with some of the key informants during the pilot study to make sure that the length of the questionnaire is not too long. The questionnaire is expected to take about one hour to be finished. The respondents agreed that the length is appropriate. The questions are designated based on theoretical foundations in quality management and Six Sigma methodology laid down in the literature. The questionnaires returned will be cross checked during the data collection stage to assure the data quality.

3.7.3 Response Rate and Data Quality in This Research Study

3.7.3.1 Enhancing Response Rates

Chadwick et al. (1984) claimed that the questionnaire survey response rate varied from a high of 95 percent to a low of 50 percent. The average rate was about 74 percent. However, Alreck and Settle (1995) were more conservative; they claimed that response rates over 30 percent are rare. Vaus (1999) pointed out that the response rate obtained in a particular study will be subjected to the combined effect of the topic, the nature of the samples and the length of the questionnaire etc. The response rate is an important consideration in survey research because a low response rate introduces bias into the sample. Yeung (1999) suggested that carefully designed research could help to increase the response rate.

3.7.3.2 Ensuring Data Quality

Yeung (1999) believed that the data quality will be decreased when relatively objective data in operations is not available. He claimed that the data reported should be assessed against the actual practices in the organization and the survey questionnaire methods should be used in conjunction with other techniques such as follow-up interviews in ensuring the quality of the data even though the quality of data is depends on the research design and data collection processes. The problem of missing response was eliminated in the present study by returning to the participants for reentering. There were a few questions not answered due to overlooking.

3.7.3.3 Pre-test and Pilot Study

Singleton et al. (1999) warned that failure to conduct adequate pre-testing can result in a meaningless study. They claimed that once the study has been conducted, it will be too late to benefit from the information. They suggested that the pre-testing should be begun as soon as the survey instrument, or even a portion of it, has been drafted. Yeung (1999) also pointed out that it is necessary to conduct a pilot study because it is necessary to compare with the suggestions in literature and the up-to-date information about the current quality management practices in industry in order to construct a reliable research instrument. Yeung further claimed that the knowledge generated by the comparison is important for evaluating the individual items and making the necessary modifications in the questionnaire which was developed largely based on literature reviews. An interview with a few of the key informants and the questionnaire survey were carried out as a pilot case study to check for clarity of wording, understanding and to validate the time required for the interview.

3.8 Data Collection

3.8.1 Qualitative Research Methods

A study by Meredith (1998 cited Richardt and Cook 1979) showed that all research conclusions drawn even if data based then 'quantitative understanding presupposes qualitative knowing' (p. 447). He pointed out that researchers could not benefit from their use of quantitative data if they cannot communicate, in common sense terms, what their numbers mean (such as the 'cost of quality' or even something as apparently straightforward as 'order size'). Yeung (1999) asserted that in order to under quantitative data more completely, researchers must have in-depth knowledge of the qualitative implications behind it. The qualitative research methods, structured interviews and review of documentation, are used here to validate, support and understanding the quantitative data collected in the survey questionnaires. The qualitative investigation also provided essential background knowledge in data analysis and interpretations in the later stage of the research.

3.8.1.1 Structured Interviews

There are a number of reasons for conducting standardized structured interviews. First of all, it focuses the interviewee so time can be used effectively; it also facilitates analysis by making responses easy to find and compare as well as minimizes variation among interviewers (Patton 2001). Patton (2001) agreed that the limitation of data is known and discussed beforehand is the strength of standardized, open-ended interviews. It also allows researchers the flexibility to request assistance in collecting data without compromising the study. However, Patton (2001) also warned that the structured interview also has its own weaknesses in that the structure of the questions does not allow the interview to pursue topics or issues that were not anticipated when the interview was written. He also pointed out that the standardized wording may limit the naturalness and relevance of questions and answers (p. 349). He advised that the weakness could be overcome by allowing the interviewees to make any comment to the interview and ask the interviewer any question at the conclusion of the interview.

3.8.1.2 Selection of Samples for Interviews in This Research Study

The targeted population for the interview-based data is the senior management and the Six Sigma teams and the quality professionals. This case study will use snowball or chain sampling as suggested by Patton (2001, p. 237), this sampling is an approach for locating information-rich key informants for information on the organization and Six Sigma projects. Patton pointed out that the process begins by asking well-situated people who know a lot about the information the researcher is going to collect or whom the researcher should talk to. Patton also suggested that the chain of recommended informants should diverge with as many possible sources as the researcher could find and then, finally converge as a few key names such as those mentioned multiple times.

The expected sample size is about 4 persons.

3.8.1.3 Protection of Human Subjects

This interview instrument will not involve the treating, testing and/or experimental manipulation of human participants. Every participant is only limited to answering the questions through interviews. The identity of key informants will be protected by assigning an alphanumeric designator to documentation that is associated with each interview. No actual names will, therefore be used in the final study.

3.8.2 Review of Documentation

The purpose of reviewing documentation is to collect information on the organizational strategies, Six Sigma project, and team members prior to the survey and also to corroborate and augment evidence from other sources (Yin 2003[1]). The reviewing of documentation will help the researcher to understand the organization by establishing the environment context of the organization. Any published documentation of this organization will help the researcher to corroborate and augment evidence on its quality strategies, the Six Sigma projects and any guiding decision models or procedures in place for the previous four year period (2004-2007). According to Yin (2003[1]), the main advantage of using documentation is to corroborate and augment evidence from other sources. It not only could help researchers to verify the correct spellings and titles or names of interviewees, it could also provide other specific details to corroborate information from other sources. Moreover, it could also help researchers to find new questions about communications and networking within the organization. However, the reviewing of documentation is not without critics, Yin (2003[1]) pointed out that the access may not be granted, and the researcher may select and/or retrieve the information based on bias. But this bias will be eliminated by using interviewing in this case study as another data source.

3.8.2.1 Protection of Company-restricted Information

Before conducting this study, the researcher will seek for permission to access the company restricted information. The data gathered from the restricted information will not be disclosed in the results of the study in order to protect respondents.

3.8.3 Selection of Samples for Survey Questionnaire in This Research Study

The target population of this survey is all of the Six Sigma belts who have had conducted, or participated in at least a Six Sigma project of the target unit for the period 2004 through 2007. The Six Sigma belts for this period will be compiled from documentation available, key informant interviewed. This will help to yield a known population of Six Sigma participants of the target unit. From the list of the total belts, a list of potential respondents will be sorted by their first names. The researcher purposed to randomly select 80 percent of the participants by putting each name on a piece of paper and folding them in half and depositing them in a large container. By pulling their names from the container, each 'belt' has an equal opportunity for selection.

The information collected from the survey will be the third source of data. This data will produce quantitative data as part of the case study evidence to determine the General Quality Practices in the company and the Operation Efficiency, Customer Satisfaction, Business Performance, Six Sigma Participants satisfaction on the Six Sigma methodology as well as the Six Sigma Methodology and Tools used in the company. The survey will follow both the sampling procedures and the instruments used in regular surveys and it will also be analyzed in a similar manner. The advantage of using a survey is it is cost effective, and it takes less time than other methods. Like all other research methods, it has its own weaknesses, such as it does not allow the researcher to probe deeply into opinions and feelings, and it could not build trust and rapport. Moreover, the researcher could not know whether the participants shared the same understanding of the topics or not.

The total number of persons interviewed and returned the questionnaire survey is summarized as Table 3.1.

Research Phase	Sample
Questionnaire survey	42 participants
Structured interviews	4 persons

Table 3.1 The summary of the total number of persons interviewed and returned the questionnaire survey
Source: this study

3.9 The Research Process

According to Patton (2002), a well-conceived strategy is the one that could provide the overall direction and a framework for action as well as for decision. This strategy is the blueprint for action for collecting data and information. The data collecting processes is shown as below:

1. Interview the key informant to get the overall picture of the Six Sigma methodology implementation.
2. Interview the key informant to identify Six Sigma Projects, team members, other key possible key informants, and opinions as to the Six Sigma methodology. Since the key informants of the case company are locating in different factories in China. The Quality Director suggested that the researcher should use the electronic interviews (Morgan and Symon 2004). The Quality Director agreed to send the interview questions to the key informants he recommended; he also offered to send the questionnaire survey to the Six Sigma participants who were selected by random sampling. The interview follow up can be made by telephone.
3. Triangulate findings from (1) interviewing the key informants, (2) Six Sigma practices surveys, and, (3) to review the documents to find out to what extent this organization implements the Six Sigma methodology in the organizational management, the value of Six Sigma methodology contributed to the organization, the benefits it brings to the Six Sigma participants and the impact on the organizational performance.

3.9.1 The Validity of Research Design

The validity of the research design will be accomplished by using multiple sources of evidence, data to check the validity of the study. The validity of survey and interviews will be checked by the triangulation method. The construct validity will be assured by using multiple sources of evidence.

3.9.2 Reliability of the research design

The goal of research reliability is to minimize the errors and biases in this study, and to ensure that any later researchers will get the same findings if they followed the same procedures as described by this study. The reliability of this case study will be accomplished by data collection and data analysis method according to Yin's suggestion (2003). The reliability of this study will include the following efforts,

1. Develop a case study database
2. Use case study protocol
3. Use both quantitative and qualitative data
4. Pretest the research instrument such as interview and survey

3.9.3 Bias minimization

Bias is any unknown or unacknowledged error created during the design, measurement, sampling, procedure, or choice of problem studied. Mehra (2002) contended that researcher bias and subjectivity are commonly understood as inevitable, researchers should be aware of their own biases, blind spots, and cognitive limitations while doing the research. In order to minimize the bias, the study will be based on multiple sources of evidences such as interviewing the key informants, analysis of the documentations and to use a previously validated instrument. The process of data triangulation will help to minimize the researcher bias.

3.9.4 Why this method is selected

As mentioned in the above, Yin (2003[1]) and Eisenhardt (1986) contented that the case study method provides researchers a great opportunity to explore a wide range of issues and helps researchers to seek for some preliminary explanations before further investigations, it also helps researchers to determine whether the research strategy is suitable for the research objective under the environmental constrains. Therefore, it is especially useful at the starting point for conducting exploratory research. Yin also claimed that the case study method allows researchers to keep the complete and meaningful characteristics of real life events of organizational and managerial processes. It has long been one of the most common research methods for use in public policy and in business and public administration (Yin 2003[2]).

In addition Patton (2002) stressed that the importance of understanding the real world's complexities in a systems perspective and the demands of viewing things as whole entities which are embedded in the context is increasing. A recent study by Olson (2005 cited Sterman 2000) showed that case study method has advantage over the survey methodology because the data yielded by surveys are not rich enough to be useful in developing system dynamics models, the data are almost never sufficient alone, therefore, they must be supplemented by other sources of data both qualitatively and quantitatively. According to Olson (2005), Sterman claimed that system research heavily depends upon qualitative inquiry, especially when the topic is related to organizational strategies to be successful.

3.10 Setting and Units of Analysis

3.10.1 Setting

This study is intent to learn about the contribution of Six Sigma methodology from the perspective of a large battery manufacturing firm where Six Sigma methodology is implemented. This large battery manufacturing firm is an international batteries manufacturing firm which engages in the development, manufacture and marketing of batteries and battery-related products. It supplies an extensive range of battery products to original equipment manufacturers, leading battery companies as well as consumer retail markets under its own brand name.

3.10.2 Units of analysis

According to Yin (2003[1]), the tentative definition of the unit of analysis is related to the way researchers defined their initial research questions. As such each unit of analysis will need a different research design and data collection method. Darke (1998) explained that "the unit of case study may be an individual, a group, and organization or it may be an event or some other phenomenon" which constitutes a 'case', and a complete collection of data for one study of the unit of analysis forms a single case. The target unit of analysis for the present study is the battery manufacturing firm (the headquarters) with its 4 units of battery producing factories in China which have been implementing or have had implemented Six Sigma Methodology. The research questions will drive this case study to employ an embedded design based on multiple tiers of analysis.

3.11 Summary

This chapter identified the research methodology and the research design. Empiricism is critical to management research as it abstracts knowledge based on the real world observations. Yeung (1999) pointed out that "the research studies in quality and operation management are shifting from artificial and rational methodologies to natural and existential paradigms". This study also employs direct observations, participants and management's perception of object reality and interpretive types of empirical methodology. Although the researcher employs interview and review of documentation as well as the fact-gathering survey methodology in this study, the use of questionnaires is the principal methodology used in data collection. The researcher also discussed the strengths and weaknesses of each of the data collection methods this study will employ. Since there is no single method that has a complete advantage over all the others more than one approach is selected (Yin 2003[1]). The researcher does her best to collect multiple evidences to ensure the data triangulation adds rigor to the process.

Chapter 4 The Use of A Research Instrument

4.1 Introduction

The aim of the research is to explore the implementation of Six Sigma in a battery manufacturing company. Reliable measurements of the concept play an important role here. The successful measure of quality improvement initiative and organizational performance largely relies on the use of a suitable research instrument and methodologies and procedures. According to Chadwick (1984), "instrument is a general name for both an interview form, a questionnaire, or other data-collection device" (p. 437). Questionnaires are used for quantitative data collection in this study. Vaus (1996) claimed that the "surveys are characterized by a structured or systematic set of data, however, the technique by which we generate the data need not be highly structured so long as each case's attribute on each variable is obtained" (p.3 & 5).

Yeung (1999) pointed out that an empirically refined and validated questionnaire may be considered as a survey instrument. He asserted that the criteria of assessing the accuracy and effectiveness of a survey instrument should be predictive and; content and construct valid as well as reliable. However, although he argued that there is no survey instrument available in the literature for Quality Management System, he believed that "the research techniques in Social and Behavior Science still can be adopted in developing an instrument in quality and operation management according to research objectives" (p. 89).

This chapter begins by summarizing the general measurement instrument development methodology which is suggested in the quality management and improvement initiatives literature. It continues by introducing the instrument used in the present study from the assignment of questions to data analyzing methods. The instrument will then be verified by use of a reliability and validity test. The researcher will also compare some of the instruments which have been developed by the renowned quality management researchers within the present study.

4.2 The Need of Adopting a New Instrument for Six Sigma initiative

Some renowned quality management researchers such as Saraph et al. (1989), Flynn et al. (1994), Badri, Davis and Davis. (1995) and Ahire et al. (1996) have developed some sophisticated instruments which have been validated empirically in industry in the last decade. These instruments provided a convenient and reliable means for measurement in the manufacturing and service sectors and in the research studies. However, most of them are for assessing TQM. In fact, Six Sigma methodology and standards are playing an important role in every business sector and are now an inseparable component of quality management. However, there is no existing instrument that has taken these factors into serious consideration.

An instrument measuring the organizational performance, customer satisfaction and Six Sigma participant satisfaction is also developed in the study. Various aspects of organizational performance related to Six Sigma methodology and quality management will also be assessed. Although organizational performance measures have been discussed by some of the renowned researchers such as Flynn et al. (1995) and Ahire et al. (1996), both of them were focused on the level of practice in the plant level instead of organization-wide study. Flynn et al. (1995) focused on measuring the market competitive performance while Ahire et al. (1996) focused on studying the product quality and supplier performance. The approach of developing and validating the instrument is an ongoing process (Dwivedi et al. 2006). As quality management paradigms are continuously shifting, therefore, developing new instruments to accurately represent the modern ideas are important (Bounds, Yorks, Adams and Ranney 1994).

4.3 Instrument Development Methods

4.3.1 The General Development Methodology

Summarizing the studies of behavioural scientists and psychologists (Likert 1967; Nunnally 1967; Sellitz et al. 1976; Kerlinger 1986; Saraph et al. 1989 and Singleton et al. 1998), Yeung (1999) developed a general methodology in developing a research instrument as Figure 4.1. The research instrument starts from an in-depth study of the theoretical foundations in the literature. The questionnaire developed is based on the literature review as well as after the research constructs or factors are identified. This researcher pre-tested the instrument in one of the largest mobile phone manufacturing firms to make sure the instrument is simple and comprehensive enough to collect the required data and make the necessary revision. After the pilot study and revision, the questionnaires are administered to the targeted participants for collecting the necessary data. The collected data will be used to analyze and verify the questionnaire. The reliability and validity of the instrument are tested and revised before it is finalized.

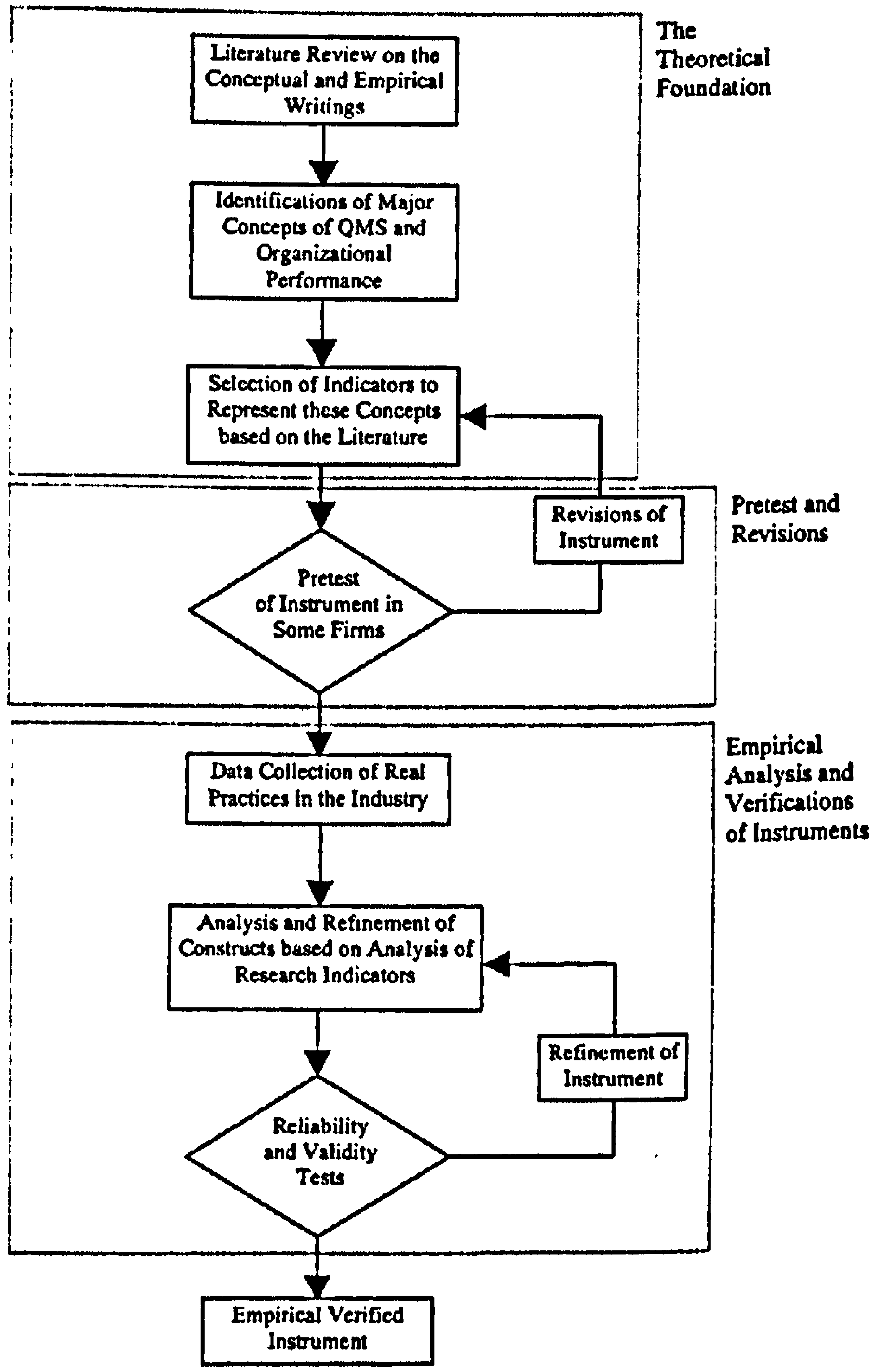


Figure 4.1 A General Instrument Development Methodology Model by Yeung (1999)

4.3.2 Construction and Refinements: Factor and Principal Component Analysis

Comrey and Lee (1992, p.1) stressed that discovering the nature of relationships between variables is a very important part of any scientific field. Factor analysis is a multivariate statistical method which can help scientists to address the problem of analyzing the structure of the interrelationships among a large number of variables of questionnaire responses by defining a set of common underlying dimensions known as factors (Hair, Anderson, Tatham and Black 1998; Comrey et al., 1992). Hair et al., pointed out that the factor analysis is an interdependence technique in which all variables are simultaneously considered in order to maximize their explanation of the entire variable set, not to predict a dependent variable(s). They further pointed out that the purposes of factor analytic techniques can be achieved from either an exploratory perspective which researchers consider it only useful in searching for structure among a set of variables or as a data reduction method or confirmatory perspective which researchers may use to test hypotheses involving issues such as which variables should be grouped together on a factor or the precise number of factors.

Although factor analysis is very similar to Principal Component Analysis (PCA), some researchers such as Yeung (1999) and Hair et al. (1998) defined that factor analysis is a general name for Exploratory Factory Analysis (EFA) and PCA. Yang and Trewn (2004) pointed out that factor analysis places more emphasis on the identification of underlying "factors" that might explain the mutual correlative relationship. However, PCA is used to determine factors in order to explain as much of the total variation in the data as possible (Yang et al., 2004 cited Dillon and Goldstein 1984). (Figure 4.2 illustrates the flow chart of factor analysis). PCA makes no assumption about an underlying causal model.

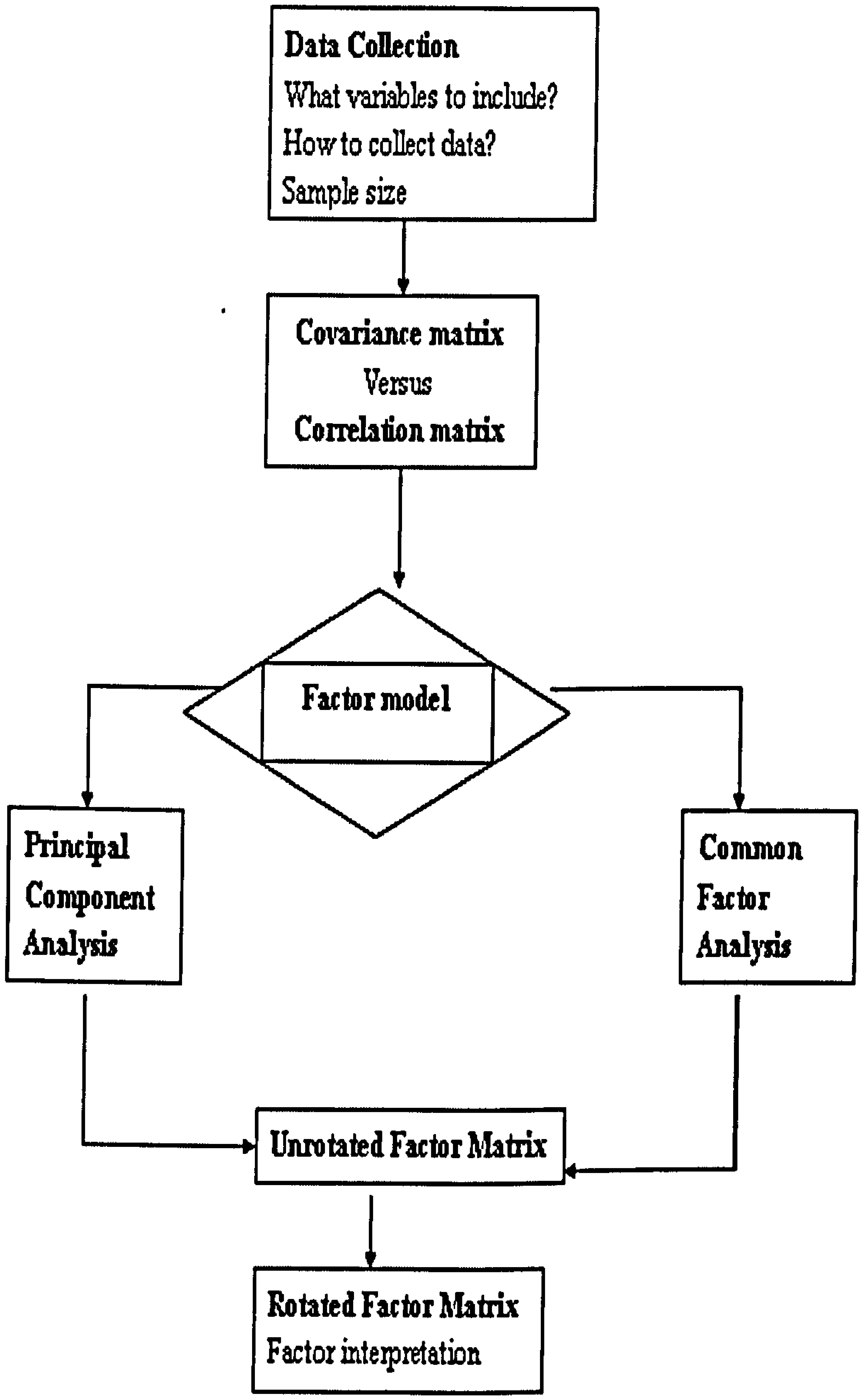


Figure 4.2 Factor analysis flow chart by Yang et al. (2004, p. 142)

Limitations of Factor Analysis. Although factor analysis uses only the latent dimensions and more restrictive assumptions, it still has several problems. Hair et al. (1998) pointed out that the first problem is that factor analysis suffers from factor indeterminacy that means for each individual respondent, just several different factor scores can be calculated from the factor model results. The second problem involves the calculation of the estimated communalities used to represent the shared variance, they argued that for larger-sized problems, the computations can take substantial computer time and resources and the communalities are not always estimable or may be invalid so that the deletion of the variable from the analysis is required.

Hair et al. (1998) and Field (2002) agreed that although there remains considerable debate which factor model is the more appropriate, empirical research has demonstrated similar results in many instances. They pointed out that in most applications, both component analysis and factor analysis arrive at essentially identical results if the number of variables is more than 30 or the communalities exceed 0.6 for most variables.

4.3.3 Testing and Verifications

Reliability and validity are the terms that social scientists used to describe the issues involved in evaluating the quality of operational definitions (Singleton et al. 1999). Both of them are used to deal with the level of excellence of a measuring instrument (Kerlinger et al. 2000). They claimed that if researchers do not know the reliability and validity of their data, little faith can be put in the results they obtained and their conclusions drawn from the results.

4.3.3.1 Reliability Measures

The reliability of a measurement is defined as the extent to which it is free from random error components (Judd et al. 1991). Kelinger et al. (1999) explained that reliability as synonymous with dependability, stability, consistency, reproducibility, predictability and lack of distortion. A reliable instrument must allow different researchers to obtain the same results or permit different researchers to use the same instrument to arrive at similar measures of the same subject at different times (Thietart et al. 2001). Yeung (1999) claimed that the reliability of an instrument is reflected by its internal consistency. The internal consistency is an approach in which a researcher examines the relationships among all the items at the same time rather than splitting the items into halves (Singleton et al. 1999). According to Thietart et al's study (2001 cited Cronbach 1951) it is shown that Cronbach's Alpha is the best known and most often used method to estimate the reliability coefficients that measure the internal cohesion of a scale without the need of splitting or duplicating items. Cronbach's coefficient value varies between 0 and 1. The closer it is to 1, the stronger the internal cohesion of the scale. Thietart et al. (2001) contended that the value of Cronbach's coefficient equal to 0.7 or above is normally accepted. However, a study by Yeung (1999 cited Nunnally 1967; Van de Venn and Ferry 1980) showed that reliability of 0.6 is acceptable in exploratory studies and some even suggest a lower value of 0.5.

4.3.3.2 Validity Measures

Validity is used to assess the relevance and the precision of research results, and assessing the extent to which we can generalize from these results (Thietart et al. 2001). It is complex, controversial, and peculiarly important subject in the behavioral research area (Kerlinger et al. 2000). Thietart et al. (2001) pointed out that in order to assess the overall validity of research, it is necessary to be sure of various more specific types of validity such as construct validity, the validity of the measuring instrument, the internal validity of the research results and the external validity of those same results (p. 196). They pointed out that among the different types of validity, the criterion-related validity content validity and construct validity are the most often used. Judd et al. (1991) also warned that reliability is the prerequisite of the validity. They argued that if a score is absolutely unreliable, the score must also be not valid.

Content Validity

Kerlinger et al. (2000) defined 'content validity is the representativeness or sampling adequacy of the content — the substance, the matter, the topic—of a measuring instrument' (p. 667). It assesses whether the substance or content of the measure represent the universe of content of the property being measured. However, they argued that it is impossible to draw random samples of items from a universe of content. The universe only exists theoretically. The content validation is basically judgmental.

Construct Validity

Construct validity is one of the most significant scientific advances of modern measurement theory and practice (Kerlinger et al. 2000). Construct validity is broadly defined by Bagozzi, Yi; and Phillips (1991) as the extent to which an organizational measures the concept it is supposed to measure. It is believed as the only one that is really relevant in social sciences (Thietart et al. 2001 cited Cronbach and Meehl 1955). Construct validity depends on the correct definition of a specified construct and hypothetical linkages presumed between the construct and indicators (Yeung 1999). It is examined by unifactorial tests and of factor loadings.

Criteria-related Validity

Criteria-related validity refers to the extent to which a measuring instrument is related to an independent measure of the relevant criterion (Wee 2005). It is used to measure the instruments which have been developed for some practical problem and outcomes other than testing hypotheses or advancing scientific knowledge (Singleton et al. 1999; Kerlinger et al. 2000). There are two types of criterion-related validity which are *predictive validity* and *concurrent validity*. Predictive validity involves the use of future performance of the criterion but the concurrent validity measures the criterion at about the same time, it is often used to validate a new test (Kerlinger et al. 2000).

Criterion related validity can be tested by correlating predictor variables on the instrument with criterion scores on another instrument (Yeung 1999). The correlation is known as the validity coefficient which indicates how well the criterion scores can be predicted from the instrument scores. Flynn et al. (1990) suggested two techniques that are generally used to test the criterion-related validity. The techniques are *simple correlation* which is used to test a summated scale with a single outcome, and the *canonical correlation* which is used to test a set of summated scales, or battery of summated scales with multiple outcomes. The criterion-related validity is tested by calculating the Pearson correlation in his study.

4.4 The Use of Instrument in Six Sigma

Theoretical Foundations from the Literature

Since its inception in 1987, Six Sigma has been gaining more attention and acceptance in industry as a quality improvement framework (Goh 2004; Hendry 2005). Its popularity has also led to an increasing level of interest from the academic community, with substantial increase in the number of academic papers published in recent years (Hendry 2005 cited Nonthaleerak and Hendry 2005). Many theories and guidelines have been provided about how Six Sigma methodology should be implemented in an organization. In the development of theories for an effective Six Sigma methodology implementation, Six Sigma 'gurus', practitioners and academic researchers have played an important role.

The construction of this research instrument is supported by theoretical foundations in the quality related literature. The section 1 of Part B of the survey questionnaire is used to measure the quality practices in the organization. It is developed based on the review of various types of literature, but Yeung's questionnaire survey approach (1999) is used as the major reference in the construction of the survey questionnaire.

4.5 Analysis and Refinement of the Instrument in this Research Study

4.5.1 The Empirical Data for Analysis

The survey questionnaires used in the present study were successfully administrated in one of the major international battery manufacturers. The case study company provided three waves of Six Sigma training for its eight business units and factories in the year of 2004 and 2006. A total of 109 persons were trained, 9 persons were certified as Black Belts and 91 were certified as Green Belts. Only five production plants had conducted Six Sigma projects between the years of 2004 to 2007. However, one of the production plants "RCM" was reluctant to participate in the study, only one copy interview question and one copy of questionnaire survey were received at the time of study and the plant refused to go further for the study and was therefore not included in this research. The population size of the four business units is 66 belts combined with 7

Black Belts and 59 Green Belts; plus 2 senior executives at the corporate level is 68 belts. Eighty percent of the population were randomly selected and required to report various aspects of quality management practices and organizational performance in the past four years through a series of structured questions on the survey instrument. Forty-two questionnaires were returned, with the response rate being about 77%. In order to provide more reliable information, senior executives who have enough experience in their company were required. This kind of data enabled the researcher to further analyze whether Six Sigma methodology is worthy to be introduced into organizations.

4.5.2 Factor Analysis of Individual Six Sigma Constructs

As mentioned above, the research instrument is designed to measure various aspects of Six Sigma implementation, including Senior Management Commitment and Involvement, Customer Focus, Supplier Management, Six Sigma team management System, Internal Quality System and the Use of Six Sigma tools. Instead of simply reducing the variables into a smaller set of manageable variables using Principal Component Analysis (PCA), this research is intended to identify the underlying constructs of Six Sigma and in quantifying the factor loading of each indicator. Factor analysis is an appropriate method for this purpose.

Analysis on the responses from the questionnaires returned from the sample was conducted using the statistical software package, SPSS 12.0. The first four distinguishing constructs of Senior Management Commitment and Involvement, Customer Focus, Supplier Management and Six Sigma Team Management System were examined separately by factor analysis. As shown in The Refined Research Instrument (see Appendix 3), the Senior Management Commitment and Involvement construct contains 7 indicators while both Customer Focus and Supplier Management constructs consist of 6 items, the Six Sigma Team Management construct contains 9 indicators. The Kaiser-Meyer-Olkin (KMO) measures of these four constructs ranged from 0.732 to 0.882, indicating that the data structures are appropriate for factor analysis (Pallant 2005; Field 2005). Factor analysis of these four individual constructs showed that each variable in the constructs loads on only one factor. The unifactor solution confirms that each of these constructs measures only one underlying idea. The variances explained by these factors are 67.597%, 52.888%, 70.825% and 66.704% respectively which are adequate. The factor loadings ranged from 0.626 to 0.937 which well exceeds the generally recommended minimum value of 0.3 (Pallant 2005; Hair et al. 1998; Kerlinger et al. 2000; Kline 1994; Pedhazur and Schmelkin 1991).

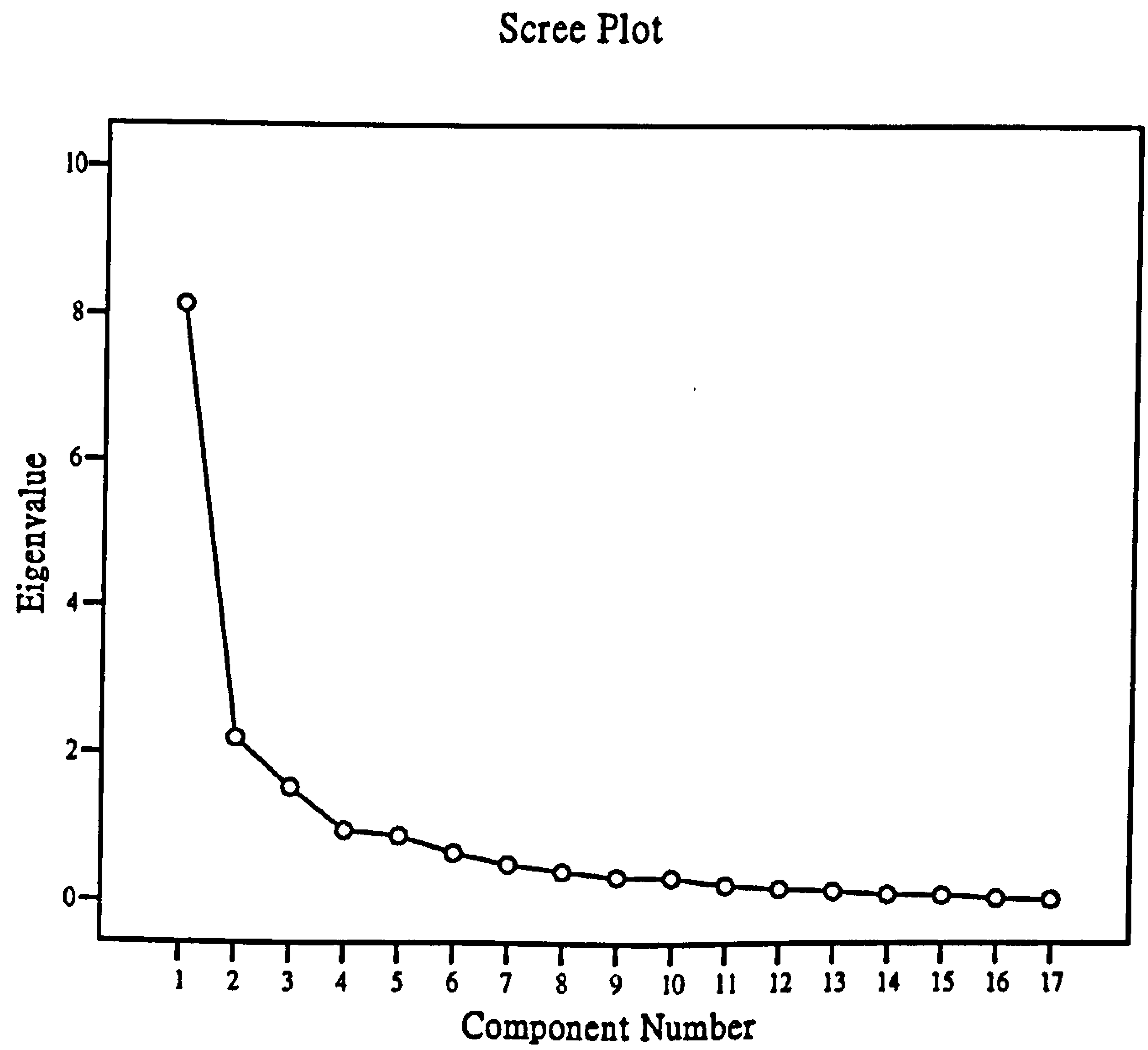
The results of the factor analysis of the constructs are shown in Table 4.1. All questions in the questionnaires are abbreviated in order to make it easier for presentation. The letters of the alphabet represent the order of the variables in the questionnaire. The detailed descriptions of each item can be found in Appendix 3.

Senior Management Commitment and Involvement		**Customer Focus**		**Supplier Management**		**Six Sigma Team Management System**	
Research Variable	Factor Loading	Research Variable	Factor Loading	Research Variable	Factor Loading	Research Variable	Factor Loading
Part_B_1 Q42	0.914	Part_B_1 Q03	0.825	Part_B_1 Q35	0.937	Part_B_1 Q10	0.907
Part_B_1 Q41	0.909	Part_B_1 Q05	0.784	Part_B_1 Q34	0.911	Part_B_1 Q12	0.903
Part_B_1 Q19	0818	Part_B_1 Q04	0.749	Part_B_1 Q38	0.909	Part_B_1 Q13	0.889
Part_B_1 Q43	0.816	Part_B_1 Q06	0.672	Part_B_1 Q37	0.872	Part_B_1 Q15	0.827
Part_B_1 Q20	0.799	Part_B_1 Q01	0.669	Part_B_1 Q36	0.750	Part_B_1 Q11	0.809
Part_B_1 Q40	0.742	Part_B_1 Q02	0.646	Part_B_1 Q39	0626	Part_B_1 Q09	0.776
Part_B_1 Q33	0.739					Part_B_1 Q14	0.774
						Part_B_1 Q23	0.757
						Part_B_1 Q26	0.680

Table 4.1 Factor Analysis of Individual Six Sigma constructs
Source: this study

4.5.3 Factor Analysis of Internal Implementation of Six Sigma Methodology

Internal implementation of Six Sigma methodology consists of more complicated and inter-dependent constructs. There are **17** items of practices which represent the internal operations of a Six Sigma methodology. The initial examination of data using KMO measure derived a value of **0.784** which indicated that the data is good correlated and is appropriate for factor analysis. For these data, Bartlett's test is highly significant **($p<0.001$)**, rejecting the null hypothesis that the variables are uncorrelated, therefore, factor analysis is appropriate (Field 2005; Pallant 2005). Three factors with eigenvalues or latent roots greater than 1 were found as shown in SPSS Output 4.1. Field (2005) pointed out that it is possible to obtain as many factors as there are variables and that each has an associated eigenvalue. Kaiser recommended retaining all factors with eigenvalues greater than 1 however, Jolliffe argued that Kaiser's criterion is too strict and suggests retaining all factors with eigenvalues more than .7 (Field 2005). Since the difference between how many factors are retained using Kaiser's methods compared to Jolliff's can be dramatic, therefore, Field (2005) stressed that factor analysis is only an exploratory tool and so it should be used to guide the researcher to make various decisions, researchers should not leave the computer to make the decisions for them. Latent Variable Criterion is the most commonly used technique to determine the number of factors to be extracted (Yeung 1999). Factor 1 accounted for considerably more variance than the remaining three (47.883% compared to 13.028%, and 9.176%); the cumulative eigenvalue for the first three factors explaining 70.086% of the total variance. Use of both the scree test criterion and Kaiser's criterion further confirms that these three factors should be extracted.



SPSS Output 4.1. The Eigenvalues of Factor 1-17
Source: this study

4.5.3.1 Rotation of Factors

Once factors have been extracted, it is possible to calculate to what degree variables load onto these factors, however, most of the variables have high loadings on the most important factor, and are small on all other factors, which makes interpretation difficult; therefore, factor rotation is employed to discriminate between factors (Hair 1998; Field 2005). There are two types of rotation that can be done (Field 2005). They are orthogonal rotation and oblique rotation. Before rotation, all factors are independent and orthogonal rotation ensures that the factors remain uncorrelated but oblique rotation allows factors to be correlated. By orthogonal rotation, the axes are turned while remaining perpendicular (Hair et al. 1998; Johnson et al. 2002; Field 2005). Since correlation between factors is permitted in the oblique rotation, it is therefore more complex to interpret (Field 2005). The orthogonal rotation is used in the present study. The rotated factor solution is shown in SPSS Output 4.2.

Rotated Component Matrix[a]

	Component		
	1	2	3
Our company has been trying to accomplish continuous improvement throughout all domains from planning through operations.	.845		
We have been analyzing all relevant quality records, such as service reports, customer complaints, work instructions to detect and eliminate potential causes of non-conforming products.	.843		
We study every process in order to eliminate any problem before it happened.	.738		
We have always recorded the scrap and rework rates of our products or process for the reference of management and workers.	.720		
We study the root causes and take corrective actions every time after a problem is found.	.681	.412	
We use Six Sigma methodology for solving every quality related problem.	.658		
Six Sigma teams handled almost all quality problems.	.645	.403	
We have been studying the variations in our production processes, identifying the undesirable variations, and acting on its sources to achieve greater consistency of product.	.620	.513	
We have not been satisfied with just meeting the required specifications in our production processes, we are making efforts to minimize the deviations from the target points.	.539	.477	.527
The Six Sigma language creates a closer bond between different business units.		.897	
We have been making use of quality cost information as a tool to reduce the overall production costs.		.838	
We have always been considering the potential quality problems in manufacturing processes in the product design stage.		.825	
Six Sigma becomes a common language in our company for different business units to talk to one another.		.779	
Our marketing staff are fully aware of and responsible for the quality of product and services they provide to our customers		.669	
We are striving to reach the Six Sigma level.			-.774
We have been trying to find out the causes for high operational costs, identifying and solving them to reduce the unit cost of manufacturing.		.458	.668
Our employees have always been rewarded by management for the improvements of product quality they produce.	.531		.546

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 4 iterations.

SPSS Output 4.2. Factor Analysis of Internal Implementation of Six Sigma Methodology
Source: this study

As can be seen from SPSS Output 4.2, the main loadings on Component 1 seem to relate to the process control and improvement in the organization. The main loadings on Component 2 seem to relate to the quality system procedure and the main loadings on Component 3 seem to relate to quality performance. Therefore, the Component 1, Component 2 and Component 3 were labelled as Process Control & Improvement, Quality System Procedure and Quality Performance respectively.

4.5.3.2 Interpretation of Factors

Three factors were extracted by factor analysis. All of the factor loadings in each factor exceed the value of 0.4 which is considered acceptable. Factor loading can be thought of as the Pearson correlation between a factor and a variable; it tells us about the relative contribution that a variable makes to a factor (Field 2005). It indicates the percentage of variance of a variable explained by its corresponding factor and hence can be used in weighing the relative importance of individual indicators (Hair et al. 1998). High factor loadings indicate that the indicators have a satisfactory representation of their underlying construct. In the present study, the underlying constructs in the internal quality system influencing each set of indicators are interpreted with extensive references to the literature. The interpretation and definitions of these constructs are attached in Appendix 3 and summarized in Table 4.2.

Factor	Number of Indicators	Interpretation of Construct	Examples of Activities
Factor 1	9	Process Control & Improvement	Analyze all relevant quality records
Factor 2	5	Quality System Procedure	Study the potential problems in the product design stage
Factor 3	3	Quality Performance	Striving for Six Sigma level

Table 4.2 The Interpretation of Factors in Internal Implementation of Six Sigma Methodology
Source: this study

However, the values in the column labelled Corrected Item-Total Correlation are all above 0.3 except the item Part_B_1_Q21 which is below 0.3. This indicates fairly bad internal consistency and identifies the item Part_B_1_Q21 as a potential problem. The values in the column labeled Cronbach's *Alpha if Item Deleted* indicates that deleting the item Part_B_1_Q21 would slightly decrease the reliability from 0.580 to 0.542 because the value 0.580 of this item is larger than the overall reliability of 0.548 (SPSS Output 4.3). Unlike the previous subscales, the overall α is quite low (0.548), and although this is keeping with what Kline says we should expect for this kind of social science data, it is well below the scales. The scale has three items, compared to seven, nine, six and five on the other scales, so its reduced reliability is not going to be dramatically affected by the number of items. If we look at the items on this subscale, they cover quite diverse themes of quality performance, and this might explain the relative lack of consistency.

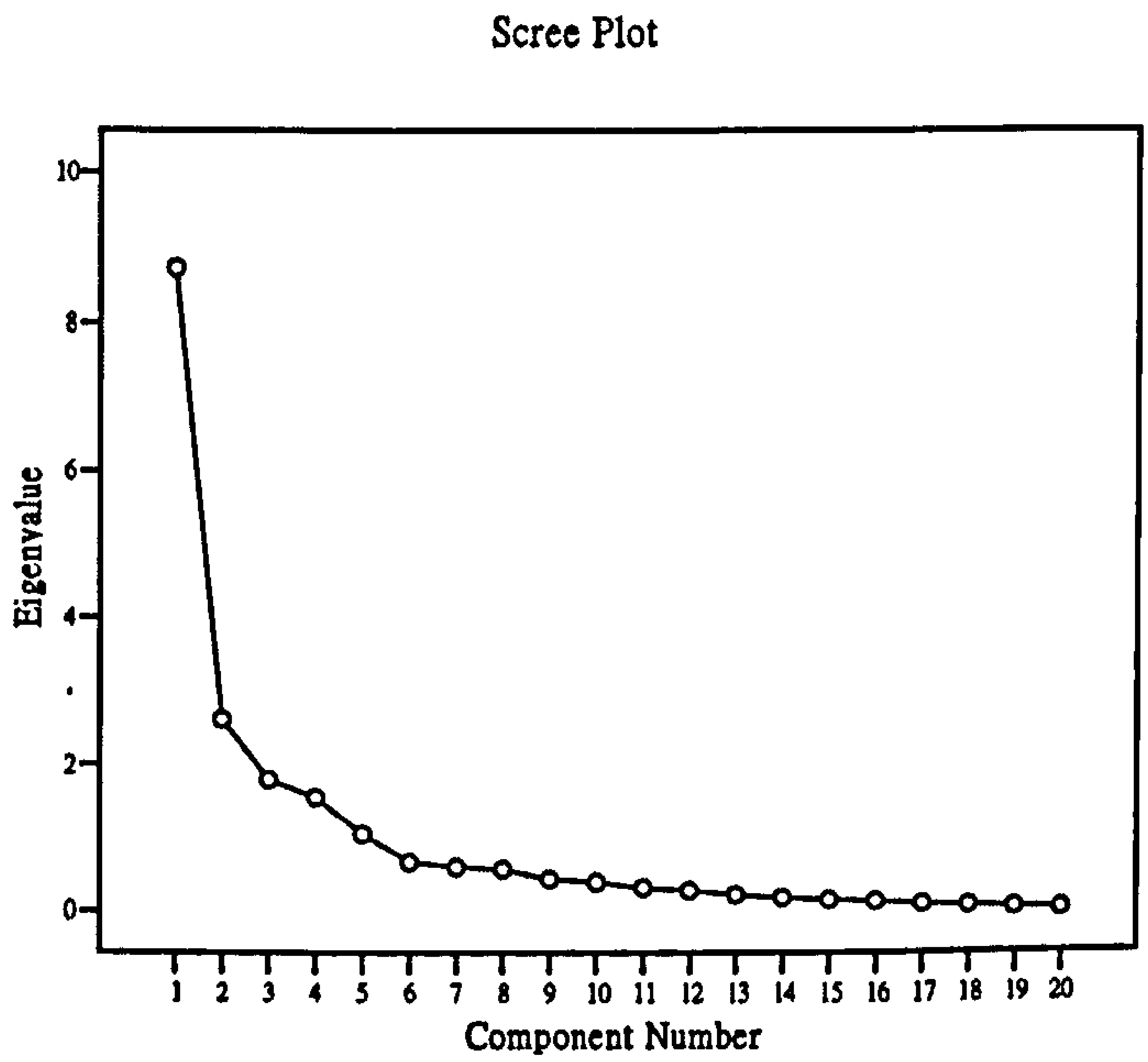
Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Our employees have always been rewarded by management for the improvements of product quality they produce.	7.17	4.191	.365	.168	.439
We are striving to reach the Six Sigma level.	9.43	5.373	.263	.084	.580
We have been trying to find out the causes for high operational costs, identifying and solving them to reduce the unit cost of manufacturing.	6.98	3.634	.464	.219	.261

SPSS Output 4.3. The Item Total Statistics of Quality Performance
Source: this study

4.5.4 Factor Analysis of Six Sigma methodology and Tools

The twenty items of Six Sigma methodology and tools are factor analyzed. The KMO value equals to **0.767** which is good (Field 2005, p.650). Five factors were produced. They have a cumulative eigenvalue of **15.753**, explaining **78.764%** of total variance. However, there is quite a clear break between the second and third components. Components 1 and 2 explain or capture much more of the variance than the remaining components (SPSS Output 4.4). There is also another break after the fourth component. From this plot, researcher retained only three components. The factor loadings range from 0.438 to 0.858 which are satisfactory (SPSS 4.5).



SPSS Output 4.4. The Scree Plot of Six Sigma methodology and Tools
Source: this study

Component Matrix[a]

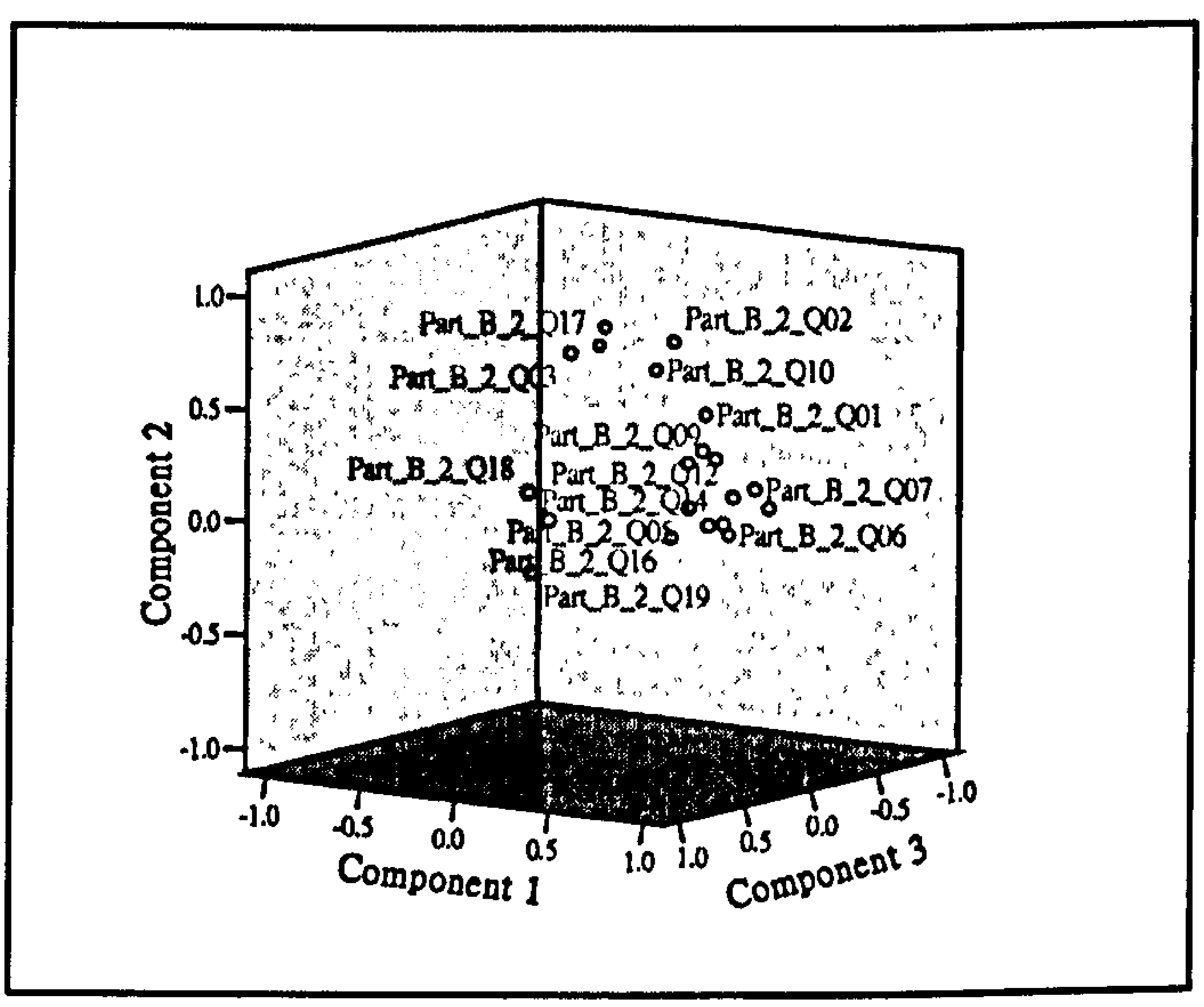
	Component		
	1	2	3
Design For Six Sigma (DFSS)	.858		
Voice of the Customer Data Collection Worksheet	.848		
Quality Data Checklist & Scorecard	.839		
DMAIC Measurement Selection Matrix	.822		
Voice of the Customer Requirement Translation and Kano Analysis	.791		
Measurement Assessment Tree Diagram	.789		
Thought Map Relations Diagram	.774		
House of Quality - Quality Functional Deployment Matrix	.760		
Suppliers-Inputs-Process-Outputs-Customers (SIPOC)	.745		
Critical to Quality CTQ Tree Diagram	.709		
Failure Modes and Effects Analysis (FMEA)	.619	.593	
Cause and Effect Matrix	.545	.489	
Customer Segmentation Worksheet	.528		
Production Schedule to Actual Scorecard	.438		
Brainstorming & Affinity Group Tool		.743	
Pareto Chart		.686	
Root Cause Analysis	.542	.580	
Six Sigma Team Roles	.545		.693
Six Sigma Project Charter	.613		.657
Team Empowerment Boundaries			.619

Extraction Method: Principal Component Analysis.
a. 3 components extracted.

SPSS Output 4.5. Factor Analysis of Six Sigma methodology and Tools
Source: this study

The factor solution is shown in SPSS Output 4.5 and a three dimensional factor plot is presented in SPSS Output 4.6. The first factor includes Design For Six Sigma (DFSS), DMAIC Measurement Selection Matrix, House of Quality - Quality Functional Deployment Matrix and Failure Modes and Effects Analysis (FMEA) which represents some advance quality management & Six Sigma analytical tools which are less commonly used in the organization. The second factor consists of Root Cause Analysis, Brainstorming & Affinity Group Tool and Pareto Chart represents some commonly used quality tool in the organization. They are simpler techniques. The third factor consists of Six Sigma Project Charter, Six Sigma Team Roles and Team Empowerment Boundaries which are used to keep track of the project result and participants' responsibilities in each project. The tools are also not very commonly used in the organization.

Component Plot in Rotated Space



SPSS Output 4.6 The Three dimensional factor plot of Six Sigma methodology and Tools
Source: this study

4.5.5 Factor Analysis of Organizational Performance

The analysis of organizational performance indicators is started by examining the Operational Efficiency. The KMO value of the study variables is 0.853 which is considered as great (Field 2005). The unifactor solution confirms that each of the construct measures only one underlying idea which explains 66.844% of the total variance. The factor loadings of these research variables range from 0.615 to 0.876, implying a good representation of indicators. The factor solution is presented in SPSS Output 4.7.

Component Matrix[a]

	Component
	1
Six Sigma methodology helps us to reduce defect and rework rates.	.876
Six Sigma methodology helps us to reduce the Total Quality Costs.	.874
Six Sigma methodology helps us to reduce the unit cost of product.	.867
Six Sigma methodology helps us to improve manufacturing lead time (Product Cycle Time).	.864
Six Sigma methodology helps us to reduce inventory turnover rate.	.834
Six Sigma methodology helps us to improve the delivery speed and reliability.	.758
Six Sigma methodology helps us to reduce employee turnover rate.	.615

Extraction Method: Principal Component Analysis.
a. 1 components extracted.

SPSS Output 4.7. Factor Analysis of Operational Efficiency
Source: this study

The factor analysis of Customer Satisfaction and Business Performance indicates that they are unifactors. The KMO value of Customer Satisfaction is 0.681 which is considered as mediocre and The KMO value of Business Performance is 0.745 which is considered as good. However, the factor analysis indicated that there were two constructs underlying Participants Comments. These two constructs explain 62.955% of the total variance which is relatively high, implying overall good representations.

Rotated Component Matrix[a]

	Component 1	Component 2
Six Sigma improved our team spirits.	.927	
Six Sigma team members are well respected in the company.	.828	
I am honored to be a member of a Six Sigma team.	.766	
I have ownership of each Six Sigma Project I participated in.	.711	
Six Sigma methodology training improved my problem solving skills.	.694	
Six Sigma Project(s) increased my sense of belonging to this company.	.641	
Six Sigma Project team members will have a better career path than those non-team members.	.567	.411
There is always a reward for the Six Sigma team who successfully finished the project.		.819
Six Sigma methodology is a valuable approach which will bring benefits to the stakeholders in the future.		.815
Six Sigma methodology creates permanent change through altering the organizational paradigm.		.737
Six Sigma projects mainly come in on budget.		.734
Six Sigma Project(s) bring me even better job satisfaction.	.481	.603
Six Sigma projects mainly come in on schedule.		.498

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 3 iterations.

SPSS Output 4.8. Factor Analysis of Participants Comments
Source: this study

As can be seen from SPSS Output 4.8, the main loadings on Component 1 seem to relate to participants satisfaction of being as a Six Sigma practitioner in the organization. The main loadings on Component 2 seem to relate to the values that Six Sigma methodology creates to the organization. Therefore, the Component 1 and Component 2 were labelled as *Job Satisfaction* and *Satisfaction with Six Sigma methodology*.

The factor loadings of these four constructs range from 0.580 to 0.949, which are satisfactory (see SPSS Output 4.9 – 4.12)

Component Matrix[a]

	Component 1
Six Sigma methodology helps us to improve the reputation of our products.	.920
Six Sigma methodology helps us to improve the overall corporate image.	.879
Six Sigma methodology helps us to improve the customer relationship.	.794
Six Sigma methodology helps us to improve product reliability.	.632
Six Sigma methodology helps us to reduce customer complaints.	.580

Extraction Method: Principal Component Analysis.
a. 1 components extracted.

SPSS Output 4.9. Factor Analysis of Customer Satisfaction
Source: this study

Component Matrix[a]

	Component
	1
Six Sigma methodology helps us to improve Profit Margins.	.934
Six Sigma methodology helps us to improve Overall Profitability.	.927
Six Sigma methodology helps us to improve market share.	.895
Six Sigma methodology helps us to improve stock price.	.780
Six Sigma methodology helps us to increase Sales Volume.	.757
Six Sigma methodology helps us to improve the Return on Investment.	.751

Extraction Method: Principal Component Analysis.
a. 1 components extracted.

SPSS Output 4.10. Factor Analysis of Business Performance
Source: this study

Component Matrix[a]

	Component
	1
Six Sigma improved our team spirits.	.949
Six Sigma team members are well respected in the company.	.820
I am honored to be a member of a Six Sigma team.	.795
I have ownership of each Six Sigma Project I participated in.	.769
Six Sigma Project(s) increased my sense of belonging to this company.	.735
Six Sigma methodology training improved my problem solving skills.	.718
Six Sigma Project team members will have a better career path than those non-team members.	.677

Extraction Method: Principal Component Analysis.
a. 1 components extracted.

SPSS Output 4.11. Factor Analysis of Job Satisfaction
Source: this study

Component Matrix[a]

	Component
	1
There is always a reward for the Six Sigma team who successfully finished the project.	.859
Six Sigma projects mainly come in on budget.	.849
Six Sigma methodology creates permanent change through altering the organizational paradigm.	.820
Six Sigma Project(s) bring me even better job satisfaction.	.748
Six Sigma methodology is a valuable approach which will bring benefits to the stakeholders in the future.	.681
Six Sigma projects mainly come in on schedule.	.650

Extraction Method: Principal Component Analysis.
a. 1 components extracted.

SPSS Output 4.12. Factor Analysis of Satisfaction with Six Sigma methodology
Source: this study

4.5.6 Factor Analysis of Attitude and Commitment to Six Sigma

The Six Sigma participants and the senior executive of the corporate level are required to report their main objectives of implementing the Six Sigma initiatives, attitude towards the philosophy of Six Sigma and the confidence level of understanding the contents and objectives of the methodology. Except for the 'attitudes", the factor analysis indicated that there were two constructs underlying it. These two constructs explain 64.154% of the total variance which is acceptable. The factor analysis of the "objectives of continuous improvement" and "understanding" showed that each variable in the constructs loads on only one factor. The KMO measures for the "objectives of continuous improvement" and "understanding" are 0.794 and 0.636 respectively. The Factor analysis of the five research variables in the "objective of continuous improvement" indicates that it is a unifactor which explain 61.691% of total variance. The factor loadings range from 0.697 to 0.874 which are satisfactory (see SPSS Output 4.13).

Component Matrix[a]

	Component 1
To increase customer confidence.	.874
To pursue even higher quality standard.	.821
To increase the consistency of product quality.	.811
To increase the financial benefits.	.708
To promote the company image.	.697

Extraction Method: Principal Component Analysis.
a. 1 components extracted.

SPSS Output 4.13 Factor Analyses of Objectives of Continuous Improvement
Source: this study

Factor analysis suggests that the company has only one purpose for implementing the Six Sigma methodology which is to drive the organization to continuously seek improvement in order to increase "customer confidence", to "pursue an even higher quality standard", to increase the consistency of product quality, to "increase the financial benefits" and to "promote the company image".

The KMO measure for the construct of "attitude towards Six Sigma methodology", which includes four variables, is only 0.389. The factor analysis suggests two factors. The factor loadings range from -0.411 to 0.855 which are acceptable (see SPSS Output

4.14 and SPSS Output 4.15). As can be seen from SPSS Output 4.14, the main loading on Component 1 seem to relate to the reliance on the Six Sigma methodology while the main loading on Component 2 seems that the participants are treating Six Sigma as another business model. After conducting the individual PCA, the Component 1 has the same loadings 0.743 on both variables (See SPSS Output 4.15) while the Component 2 has the same loadings 0.768 on the 2 variables (See SPSS Output 4.16). Therefore, the Component 1 and Component 2 were labelled as Application and Practice of Six Sigma Methodology and Treating Six Sigma as another business model respectively. The factor analysis might imply that the Six Sigma practitioners did not know the positioning of the Six Sigma methodology in the organization very well. However, the reliability index of Cronbach's Alpha test is still unacceptable (reliability measures will be discussed in the next section). A low Cronbach's Alpha test value indicates an inconsistency in answering the questions and hence the reliability of the scale is questionable.

Rotated Component Matrix[a]

	Component	
	1	2
We have been always reviewing the documented Six Sigma practices to see whether they are the most efficient ways and try to improve them.	.855	
We see Six Sigma initiative as a marketing tool.	.411	
We believe that Six Sigma is just another business overhead, it will not improve our product quality.	.413	.820
Our management cares about how Six Sigma can improve the efficiency of the entire company.	.565	-.706

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 3 iterations.

SPSS Output 4.14 Factor Analysis of Attitudes towards Six Sigma methodology
Source: this study

Component Matrix[a]

	Component
	1
We see Six Sigma initiative as a marketing tool.	.743
We have been always reviewing the documented Six Sigma practices to see whether they are the most efficient ways and try to improve them.	.743

Extraction Method: Principal Component Analysis.
a. 1 components extracted.

SPSS Output 4.15 Factor Analysis of Attitudes towards Six Sigma methodology (Application and Practice of Six Sigma Methodology)
Source: this study

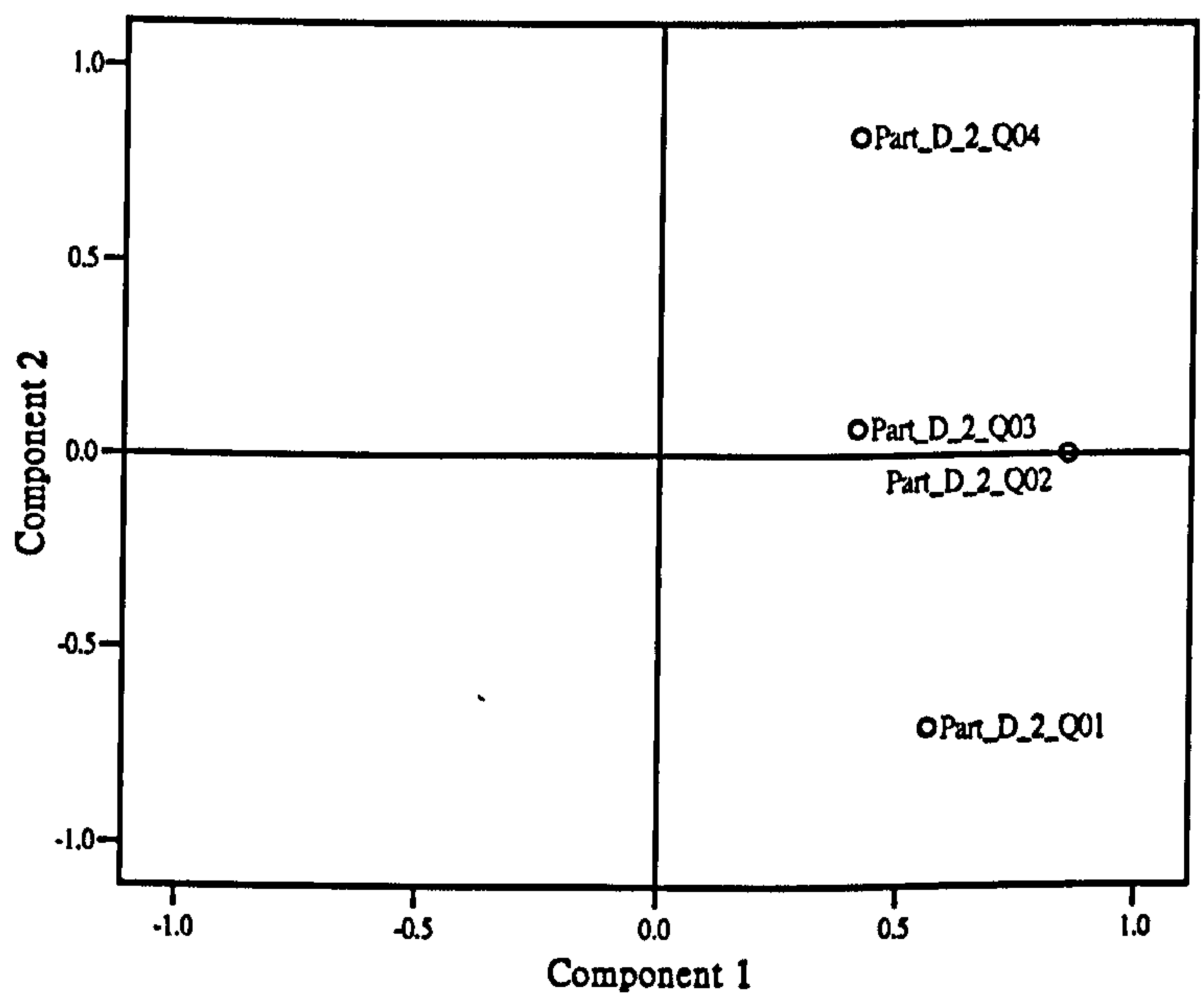
Component Matrix[a]

	Component
	1
We believe that Six Sigma is just another business overhead, it will not improve our product quality.	.768
Our management cares about how Six Sigma can improve the efficiency of the entire company.	.768

Extraction Method: Principal Component Analysis.
a. 1 components extracted.

SPSS Output 4.16 Factor Analysis of Attitudes towards Six Sigma methodology (Treating Six Sigma as another business model)
Source: this study

Component Plot in Rotated Space



SPSS Output 4.17 The Two Dimensional Factor Plot of the Attitudes towards Six Sigma methodology
Source: this study

The factor analysis of "understanding of Six Sigma methodology" suggests that it is a unifactor construct. Factor loadings range from 0.856 to 0.966 and the total variance explained is 83.680%. Both the understanding of the objectives and functions of Six Sigma methodology and the philosophy of Six Sigma are assessed in the questionnaire. The results suggested that the understanding of the objectives and functions of Six

Sigma methodology is highly correlated with the understanding of the Six Sigma philosophy, suggesting that knowledge of Six Sigma philosophy and the organization's objective of implementing the Six Sigma methodology might be complementary to each other.

Component Matrix[a]

	Component
	1
We udnerstand the contents of Six Sigma well.	.966
We understand the objectives and functions of Six Sigma well.	.919
We understand the philosophy and techniques of Six Sigma well.	.856

Extraction Method: Principal Component Analysis.
a. 1 components extracted.

SPSS Output 4.18 Factor Analysis of Understanding of Six Sigma Methodology
Source: this study

4.6 Reliability and Validity of the Instrument in this Research Study

4.6.1 Reliability Measures

The Cronbach's Alpha tests of all the scales of this instrument are shown in the Table 4.3. All constructs have reliability value higher than 0.7 except for the "Striving for Higher Quality Performance", and "attitudes towards Six Sigma methodology" which are more difficult to measure. However, the overall reliability is high especially when considering that most of constructs are broadly defined and require diversified indicators.

Construct	**Cronbach's Alpha Test**
Quality Management System	
Senior Management Commitment and Involvement	0.903
Customer Focus	0.816
Supplier Management	0.910
Six Sigma Team Management System	0.935
Internal Implementation of Six Sigma initiative	
Process Control and Improvement	0.922

Quality System Procedure	0.892
Striving for Higher Quality Performance	0.548
Use of Six Sigma methodology and Tools	
Quality Management & Six Sigma Analytical Tools	0.932
Basic 7 QC (New/Old) Tools	0.768
General Project Management Tools	0.824
Organizational Performance	
Operational Performance	0.908
Customer Satisfaction	0.823
Business Performance	0.918
Participant Comment	
Participant Satisfaction	0.887
Satisfaction with Six Sigma Methodology	0.859
Attitudes and Commitment to Six Sigma	
Continuous Improvement Objectives	0.800
Application and Practice of Six Sigma Methodology	0.190
Treating Six Sigma as another business model	0.244
Understanding	0.895

Table 4.3 The reliability Indices for All Scales
Source: this study

4.6.2 Validity Measures

4.6.2.1 Content Validity

Researcher has conducted an extensive review of the literature to ensure the content validity of the present instrument. Moreover, the instrument has been reviewed by quality management professionals and Six Sigma professionals from the industry. Furthermore, a long questionnaire of thirteen pages which encompasses 108 research questions was planned to comprehensively cover the research issues.

4.6.2.2 Construct Validity

The construct validity of the present instrument is assessed by factor analysis. The factor analysis results are summarized in the Table 4.4. The factor loading indicates the correlation between the indicator and its corresponding factors. A high factor loading proved the construct validity. All research constructs have an average factor loading of at least 0.717, indicating a satisfactory representation of indicators. The total variance explained by factor(s) for all constructs is higher than 50% which ensures practical significance for the derived factors (Hair et al. 1998)

Concept of Interest	Number of Factor(s)	Factor Loading		Variance Explained by Factor(s)
		Ranges	Average	
Senior Management Commitment and Involvement	1	.739-.914	.820	67.597%
Customer Focus	1	.646-.825	.724	52.888%
Supplier Management	1	.626-.937	.834	70.825%
Six Sigma Team Management System	1	.680-.907	.814	66.704%
Internal Implementation of Six Sigma initiative	3	.539-.845	.721	70.086%
Use of Six Sigma methodology and tools	5	.560-.895	.758	78.764%
Operational Efficiency	1	.615-.876	.813	66.844%
Customer Satisfaction	1	.580-.920	.761	59.691%
Business Performance	1	.751-.934	.841	71.278%
Participants Comments	2	.498-.927	.717	62.955%
Continuous Improvement Objectives	1	.697-.874	.782	61.691%
Attitudes	2	.411-.855	.698	64.154%
Understanding	1	.856-.966	.914	83.680%

Table 4.4 A Summary of Factor Loadings and Explained Variance for the Concepts of Interest
Source: this study

Factors which are derived from a factor analysis are further assessed by unifactorial tests. To prove the factors are acceptable, a number of assessments should be undertaken to determine construct and content validity of the factors. Firstly, the factors should be subjected to a tentative test for construct validity. Each factor should also be subjected to an individual principle components analysis. If each factor was valid as a construct, then its set of variables would form a single factor once again (unifactorial determination) (Black et al. 1996 cited Nunnally 1967). All KMO measures are equal to or greater than 0.5 which is acceptable. All variance explained by factors are greater than 50% which is significant.

Factor	KMO	Variance Explained
Internal Implementation of Six Sigma initiative		
Process Control and Improvement	0.824	62.633%
Quality System Procedure	0.817	71.209%
Striving for Higher Quality Performance	0.562	52.611%
Use of Six Sigma methodology and Tool		
Quality Management & Six Sigma Analytical Tools	0.857	55.086%
Basic 7 QC (New/Old) Tools	0.701	69.326%
General Project Management Tools	0.644	74.071%
Participants Comments		
Job Satisfaction	0.773	61.555%
Satisfaction with the methodology	0.842	59.631%
Attitudes		
Application and Practice of Six Sigma Methodology	.860	76.182%
Treating Six Sigma as another business model	.760	68.065%

Table 4.5A Summary of KMO value and Explained Variance of the Extracted Factors
Source: this study

4.6.2.3 Criterion-related Validity

Criterion-related validity sometimes called predictive validity or external validity is used to compare the test or scale scores with one or more external variables, or criteria (Badri et al. 1995; Kerlinger et al. 2000). Yeung (1999) claimed that the quality activities and quality management systems are presumed to be the predictors of organizational performance. The correlation between the quality activities constructs and organizational performance is computed and shown as in Table 4.6. Except for the "Use of Six Sigma methodology and tools", all Six Sigma management practices are significantly correlated with "Operational Efficiency". The "Supplier Management" and "Senior Management Commitment and Involvement", "Striving for Higher Quality Performance" have the strongest correlation with the "Operational Efficiency" constructs.

On the other hand, almost half of the Six Sigma management practices are weakly correlated with the "Customer Satisfaction". It is interesting to find that the use of

"Quality Management & Six Sigma Analytical Tools" nearly has not correlation with "Customer Satisfaction", but the use of "Basic 7 QC (New/Old) Tools has the strongest correlation with the "Customer Satisfaction". The "Senior Management Commitment and Involvement" also has very weak correlation with "Customer Satisfaction", it is in sharp contrast to the "Operational Efficiency". Moreover, the relation between the Six Sigma management practices and "Business Performance" is relatively weak. This reflects the fact that business performance is influenced by a wide range of factors other than the Six Sigma methodology.

All Six Sigma management practices appears to have an effect on the Six Sigma practitioners' "Job Satisfaction" except the Senior Management Commitment and Involvement" and the use of "Quality Management & Six Sigma Analytical Tools". Except the "Quality Management & Six Sigma Analytical Tools" and "General Project Management Tools", all Six Sigma management practices also appears to have a quite significant effect on the "Satisfaction with Six Sigma methodology".

PREDICATORS	Operational Efficiency	Customer Satisfaction	Business Performance	Job Satisfaction	Satisfaction with Six Sigma methodology
Senior Management Commitment and Involvement	0.562**	0.094**	0.277	0.072	0.478**
Customer Focus	0.516**	0.338*	0.231	0.315**	0.472**
Supplier Management	0.652**	0.166	0.305*	0.248	0.556**
Six Sigma Team Management System	0.487**	0.389*	0.278	0.434**	0.591**
Process Control and Improvement	0.422**	0.231	0.131	0.312*	0.431**
Quality System Procedure	0.403**	0.141	0.289	0.219	0.476**
Striving for Higher Quality Performance	0.518**	0.280	0.260	0.367*	0.482**
Quality Management & Six Sigma Analytical Tools	-0.158	-0.007	0.012	0.092	-0.060
Basic 7 QC (New/Old) Tools	0.164	0.478	0.258	0.539	0.336*
General Project Management Tools	0.021	0.277	0.217	0.362*	0.130

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Table 4.6. Correlation Matrix between the Constructs of Quality Management and Organizational Performance
Source: this study

The understanding of Six Sigma philosophy is assumed to have an impact on the implementation of Six Sigma methodology. The results of correlation analysis shown in Table 4.7 suggest that "Understanding Six Sigma philosophy" seems to have the strongest effect on the Six Sigma implementation or its related activities. Additionally, the "Application and Practice of Six Sigma methodology" is also important while treating Six Sigma as another business model seems to have quite a weak influence.

PREDICATORS	Senior Management Commitment & Involvement	Customer Focus	Supplier Management	Six Sigma Team Management System
Continuous Improvement Objectives	0.321*	0.130	0.203	0.273
Application and Practice of Six Sigma Methodology	0.298	0.245	0.198	0.343*
Treating Six Sigma as another business model	0.211	0.125	0.108	0.160
Understanding	0.218	.464**	.256	.602**

PREDICATORS	Process Control and Improvement	Quality System Procedure	Striving for Higher Quality Performance
Continuous Improvement Objectives	0.216	0.206	0.268
Application and Practice of Six Sigma Methodology	0.153	0.455**	0.125
Treating Six Sigma as another business model	0.153	0.116	.410**
Understanding	0.600**	0.388*	0.388*

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Table 4.7 Correlation Matrix between the Attitude to Six Sigma methodology and Six Sigma Management Activities
Source: this study

Both tests suggested that the predictor variables in the instrument are significantly related with criterion variables and the strengths of the correlation are well justified theoretically. This provides strong evidence of the criterion-related validity of the instrument.

4.7 Discussions, Comparisons and Analysis

4.7.1 The Methodological Considerations in Analysis

4.7.1.1 Identification of Constructs

Kline (1994) pointed out that researchers may identify constructs by two major approaches. The first approach is to identify some presumed constructs and their corresponding indicators based on their interest. After the constructs are identified, researchers may collect the necessary data and confirm the validity and reliability of their measures. They can put in as many variables as possible and see what loads on the relevant factor in exploratory analysis. Then, the constructs can be identified functionally and empirically by using factor analysis and verified in further analysis of validity and reliability.

4.7.1.2 Exploratory and Confirmatory Factor Analysis

Most of the quality management instruments developed by the renowned researchers such as Saraph et al. (1989), Flynn et al. (1994) and Ahire et al. (1996) were developed based on literature review and experts' opinions. The resulted constructs should therefore be justified automatically based on the theoretical foundation in the literature. Those selected indicators are generally having a good representation of the constructs.

However, Yeung (1999) criticized that since these factors were defined based on the knowledge of the literature, it provides only little empirical understanding of the subject. Therefore, in lieu of exploring the real patterns of quality management practices, this approach can only simply verify whether the constructs suggested in the literature remain valid. In contrast, by the second approach, the factors are extracted functionally from the industry based on real practices. However, Yeung argued that the use of the second approach is quite difficult and sometimes may be fruitless because it essentially depends on the EFA or PCA techniques. The problem of depending on the EFA or PCA techniques is that they are based on the inter-item correlation of research variables and these variables can be correlated with many different underlying factors simultaneously which caused variance error (Yeung 1999).

Ahire et al. (1996) pointed out that the use of EFA has some major limitation. First of all, the items are assigned to factors on which they load most significantly, but an item may also load on more than one factor, in this case, it may affect measurement of all these factors simultaneously. Second, a factor may also consist of items that are correlated with one another only statistically, and thus, their correlation cannot be theoretically explained. Third, scale refinement based only on Cronbach's alpha may not be adequate under all circumstances. Finally, the lack of unidimensionality can lead to artificial correlations among constructs developed. In order to overcome the inherent limitations of the EFA approach, they suggested researchers to use the Confirmatory Factor Analysis (CFA) Approach. According to Ahire et al. (1996), the CFA is similar to EFA except that the hypotheses that form constraints are embedded in the analysis. CFA is a newer method with a stronger base in statistical hypothesis testing theory (Kerlinger et al. 2000). However, Yeung (1999) stressed that CFA is only used to confirm factors which have been identified by researchers or verify factors that have been explored by EFA; it is not more advanced than the traditional technique of EFA. Actually CFA and EFA are complementary to each other; EFA is used in exploratory studies while CFA is employed only when researchers have an in-depth knowledge of the factor structures (Hair et al. 1998).

Bentler and Chou (1987 p. 95) suggested that CFA is more useful in analyzing a relatively small set of variables because when increased the number of free parameters will decrease the degrees of freedom as well as the goodness-of-fit X^2 test. Therefore, the selection of EFA or CFA in the analysis of scales depends on the breadth or depth of the research (Yeung 1999 cited Harries and Schaubroeck 1990). Since EFA allows a wider definition of scales, it will be used in the present study to explore the underlying factor structures of a quality management practice.

4.7.2 Comparison with other Instruments

4.7.2.1 The Effects of Using Different Sample and Data

Compared to the instruments used in the previous twelve years, the present study has a focus on measuring the values of Six Sigma methodology on its stakeholders in a single battery manufacturing organization which has approximately 14,600 employees in more than 16 countries worldwide. Since the objective of the present study is to find out the factor patterns underlying the Six Sigma activities in an organization, use of "manager" or "engineer" as the unit of analysis is not appropriate. The "company" is used as the unit of analysis. Direct contact with its Quality Director enhanced the data quality and ensured a reasonably high response rate and a large sample size will be obtained. Table 4.8 provides a summary of this information compared with some renowned instrument.

Saraph et al. (1989), Flynn et al. (1994) identified 8, 11 factors respectively in their study. These factors identified were based on an extensive review of the conceptual and/or empirical literature. Replications of Saraph et al's work, Badri et al. (1995) evaluated the criterion-related validity of a combined set of 8 measures of quality management by examining the multiple correlation coefficient computed for the 8 measures and a measure of business unit quality performance. Using a similar approach, Ahire et al. (1996) identified 10 factors in their study and was examined strictly by using CFA. However, Yeung (1999) criticized that these researchers focus only on collecting the data of quality management activities in lieu of measuring the level of practice of individual activities and resulting that these instruments do not assess the extent to which the quality construct was actualized in the companies.

4.7.2.2 Comparisons of Identified Constructs

Saraph et al. (1989) proposed measures of overall organizational quality management for both manufacturing and service firms and provided a synthesis of the quality literature by identifying 8 critical factors of quality management in a business unit. The eight factors identified were "role of divisional top management and quality policy", "role of quality department", "training", "product/service design", "supplier quality management", "process management/operation procedures", "quality data and reporting", and "employee relations". However, both of Ahire et al. (1996) and Black et al. (1996) found that Saraph et al. (1989) at least excluded two important constructs: customer focus and Statistical Process Control (SPC). Yeung (1999) argued that since Saraph et al.'s instrument was developed for the use of all industries, SPC may therefore not be as important in the service industry as it is in the manufacturing sector.

Both of Flynn et al. (1994) and Black et al. (1996) excluded the "training" in their instruments. And, Flynn et al. (1994) and Ahire et al. (1996) did not include "role of quality department" in their researches. "Cleanliness and organization" defined by Flynn et al. (1994) and "benchmarking and SPC" defined by Ahire et al. (1996) are excluded in the present research because cleanliness and benchmarking are not considered as important elements in Six Sigma implementation in which SPC is only seen as an indicator of the level of Six Sigma methodology and tools used in Six Sigma initiatives; it is not a construct by itself. Process management is considered as an important factor for driving improvement in Six Sigma projects but which is excluded in both of Ahire et al.'s (1996) and Black et al.'s researches. The instrument comparison is presented in Table 4.9.

	Saraph et al. (1989)	Flynn et al. (1994)	Badri et al. 1995	Ahire et al. (1996)	The Present instrument
Focus of Instrument	Quality Management	Quality Management	Quality Management	Quality Management	Quality Management / Six Sigma
Major Focus on Literature Review	Conceptual	Conceptual and Empirical	Conceptual and Empirical	Conceptual and Empirical	Conceptual and Empirical
Targeted Industry	Manufacturing and service sector	Machinery, transportation components and electronics manufacturing plants with greater than 100 employees.	Service and manufacturing firms in the United Arab Emirates	Industry-motor vehicle parts and accessories industry	Battery manufacturing firm
Sample Size	20 firms with 162 divisional quality managers	716 workers and managers in 42 plants	424 of 854 firms agreed to participate in the study	371 plants with 100 or more employees	One firm
Valid Response Rate	91% in terms of managers	56 % in terms of plants	49.6% in terms of firms	37% response rate Mail survey	
Unit of Analysis	Divisional quality managers	Plants level	Managers	Plants level	Firm
Target of Measurement	Level of practice	Level of practice	Level of practice	Level of practice	Level of effect
Development Methodology	Drawing primarily upon QM principles espoused by the quality gurus. Construct validity checked using principal components factor analysis	Extract factors from literature survey; Tested by EFA and other techniques	Extract factors from Saraph et al. (1989), Tested by Spearman rank correlation coefficients.	Extract factors from literature survey; Tested by CFA and other techniques	Extraction of factors mainly by EFA based on actual level of practices; Tested by EFA and other techniques
Number of Factors Identified	8 factors, 66 items	11 factors, 48 items retained factors	8 factors, 66 items	10 factors, 55 items	10 factors, 65 items
Organizational Performance Measurement	Not measured	Market competitive performance	Not measured	Product quality, Supplier performance	Operational Efficiency, Customer Satisfaction, Business Performance, Participant's Job satisfaction, Satisfaction with Six Sigma methodology

Table 4.8 Comparison of the Present Instrument with Some Renowned Instruments
Source: this study

Saraph et al. (1989)	Flynn et al. (1994)	Badri et al. 1995	Ahire et al. (1996)	The Present instrument
Role of divisional top management and quality policy		Role of divisional top management and quality policy	Top management commitment	Senior Management Commitment and Involvement
Role of quality department		Role of quality department		
Training		Training	Employee training	
Product/service design	New product quality, Inter-functional design process	Product/service design	Design quality management	
Supplier quality management	Supplier management	Supplier quality management	Supplier quality management	Supplier management
Process management/ operating procedures	Process control, Process management	Process management/ operating procedures		Process Control and Improvement
Quality data and reporting	Feedback information	Quality data and reporting	Internal quality information usage	
Employee relations	Quality improvement reward, Selection of teamwork potential, Teamwork	Employee relations	Employee empowerment, Employee involvement	Team Management and Deployment
	Customer Interaction		Customer focus	Knowledge of Customer Requirement, Customer-oriented,
	Cleanliness and organization			
			Benchmarking	
			SPC usage	Common Problem Defining Tools, Problem Measurement Tools, Problem Analysing Tools,

				Advanced Methodologies and Tools
				Six Sigma implementation procedures
				Striving for reach Six Sigma level
				The use of Six Sigma techniques

Table 4.9 Comparisons of Constructs Identified in other instruments
Source: this study

4.7.2.3 Analysis of Constructs in the Present Instrument

Five constructs of the present instrument are selected based on the previous studies; four other constructs are extracted. Four constructs which represent the use of Six Sigma methodology and Tools are derived by factor analysis. The present research consolidates the previous studies (Saraph et al. 1989; Flynn et al. 1994; Ahire et al. 1996; Black et al. 1996; Yeung 1999; Antony 2004) and develops an even more comprehensive measurement. Three factors are found from factor analysis of the 17 items of internal operations of Six Sigma initiative. The resultant constructs, which show some difference from those identified in the literature, may imply some changes in the Six Sigma implementation practices from general quality management.

The first factor extracted by EFA, which contains 9 items, is identified as "Process Control and Improvement". A close examination of the research variables revealed that the variables are mainly rigorous procedures of eliminating problems before it happened, are actually part of the process assurance system. Other items, such as identifying the undesirable variations in order to achieve greater consistency of product, and making efforts to minimize the deviations from the target points were identified as a single factor, implying that continuous improvement is highly valued in the organization.

A number of Six Sigma methodology procedure requirements were also included in this analysis. They are identified as three constructs. The first type of statements, mainly concerning the process control (studying the variations in production processes and identifying the undesirable variances) of a Six Sigma project, is regarded as "Process Control and Improvement". The second type of statements, which encompasses the Six Sigma implementation procedures such as considering the potential quality problems in manufacturing processes in the product design stage, is identified as "Quality System Procedure". The last type of statements, which encompasses the pursuing of an even higher quality level such as striving for reach the Six Sigma level and rewarding employees for making quality improvement, is identified as "Striving for Higher Quality Performance".

It is also interesting to find that "Operational Efficiency" construct has the strongest correlation with "Supplier Management" and then the "Senior Management Commitment and Involvement". The result reflects that when an organization has a good supplier management system, it helps to improve the operational efficiency. Also, the senior managements' commitment on the quality plays a critical role in the operational efficiency. Moreover, the analysis result also shows that the Six Sigma participants' job satisfaction is significantly correlated with the problem solving tools "Basic 7 QC (New/Old) Tools"; it shows that the employees were happy with their job when they were capable to solve their work problems by using some simple tools. In short, an organization providing suitable Six Sigma training helps to improve the employees' job satisfaction level.

4.7.3 Implications

The analysis of constructs extracted empirically from the organization suggests that the factors of Six Sigma implementation are not only structured based on different quality management functions such as studying the root causes, analyzing the quality records and taking corrective actions; they also depend on the level of practice of individual activities and how the Six Sigma Methodology is introduced into the organization. The level of practice of individual activities and the structure of a Six Sigma system are, in turn, dependent on how good the quality system is built in the organization. A Six Sigma system is also highly influenced by the quality system standards in the organization. The present research indicates that Senior Management Commitment and Involvement, Customer Focus, Supplier Management, Six Sigma Team Management System, Process Control and Improvement and Quality System Procedure appear to be basic requirements in the organization's Six Sigma implementation system. However, when the organization is striving for higher quality performance, training and the use of Six Sigma Tools become more important.

While academics are still debating the effectiveness of Six Sigma Methodology, although it is not a panacea, it appears to have had a certain valuable impact on the organization. It is expected that the Six Sigma methodology will be widely used in the organization in the future. It is seen that the organization has started to set up more rigous Six Sigma projects and team management systems.

4.8 Conclusion

The present research has employed a different approach and extracted factors mainly based on actual practices in the industry and by using EFA. The factors structure of constructs pointed out the importance of Six Sigma methodology. These constructs shows the effectiveness of Six Sigma methodology and the organization's effort on the quality pursuance. This enables the present instrument to capture the characteristics of the Six Sigma methodology.

The present instrument provides a complete measure of Six Sigma methodology and its impact on its stakeholders. Many of the scales used here are broadly defined. They have been refined and verified in validity and reliability tests. The content, construct and criterion-related validity and internal consistency presented in this chapter assured the objectivity and accuracy of all data collected by the questionnaires.

Chapter 5 The Path Analytic Model

5.1 Introduction

Modeling is a first and crucial step in moving toward analysis for determining the usefulness of the output from the research study. It is a process of formalizing our framework for interpreting the world around us by abstracting from a reality that is otherwise too complex to understand (Bradley and Schaefer 1998, p. 23). Modelling is widely used as a decision-making tool in everyday management practice for explaining or predicting a phenomena or systems (Thietart et al. 2001). Aravindan and Devadasan (1996) pointed out that the industrial world is flooded with numerous confusing quality management concepts and ideas. Bradley et al. (1998) stressed that we must have a formal model to guide us in picking out the information that is relevant to the issue before us because facts alone do not give us understanding about why something has happened or how something is operated. Modelling involves us in identifying which things in the world are problems and what their potential causes and solutions are.

A business process comprises a set of activities logically interrelated (Carpinetti, Buosi and Gerólamo 2003 cited Harrington 1991). Through business process modelling, it is possible to get a clear picture of activities and their interrelationships, resources and organizational units responsible for the activities, as well as the flow of information through operational and supporting processes of the internal value chain (Carpinetti et al. 2003). Bradely et al. (1998) claimed that using formal modelling sometimes causes the discovery of theoretical concepts that would have otherwise remained extremely difficult to understand but prove to be quite common and useful once we are aware of them. The ideas in Six Sigma methodology have captured the attention of organizational researchers worldwide and also have been widely discussed in the literature. However, the author is not able to identify any attempts which have been made to establish Six Sigma implementation management models in her literature review. Only a few of researchers such as Swamidass and Newell (1987), Anderson et al. (1995) and Flynn et al. (1995) have developed the empirical models in quality management. They attempted to explain the relations between the effectiveness of some quality management practices and the organizational performance. The present chapter tries to develop a theory by focusing on the solid component in Six Sigma initiatives. Path analysis and Canonical Correlation Analysis (CCA) are employed to provide a more complete picture on the relationships between the Six Sigma implementation and organizational performance. Path analysis is used as the main technique in building the model while CCA is used in the further analysis of the association between the constructs and performance measures. More than just presenting a brief review on the path analysis method, this chapter also describes how a path analytic model is developed based on the empirical data.

5.2 Path Analysis

Pedhazur (1982, Chapter 15) claimed that primarily for historical reasons, the term path analysis has been used to refer to the analysis of causal models when single indicators are employed for each of the variables in the model. Because of the great popularity of the LISREL computer program (Pedhazur et al 1991 cited Joreskog & Sorbom, 1989) for the analysis of causal models, some researchers and authors refer to them as LISREL, or LISREL-type models. Some other terms such as causal modelling, analysis of covariance structures, latent variable models, structural modelling, and structural equation modelling (SEM) are also being used.

Path analysis is a graphic method of studying the presumed direct and indirect influences of independent variables on each other and on dependent variables. It is a method of presenting and testing "theories" (Kerlinger 2000 cited Kerlinger & Pedhazur 1973 and Pedhazur 1996). Sewell Wright developed the path analysis in 1921 and was made popular in the behavioral sciences by Duncan in 1966 and Blalock in 1971 (Comrey et al. 1992; Kerlinger 2000; Yang et al. 2004). The path analysis method employs simple bivariate correlations to estimate the relationships in a system of structural equations. It is based on specifying the relationships in a series of regress-like equations that can then be estimated by determining the amount of correlation attributable to each effect in each equation simultaneously (Hair et al. 1998). They further pointed out that the path analysis is termed "structural equation modelling" when it is employed with multiple relationships among latent constructs and a measurement model.

Path diagrams are the basis of path analysis which portrays a complete set of relationships among the model's constructs. The causal relationships are depicted by straight arrows, with the arrow to come out of the predictor variable and the arrowhead pointing to the dependent construct of variable. The curved arrows represent the correlations between constructs or indicators but no causation is implied (Hair et al. 1998; Loehlin 1998). The diagram allows researchers to break down correlation into components that are due to different factors in a structured system, it permits predictions of how a change in any one variable in the system affects the values of other variables in the system (Heise 1969).

Kerlinger (2000) stressed that correlations do not imply causality although path analysis is termed as "causal modelling", it is misleading and which is not really casual because the level of control in the social and behavioral science studies is much lower than that what Wright can do in controlling on the genetic and breeding variables.

5.2.1 The Basic Idea of Path Analysis

The primary goal of path analysis is to interpret the relationships among variables by constructing structural relationship models. Yang et al. (2004) pointed out that there are two kinds of relationships among variables: one is called causation relationship or cause and effect relationship and the other one is called causal correlation relationship. According to Yang et al. (2004, p.225), the causation is defined as the cause and effect relationship while the casual correlation relationship is defined as a covariant relationship among variables, however, they pointed out that it is unclear if there is a cause and effect relationship.

More than estimation of multiple interrelated dependence relationships, path analysis has the ability to incorporate a hypothesized and unobserved concept into the analysis (Hair et al. 1998; Yang et al. 2004). A distinction is made between variables or constructs that acts only as a predictor or "cause" for other constructs or variables in the model and are not influenced by other constructs or variables in the system (exogenous variables) and constructs or variables that are affected by others (endogenous variables) or in at least one causal relationship (Hair et al. 1998; Johnson et al. 2002).

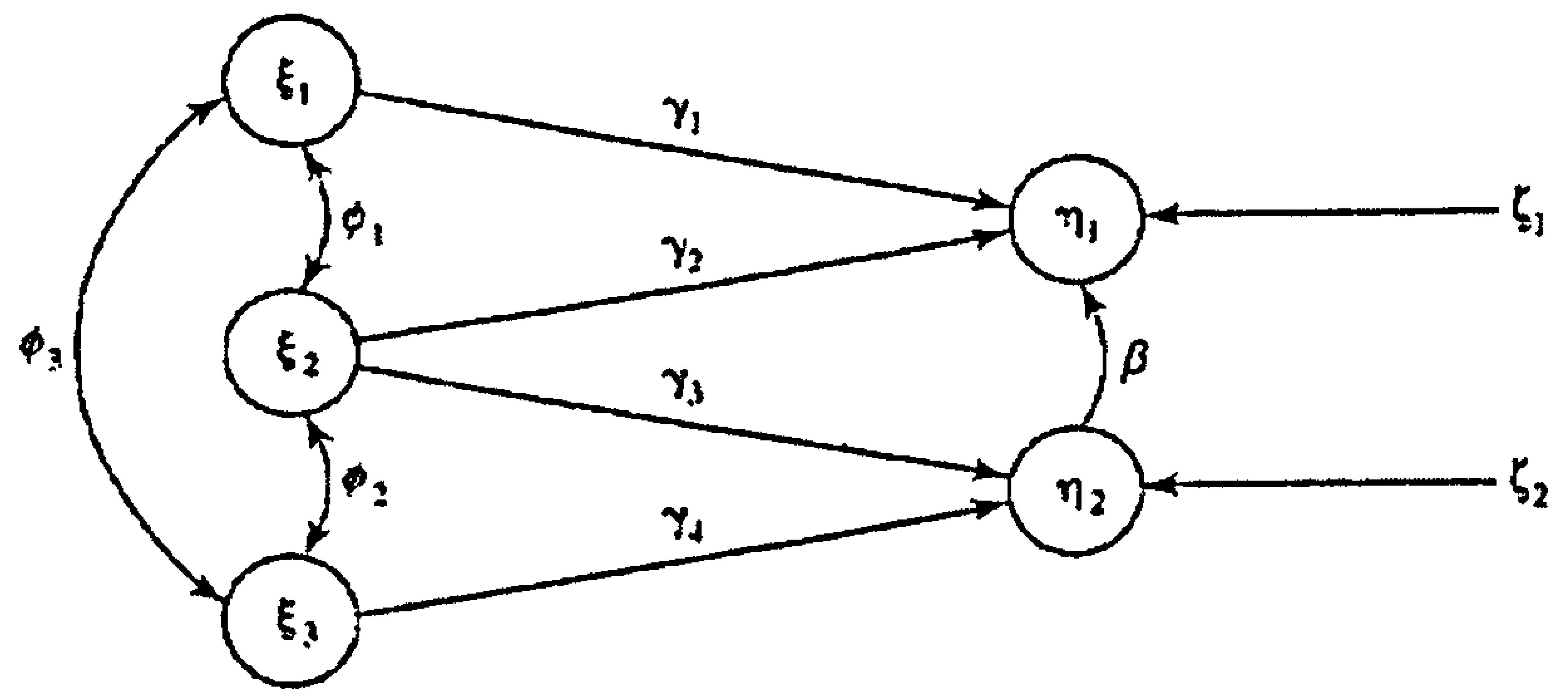


Figure 5.1 A Path Diagram Portraying a Set of Relations

5.2.2 The Direct and Indirect Causal Paths

Maruyama (1998, p. 36) pointed out that it is possible to decompose the relationships between variables in any model into causal effects and noncausal relationships by using the logic introduced by path analysis. He further explained that the causal effects can be broken down into direct effects which go directly from one variable to a second variable and the indirect effects are the effects which occur between two variables that are mediated by one or more intervening variables. For the noncausal relationships, there are relationships between two variables that occur (a) because both caused by a third variable and (b) because in models with more than one cause and effect are not theoretically articulated.

Loehlin (1998, p. 8) shows a clear illustration of the direct and indirect causal effects in path diagrams. A direct effect is represented by a single causal arrow between the two variables concerned. In Figure 5.2 (a) variable B has a direct effect on variable C. There is a causal arrow leading from B to C. If B is changed, C will also be changed. Variable A, however, has only an indirect effect on C because there is no direct arrow from A to C. There is only an indirect causal effect transmitted via variable B, that means, if A changes, B will change and affect C under the condition that other things being equal. Therefore, A can be said to have a causal effect on C even if the effect is indirect.

In Figure 5.2 (b) variable B has a direct effect on variable D, an indirect effect on variable C, and no causal effect on variable A at all.

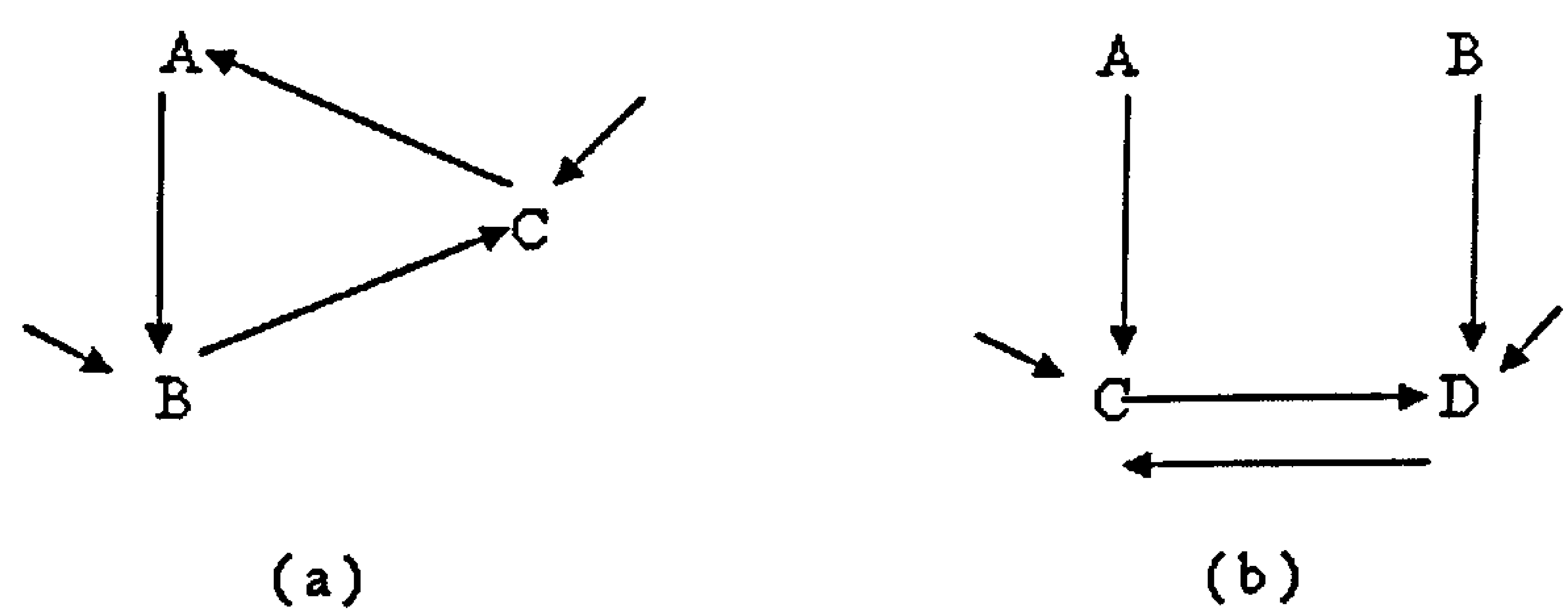


Figure 5.2 Path diagram with (a) a feedback loop and (b) mutual influences

5.3 Research Hypothesis and Model in This Research Thesis

Path analysis which defines possible relationships in only the most general form and then allows the multivariate technique to estimate relationship(s) is essentially an exploratory research technique (Hair 1998; Heize 1969). Singleton et al. (1999) contended that exploratory studies are undertaken when there is relatively little knowledge about something, perhaps because of its "deviant" character or its newness. They pointed out that the research plan in an exploratory study is more open than in other kinds of research. Researchers can make the decisions about the kinds of instruments needed and the key persons with whom one will need to speak at first but the paths down which these initial steps may lead are almost impossible to foresee. Therefore, researchers do not determine every path in the model and then decide whether the overall model fits empirical data or not in a single test (Yeung 1999). Researchers have to discover the significant variables in the field situation, to discover relations among variables, and to lay a groundwork for later, more systematic and rigorous testing of hypotheses (Kerlinger 2000; Asher 1983).

Concluding from some researchers' work such as Bentler et al. (1987), Harries and Schaubroeck (1990) and Baumgarter and Homburg (1996), Yeung (1999) pointed out that exploratory research technique is more appropriate for analysing a complicated model than confirmatory technique because confirmatory technique often results in rejecting a model even though it actually has a good representation and explanation of real world phenomenon.

The development of a path analytic model for the Six Sigma methodology and its contribution to its stakeholders is based on a series of cause and effect assumptions among research constructs. The measurement of different constructs in it and its contributions is based on the research instrument used in Chapter 4. All constructs in the present study are included in developing the outcomes.

Formulation of Hypothesis 1 – 2

Uncompromising support and commitment from top management is the most critical success factor of Six Sigma implementation (Henderson and Evans 2000; Black and Revere 2006; Antony et al. 2007). Implementation of Six Sigma requires culture change in the organization (Antony 2006; Black et al. 2006). If top management is not totally committed to continuous quality improvement in every way and the organization does not completely change its culture to total and continuous quality improvement it is a waste of time to adopt and practice Quality Management (Black et al. 2006 cited Deming). Flynn et al. (1995) and Antony et al. (2005 cited Tennant 2001) pointed out that top management leadership changes the attitudes of participants, Tennant further pointed out that the top management team need to be visibly supportive of every aspect of six sigma initiative and they must demonstrate by their active participation, involvement and by their actions that such support is more than lip service. Bounds et al. (1994) stressed that the managerial system is primarily responsible for the performance problems. Therefore, the first three hypotheses are developed as follows:

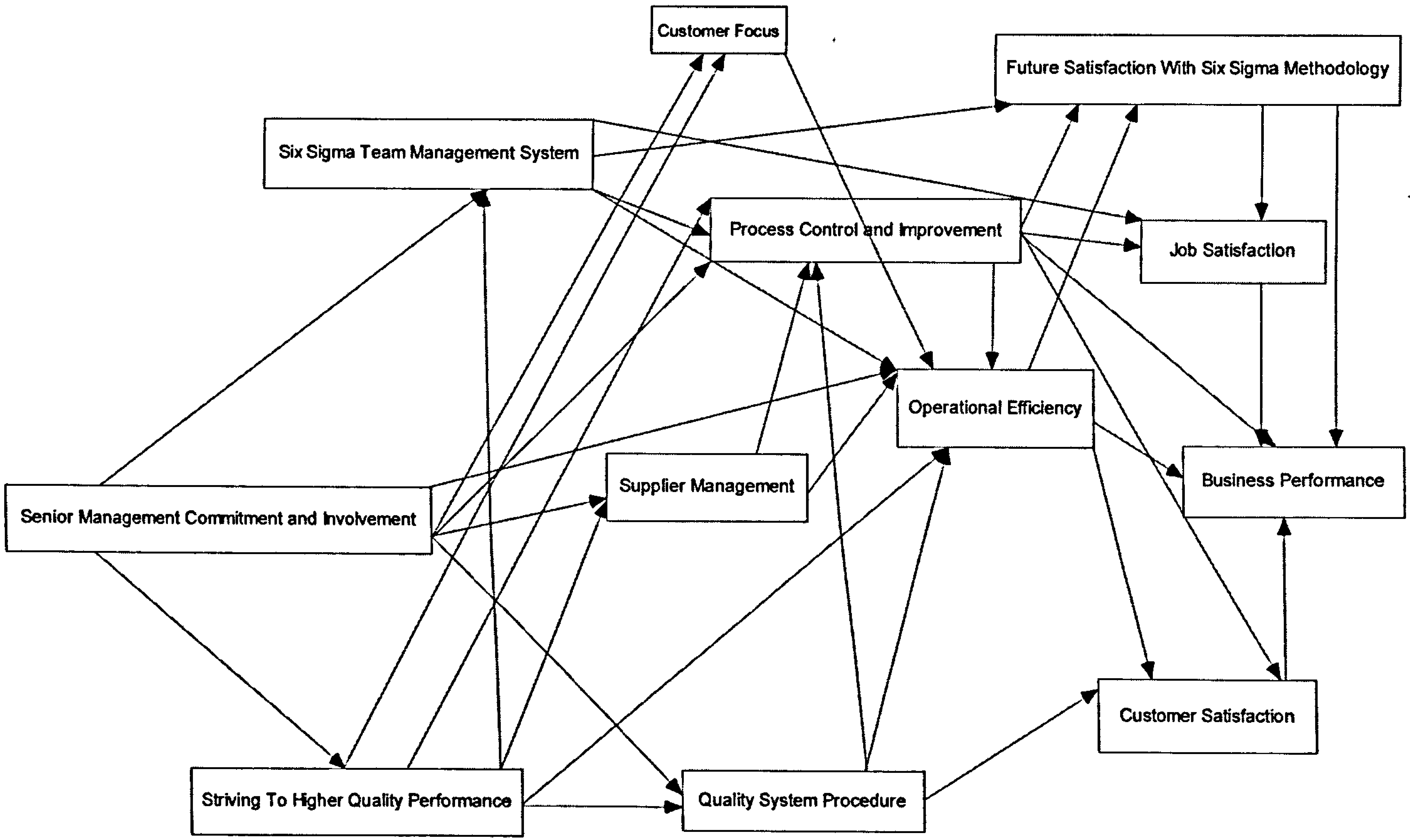


Figure 5.3. The Path Analytic Model Portraying Quality Management System and Organizational Performance Relationships
Source: this study

Postulated Cause and Effect Relationships (Hypotheses 1-2)

H1: The aim of Striving for Higher Quality Performance is directly related to senior management commitment and involvement.

H2: Six Sigma Team Management System is directly related to senior management commitment and involvement and the aim of striving for higher quality management.

Formulation of Hypothesis 3-6

The successfulness of adoption and implementing Six Sigma methodology are dependent on the senior management commitment and involvement, team management system and training (Coronado et al. 2002; Antony et al. 2002; Antony et al. 2005). The structure and operational aspects of Six Sigma methodology include Customer Focus, Supplier Management, and Quality System Procedures. Process Control and Improvement is supported by the management system, organization infrastructure and cultural elements, such as senior management commitment and the attitudes of employees (Coronado et al. 2002; Antony et al. 2002; Motwani et al. 2004; Antony et al. 2005; Bounds et al. 1994). As a result, the second set of hypotheses is laid down as the following:

Postulated Cause and Effect Relationships (Hypotheses 3-6)

H3: Customer Focus is directly related to senior management commitment and involvement, the aim of Striving for Higher Quality Performance and Six Sigma Team Management System.

H4: Process Control and Improvement is directly related to senior management commitment and involvement, the aim of striving for higher quality performance, Six Sigma Team Management System, Supplier Management and Quality System Procedure.

H5: Supplier Management is directly related to Senior Management Commitment and Involvement and the aim of Striving for Higher Quality Performance.

H6: Quality System Procedure is directly related to Senior Management

Commitment and Involvement and the aim of Striving for Higher Quality Performance and Six Sigma Team Management System.

Formulation of Hypothesis 7- 11

It is found that Six Sigma methodology implementations have important effects on organizational performance and the satisfaction on the organization's stakeholders. Process Control and Improvement plays the critical role in improving operational efficiency, Customer Satisfaction, Six Sigma participants' Job Satisfaction, whether the users are satisfied with the methodology they are using and Business Performance. Senior management commitment and involvement, the aim of Striving for Higher Quality Performance, Six Sigma Team Management System all influence the adaptation and implementation of Six Sigma methodology and affect the organizational performance and its stakeholders satisfaction indirectly. Customer Satisfaction may be influenced directly by the operational efficiency, along with other elements in the quality system. Whether the change agents and the organization are satisfied with the methodology may also be directly affected by the Six Sigma Team Management System and Operational Efficiency along with other elements in the quality system. Six Sigma practitioners' Job Satisfaction may be directly affected by Six Sigma Team Management System, Operational Efficiency and whether the quality methodology satisfied them. Business performance may be dependent directly on other aspects of organizational performance and Process Control and Improvement (Bounds et al. 1994; Kumar, Saranga, Ramírez-Márquez and Nowicki 2007).

Postulated Cause and Effect Relationships (Hypotheses 7-11)

H7: Operational Efficiency is directly related to senior management commitment and involvement, the aim of Striving for Higher Quality Performance, Six Sigma Team Management System, Customer Focus, Supplier Management, Quality System Procedure and Process Control and Improvement.

H8: Satisfaction with Six Sigma Methodology is directly related to senior management commitment and involvement, striving for higher quality performance, Six Sigma Team Management System, Process Control and Improvement and Operational Efficiency.

H9: Six Sigma practitioners' Job Satisfaction is directly related to senior management commitment and involvement, Striving for Higher Quality Performance, Six Sigma Team Management System, process control and improvement and operational efficiency.

H10: Customer Satisfaction is directly related to Senior Management Commitment and Involvement, striving for higher quality performance, Six Sigma Team Management System, Customer Focus, Supplier Management, Quality System Procedure, Process Control and Improvement and Operational Efficiency.

H11: Business Performance is directly related to process and improvement, Operational Efficiency, Six Sigma participants' Job Satisfaction and Customer Satisfaction.

These assumptions are made in an exploratory manner and the analysis of these assumptions is a theory trimming process which results in a validated quality management model. A path diagram portraying these sets of hypotheses is presented in Figure 5.3.

5.4 Results and the Revised Model

5.4.1 Descriptive Statistics and Correlation Matrix

Statistics

The level of belts

N	Valid	42
	Missing	0
Minimum		0
Maximum		1

The level of belts

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Green Belts	32	76.2	76.2	76.2
	Black Belts or above	10	23.8	23.8	100.0
	Total	42	100.0	100.0	

Table 5.1 Frequency Table of The level of belts
Source: this study

From the output shown above (Table 5.1), we know that there are 32 Green Belts (76.2 percent) and 10 Black Belts (23.8 percent) in the sample, giving a total of 42 respondents. The distribution of the 42 respondents from each individual business unit is shown below (Table 5.2), 2 respondents from Headquarters, 13 respondents from the plant SBD, 16 respondents from the plant RCP, 4 from the plant PCD and 7 from the plant RBD.

Statistics

The name of plant

N	Valid	42
	Missing	0
Minimum		0
Maximum		4

The name of plant

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Headquarters	2	4.8	4.8	4.8
	SBD	13	31.0	31.0	35.7
	RCP	16	38.1	38.1	73.8
	PCD	4	9.5	9.5	83.3
	RBD	7	16.7	16.7	100.0
	Total	42	100.0	100.0	

Table 5.2 Frequency Table of The name of plant
Source: this study

The ratings of the case company on these seven constructs of the Six Sigma management practices and five aspects of organizational performance were calculated based on the factor loadings on their corresponding indicators. The overall mean values of these constructs in the case study company are presented in Table 5.3. A seven-point scale was used with a rating of seven being very close to the suggestions in the literature and hence a desirable practice. The results in Table 5.3 show that this battery manufacturing organization generally has a low level of "Quality System Procedure", "Supplier Management" and "Satisfaction with Six Sigma Methodology". Qualitative investigations suggest that the case company is just beginning to start up a formal Quality System Procedure and Supplier Management system when the new Quality Director come into the company at the middle of 2007. The standard deviations of these two constructs are also relatively high, indicating a great variation in these practices among the sampled business units. Likewise, the qualitative investigation suggest that the low level of Satisfaction with Six Sigma Methodology is because the case company is using the Six Sigma methodology for reducing the material scrap rate, the methodology is not fully utilized at the case company.

Descriptive Statistics

	Mean	Std. Deviation	N
Senior Management Commitment and Involvement	5.065	1.002	42
Customer Focus	5.143	0.697	42
Supplier Management	4.774	1.198	42
Six Sigma Team Management System	5.029	0.985	42
Process Control and Improvement	5.071	0.850	42
Quality System Procedure	4.514	1.103	42
Striving for Higher Quality Performance	5.024	0.766	42
Operational Efficiency	5.061	0.850	42
Customer Satisfaction	5.762	0.800	42
Business Performance	5.036	0.899	42
Job Satisfaction	5.626	0.838	42
Satisfaction with Six Sigma Methodology	4.897	0.886	42

Table 5.3 Descriptive Statistics of the case company
Source: this study

		1	2	3	4	5	6	7	8	9	10	11	12
1	Senior Management Commitment and Involvement	1.00											
2	Customer Focus	0.624**	1.00										
3	Supplier Management	0.821**	0.603**	1.00									
4	Six Sigma Team Management System	0.653**	0.755**	0.644**	1.00								
5	Process Control and Improvement	0.631**	0.742**	0.636**	0.904**	1.00							
6	Quality System Procedure	0.826**	0.735**	0.722**	0.726**	0.619 **	1.00						
7	Striving for Higher Quality Performance	0.651**	0.524**	0.697**	0.632**	0.660**	0.483**	1.00					
8	Operational Efficiency	0.562**	0.516**	0.652**	0.487**	0.422**	0.403**	0.518**	1.00				
9	Customer Satisfaction	0.094	0.338*	0.166	0.389*	0.231	0.141	0.280	0.485 **	1.00			
10	Business Performance	0.277	0.231	0.305*	0.278	0.131	0.289	0.260	0.694*	0.634**	1.00		
11	Job Satisfaction	0.072	0.315*	0.248	0.434**	0.312*	0.219	0.367*	0.340*	0.688**	0.452**	1.00	
12	Satisfaction With Six Sigma Methodology	0.478**	0.472**	0.556**	0.591**	0.431**	0.476**	0.482**	0.691**	0.598**	0.629**	0.662**	1.00

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Table 5.4 The Correlation Matrix Between All Constructs

Source: this study

Correlation is used when the researcher wants to explore the strength of the relationship between two continuous variables (Pallant 2007). Correlation not only tells us the strength of association between two variables, it also indicates the change in one variable with a change in the other (McClendon 2002). Field (2005) suggested that a correlation of ± 0.5 is a strong correlation. The correlation matrix shows that Senior Management Commitment and Involvement and Quality System Procedure are strongly correlated to most other Six Sigma management practices constructs, indicating that they might be the most influential elements. Six Sigma Team Management System and Process Control and Improvement have the strongest correlation, suggesting good team management is highly related to process improvement. Business Performance and Job Satisfaction are strongly correlated, suggesting that business growth is highly related to employees' Job Satisfaction. However, Customer Satisfaction is weakly associated with the other constructs. This shows that it might be quite a distinguished construct in the Six Sigma Management practices, in the sense that it might be somewhat independent to the overall adoption and implementation of Six Sigma methodology.

5.4.2 Level of Implementation

5.4.2.1 Two Groups of Six Sigma Belts

Ingle et al (2001) claimed that Six Sigma Black Belt programme is very important to Motorola's success as it helps in facilitating comparisons between diverse products and services. The Black Belts are viewed as subject matter experts and skilled data analysts in Motorola. They also play important roles of mentors, team leaders, facilitators and trainers. In GE, senior jobs require Black Belt accreditation to qualify for consideration. Green Belt employees are not required to have the same level of experience in the use of statistics or leadership skills in Motorola. Green Belts, however, in GE, Green Belt is required to have a similar skill set to a Black Belt and assists in the completion of Black Belt projects.

Factors in Quality Management System	Scores in Factors (Scale 1-7, with a rating of 7 being a good practice suggested in the Six Sigma literature		
	Green Belts Group 0 (N = 32)	Black Belts or above Group 1 (N = 10)	Level of Significance
Senior Management Commitment and Involvement	5.085	5.000	0.819
Custom Focus	5.255	4.783	0.061
Supplier Management	4.672	5.100	0.330
Six Sigma Team Management System	4.497	4.400	0.765
Process Control and Improvement	5.080	5.044	0.910
Quality System Procedure	4.606	4.220	0.340
Striving For Higher Quality Performance	4.948	5.267	0.256
Quality Management And Six Sigma Analytic Tools	3.946	3.721	0.546
Basic 7 QC Tools (New/Old) Tools	5.354	5.800	0.141
General Project Management Tools	3.854	5.100	0.006

Table 5.5 Comparisons of Six Sigma Management Practices between Green Belts and Black Belts or above
Source: this study

To investigate the difference in Six Sigma Management practices and organizational performance among two different levels of Six Sigma belts, independent sample T-tests were conducted. Table 5.5 presents the results of comparison between the Green Belts and Black Belts or above concerning their Six Sigma Management practices. It was found that there is no significant difference from Green Belts and Black Belts in any management practices except the General Project Management Tools. That means Black Belts or above found the General Project Management Tools more useful than the lower level of belts.

Factors in Quality Management System	Scores in Factors (Scale 1-7, with a rating of 7 being a good practice suggested in the Six Sigma literature		
	Green Belts Group 0 (N = 32)	Black Belts or above Group 1 (N = 10)	Level of Significance
Operational Efficiency	5.005	5.243	0.445
Customer Satisfaction	5.750	5.800	0.866
Business Performance	5.016	5.100	0.799
Job Satisfaction	5.549	5.871	0.294
Satisfaction with Six Sigma Methodology	4.818	5.150	0.307
Continuous Improvement Objectives	6.325	6.420	0.650

Table 5.6 Comparisons of Organizational Performance between Green Belts and Black Belts or above
Source: this study

Table 5.6 presents the comparisons between Green Belts and Black Belts of the case company in organizational performance. The figures also show that there is no significant difference in any aspects of organizational performance between the two belts levels.

5.4.2.2 Performance Difference between the Five Production Plants

Although the four production plants are the sister companies all under the same management of the case company, the number of Six Sigma belts trained are not equal. It is therefore, doubtful whether the four production plants in the case company can really produce the same fruitful results. One-way ANOVA is use to test the differences among the 4 production plants and the headquarters. Table 5.7 presents the results of comparisons between the business units concerning their Six Sigma Management system and organizational performance. It was found that there is statistically significant difference among the four production plants in Senior Management Commitment and Involvement as well as Quality System Procedure. However, there is no significant difference from the 4 production plants in Customer Focus except

SBD and RBD. Table 5.7 also shows that SBD and RCP indicate a significant difference with RBD in Supplier Management. SBD is also significantly different with RBD in Six Sigma Team Management System and Process Control and Improvement. PCD is statistically significantly different from RBD. About the Six Sigma tools uses, the result suggests that only SBD has a significant difference with RCP in the uses of Basic 7 QC Tools (New/Old) Tools, collectively, the results show that there is no significant difference in the overall Six Sigma tools use among the production plants. The below figures also show that there is no significant difference among the 4 production plants in the organizational performance except RBD is different from SBD in Operational Efficiency and different from RCP in Continuous Improvement Objectives at a significant level.

Dependent Variables	Multiple Comparisons				
	Overall Sig.	(I) The name of business unit	(J) The name of business unit	Mean Difference (I-J)	Sig.
Senior Management Commitment and Involvement	0.000	SBD	RCP	-1.1614	0.001
			RBD	-2.0989	0.000
		RCP	RBD	-0.9375	0.047
		PCD	RBD	-1.46429	0.019
Customer Focus	0.007	Headquarter	RBD	-1.54762	0.024
		SBD	RBD	-0.84249	0.041
Supplier Management	0.000	SBD	RBD	-2.47619	0.000
		RCP	RBD	-1.52827	0.005
Six Sigma Team Management System	0.048	SBD	RBD	-1.12821	0.040
Process Control and Improvement	0.009	Headquarter	RBD	-1.89683	0.024
		SBD	RBD	-1.05495	0.036
Quality System Procedure	0.000	Headquarter	RBD	-2.4000	0.013
		SBD	RBD	-1.90769	0.000
		RCP	RBD	-1.50000	0.005

		PCD	RBD	-2.2000	0.002
Basic 7 QC Tools (New/Old) Tools	0.027	SBD	RCP	0.84135	0.039
General Project Management Tools	0.010	Headquarter	RBD	2.88095	0.025
Operational Efficiency	0.004	SBD	RBD	-1.3438	0.003
Continuous Improvement Objectives	0.024	RCP	RBD	-0.79107	0.014

The mean difference is significant at the .05 level

Table 5.7 Comparisons of Six Sigma Management Practices between the Business Units.
Source: this study

5.4.3 Path Analytic Results

5.4.3.1 Multiple Regression Analysis

The postulated cause and effect relationships between a dependent variable and a set of independent variables were analyzed by stepwise multiple regression. The stepwise methods select the predictor that best predicts the outcome variable – it does this by selecting the predictor that has the highest simple correlation (Field 2005). Additional predictors are added if they make a significant contribution to the predictive power of the model (Hair et al. 1998; Field 2005; Norusis 2006). The standard multiple regression which involves all of the independent variables being entered into the equation at once helps to show how much unique variance each of the independent variables explains in the dependent variable over and above the other independent variables included in the set (Pallant 2005).

Pallant (2005) pointed out that multicollinearity occurs when the independent variables are highly correlated (r=0.9 and above). It poses a problem only for multiple regression because simple regression only requires one predictor (Field 2005). Flynn et al. (1995) and Field (2005) warned that the high levels of multicollinearity between independent variables can lead to difficulties in the drawing of inferences on the basis of the regression estimates. According to Flynn et al. (1995 cited Lewis-Beck 1980), a stronger indicator of multicollinearity is a higher R^2 value combined with statistically insignificant coefficients when each independent variable is regressed on all others. Variance Inflation Factor (VIF) indicates whether a predictor has a strong linear relationship with the other predictor(s) (Field 2005). The value of VIF is the inverse of the Tolerance value (1 divided by Tolerance). Pallant (2005, p. 150) suggested that VIF values above 10 indicate multicollinearity. She further suggested using a cut-off points (tolerance value of less than 0.10, or a VIF value of above 10) for determining the presence of multicollinearity. All VIFs in the present model, as shown in Table 5.9, are less than 10 implying that multicollinearity among predictor variables is not high. This also provides evidence that each construct in the model represents a unique characteristic of Six Sigma practices.

The coefficient of determination (R^2) which measure the proportion of the variance of the dependent variable about its mean that is explained by the independent, or predictor, variables. The coefficient can vary between 0 and 1, the greater the explanatory power of the regression equation, the better the prediction of the dependent variable (Hair et al. 1998). Pallant (2005) suggested researchers who have a small sample using the adjusted R^2 rather than using the normal R^2 value. A standardized partial correlation coefficient, which also represents the path coefficient (*P*), measures the strength of the relationship between a dependent and a predictor variable when predictive effects of the other independent variables in the regression model have been controlled for. A relatively high threshold, a significant level of .05 is used to retain paths, the interest of being conservative in estimating direct and indirect effects helps to enhance the reliability of the path model (Asher 1983; Flynn et al. 1995). With reference to Table 5.9, the F-statistics indicate the overall fits of individual multiple regression models. All individual regression models are statistically significant (probability or $p < 0.01$), implying an overall strong relationship between predictors and dependent variables.

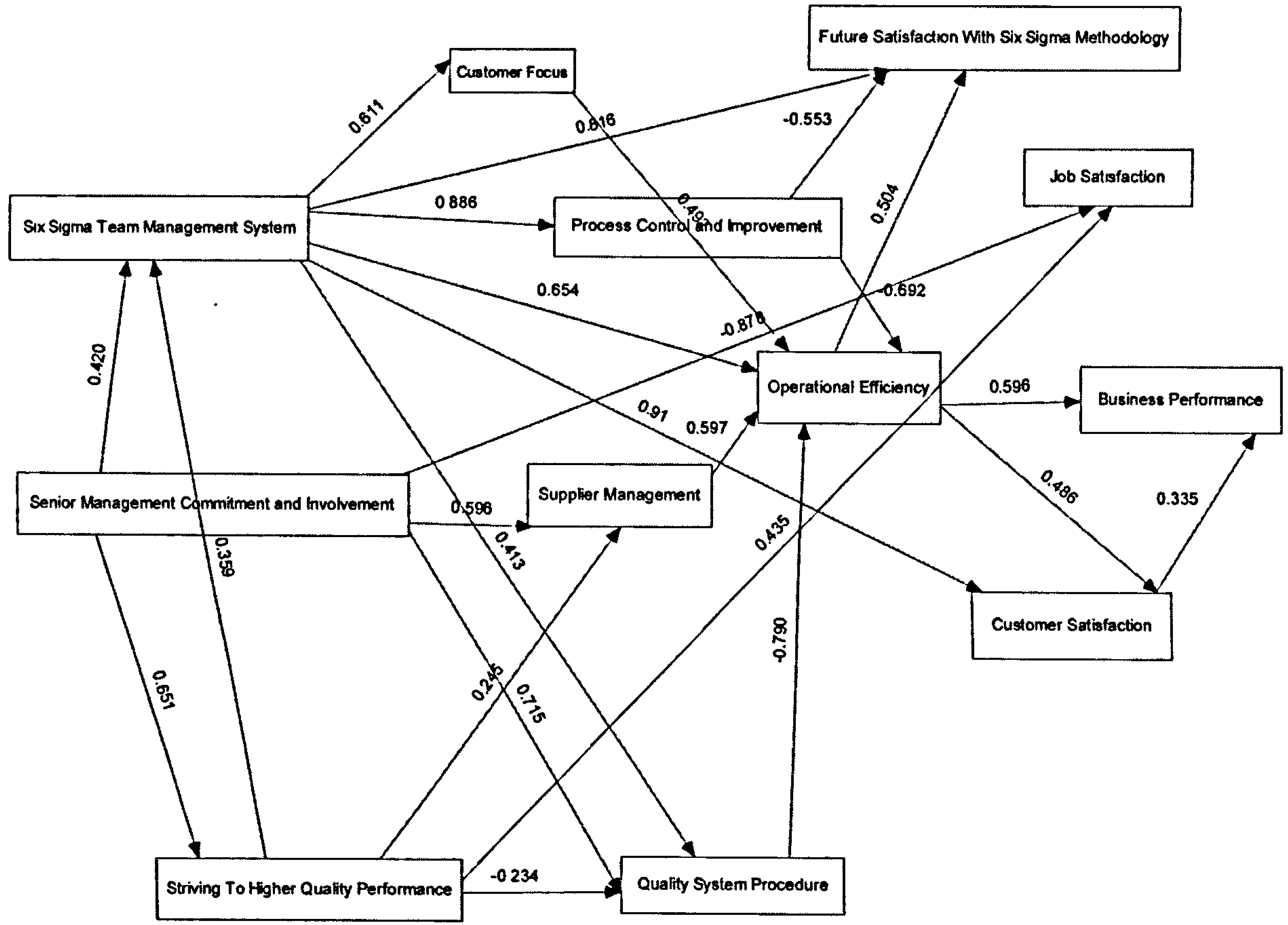


Figure 5.4. The Path Analytic Model Portraying Quality Management System and Organizational Performance Relationships
Source: this study

5.4.3.2 Interpretation of Results

Hypothesis 1-2

The results of analysis in Table 5.12 show that Senior Management Commitment and Involvement is directly related to the aim of Striving for Higher Quality Performance. With only one predictor variable, the adjusted R^2 is 0.410 implying that 41% of the total variance in the aim of Striving for Higher Quality Performance can be accounted for by senior management commitment and involvement. The path coefficient (*P*) is 0.651 ($p<0.001$). This leads to the acceptance of the first hypothesis that the aim of Striving for Higher Quality Performance is dependent on the senior management commitment and involvement.

Six Sigma Team Management System is dependent on senior management commitment and involvement ($P=0.411$, $p=0.008$) and the aim of striving for higher quality management ($P=0.360$, $p=0.021$). The first two sets of hypotheses are supported based on the results of path analysis. The cause and effect relationships among them are justified theoretically. The resultant path analytic model is shown in Figure 5.4.

Hypothesis 3-6

The hypotheses 3-6 seem to enjoy weaker theoretical support and rejecting part of these assumptions leads to the revisions of the hypothesized model. Customer Focus is dependent on Six Sigma Team Management System ($P=0.611$, $p<0.001$) but not senior management commitment and involvement and the aim of Striving for Higher Quality Performance. Six Sigma Team Management System ($P=0.886$, $p<0.001$) is making a significant unique contribution to explaining the dependent variable Process Control and Improvement, when the variance explained by all other variables in the model is controlled for. But Senior Management Commitment and Involvement ($P=0.126$, $p=0.412$), Striving for Higher Quality Performance ($P=0.078$, $p=0.468$), Supplier Management ($P=0.058$, $p=0.656$) and Quality System Procedure ($P=-0.208$, $p=0.151$) are making less of a contribution to Process Control and Improvement. Six Sigma Team Management System in this study refer to the ways six sigma participants are motivated to improve quality (see Appendix 3). The result seems to suggest that if the organization could increase the Six Sigma Team Management

System scores by one standard deviation (which is 0.985, from the below Descriptive Statistics table (Table 5.8)), then the Process Control and Improvement scores would be likely to increase 0.886 standard deviation units. If we multiplied this value by 0.852 (the standard deviation of Process control and improvement scores), we would get 0.886 x 0.852 = 0.755. The total variance R^2 (81.8%) explained is high; imply that Process Control and Improvement is mainly relies on the Six Sigma Team Management System.

Descriptive Statistics

	Mean	Std. Deviation	N
Process Control and Improvement	5.071	0.852	42
Senior Management Commitment and Involvement	5.909	1.169	42
Striving for Higher Quality Performance	5.024	0.766	42
Six Sigma Team Management System	5.029	0.985	42
Supplier Management	4.774	1.198	42
Quality System Procedure	4.514	1.103	42

Table 5.8 Descriptive Statistics of Hypothesis 4
Source: this study

Senior Management Commitment and Involvement (P=0.596, p<0.001) and Striving for Higher Quality Performance (P=0.245, p=0.048) are making a significant unique contribution to the prediction of Supplier Management but not the Six Sigma Team Management System (P=0.100, p=0.412). The total variance (70.3%) explained is high; imply that Supplier Management mainly relies on Senior Management Commitment and Involvement and the aim of Striving for Higher Quality Performance.

Quality System Procedure is dependent on Senior Management Commitment and Involvement (P=0.715, p<0.001), Six Sigma Team Management System (P=0.413, p=0.001) and the aim of Striving for Higher Quality Performance (P=-0.243, p=0.032). However, Senior Management Commitment and Involvement is a more influential factor to Quality System Procedure, compared with the aim of Striving for Higher Quality Performance and Six Sigma Team Management System. The total variance (75.5%) explained is high; and this implies that Quality System Procedure mainly relies on Senior Management Commitment and Involvement, the aim of Striving for Higher Quality Performance and Six Sigma Team Management System.

Hypotheses 7-11

The last five hypotheses postulate the cause and effect relationships between the Six Sigma management practices and organizational performance. Operational Efficiency is postulated to be influenced directly by all the constructs in the Six Sigma management practices. However, the path analysis results show that it is affected directly only by Quality System Procedure (*P*=-0.790, p=0.005), Supplier Management (*P*=0.597, p=0.008), Customer Focus (*P*=0.492, p=0.016), Process Control and Improvement (*P*=-0.692, p=0.022) and Six Sigma Team Management System (*P*=0.654, p=0.039). The Satisfaction with Six Sigma Methodology is directly related to Operational Efficiency (*P*=0.504, p<0.001), Six Sigma Team Management System (*P*=0.816, p=0.003) and Process Control and Improvement (*P*=-0.553, p=0.036).

The Job Satisfaction is dependent on Senior Management Commitment and Involvement (*P*=-0.878, p=0.004) and the aim of Striving for Higher Quality Performance (*P*=0.435, p=0.031) but not Six Sigma Team Management System (*P*=-0.631, p=0.092), Quality System Procedure (*P*=0.370, p=0.195), Process Control and Improvement (*P*=-0.344, p=0.292) and Operational Efficiency (*P*=0.297, p=0.080). However, Senior Management Commitment and Involvement is a more influential factor to Job Satisfaction, compared with Striving for Higher Quality Performance and operational Efficiency.

Customer Satisfaction is directly related to Operational Efficiency (P=0.486, p=0.018) and Six Sigma Team Management System (P=0.910, p=0.019) but not Senior Management Commitment and Involvement (P=-0.348, p=0.258), Striving for Higher Quality Performance (P=0.220, p=0.284), Customer Focus (P=0.226, p=0.356), Supplier Management (P=-0.227, p=0.404), Quality System Procedure (P=-0.122, p=0.719) and Process Control and Improvement (P=-0.670, p=0.068). Business Performance is directly related to Operational Efficiency (*P*=0.596, p<0.001) and Customer Satisfaction (P=0.335, p=0.030). Operational Efficiency is a more influential factor to Business Performance, compared with Customer Satisfaction.

Hypothesis	Dependent Variable	F	Probability	Adjusted R^2	VIF	Independent Variable	P	t	Probability
Hypothesis 1	Striving for Higher Quality Performance	29.475	0.000	0.410	1.000	Senior Management Commitment and Involvement	0.651	5.429	0.000
Hypothesis 2	Six Sigma Team Management System	19.586	0.000	0.476	1.737	Senior Management Commitment and Involvement	0.42	2.816	0.008
					1.737	Striving for Higher Quality Performance	0.359	2.407	0.021
Hypothesis 3	Customer Focus	18.959	0.000	0.568	2.090	Senior Management Commitment and Involvement	0.236	1.588	0.120
					1.995	Striving for Higher Quality Performance	-0.016	-0.111	0.913
					2.004	Six Sigma Team Management System	0.611	4.201	0.000
Hypothesis 4	Process Control and Improvement	37.840	0.000	0.818	5.183	Senior Management Commitment and Involvement	0.126	0.830	0.412
					2.562	Striving for Higher Quality Performance	0.078	0.733	0.468
					2.758	Six Sigma Team Management System	0.886	8.007	0.000
					3.722	Supplier Management	0.058	0.449	0.656
					4.517	Quality System Procedure	-0.208	-1.468	0.151

Hypothesis	Dependent Variable	F	Probability	AdjustedR^2	VIF	Independent Variable	P	t	Probability
Hypothesis 5	Supplier Management	33.353	0.000	0.703	2.090	Senior Management Commitment and Involvement	0.596	4.845	0.000
					1.995	Striving for Higher Quality Performance	0.245	2.041	0.048
					2.004	Six Sigma Team Management System	0.100	0.829	0.412
Hypothesis 6	Quality System Procedure	43.177	0.000	0.755	2.090	Senior Management Commitment and Involvement	0.715	6.405	0.000
					1.995	Striving for Higher Quality Performance	-0.243	-2.23	0.032
					2.004	Six Sigma Team Management System	0.413	3.772	0.001
Hypothesis 7	Operational Efficiency	6.983	0.000	0.505	5.368	Senior Management Commitment and Involvement	0.435	1.711	0.096
					2.608	Striving for Higher Quality Performance	-0.014	-0.078	0.938
					7.671	Six Sigma Team Management System	0.654	2.149	0.039
					3.126	Customer Focus	0.492	2.533	0.016
					3.743	Supplier Management	0.597	2.811	0.008
					5.722	Quality System Procedure	-0.790	-3.005	0.005
					6.894	Process Control and Improvement	-0.692	-2.399	0.022

Hypothesis	Dependent Variable	F	Probability	Adjusted R^2	VIF	Independent Variable	P	t	Probability
Hypothesis 8	Satisfaction with Six Sigma Methodology	11.555	0.000	0.563	2.275	Senior Management Commitment and Involvement	-0.061	-0.393	0.697
					2.226	Striving for Higher Quality Performance	0.110	0.712	0.481
					6.062	Six Sigma Team Management System	0.816	3.21	0.003
					6.043	Process Control and Improvement	-0.553	-2.177	0.036
					1.614	Operational Efficiency	0.504	3.842	0.000
Hypothesis 9	Job Satisfaction	4.654	0.001	0.348	5.172	Senior Management Commitment and Involvement	-0.878	-3.063	0.004
					2.366	Striving for Higher Quality Performance	0.435	2.242	0.031
					8.338	Six Sigma Team Management System	0.631	1.732	0.092
					4.936	Quality System Procedure	0.370	1.320	0.195
					6.511	Process Control and Improvement	-0.344	-1.07	0.292
					1.712	Operational Efficiency	0.297	1.801	0.080

Hypothesis	Dependent Variable	F	Probability	Adjusted R^2	VIF	Independent Variable	P	t	Probability
Hypothesis 10	Customer Satisfaction	3.882	0.003	0.360	5.830	Senior Management Commitment and Involvement	-0.348	-1.152	0.258
					2.609	Striving for Higher Quality Performance	0.220	1.088	0.284
					8.713	Six Sigma Team Management System	0.910	2.467	0.019
					3.716	Customer Focus	0.226	0.937	0.356
					4.613	Supplier Management	-0.227	-0.845	0.404
					7.242	Quality System Procedure	-0.122	-0.363	0.719
					8.060	Process Control and Improvement	-0.670	-1.888	0.068
					2.438	Operational Efficiency	0.486	2.494	0.018
Hypothesis 11	Business Performance	16.23	0	0.598	1.285	Process Control and Improvement	-0.225	-2.008	0.052
					1.516	Operational Efficiency	0.596	4.890	0.000
					2.005	Job Satisfaction	0.090	0.639	0.526
					2.231	Customer Satisfaction	0.335	2.262	0.030

Table 5.9 The Path Analytic Results
Source: this study

5.4.4 Analysis of Effects on Organizational Performance

Pedhazur (1982) pointed out that there is a distinction made between direct and indirect effects of independent variables in the causal models analysis. A total effect of an independent variable on a dependent variable is defined as the sum of its direct and indirect effect(s). They represent the extent to which a construct influences on the other. He further pointed out that a variable has or has not a direct effect on another variable depends on the causal model. Moreover, a variable may have more than one indirect effect on another variable. The results of direct, indirect and total effects are shown in Table 5.10. Generally, senior management involvement and commitment has a great effect on all other constructs. The total effect of Six Sigma Team Management System on Customer Satisfaction is greater than other elements in the Six Sigma management practices.

The relative impacts of individual constructs in the Six Sigma management practices on organizational performance can be found by calculating the total of direct and indirect effects. Process Control and Improvement (Total effects = -0.652) and Quality System Procedure (Total effects = -0.608) have the strongest negative impact on Operational Efficiency while Senior Management Commitment and Involvement (Total effects = 0.529) and Supplier Management (Total effects = 0.524) have the strongest positive effect on it. Customer Focus (Total effects = 0.463) and Striving for Higher Quality Performance have slightly less important effects.

Satisfaction with Six Sigma Methodology is much dependent on Operational Efficiency (Total effects = 0.524). Senior Management Commitment and Involvement (Total effects = 0.468) and Six Sigma Team Management System (Total effects = 0.427) have slightly less impact on it. Process Control and Improvement (Total effects =-0.882) has the strongest negative effect on the Satisfaction with Six Sigma Methodology.

Six Sigma Participants' Job Satisfaction is influenced primarily by the aim of Striving for Higher Quality Performance (Total effects = 0.556). Six Sigma Team Management System is the second most important element in the Six Sigma management practices leading to job satisfaction (Total effects = 0.545). Operational Efficiency (Total effects

= 0.316) and Quality System Procedure (Total effects = 0.250) have less effect on the Job Satisfaction. Process Control and Improvement (Total effects = -0.550) has the strongest negative impact on it while Senior Management Commitment and Involvement (Total effects = 0.072) has considerable indirect impact.

Additionally, Operation Satisfaction (Total effects = 0.494) is the most important positive element in the Six Sigma management practices leading to Customer Satisfaction. Six Sigma Team Management System (Total effects = 0.476) and Customer Focus (Total effects = 0.445) have slightly less important positive effects while Process Control and Improvement (Total effects = -0.962) has very strong negative impact on Six Sigma Team Management System.

Business Performance is strongly affected by Operational Efficiency (Total effects = 0.798) but Customer Satisfaction (Total effects = 0.335) has less impact on it. However, Process Control and Improvement (Total effects = -0.980) is greatly associated with Business Performance negatively.

Dependent Variable	Independent Variable	Standardized Direct Effect	Standardized Indirect Effect	Standardized Total Effect
Striving for Higher Quality Performance	Senior Management Commitment and Involvement	0.651	0.000	0.651
Six Sigma Team Management System	Senior Management Commitment and Involvement	0.420	0.234	0.654
	Striving for Higher Quality Performance	0.359	0.000	0.359
Customer Focus	Senior Management Commitment and Involvement	0.236	0.389	0.625
	Striving for Higher Quality Performance	-0.016	0.219	0.203
	Six Sigma team management system	0.611	0.000	0.611
Process control and improvement	Senior Management Commitment and Involvement	0.126	0.505	0.631
	Striving for Higher Quality Performance	0.078	0.354	0.432
	Six Sigma team management system	0.886	-0.080	0.806
	Supplier Management	0.058	0.000	0.058
	Quality System Procedure	-0.208	0.000	-0.208
Supplier management	Senior Management Commitment and Involvement	0.596	0.225	0.821
	Striving for Higher Quality Performance	0.245	0.036	0.281
	Six Sigma team management system	0.100	0.000	0.100

Dependent Variable	Independent Variable	Standardized Direct Effect	Standardized Indirect Effect	Standardized Total Effect
Quality System Procedure	Senior Management Commitment and Involvement	0.715	0.111	0.826
	Striving for Higher Quality Performance	-0.243	0.148	-0.095
	Six Sigma team management system	0.413	0.000	0.413
Operational efficiency	Senior Management Commitment and Involvement	0.410	0.119	0.529
	Striving for Higher Quality Performance	-0.013	0.262	0.249
	Six Sigma team management system	0.615	-0.493	0.122
	Customer Focus	0.463	0.000	0.463
	Supplier Management	0.562	-0.038	0.524
	Quality System Procedure	-0.743	0.135	-0.608
	Process Control and Improvement	-0.652	0.000	-0.652
Satisfaction with Six Sigma methodology	Senior Management Commitment and Involvement	-0.060	0.528	0.468
	Striving for Higher Quality Performance	0.107	0.184	0.291
	Six Sigma team management system	0.799	-0.372	0.427
	Process Control and Improvement	-0.541	-0.341	-0.882
	Operational Efficiency	0.524	0.000	0.524

Dependent Variable	Independent Variable	Standardized Direct Effect	Standardized Indirect Effect	Standardized Total Effect
Job Satisfaction	Senior Management Commitment and Involvement	-0.878	0.950	0.072
	Striving for Higher Quality Performance	0.435	0.121	0.556
	Six Sigma team management system	0.631	-0.086	0.545
	Quality System Procedure	0.370	-0.120	0.250
	Process Control and Improvement	-0.344	-0.206	-0.550
	Operational Efficiency	0.316	0.000	0.316
Customer satisfaction	Senior Management Commitment and Involvement	-0.332	0.422	0.090
	Striving for Higher Quality Performance	0.210	0.152	0.362
	Six Sigma team management system	0.869	-0.393	0.476
	Customer Focus	0.216	0.229	0.445
	Supplier Management	-0.217	0.222	0.005
	Quality System Procedure	-0.117	-0.167	-0.284
	Process Control and Improvement	-0.640	-0.322	-0.962
	Operational Efficiency	0.494	0.000	0.494

Dependent Variable	Independent Variable	Standardized Direct Effect	Standardized Indirect Effect	Standardized Total Effect
Business performance	Process Control and Improvement	-0.216	-0.764	-0.980
	Operational Efficiency	0.606	0.192	0.798
	Job Satisfaction	0.086	0.000	0.086
	Customer Satisfaction	0.335	0.000	0.335

Table 5.10 Analysis of Path Effects
Source: this study

5.5 Canonical Correlation Analysis

5.5.1 The Objectives of Canonical Correlation Analysis

Pedhazur (1982) argued that path analysis has a limited power in detecting the interest effects between multiple independent and multiple dependent variables or, between two sets of variables. He contended that Canonical Analysis (CA) is for the purpose of studying relations between two sets of variables. Hair et al. (1998) claimed that Canonical correlation is the only technique available for examining the relationship with multiple dependent variables. Canonical correlation analysis (CCA) can be viewed as a logical extension of multiple regression analysis; the objective of it is to correlate several metric dependent variables and several metric independent variables simultaneously; it is the most appropriate and powerful multivariate techniques in the situations with multiple dependent and independent variables (Hair et al. 1998; Afifi, Clark and May 2004). They further pointed out that the unique feature of CCA is that it does not stop with the derivation of a single relation between two sets of variables. Yeung (1999) concluded that by using CCA, it is possible to detect whether there are some particular sets of quality management constructs that are related to other sets of measures in organizational performance.

The basic idea of CCA is to parsimoniously describe the number and nature of mutually independent relationships existing between the two sets of variables which begins with finding one linear combination of the Y's, say $U_1 = a_1Y_1 + a_2Y_2 + \ldots a_QY_Q$ and one linear combination of the X's, say $V_1 = b_1X_1 + b_2X_2 + b_PX_P$ (Stevens 2002; Afifi et al. 2004). In general, if one has p variables in one set and q in the other set, the number of possible canonical correlations is equal to the minimum of P (the number of x variables) and Q (the number of y variables) (Hair et al. 1998; Stevens 2002; Afifi et al. 2004). After the variance in the first pair of canonical variates is derived, then the analysis will find an uncorrelated dimension of the variable that is the next most reliable, and so on (Stevens 2002).

5.5.2 Results and Interpretations

The relationships between two sets of variables, the Six Sigma implementations and organizational performance measures, were examined by CCA. Several pairs of canonical variates were produced as shown in Table 5.11 and Table 5.12. However, the number of meaningful pairs of canonical correlation to be extracted is based on three criteria: (1) level of statistical significance of the function, (2) magnitude of the canonical correlation, and (3) redundancy measure for the percentage of variance accounted for from the two data sets (Hair et al. 1998, p. 450). The level of significance of a canonical correlation that is generally considered to be the minimum acceptable for interpretation is the .05 level. For the Magnitude of the Canonical Relationships, Hair et al. (1998) claimed that no generally accepted guidelines have been established regarding suitable sizes.

Dimension	Canonical Correlation	F	df1	df2	p
1	.922	2.594	50.00	126.50	.000
2	.719	1.251	36.00	106.67	.190
3	.520	0.801	24.00	84.71	.726
4	.437	0.639	14.00	60.00	.821
5	.253	0.352	6.00	31.00	.903

Table 5.11 Tests of Canonical Dimensions
Source: This study

	Dimension 1
Management Practices Variables	
Senior Management Commitment and Involvement	-.385
Customer Focus	-.685
Supplier Management	-.460
Six Sigma Team Management System	-.820
Process Control and Improvement	.880
Quality System Procedure	.600
Striving for Higher Quality Performance	.066
Quality Management And Six Sigma Analytical Tools	.452
Basic 7 QC (New/Old) Tools	-.462
General Project Management Tools	-.403
Performance Variables	

Operational Efficiency	-.684
Customer Satisfaction	-.370
Business Performance	.401
Job Satisfaction	-.200
Satisfaction With Six Sigma Methodology	-.278

Table 5.12 Standardised Canonical Coefficients
Source: this study

Table 5.11 indicates that one of the five canonical dimensions is statistically significant at the 0.05 level. Dimension 1 had a canonical correlation of 0.922 between the sets of variables. The second set of variates, however, has a high p-value of 0.190 and is thus invalid. Resulting in only one set of variables retained. This result implies that Six Sigma management practices constructs aggregates only one set of effects on organizational performance. In other words, there is no particular set of the Six Sigma management constructs which causes some particular effects on a certain aspect of organizational performance. Table 5.12 presents the standardized canonical coefficients for the first dimensions across both sets of variables. For the management practices variables, the first canonical dimension is most strongly influenced by Process Control and Improvement (0.880). For performance variables, the dimension 1 was comprised of Operational Efficiency (-0.684), Business Performance (0.401), Customer Satisfaction (-0.370). As shown in Table 5.12, Quality Management and Six Sigma Analytical Tools have a greater effect on organizational performance positively. This may be due to the fact the other tools are not well comprehended in the case company. According to Yeung (1999 cited Ittner and Larcker 1997), electronics manufacturing firms have a poor use of quality tools when compared with the automobile industry.

5.6 Discussion

5.6.1 Path Analysis and Structural Equation Modelling – A Choice of Methodologies

Hughes et al. (1986), Loehin (1987) and Blalock (1985) revealed that although

Structural Equation Modelling or causal modelling is similar to path analysis. There is an important distinction between them. Path analysis provides a parameter to estimate the direct and indirect links between observed variables while SEM explains covariation in the data (cited in Narasimhan and Jayaram 1998, p. 164). Joreskog and Sorbom (1998), as cited by Narasimhan et al. (1998) believed SEM is a specialized statistical technique which is able to provide parameter estimates for relationships among unobserved variables. A structural equation model implicitly posits a certain covariance structure whose concordance with the observed covariance based on the data can be tested. However, Stone-Romero, Weaver and Glenar (1995) warned that although the findings of SEM analyses allow researchers to test the plausibility of theoretical models that link unobserved variables to one another and assume the existence of causal connections between such variables, the same findings do not allow for conclusions about either the existence of causality, or the direction of causal flow.

Since the application of SEM is subject to a number of constrains, Baumgartner and Homburg (1996) suggested that researchers should have a careful thought to model specification issues before the data are collected. Structural equation models are only the most profitable when the theoretical frameworks are well-defined and moderately complicated. They also warned that "SEM is not the most useful technique in the early, exploratory stages of research when the measurement structure underlying a set of items is not well established and theoretical guidance concerning possible patterns of relationships among constructs is lacking" (p. 158). Although a few studies on the relationships between Six Sigma management practices constructs and organizational performance were conducted recently (Antony 2004; Antony et al. 2005; Banuelas et al. 2006), the subject of Six Sigma methodology is still a developing topic for empirical studies. Currently, there are no models that have been established describing the relationships among Six Sigma management practices constructs by focusing on the Six Sigma methodology. As pioneering empirical work in this topic, the analysis in this chapter was based on path analytic approaches which are more suitable in the exploratory stage (Brannick 1995).

Harris and Schaubroeck (1990), as cited by Yeung (1999), pointed out that the choice of path analysis and SEM in casual modelling is dependent on breadth versus depth of research. Long (1983) revealed that SEM is a more appropriate tool when researchers have more in-depth knowledge on the relationships between variables that are being studied and the variables are relatively few (cited in Yeung 1999). Bentler et al. (1987) pointed out that SEM is only good for a model with less than 20 variables otherwise computation will become impractical. Their suggestion is supported by Harris et al. (1990 cited in Yeung 1999), analysing of more than 20 observed variables becomes extremely not effective and misspecification is likely to occur. Considering that these constructs in the path diagrams were developed based on factor analysis of more than 90 observed variables, it is virtually impossible to obtain a good fit model by using SEM.

The use of structural modelling is in the tremendous growth phase during the past several decades (Bentler 1987); the use of it has also been increased dramatically in the field of quality and operations management in the past decade. However, there are still very few Six Sigma articles that use path analytic techniques. Empirical research in it is not yet matured; it still has many areas that have not yet been explored. As pointed out by Linderman et al. (2002), Six Sigma lacks a theoretical underpinning and a basis for research other than "best practice" studies. This certainly requires more frequent use of exploratory techniques such as path or factor analysis.

5.6.2 Comparisons with Other Empirical Models

Pandey (2007) conducted a systematic study on Six Sigma and its impacts on operationally efficient and strategically effective situations. However, since the main objective of his study was focusing on Human Resource functions performances, the study was conducted primarily by qualitative methods; and he proposed no models in the Six Sigma management. Some other researchers such as Antony et al. (2005), Haikonen, Savolainen and Järvinen (2004) and Savolainen and Haikonen (2007) have studied the relationships between Six Sigma methodology and the benefits of it in the surveyed companies and proposed a simple framework explaining their relationships. Other studies (Henderson et al. 2000) have carried out systematic investigations on Six Sigma methodology and its contribution to organizational performance. However, the main objectives of their studies were to find out success factors for the implementation of Six Sigma. Other quality management studies (Sakakibara, Flynn, Schroeder and Morris 1997; Narasimham et al. 1998; Rho and Yu, 1998) are viewed as a part of the organizational management practices and not the focus of the research. Only quality management practices were simply measured in these studies.

Anderson et al. (1995) developed a more comprehensive empirical model based on Deming's 14 Points. They developed the model for examining the ways quality management practices leads to customer satisfaction. The path analytic results indicate the support for many of the relationships in the proposed theory, only two of the eight direct paths are statically non-significant the relationship between Learning and Process Management and between Continuous Improvement and Customer Satisfaction. Another comprehensive quality model developed by Flynn et al. (1995) is to measure the eight constructs of quality practices and three aspects of organizational performance.

5.6.2.1 Similarities among Empirical Models

The Importance of Senior Management Leaderships on Quality

Although the present research and the other studies were conducted in different industries at different periods of time, these models generally support the importance of senior management leadership. The empirical correlations reported in Anderson et al.'s study (1995) showed that a direct path from Visionary Leadership to Process Management. Flynn et al. (1995) also found that top management support is the key source of improving a wide range of organizational practices including supplier management process management and work attitude. In the present model, the influence of senior management leadership was found to be strong and very extensive. Senior management leadership has strong total effect on the aim of striving for higher quality performance, Six Sigma Team Management System, Customer Focus, Process Control and Improvement, Supplier Management, Quality System Procedure, Operational Efficiency and Satisfaction with Six Sigma methodology.

5.6.2.2 Differences in Research Findings

Since Anderson et al. (1995) and Flynn et al. (1995) used the same source of data from a manufacturing database to develop their models; therefore, it is not practical to compare the difference between these two models. However, a few important differences between the present model and these two models are found. In Anderson et al.'s (1995) model, process management was found to have the most direct positive effects on organizational performance, however, in the present study, the total effect of Process Control and Improvement has very strong negative effects on organizational performance measures such as Satisfaction with Six Sigma methodology, Customer Satisfaction and Business Performance. Customer relationship, which referred to interactions with customers in Flynn et al.'s (1995) model, was found to have no effect on other quality management practices or organizational performance. In the present model, the construct of "Customer Focus", is used to represent the customer interactions and the focus on customers' needs, which has total effect on Operational Efficiency and Customer Satisfaction.

5.6.2.3 Differences in Research Design

The research design between the present study and the other two researches is very different. With the focus on Six Sigma management practices, the present study develops research constructs based on Exploratory Factor Analysis (EFA) which preserves the practical nature of these constructs; the constructs are developed based on real practices and Six Sigma professionals as well as on the basis of the literature. Some constructs developed here, including Satisfaction with, Six Sigma Team Management System, Six Sigma Methodology and Job Satisfaction were not considered in the other studies.

Another major difference in the present study concerns the measurement of organizational performance. However, Anderson et al. (1995) focused mainly on measuring the customer satisfaction while Flynn et al. (1995) studied the impact of quality management practices on performance and competitive advantages with a trimmed model which indicated the perceived quality market outcomes, internal measure of percent that passed final inspection without requiring rework, and competitive advantage. Competitive advantage referred to operational efficiency, and perceived quality market outcome and customer satisfaction. With five constructs, the present study measures the organizational performance that was measured by Operational Efficiency, Customer Satisfaction, Satisfaction with Six Sigma methodology, Job Satisfaction and Business Performance. In Anderson et al.'s (1995) and Flynn et al.'s (1995) studies, organizational performance was assessed by comparing with major competitors based on perceptions of the senior management. The present study measures the changes in various aspects of organizational performance over the past four years and enables the researcher to achieve more reliable and objective performance data.

According to Flynn et al.'s study, the "perceived quality market outcomes" referred to customer satisfaction on the product quality and image. It might be a theoretical fake to assume customer satisfaction in that these influence the operational efficiency. Flynn et al. (1995) also found that process flow management mainly referred to process control has a direct effect on perceived quality market outcomes and percentage of scrap and rework, but not on competitive advantage. The present study found that process control and improvement in the case company has direct and indirect negative impacts on a wide range of organizational performance measures including Satisfaction with Six Sigma methodology, Job Satisfaction, Customer Satisfaction and Business Performance, but only directly and negatively impact on Operational Efficiency.

5.6.2.4 Differences in the Research Environment

Although the focus and methodologies used in developing the research instruments are quite different between the present study and the previous two, the analysis procedures are almost the same. Both of the present study and Flynn et al. (1995) applied path analysis with "theory trimming" procedures. The major difference of the present study is perhaps the research environment.

Flynn et al. (1995) studied 42 firms which included machinery, transportation components and electronics industries in the US. The present study employed 42 samples from 4 production plants of a large battery manufacturer headquartered in Hong Kong. By focusing on a particular industry, the findings should be more convincing in that a particular industrial environment is studied even though the data came from a single industry (Garvin 1983). The finding in the present study shows that the relationship between Senior Management Commitment and Involvement and the cultural elements, operational practices and organizational performance were quite strong except it is negatively associated with Job Satisfaction. The reason that Senior Management Commitment and Involvement has negative effect on the Job satisfaction might be due to the Six Sigma projects being nominated by the senior management who introduced the Six Sigma methodology into the organization, instead of being studied and decided by Six Sigma teams.

5.6.3 Analysis and Implications

5.6.3.1 A Chain Effect Initiated by Senior Management Commitment and Involvement on Quality

The research results here provide important evidence for a number of presumptions in quality management and Six Sigma implementation. The empirical model developed in this study elaborates the model of chain reaction of quality improvement suggested by Deming (1986, p. 2). The present model, as shown in Figure 5.3, can be broken down into three major elements which represent a series of chain reactions within the case company initiated by Senior Management Commitment and Involvement on quality pursuance. Figure 5.5 portrays these elements. The primary driving force of the Six Sigma initiatives is the senior management commitment and leadership. Senior management commitment causes changes in the cultural elements, boosts the aim of striving for higher quality performance and enhances team management. The culture of pursuing higher quality in the organization helps to improve the implementation of quality initiatives. Operational efficiency, customer satisfaction and business performance will be improved if process operations are improved.

Critical success factors for the successful implementation of Six Sigma methodology is a top-down approach (Antony et al. 2002; Banuelas et al. 2002). Senior management's continuous support and commitment to quality improvement helps to change the attitudes of middle management which in turn motivate the employee involvement (Black et al. 2006 cited Deming). Yeung (1999) argued that the quality system will be collapsed if the senior managements imposed their own responsibilities of quality improvement to lower level of management. The aim of striving for higher quality performance and Six Sigma team management system support Six Sigma management practices. In turn, the Six Sigma Team Management system has significant impact on Operational Efficiency, Customer Satisfaction, Job Satisfaction and Satisfaction with Six Sigma Methodology directly. However, the aim of Striving for Higher Quality Performance does not have the same depth of impact on these performances. Quality drivers, cultural elements, operational support systems and process management are identified as major components of the successful implementation of Six Sigma methodology. These components joined together to enhance the organizational performance. From the proposed model Fig. 2.1 indicating the research approach in a mapped form it was expected that Six Sigma Team Management System; Senior Management Commitment and Involvement; Striving for Higher Quality Performance would lead to Customer Focus; Internal Quality System and ultimately improved Organisational Performance

This was found in Fig 5.4 to be more than expected as the mapped model was found to also include factors which required some relabeling and additions

1) Six Sigma Team Management System; Senior Management Commitment and Involvement; Striving for Higher Quality Performance

These led to:

2) Customer Focus; Process Control and Improvement; Supplier Management; Quality System Procedure

These led to:

3) Satisfaction with Six Sigma; Operational efficiency; Job satisfaction; Customer Satisfaction and ultimately

4) Business Performance

Of those factors above the most influential for the overall business performance of the case study company to be found were the i) process of senior management commitment and involvement ii) the Six Sigma team management system, and; process management control and improvement (see 5.6.3.2.). Therefore, while the literature indicates striving for higher quality performance is a driving force of improved business performance for the company studied in relation to Six Sigma this was not as major a factor as other drivers. It is believed the new factor of process management control and improvement that was found after the Fig. 2.1 was created has replaced this as of greater importance. This could also be the case for the internal quality system in Fig. 2.1 which became quality system procedure as Fig, 5.5. The path analytic model Fig. 5.4 helps us to understand the dynamics of these relationships for Fig. 5.5 that have been found and discussed in detail throughout the chapter 5.

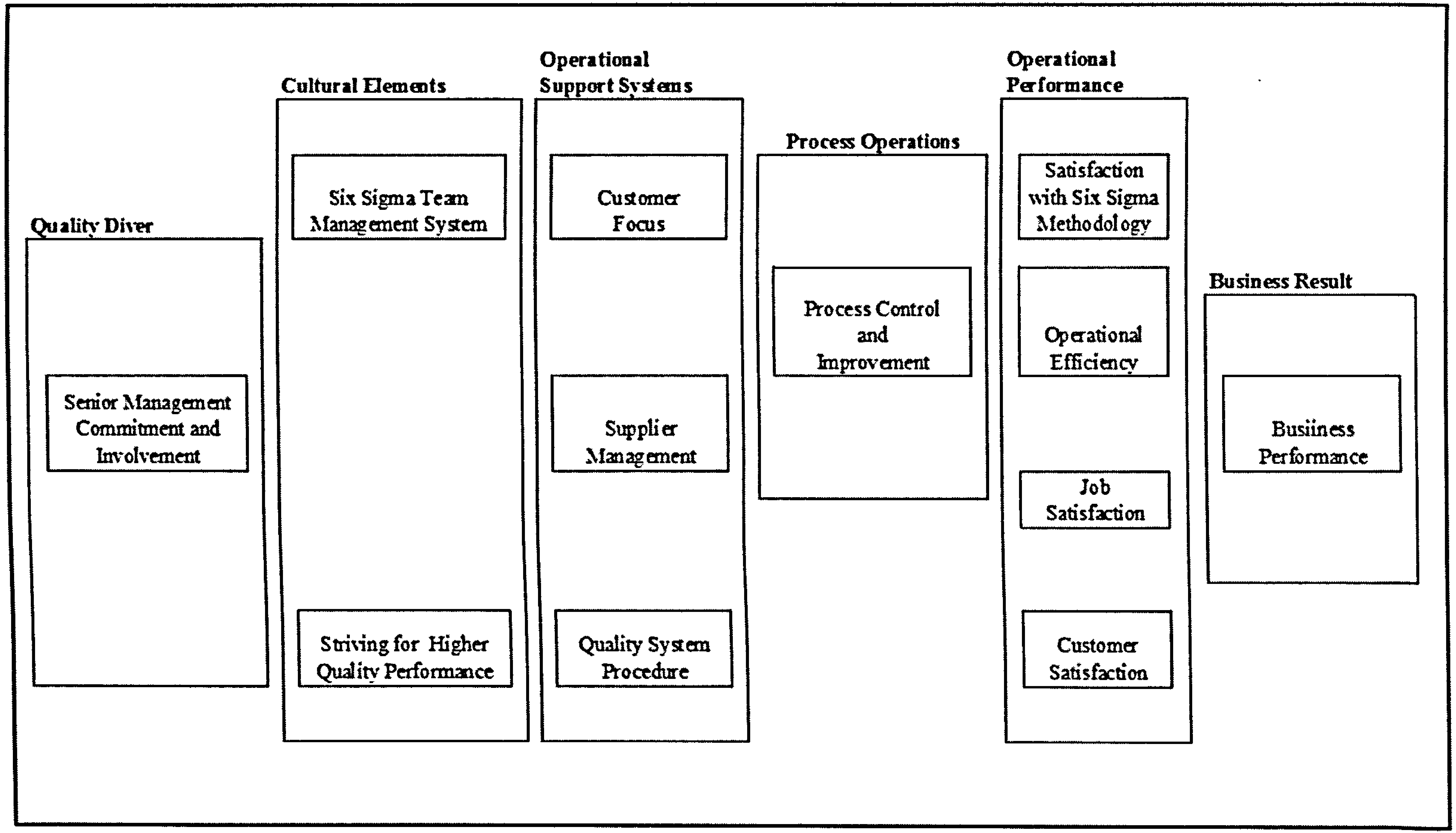


Figure 5.5 An Analysis of Major Components in a Series of Chain Reactions of Six Sigma Management System and Organizational Performance Relationship
Source: this study

5.6.3.2 Stressing the Most Influential Factors

The research results show that Six Sigma management practices are interrelated to form a complicated structure of Six Sigma management system. However, out of the seven constructs of the present study, Six Sigma Team Management System, Senior Management Commitment and Involvement and Process Control and Improvement were found to be the most influential factors for the organizational performance. These findings revealed the possibility of successful implementation of Six Sigma methodology by pinpointing three critical areas – leadership, Six Sigma team management and process management. The present study suggests that the values of the Six Sigma methodology largely depends on the visionary leadership, team and process management, together with a progressive development of Six Sigma cultures.

5.7 Conclusions

The empirical model of the present study portraying the relationship between the Six Sigma management constructs and organizational performance was developed by using path analytic approaches. The model, developed in a battery manufacturing organization with its headquarters in Hong Kong, suggests the Six Sigma management constructs and organizational performance measures are highly associated. This provides some empirical evidence that Six Sigma methodology is valuable to the organization. The results of analysis also revealed that Six Sigma management constructs are related with each other as a set of tools improving organizational performance and contribute values to the company's stakeholders. The results of CCA further support this finding; there is no special set of quality management practices which lead to a particular type of organizational performance. The relationships between Six Sigma management constructs and organizational performance are viewed as a series of chain effects. Senior Management Commitment and Involvement is the driver, fostering quality cultures and effective operational systems. However, operational performance is directly improved by Six Sigma Team Management System and managing the processes system effectively.

The research constructs are derived empirically by using EFA. The model developed here serves as a reference in the future development of conceptual quality model. It is suggested that the contribution of Six Sigma methodology may be assessed by operational efficiency, satisfaction with Six Sigma methodology, customer satisfaction, job satisfaction and business performance.

The present model identifies the roles of Six Sigma methodology in both cultural and system elements in supporting process improvement and enhancing organizational performance. Senior Management Commitment and Involvement, Six Sigma Team Management System and Process Control and Improvement appear to be the critical successful factors in the Six Sigma management practice which are associated with organizational performance. While emphasizing the value of Six Sigma methodology is depending on a balanced development of quality system, the model reveals that the system is underpinned by these critical elements of Six Sigma management practices.

Chapter 6 Presentation and Analysis of Qualitative Data

6.1 Introduction

The primary purpose of this chapter is to present the qualitative findings in a large battery manufacturing firm. The following research questions were addressed in this study:

1. To what extent is the organization implementing Six Sigma?
2. To what extent does Six Sigma methodology impact the organizational performance?
3. To what extent does this organization improve the customer satisfaction level after implementing the Six Sigma methodology?
4. To what extent does the organization actually use the tools and techniques of Six Sigma and how is it familiar with the tools and techniques?
5. To what extend the Six Sigma participants will be promoted to the managerial level in this organization?

6.2 Organization of the Analysis

The research methodology for this case study used a mixed method approach (qualitative and quantitative methods) for data collection and analysis with embedded units of analysis. Because of the complexity involved in a multi-method, multi-level analysis, for easy understanding, the data analysis results are presented in (a) documentation, and (b) interviews.

6.2.1 Results Concerning Documentation

The objectives of first presenting the documentation result in the case company served two main purposes. The search provided (1) information about the organization; (2) a list of Six Sigma projects summaries and the applicable change agent of record for most performance improvement.

6.2.2 Documentation Results Concerning Research Question One

The primary documentations collected from the case company regarding the introduction of Six Sigma methodology to the case company were Six Sigma Implementation Handbook, the trained Six Sigma Green Belt and Black Belt name lists, and Six Sigma Project Summaries.

6.3 Information of the Case Company

The case company is principally engaged in the development, manufacture and marketing of batteries and battery-related products. It has rapidly expanded to become one of the world's major suppliers of primary and rechargeable batteries. It is the largest consumer battery manufacturer in China. It supplies an extensive range of battery products to original equipment manufacturers, leading battery companies as well as consumer retail markets under its own brand name.

The case company is one of the main business units of a large industrial conglomerate called the "Group". The case company itself has been listed on the Mainboard of one of the Asian country's Exchange Securities Trading Limited since 1991 and currently a component stock of that country's Regional Index.

Its production facilities are located in 5 cities and countries of Asia, supported by marketing and trading offices in 16 countries and cities in Asia, America and Europe. The case company is the number one battery manufacturer in Asia outside Japan and the top ten battery manufacture in the world. The Group currently employs about 11,300 people worldwide and occupies a total floor area of approximately 220,000 square metres.

6.3.1 High Quality Pursuance

The headquarters of the case company launched 3 waves of Six Sigma Training since 2004. The first wave was conducted in March 20th to April 30th 2004 by Hong Kong City University. The second wave was conducted in May 17th to June 28th 2004 by

Hong Kong Productive Council. A total of 20 Green Belts were trained at that year; the case company assigned 18 persons to the training but only 16 of them were assigned by the 4 units of production plants. The participant of each department of the case company is summarized as below:

Engineering	2 persons
Process Engineering	2 persons
PIR	1 person
Production Manufacturing Control	2 persons
Product Design	1 person
Production	3 persons
Quality Assurance	5 persons
Total	**16 persons**

Table 6.1 The participant summary of 2004 Green Belt Training
Source: this study

The third wave of Green Belt Training was conducted by Hong Kong Productive Council in the year of 2006. The third wave had a total of 69 participants but only 55 persons were assigned by the case company. 12 participants of "RCM" were taken out from the list because "RCM" refused to participate in the study, therefore, only 43 participants were left. The participant of each department of the case company is summarized as below.

Engineering	8 persons
General Office	2 persons
KYP-Prod	1 person
PA	1 person
Process Engineering	2 persons
PIR	2 persons
Pro-Cell	2 persons
Pro-Pack	2 persons
Product Design	3 persons
Product Development	1 person
Production	9 persons
Production Manufacturing Control	2 persons
Quality Assurance	6 persons

Store	1 person
Quality Department	1 person
Total	**43 persons**

Table 6.2 The participant summary of 2006 Green Belt Training
Source: this study

The case company started launching Black Belt Training in the year of 2006. The training started from April to September of 2006. The Black Belt Training was conducted by a Consultancy Firm. The group assigned 20 persons to participate in the training, including 8 sit-in persons. Each participant has to finish one assigned project in order to be certified as a Six Sigma Black Belt except the sit-in persons. The case company has had 9 persons who participated in the training and all of them were certified as Six Sigma Black Belt, the 2 persons sent by "RCM" were excluded; The participant of each department of the case company is summarized as below.

General Office	2 persons
Engineering	1 person
Quality Assurance	4 persons
Total	**7 persons**

Table 6.3 The participant summary of 2006 Black Belt Training
Source: this study

The case company has launched 11 Six Sigma Black Belt projects between the year of 2006 and 2007. Two of the projects were conducted by "RCM", the business unit which refused to participate in the study. After taken the two projects out, there were 3 Black Belt projects that were finished in the year of 2006 and 6 Black Belt projects were finished in the year of 2007 by the 4 business units. The projects that were assigned by the Chief Operational Officer (COO) which was mainly focusing on improving Roll Throughput Yield (RTY) and Final Product Yield (FPY). The project titles and benefit claimed by each business unit are summarized as Table 6.4.

No of Projects	Business Unit	Project Title	Problem Tackled	Project Type BB or GB	Annual Financial Savings	Other Benefits Claimed	Status
1	RBD	To increase the Rolled Throughput Yield (RTY) of PA70AAAHC from 91.75% to 95.88% so as to increase the manufacturing Final Product Yield (FPY) from 88.58% to 94.34%.	Soften the Positive electrode softening and reduced the scrap	Black Belt	HK$ 351,120	Zero returned batteries from customer which saves the rework time and costs.	Done by Mar. 07
2	RBD	To increase the Rolled Throughput Yield (RTY) of PA70AAAHC from 91.75% to 95.88% so as to increase the manufacturing Final Product Yield (FPY) from 88.68% to 94.34%.	De-burr the Positive electrode and reduced the scrap	Black Belt	HK$ 1,235,712	Zero returned batteries from customer which saves the rework time and costs.	Done by Mar. 07
3	RBD	To increase the Rolled Throughput Yield (RTY) of PA70AAAHC from 91.75% to 95.88% so as to increase the manufacturing Final Product Yield (FPY) from 88.68% to 94.34%.	Improved the Positive electrode pasting	Black Belt	HK$ 408,456	Zero returned batteries from customer which saves the rework time and costs.	Done by Mar. 07
Total Saving of each company					HK$1,995,288		
4	RCP	To improve the production process throughput yield of AAALH series from 91% to 98% so as to improve the manufacturing Final Product Yield (FPY) from 99% to 99.9%	Improved the electrode preparation	Black Belt	HK$ 307,801		Done by Dec. 06
5	RCP	To improve the production process throughput yield of AAALH series from 91% to 98% so as to improve the manufacturing Final Product Yield (FPY) from 99% to 99.9%	Improved the cell assembly	Black Belt	HK$ 304,752	Reduce the backlog of work because the process takes less time. Reduced manpower in process. Increased customers' confident level in its delivery capability.	Done by Dec. 06
Total Saving of each company					HK$ 612,553		

To be continued

No of Projects	Business Unit	Project Title	Problem Tackled	Project Type BB or GB	Annual Financial Savings	Other Benefits Claimed	Status
6	PCD	To increase the production process Rolled Throughput Yield (RTY) of 300SCHP from 79.74% to 92.8% so as to increase the Final Product Yield (FPY) from 92.31% to 99%.	Improved the matching process and electrode process	Black Belt	HK$ 479,736	Reduced the scrap	Done by Dec. 06
7	PCD	To increase the Rolled Throughput Yield (RTY) of production process form 90% to 97% so as to increase the Rolled Throughput Yield (RTY) of PP1000DH form 84% to 90%.	Improved the main effect of discharging time, Open Circuit Voltage (OCV), Weight of electrode and the electrode loss.	Black Belt	HK$ 1,497,600	Reduced the lead time of PP1000DH by 1%, and can reduce handling on scrap of PP1000DH by 5 Man Days per month.	Done by Jun. 07
Total Saving of each company					HK$1,977,336		
8	SBD	To increase the production process throughput from 89.3% to 95% so as to increase the manufacturing Final Product Yield (FPY) from 98.64% to 99.5%.	Improved the thickness of Jelly flat, alignment of positive and negative electrode and short circuit	Black Belt	HK$ 571,464		Done by Jan. 07
9	SBD	To increase the production process throughput of 103450L165R from 89.3% to 95% so as to increase the manufacturing Final Product Yield (FPY) form 98.64% to 99.5%.	Improved the cell thickness, leakage, cell capacity and Open Circuit Voltage (OCV).	Black Belt	HK$ 544,860		Done by Jan. 07
Total Saving of each company					HK$1,116,324		
Total Saving of overall projects					HK$5,701,501		

Table 6.4 The Six Sigma Black Belt Project and Benefits claimed summaries

Source: this study

In order to make an even better improvement, the case company employed a quality expert as its Quality Director to be in charge of the overall quality activities in the company in July of 2007. The Quality Director, who is certified as a Six Sigma Black Belt by General Electric and has unparallel experience in Six Sigma Projects management. Very soon after he took up his office, he published a Six Sigma Implementation Handbook with all detailed guidelines to help the company better understanding the Six Sigma implementation. The Quality Director also built up a Six Sigma network which connected the headquarters with every production plant. The headquarters has full authority and responsibility to approve the annual Six Sigma action plan of each production plant as well as to certify its belts.

The Quality Director also proposed a Six Sigma belts re-qualification scheme, each Six Sigma belt has to finish two Six Sigma projects with half a million Hong Kong dollars bottom line saving every year in order to be qualified as a Six Sigma belt. The Six Sigma project is executed by Six Sigma Green Belt and Black Belt with Master Black Belt's supervision. The Quality Director is also proposing to nominate Six Sigma plant representative(s) as the full time promotion team (Six Sigma Club) which is based on independence from other functions (such as manufacturing, development etc.) to lead Six Sigma projects and to drive the number of belts and number of projects completion for continuous quality improvement.

6.3.2 Six Sigma Organization Roles and Responsibilities

Six Sigma Champion

A senior manager such as General Manager or Deputy General Manager or equivalent is appointed as the Six Sigma Champion to chair and support the Six Sigma initiatives. The Six Sigma Champion is instructed to put the Six Sigma initiatives on the highest management priority.

Full Time Promotion Team (FTPT) – Six Sigma Club Members

FTPT or Six Sigma Club Members are responsible to interpret the Voice of Customer, to improve the operational effectiveness of the organization and to plan, guide and coordinate Six Sigma activities in the unit. The function of FTPT is separate from the manufacturing and non-manufacturing function in order to maintain impartiality. The FTPT leader functionally reports to the Six Sigma Club Chairman (the Quality Director of the headquarter.

Master Black Belt (MBB)

Master Black Belts are typically assigned to a specific area or function of a business or organization such as Quality, Human Resource or Legal, or specific process area such as manufacturing or billing. MBB work closely with Process Owner (PO) to ensure that quality objectives and target are set, plans are determined and progress is tracked. MBB is also responsible for providing coaching and education to his/her Six Sigma team.

Process Owner (PO)

Process Owner is the person who is individually responsible for a specific process.

Black Belt (BB)

The Black Belt is the soul and heart of the Six Sigma quality initiatives. The BB is a full time change agent who is responsible to lead quality projects unit the projects are completed. The BB should finish three projects for his or her first qualification and complete two projects every year for maintaining his/her BB qualification. BB is responsible for coaching Green Belts through the project completion.

Green Belt (GB)

Green Belts are the employees who have finished Six Sigma training and completed two Six Sigma projects and completed at least one Six Sigma project every year to maintain their GB qualification. GB is a part-time change agent who should maintain his/her regular work role and responsibilities but spending 20% to 50% of his/her time on his/her Six Sigma project(s).

6.4 Documentation Results Concerning Research Questions

The primary documentations collected from the case company regarding the introduction of Six Sigma methodology to the case company were Six Sigma Implementation Handbook, the trained Six Sigma Green Belt and Black Belt name lists, training material, Six Sigma Project Summaries, and the case company's Six Sigma Implementation Handbook. For the performance period 2004 through 2007, the case company completed nine Six Sigma Black Belt projects. The projects were mainly focusing on improving the Rolled Throughput Yield (RTY) in order to increase the manufacturing Final Product Yield (FPY).

RBD Plant

RBD completed three Six Sigma black belt projects in the March of 2007. Although the three projects were led by different Six Sigma Black Belts, all of the three projects were focused on increasing the Roll Throughput Yield (RTY) of the same product PA70AAAHC from 91.75% to 95.88%. Project 1 was conducted by the Positive Electrode Soften Team. The project team found that there were softness out of specification limits and a crack was found in an electrode in the eighth process step. After studying the main root causes, they found that by increasing the diameter across part of the pin and the adding of a scraper on the electrode in order to brush the dust away helps to improve the softness problem. The team also found that by using the M-coating machine for picking and placing the electrode, and by using the conveyor belt to collect and transfer the electrode helps to tackle the problem of cracking. The result of the project was better than expected. The RTY was increased to 96.04% and the FPY was increased to 94.55%. The team estimated that the project would save the plant HK$351,120 material scraps per year.

The second project was conducted by Positive Electrode De-burr Team. By using the

DMAIC method, the team defined the problem of burr and cracks which happened in the ninth process step. After analyzing the root causes, they learnt that both of the burrs out of specification and electrode crack control could be improved by installing spring pressure near the adjustment screw, or just simply by removing dust on the roller surface. The team claimed that the result of the project was better than expected. The RTY was also increased to 96.04% and the FPY was increased to 94.55%, but the material scrap they could save every year is HK$1,235,712.

The third project was conducted by the Positive Electrode Pasting Team. By using the DMAIC method, the team defined the problem of the weight of electrode which was out of specification at the electrode forming process in the first step. After analyzing the root causes, the team found that the problems could be improved by using transistor control and modifying the brush powder tank with a taper mouth to solve the problems. The team also claimed that the result of implementing Six Sigma was better than their expectation. The RTY was increased from 91.75% to 96.04% and the manufacturing FPY was increased from 88.68% to 94.55%. The team estimated that the project would save the plant HK$408,456 per year.

All of the three teams claimed that after implementation of Six Sigma projects, they received zero returned batteries from their customer which saved rework time. The organizational performance is therefore improved. The teams also claimed that the projects also help to increase the customer confidence level on their products. The Sales and Marketing Department of the headquarters conduct a customer satisfaction survey every year but which is not available for the present study, therefore, to what extent does this organization improve the customer satisfaction level after implementing the Six Sigma methodology could not be fully evaluated.

According to the project summaries, DMAIC is the major methodology used in the second and third projects. The second team claimed that DMAIC is a platform for problem solving among team members. The third team sees that the DMAIC methodology is a very important step in every improvement process.

RCP Plant

RCP plant conducted and completed two Six Sigma Black Belt projects in 2006. Like the RBD plant, both of the projects were focused on improving the production process throughput yield of AAALH series from 91% to 98% so as to improve the manufacturing Final Product Yield (FPY) from 99% to 99.9%. Project 1 focused on solving the problems of the weight and thickness of electrode preparation. After studying the main effects (ME), the project team found that the weight problem (ME 1) was caused by the incorrect machining definition, incorrect setting of scraper and incorrect setting of besom; the thickness problem (ME 2) was caused by incorrect rolling machine setting, incorrect setting of powder mixture machine and incorrect diameter of powder.

Y Performance		Y 1 Performance	
RTY	74%	TPY	93.01%
DPMO	242071	DPMO	69900
Sigma level	2.2	Sigma level	3.0

Table 6.5 The performance level of the Y and Y 1 before implementing Six Sigma (Project Summary of RCP)
Source: this study

By using the DMAIC methodology, the team found that by standardizing the adjustment method, re-design the shape of scraper and standardizing the mounting method helps to improve the ME 1. The ME 2 could be solved by increasing the charge pressure of the rolling machine, increasing the power mixture time and change in the powder's diameter specification. The result achieved is shown in Table 6.6. The team estimated that the project helps the plant to save HK$307,801 per year.

Y Performance				Y 1 Performance		
	Before	After			Before	After
RTY	74%	92.2%		TPY	93.01%	98.56%
DPMO	242071	86800		DPMO	69900	13903
Sigma level	2.2	3.1		Sigma level	3.0	3.7

Table 6.6 Results achieved of project 1 (Project Summary of RCP)
Source: this study

The second project team focused on solving the problems of electrode damage and short circuit in the cell assembly process. After studying the main effects (ME), the project team found that the electrode damage (ME 1) was caused by the incorrect coiling pin set up, worn coiling pin and incorrect welding energy parameter setting; while the short circuit problem (ME 2) was caused by blunt cutter, variation in thickness and variation in burr. The team found that just simply checking the sharpness of a pin could correct the coiling pin set up. Installing a positive position device and to prepare a convention table by using the correct parameter could improve the worn coiling pin and incorrect welding energy parameter setting. For the ME 2, the team claimed that by adding verification after setting using paper could help to solve the problem of a blunt cutter. Re-adjusting the M-coating parameter helps to improve the flexible of +ve which improved the variation in thickness of coating finally. The variation in burr could be tackled by adding one more coiling rolling process just before coiling.

With the same improvement result Table 6.7, the team estimated that the project would help the plant save HK$304,752 per year.

Y Performance				Y 1 Performance		
	Before	After			Before	After
RTY	74%	92.2%		TPY	93.01%	98.56%
DPMO	242071	86800		DPMO	69900	13903
Sigma level	2.2	3.1		Sigma level	3.0	3.7

Table 6.7 Results achieved of project 2 (Project Summary of RCP)
Source: this study

The second project team claimed that after implementing the DMAIC methodology method, the process time was reduced so as the backlog of work and manpower were reduced. The operational efficiency is therefore improved. They believed the improvement will help to increase their customers' satisfaction level in their delivery capability. Since the customer satisfaction survey is conducted by the Sales and Marketing Department of the headquarters, which is also not available for the present study, therefore, to what extent does this organization improve the customer satisfaction level after implementing the Six Sigma methodology could not be fully evaluated.

According to the project summaries, DMAIC is the major methodology used in the second project team. The team claimed that DMAIC helps to identify, quantify and eliminate sources of variation; it also helps to improve and sustain the performance level of control plans. The team also found that other Six Sigma tools such as FMEA, DOE, SPC, etc are very important for its process capability improvement.

PCD Plant

RBD completed one project in the end of 2006 and one in June of 2007. The first project was implemented in order to increase the production process Rolled Throughput Yield (RTY) of 300SCHP from 79.74% to 92.8% so as to increase the Final Product Yield (FPY) from 92.31% to 99%. Both of the project teams were led by a Master Black Belt of the consultancy firm. By using a DMAIC methodology, the team defined the problem of relative low RTY of 300SCHP as below Table 6.8.

Process Step	**Problem**	**PPM/Cpk**	**Sigma level**
Matching process	1. Capacity	Cpk = 0.89	2.6
	1. Electrode Weight	Cpk = 1.05	3.1
	2. Electrode Grading	Cpk = 0.73	2.2
	3. Broken	4400ppm	4.3

Table 6.8 Problem Definition of project 1 (Project Summary of PCD)
Source: this study

After defining the problem, the Six Sigma team suggested the possible solutions for root causes as Table 6.9.

Main Effect	**Root Cause**	**Possible Solution**
ME 1:	a. Welding energy	a. Fix the machine with specified welding energy

Capacity	b. Vacuum strength of electrolyte dispensing	b. Use a vacuum sensor with warning signal to control the vacuum strength of electrolyte dispensing
	c. Temperature of aging before matching	c. Fix a temperature control room for aging
ME 2: Electrode Weight	a. Pre-press foam thickness variation	a. Adjust the gap distance with a pair of dial gauge on the rollers to control the parallelism of rollers.
	b. Brush distance from container	b. Fix the brush distance from the container with measurement device.
	c. Brush speed variation	c. Fix the brush speed
ME 3: Electrode grading	a. Width of electrode variation	a. Use the gauge block to adjust the width and parallelism between cutting tool and position guide.
	b. Position of cutting electrode	b. Control the parallelism of brush across the electrode.

Table 6.9 Main Root Causes and the Solution of project 1 (Project Summary of PCD)
Source: this study

	Before			After		
	RTY	DPMO	Sigma Level	RTY	DMPO	Sigma level
ME 1 - Capacity	90.0%	100019	2.7	97.0%	30073	3.3
ME 2 - Electrode weight	99.84%	1557	4.3	99.9%	1045	4.5
ME 3 - Electrode grading	98.59%	14129	3.6	99.28%	7222	3.9
Y 1 – Production process	85.23%	158700	2.5	93.26%	67400	3.0
Y -	51.45%	485500	1.5	65.28%	347200	1.9

Table 6.10 Results achieved after implementation and control of project 1 (Project Summary of PCD)
Source: this study

Referring to the Table 6.10, all of the RTY, DPMO and Sigma level had been improved after implementing the Six Sigma methodology. The team estimated that the annual saving after the project was HK$479,736 under the current production volume.

The second project was conducted in order to increase the Rolled Throughput Yield (RTY) of production process from 90% to 97% so as to increase the Rolled Throughput Yield (RTY) of PP1000DH form 84% to 90%. The project team evaluated the financial loss on the turn-back of PP1000DH was HK$213,947 per month. By using the DMAIC methodology, the team defined the problem as Table 6.11.

Process Step	Problem	PPM/DPMO	Cpk	Sigma Level
Electrode preparation	Electrode loss	17200	1.2	3.6
	Weight of electrode	13906	1.23	3.7
Activation	Discharge time	13903	1.24	3.7
	OCV	28716	1.12	3.4

Table 6.11 Problem Definition of project 2 (Project Summary of PCD)
Source: this study

The possible solutions are concluded after defining, measuring and analysing the problems in the production process, the measurement of the problems is summarized as below Table 6.12.

Main Effect	Root Cause	Possible Solution
ME 1: Discharge time	a. The ambient temperature during activation and aging time before activation	Record the aging time and activate in the oven of constant temperature
ME 2: OCV	a. Aging time before activation and the ambient temperature during activation and aging	Record the aging time, activate and then aging in the oven of constant temperature
ME 3: Weight of electrode	a. Width of foam	Changing from slitter to rolling cutter
	b. Space between two powder pasting roller	Use 1 pair of pasting rollers instead 2 pairs of pasting rollers

ME 4: Electrode loss	a. Variation of gap between powder pasting roller and variation of number of powder brusher	Use one pair of powder pasting rollers and 4 pairs of powder brushers

Table 6.12 Main Root Causes and Solution of project 2 (Project Summary of PCD)
Source: this study

Main Effects	Before Improvement		After Improvement	
	CPK/DPMO	Sigma Level	CPK/DPMO	Sigma Level
Discharge time	1.24	3.7	1.54	4.6
OCV	1.12	3.4	1.56	4.6
Weight of electrode	1.23	3.7	1.57	4.7
Electrode loss	17200	3.6	2000	4.3
Y 1	80762	2.9	25000	3.5
Y	158700	2.5	93000	2.8

Table 6.13 Results achieved after implementation and control of project 1 (Project Summary of PCD)
Source: this study

Significant improvement in result was obtained after the implementation and control efforts. The team claimed that the scrap of 8.4KP PP1000DH was saved in a month; they estimated that the annual saving could be HK$124,800. The production lead time was also reduced by 1% which saved the plant 5 'Man Days' per month on producing the PP1000DH. They also found that many analysis and control methods such as DOE and GR&R etc. are very useful in the production processes.

SBD Plant

Project 1

SBD plant started conducting two Six Sigma projects in 2006 and finished in January of 2007. The two projects were conducted in order to increase the production process throughput of 103450L165R from 89.3% to 95% so as to increase the manufacturing Final Product Yield (FPY) from 98.64% to 99.5%. Both of the project teams were led by a Master Black Belt of the consultancy firm. The first team was assigned to solve the problem of electrode winding problem of 103450L165R. Before implementing Six Sigma methodology, the performance level of Y and Y 1 are shown as below.

Performance level of Y	**Performance level of Y 1**
FPY = 98.64 %	RTY = 89.35%
DMPO = 13552ppm	DPMO = 106788ppm
Sigma Level = ~3.7	Sigma Level =~2.7

Table 6.14 Performance level of project 1 before implementing Six Sigma methodology (Project Summary of SBD)
Source: this study

By using the DMAIC methodology, the team defined the problem as Table 6.15 and suggested the measurements as Table 6.16

Process Step	**Problem**	**PPM/DPU**	**Cpk**	**Sigma Level**
Electrode Winding (X 1)	1. Thickness of Jelly flat	PPM: 39784	1.21	~3.6
	2. Alignment of +/- ve electrode	DPU: 0.01	1.27	~3.8
	3. Short circuit	DPU: 0.0024	1.43	~4.3

Table 6.15 Problem Definition of project 1 (Project Summary of SBD)
Source: this study

Main Effect	**Main Root Cause and Solution**
ME 1: Thickness of Jelly flat	Root cause: Use same separator tension for different models with different separators. Solution: Increase the weight hanged to the separator.
	Root cause: Mandrel width (15.85mm) is narrow. Solution: Increase the mandrel width

	Root cause: Wrong separator is used. Solution: Stick colour label on the core of the separator for segregation.
ME 2: Alignment of +/- ve electrode	Root cause: In the electrode winding machine, the electrode channel's width is too wide, 0.20mm wider than the electrode width. Solution: Add a guiding system to control the alignment.
	Root cause: Electrode camber (i.e. edges of electrode is curvy) is greater than 1 mm/m. Solution: Improve the temperature variation inside the oven.
ME 3: Short circuit	Root cause: The distance between suction nozzle and electrode channel is too far (>1mm). Solution: Connect the electrode channel and suction nozzle together to fix the distance below 1mm.

Table 6.16 Main Root Causes and Solution of project 1 (Project Summary of SBD)
Source: this study

After implementing the analyzing, improvement and control technique, the performance of Y and Y1 was significant (Table 6.17).

Performance level of Y		**Performance level of Y 1**	
Before	After	Before	After
FPY=98.64%	FPY=99.51%	FPY=89.35%	FPY=95.05%
DPMO=13552ppm	DPMO=4902ppm	DPMO=106788ppm	DPMO=49834ppm
Sigma Level=~3.7	Sigma Level=~4.0	Sigma Level=~2.7	Sigma Level=~3.1

Table 6.17 Results achieved after implementation and control of project 1 (Project Summary of SBD)
Source: this study

The team estimated that the project could help the plant save HK$571,464 on scrap material per year. They believed that the financial saving could even be enlarged if the solutions were applied to other models. After implementing the Six Sigma, the team found that the DOE was a very powerful tool for defining the root causes in the project while the Gauge R&R was a very important tool in the measurement system.

Project 2

The second project team focused on solving the problems of cell thickness, leakage, cell capacity, open circuit voltage (OCV), delta OCV and impedance (Ri). The performance level of Y and Y1 was the same as project 1. By using the DMAIC methodology, the team defined the problem as Table 6.18. The monthly financial loss of the following problem was about HK$594,924 a year. The team analysed the problem and suggested the measurements as Table 6.19

Process Step	Problem	PPM/DPU	Cpk	Sigma Level
Formation & aging (X 2)	1. Cell thickness	PPM: 31137	1.12	~3.3
	2. No. of leakage	DPU: 0.0018	1.43	~4.3
	3. Cell capacity	PPM: 891	1.56	~4.6
	4. OCV	PPM: 2109	1.48	~4.4
	5. Delta OCV	PPM: 743	1.55	~4.6
	6. Impedance (Ri)	PPM: 1401	1.54	~4.6

Table 6.18 Problem Definition of project 2 (Project Summary of SBD)
Source: this study

Main Effect	Main Root Cause and Solution
ME 1: Cell thickness	Root cause: Temperature of control unit of formation unit during operation is high (~45°C). The electronic components of control unit are affected; hence the charging current is above the specification. Solution: Divide formation program into 2 steps. 30 minutes rest time is added between 2 steps.
	Root cause: In the formation program, the C rate of last step charging is too high (0.8C). Solution: Reduce the C rate of last step charging to 0.6C.
ME 2: Leakage	Root cause: Some channels of formation unit are malfunction. Solution: Replace by contact pin with higher spring force.

	Root cause: Wrong formation program is used. Solution: It is specified that only one model of cell can be activated in one formation unit. Only one formation program is stored in formation unit.
ME 3: Short circuit	Root cause: Machine maintenance frequency is low (every 12 weeks). Solution: Change the maintenance frequency of formation unit to 2 times per month.
	Root cause: Total capacity of cells in one formation unit exceeds the machine limit. Solution: Reduce the charging current to 0.6C.
ME 4: OCV	Root cause: Wrong formation program is used. Solution: It is specified that only one model of cell cannot be formatted in one formation unit. Only one formation program is stored in formation unit.
ME 5: Delta OCV	Root cause: Room temperature of aging room is above specification (>25°C). Solution: Add a fan to lower the temperature.
	Root cause: After OCV1 measurement, the cell is wrongly placed on the position of tray. Solution: Replace the plastic tray by nest tray.
ME 6: Impedance	Root cause: Machine maintenance frequency is low (every 12 weeks). Solution: Change the maintenance frequency of impedance meter to 1 time per month.

Table 6.19 Main Root Causes and Solution of project 1 (Project Summary of SBD)
Source: this study

After implementing the analyzing, improvement and control techniques, the team got the same performance level of Y and Y1 as the project 1 (Table 6.20). But the annual financial saving is slightly less than the project 1. The saving from the scrap material is about HK$544,860 per year. Similar to project 1, the saving could be enlarged if the solutions are applied to other models.

Performance level of Y		Performance level of Y 1	
Before	After	Before	After
FPY=98.64%	FPY=99.51%	FPY=89.35%	FPY=95.05%
DPMO=13552ppm	DPMO=4902ppm	DPMO=106788ppm	DPMO=49834ppm
Sigma Level=~3.7	Sigma Level=~4.0	Sigma Level=~2.7	Sigma Level=~3.1

Table 6.20 Results achieved after implementation and control of project 2 (Project Summary of SBD)
Source: this study

6.5 Interview Results Concerning Research Questions

The purpose of interviewing the Quality Director and subject matter experts of the case company as key informants was to document and define the usage of Six Sigma and its impacts on the stakeholders of the case company during the years 2004 to 2007. Before conducting the interviews with the key informants of the case company, the researcher conducted a pilot test with the Quality Director of the case company and two other Six Sigma practitioners with another company to make sure the instrument was reliable and valid; no problems being encountered. Six interviews questions were received, but were from the plant which was excluded in the present study; the other copy received did not also belong to the analysis unit. Therefore, only 4 copies of the interview questions will be used in the present study. The demographics information is shown as below Table 6.21.

Source	Gender	Function/department	People-direct	Years in industry	Position
AAA	M	Quality - Headquarter	350	16	Quality Director
AAB	M	Quality - Headquarter	349	> 1	Quality Manager
ABA	M	Quality Assurance	52	24	Manager
ABB	M	Quality Assurance	53	6	Manager
ABC	M	Quality Assurance	66	12	Assistant Manager

Table 6.21 Interview respondent demographics
Source: this study

The interview questions are divided into two large sections, the first section is intended to record the demographic information of interviewees. The second section is intended to yield information concerning organizational and the improvement strategy. The second section is divided into five sub-sections as, a) what is Six Sigma in the eyes of the case company, b) deployment of Six Sigma, c) results of implementation, d) other information related to the implementation of Six Sigma, and e) lessons learned from the implementation.

Purpose of Inquiry	Interview Question	Research Question
Perception of Six Sigma	2A3, 2A5, 2A6, 2A7	Q1,
Reason of introducing Six Sigma	2A1, 2A4, 2A6	Q1, Q3,
Indicator of successful implementation	2A2, 2B11, 2B12, 2B14, 2C15, 2C16, 2D17, 2D19, 2E21, 2E22, 2E23, 2E24, 2E25	Q1, Q2, Q3
Indicator of Customer focus	2A4,	Q3,
The usefulness of Six Sigma tools	2A10, 2B13	Q4,
Six Sigma team management system	2A8, 2A9, 2A10, 2B12	Q4, Q5,

Table 6.22 Relationship of Interview Questions to Research Questions

Source: this study

6.5.1 Interview Results Concerning Research Question One

The Six Sigma methodology was introduced by the COO intended to solve the problems at both the corporate level (AAA, AAB and ABB) and process level (AAB, ABB and ABA), such as:

- Formulating, integrating, and executing new business strategies and missions (AAB and ABA),
- Dealing with constantly changing customer requirement (AAA, AAB, ABA and ABB), accelerating globalization (AAB and ABB),
- Improving profitability and corporate performance (AAA, AAB, ABA and ABB), Accelerating innovation (AAA, AAB and ABB),
- Improving marketing channels (AAB, ABA and ABB),

- Enhancing and shortening the corporate learning cycle - the time it takes to translate market intelligence and competitive data into new business practices (AAB)
- Maintaining the relationship with your employees, customers, suppliers and shareholders etc. (AAB), and
- Managing and mitigating business risk (AAB, ABA and ABB).

Although Six Sigma was used as a process improvement tool (AAA, AAB and ABA) as well as a business strategy driver (AAB, ABA and ABB), all the Six Sigma Black Belts projects conducted were mainly focused on process improvement; reducing production scraps; reducing customer complaints; reducing product Return Rate (PRR) and Fall-off-rate (AAA, AAB, and ABA). ABB claimed that his plant used Six Sigma as a business strategy driver to tackle any problems in the company as well as for improving the profitability.

6.5.2 Interview Results Concerning Research Question Two

AAA claimed that Six Sigma methodology largely helped to improve the organizational effectiveness. He pointed out that in most cases, the Roll Throughput Yield were improved from 89% to 95%. He further pointed out that Green Belt project could bring the result in 3 or 4 months, the Black Belt project could bring the result in 6 to 9 months because the Black Belt project was more complicated. AAB even claimed that he could see the result immediately after implementing Six Sigma. AAA further claimed that the case company was only implementing the conventional Six Sigma methodology at this early stage which is not able to shorten the new product development time but the conventional Six Sigma does help to save money and improve the yield rate significantly. ABB of PCD plant claimed that it took 2 years for seeing the benefit, however, the two projects summaries showed that the plant received significant financial saving after the projects; the second project even recorded man hour and lead time reduction. However, the case company had not ever laid off any employee because of the man hours saved (AAA, AAB, ABA).

6.5.3 Interview Results Concerning Research Question Three

All of the interviewees agreed that to increase the customer satisfaction and to meet the customer's changing requirement were the main reasons that the case company introduced Six Sigma into the organization. However, the individual production plant had not conducted a Customer Satisfaction Survey, the survey which was conducted by the Sales and Marketing Department of the headquarters was not available for the present study. Therefore, to what extent the customer satisfaction level was improved after implementation of Six Sigma was not properly known. However, as shown in Table 6.4, the RBD plant claimed that it received zero return rates from its customers; it helped to increase the customers' satisfaction level.

6.5.4 Interview Results Concerning Research Question Four

The case company provided quite a comprehensive Six Sigma training to its belts. Basic statistics for process improvement, process capability, cause and effect matrix, and FMEA. However, the uses of tools were quite different in each individual plant. Process Mapping, SIPOC, GR&R, Cpk/Zst Calculation, QFD, FMEA, Regression Analysis, 7QC Tools, ANOVA, hypothesis test, SPC, DOE, etc. are the mostly used (AAA). Fish bone and Logic tree are the most frequently used in the company (AAB). P-chart, Pareto Chart, Fish bone, Gauge R&R, and Box Plot are the mostly used tools in SBD plant (ABA). However, in RBD, only Pareto Chart and Process Mapping are used the most often (ABB).

6.5.5 Interview Results Concerning Research Question Five

The total number of Six Sigma belts is decreasing, but the actual number was not known because the Human Resource Department had not updated the information at the time of study. AAA claimed that the reason of the decreasing number of belts was because the belts might find an even better job. He also claimed that the company was not going to replace the lost position at the moment because the company was not very satisfied with the results that the Six Sigma projects brought. AAA also pointed out that the company spent about two millions Hong Kong Dollars on the Six Sigma initiatives, but some project results were not really very pleasing. AAA claimed that the average saving of each project is about half a million Hong Kong Dollars. However, 5 out of 9 projects did not hit the target. Therefore, the COO decided not to make any extra investment. In order to achieve improvement in the quality level, the COO set up a quality department in the Headquarters in the mid 2007. He hired a Quality Director in July of 2007 to oversee all the quality issues of the organization and employed a Quality Manager in the December in the same year to assist the Quality Director.

The Quality Director restructured the Six Sigma team management system (AAA). The Quality Director was purposing to make all the Black Belts as full time change agents. All certified belts have to complete 2 Six Sigma projects every year with HK$500,000 saving each to be re-qualified as a belt. The belts could receive 10% of the saving as reward. But there was not any plan to promote the Six Sigma participants to the managerial level (AAA).

6.6 Conclusions

This chapter presented the results of the research based on data collected from two sources: documentation of subject matter and expert interviews. The results were shown based on the embedded units of analysis, culminating in a triangulated presentation based on the research questions. This approach to presenting data, through triangulation of information, ensured that no one particular source was overriding any other. The discussion of results, conclusions and recommendations based on the data collected are presented in Chapter 7.

Chapter 7 Conclusions and Future Work

7.1 Introduction

The primary purpose of this chapter is to present the analysis and interpretation of what was found in the research and to recommend ideas for future research. This chapter is divided into three sections: (a) summary of study results and discussion of results by research question, (b) limitations, and (c) recommendation for future work.

7.2 Summary of Study Results

The objective of the present study was to explore the impact of Six Sigma methodology to the stakeholders of a large battery production firm within the context of Six Sigma methodology implemented through the year of 2004 to 2007. The study specifically addressed five exploratory issues: the extent the Six Sigma methodology could be employed, the organizational performance as it is impacted by implementing the initiative, are customers be better off by the initiative, the usefulness of Six Sigma tools and techniques, and the career path of Six Sigma practitioners. This study explored what, if any, positive impacts brought by Six Sigma initiatives to the stakeholders of this large international battery manufacturing firm.

7.2.1 Findings

This section presents a summary of the key findings derived from the data analysed in Chapter 4 to Chapter 6. Study findings are presented by research questions summarizing the results derived by the case company. The uses of Six Sigma methodology, the extent of deployment, and learning captured will also be discussed in the next section.

7.2.1.1 Research Question One

To what extent is the organization implementing Six Sigma? Although the original goal of Six Sigma was to focus on the manufacturing process, over the past few years, manufacturing companies have been successful in leveraging Six Sigma (Kumar, Saranga, Ramírez-Márquez and Nowicki 2007), it became clear that the distribution, marketing and customer order processing functions also needed to focus on reaching Six Sigma quality standards (Smith 1993 cited in Henderson et al. 2000). Kumar et al. (2007) claimed that as a corporate strategy, Six Sigma is used to reduce the number of defective units from manufacturing processes thereby reducing costs and improving profits. Like many companies, the selection of process improvement projects is probably the most difficult aspect of Six Sigma (Pande et al. 2000). The organization is quite new in implementing Six Sigma; the first wave of training was started in 2004. The Black Belt training was started in 2006. The extent of Six Sigma implementing was therefore very limited. According to the organization's website, this large international battery manufacturing firm has a total of 26 business units in Asia; 1 Office, 16 production plants, 6 Sales & Marketing and 3 Representative Offices. Only 11 registered Six Sigma Black Belt projects were conducted in 5 production plants, 9 of them were counted in the present study. Although all of the projects conducted in the year of 2006 and 2007 were focused on process improvement and scrap material saving, the Quality Director believed that Six Sigma is a very useful and correct way of working to tackle problem in both of Corporate and Process level in the coming years. He also pointed out that Six Sigma has some unique values which are not found in the other quality approaches:

> "In other quality approach like TQM, ISO9000, 5S, TPS, QCC and so on, just mentioning about improvement, even like the philosophy of "zero defect", how zero is real "zero"? For Six Sigma, the initiative has established an ultimate goal or World Class Industrial Best Practice Level for benchmarking of "Six Sigma Quality Level (Z-Level)" that is "3.4 DPMO" (DEFECT value). Six Sigma has quantified "tangible defect value" for world class quality improvement target as well as providing well-structured methodologies (i.e. DMAIC, DFSS-DIDOV, etc.) to utilize quality tools and statistics to up-level quality performance".

Not only all the Black Belts will be employed as full time change agent, the organization is also introducing Six Sigma methodology into other business units in the year of 2008. The extent of Six Sigma implementation will be enlarged in the very near future.

7.2.1.2 Research Question Two

To what extent does Six Sigma methodology impact the organizational performance? Henderson el al. (2000) claimed that the Six Sigma has been the latest thrust for many organizations seeking to improve their performance effectiveness after TQM even they claimed that Six Sigma is still has been defined as a quality improvement program with a goal of reducing the number of defects to as low as 3.4 parts per million opportunities in Motorola. The purpose of this research question is to study how this methodology improves the organization's performance and effectiveness. If based only on this criterion, the case company did not make a significant improvement on its organizational performance; the sigma level of the case company is less than 4. The sigma level improvement of each project is shown as below.

Plant	Project No.	Y Performance	Y1 Performance
RBD	1	No information	
RBD	2		
RBD	3		
RCP	1	0.9	0.7
RCP	2	0.9	0.7
PCD	1	0.4	0.5
PCD	2	0.3	0.6
SBD	1	0.3	0.4
SBD	2	0.3	0.4

Table 7.1 Sigma level improvement
Source: this study

However, there are noticeable cases where Six Sigma failed to deliver the desired results. Aviation Week magazine also conducted a survey among major aerospace companies and found that less than 50 percent of the companies expressed satisfaction with results from Six Sigma projects, nearly 30 percent were dissatisfied and around 20 percent were somewhat satisfied (Zimmerman et al. 2005). The Quality Director of the case company also was not satisfied with the Six Sigma projects results. According to the Questionnaire survey result of the present study, the means of Operational Efficiency and Business Performance are 5.061 and 5.036 respectively (Table 5.1) which are not very high. The project summaries also showed that the man hours saving is also not very significant. Each Six Sigma project did not make the same saving; 5 out of 9 projects did not make the bottom-line saving up to HK$500,000 although the total saving from the 9 project is HK$5,701,501, which is more than two times on investment. The financial savings did fulfill with the standard claimed by Juran Institute, Inc. and Greenwich Associates (2002 cited in Anon[4] 2002). The result may be explained by 1) it was the first time for the Six Sigma Black Belts to implement a Six Sigma project, and the belts might not be able to master the project management techniques very well, 2) and, the projects were assigned by the COO, which was not defined by the regular Six Sigma techniques, the problems the Six Sigma Teams tackled might not be the main problems of the organization, 3) the Six Sigma belts are part-time change agents only, they did not devote all of their time on the project management, the results might be therefore affected, 4) the Six Sigma team structure of each team included mainly the employees who were related to production and quality, no HR or Financial departments were involved, it might decrease the effective possibility as suggested by Kullmann (2005), 5) the Quality System Procedure is the construct which has the lowest mean value, 4.514 (Table 5.1) from the questionnaire survey, and the mean value of the Striving for Higher Quality Performance is the fourth lowest 5.024 which might be the other factors affect the impact on the organizational performance.

7.2.1.3 Research Question Three

To what extent does this organization improve the customer satisfaction level after implementing the Six Sigma methodology? Erwin (1998) claimed that Six Sigma is a concept that concentrates on the customer rather than the product. However, customer satisfaction is not commonly based on contact with only one person or one aspect of an organization. It usually involves many facets of the business, such as customer service, product or service delivery, product quality, etc. (Behara et al. 1995). It is therefore, more difficult to reach Six Sigma level in the customer satisfaction arena. Although the main objective of introducing the Six Sigma methodology into the organization is not to improve the Customer satisfaction, and the Customer Satisfaction Survey was not available for the present study, the questionnaire survey (Table 5.1) shows the organization is quite customer focused, the mean value of the Customer Satisfaction is 5.762 which is the highest score in the present study. In addition, the Customer Focus construct is 5.143, which is the third highest value in the survey showing that the effort of the organization to reduce the defect rate of its product in order to minimize the product return from its customers satisfied its buyers. The project summaries also showed the RBD plants received zero return rate from its customers after the Six Sigma projects, it could be concluded that the customer satisfaction level would be therefore improved.

7.2.1.4 Research Question Four

To what extent does the organization actually use the tools and techniques of Six Sigma and how is it familiar with the tools and techniques? Antony et al. (2005) claimed that the ability to integrate both statistical and non-statistical tools and techniques with the DMAIC framework in a systematic in a systematic and disciplined manner is one of the success factors of Six Sigma. However, there is very few studies have been reported about the usage of Six Sigma Tools and techniques in the Six Sigma projects. The purpose of this research question is to provide an analysis of the usage of Six Sigma tools and techniques in a big battery manufacturing firm.

	Tools/Techniques	Mean
1	Suppliers-Inputs-Process-Outputs-Customers (SIPOC)	4.24
2	Failure Modes and Effects Analysis (FMEA)	4.81
3	Root Cause Analysis	4.50
4	Brainstorming & Affinity Group Tool	4.38
5	Thought Map Relations Diagram	3.52
6	Customer Segmentation Worksheet	3.48
7	Voice of the Customer Data Collection Worksheet	3.43

8	Voice of the Customer Requirements Translation and Kano Analysis	2.88
9	House of Quality - Quality Functional Deployment Matrix	3.38
10	Cause and Effect Matrix	4.19
11	Critical to Quality CTQ Tree Diagram	3.90
12	DMAIC Measurement Selection Matrix	3.17
13	Design For Six Sigma (DFSS)	2.69
14	Measurement Assessment Tree Diagram	2.76
15	Quality Data Checklist & Scorecard	3.40
16	Production Schedule to Actual Scorecard	3.17
17	Pareto Chart	5.60
18	Six Sigma Team Roles	4.05
19	Team Empowerment Boundaries	3.38
20	Six Sigma Project Charter	3.76

Table 7.2 Tools and techniques used by the organization to utilize Six Sigma
Source: this study

Table 7.1 illustrates the most commonly used statistical and non-statistical tools and techniques used in Six Sigma projects by the organization. The table was developed with the purpose of showing information in the usage of tools, techniques and problem-solving methods. Respondents were asked to rate the usage of tools and techniques on 7 Point scales of 1 to 7, where "1" indicates "never use" and "7" indicates "extensive use". As can be seen from the above table, the use of Six Sigma tools and techniques are not extensive. The most commonly used tools and techniques include Pareto Chart, FMEA and Root Cause Analysis which offer visual representation and are easier to use. The result is also matched with Antony et al.'s study (2005).

However, the analysis unit is combined by 4 production plants which had implemented Six Sigma in the year 2004 to 2007. The ways of conducting Six Sigma projects were quite different between these production plants even they are under the management of same headquarter. Therefore, the choice of use of Six Sigma tools and techniques were a bit different. The RBD plant, DMAIC method was mentioned in the two out of three projected conducted showing that the DAMIC is a very important method in the improvement process. The third team also suggested the future project team to make sure the Gage R&R should be done and accepted before going to the Measurement phase; the DOE should be match with the practical resolution of the test instrument, implying that the team was not very familiar with the tools or techniques. Both of RCP Six Sigma teams claimed that they found the DMAIC, FMEA, DOE and SPC etc. were very useful in the capability improvement. RCP might use the tools and techniques in fuller extent and also more familiar with the tools and techniques than the RBD plant. PCD teams also found that many tools and techniques could be applied in for determining the best solutions of the problems they tackled. But how familiar were they with the tools and techniques are not known. The first Six Sigma project team of SBD plant claimed that they learnt many new tools in the Six Sigma training and stressed that most of the tools they learnt could be applied in their daily operation, especially Gauge R&R and DOE.

7.2.1.5 Research Question Five

To what extent the Six Sigma participants will be promoted to the managerial level in this organization? One of the Six Sigma Training centers "The Six Sigma Institution' claimed that it is possible for a certified Six Sigma Black Belt to get a job with 1 million Hong Kong Dollar annually, the Six Sigma Black Belt training is quite costly and time consuming. The Black Belt Training time is from 35 hours to 90 hours or more. The fee is about USD2,000 to USD6,000 or even more. Will people be awarded in their career path after investing such amount of money and/or time on the Six Sigma training? The main aim of this research question is to help the prospect Belts to learn more about the prospect of their career path.

Many articles discuss about the use of rewards in successful Six Sigma implementation programs. Buch and Tolentino (2006 cited Larson 2003) claimed that the general prescriptions in the literatures seem to advocate the use of intrinsic rewards over extrinsic rewards. It is also recommended that companies use the social rewards of Six Sigma involvement as vehicles of satisfying employees' affiliation and relatedness needs. There is no article while discussed whether the Six

Sigma participants will be promoted to the managerial level. The result suggested that the organization provided Black Belt training to the personnel who was already in the managerial level at the time of training except one was in the supervisor level. The first wave of the Green Belt trainees were at supervisory or managerial level, but the second and third waves of Green Belt training were extended to Foreman, Engineers and Technician. The Quality Director claimed that the organization has no promotion plan for the belts, but the belts will be rewarded 10% of the saving they made in the projects each year. The finding is very different from Ingle et al.'s (2001) study which found that the Six Sigma Black Belts and Master Black Belts are the primary source for future top leaders in GE. Although there was no a promised opportunity for the promotion, the Six Sigma practitioners were quite satisfied with their job, the mean value of Job Satisfaction is 5.626 (Table 5.1) which is the second highest scores in the study. The finding in the present study suggests that both Green and Black Belts report it likely or near likely that Six Sigma will lead to social rewards and such intrinsic rewards as job satisfaction and the development of new skills (See Table 4.6). However, ABB claimed that there is still a lot of room for improving the rewarding, motivational and re-training systems.

According to expectancy theory of work motivation, the finding of the present study has positive motivational implications for participants, whose effort levels are related to their instrumentality scores for these outcomes. However, the motivational implications are less positive for the participants who prefer tangible or measurable reward to learning some problem solving techniques (refer to Table 4.6) even the competency of using quality tools might help them win a better job in the future. The study also found that the reward that the Six Sigma participants could get is related with the quality system of the organization. Six Sigma projects were assigned by the COO, from the project summary (Table 6.4), it is obvious to find that some of the projects were focused on tackling some minor problems; the savings from the projects were therefore not significant. The rewards would therefore not be equitable to every participant. This practice would not only limit the financial reward that the Six Sigma teams could receive, it could also lower their satisfaction level on the projects. This suggests that the organization is not very experienced in the Six Sigma project management, Six Sigma team management and quality management.

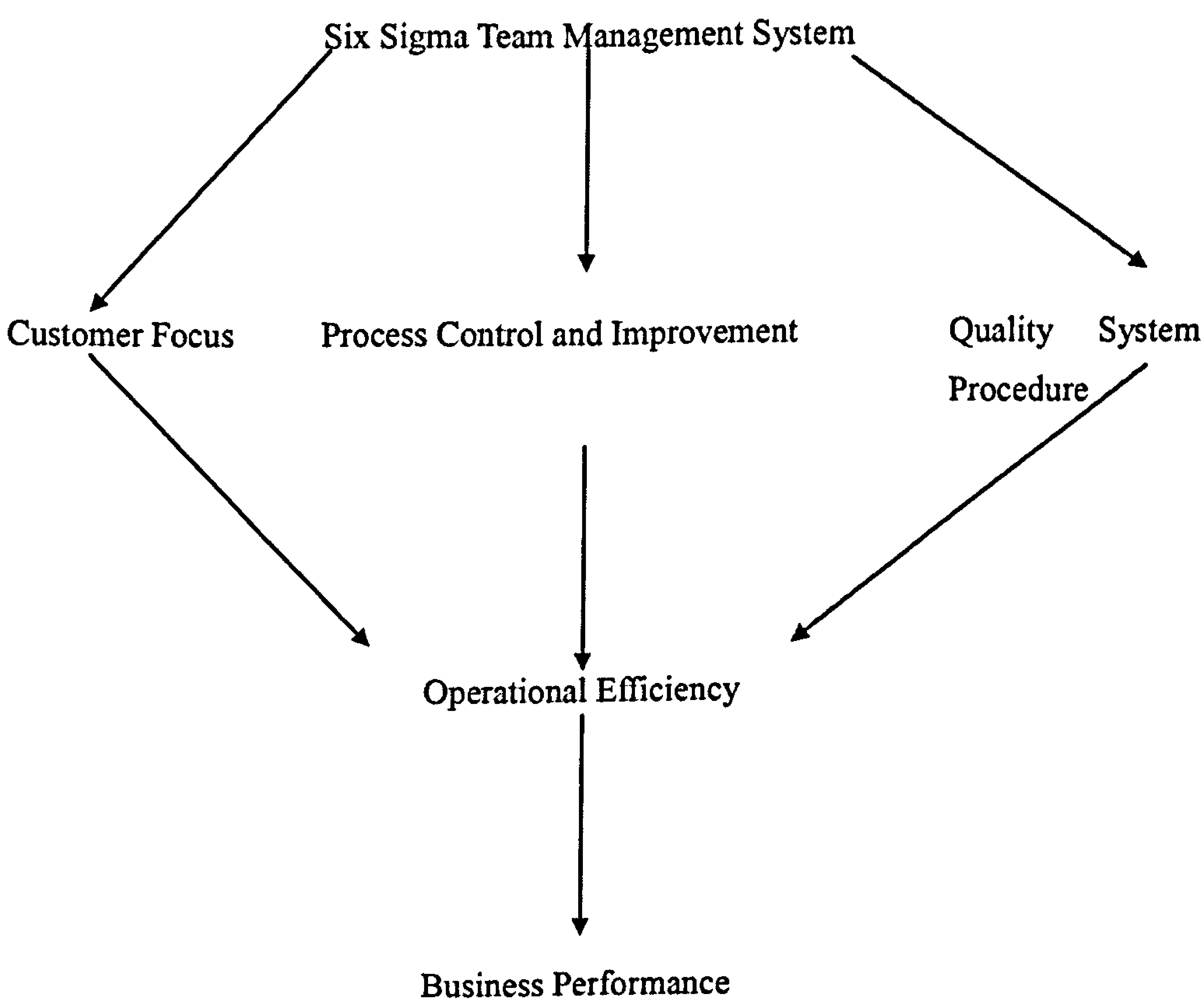
Since it is difficult to develop a monetary reward system that everyone will perceive as equitable (Buch et al. 2006 cited Larson 203), it is suggested that the organization is better to rely on recognition. Recognition is considered as one of the most powerful forms of Six Sigma motivation, and such companies such as Motorola and GE which have earned the most benefits from Six Sigma have relied heavily upon its power (Buch et al. 2006 cited Ashkenas et al., 2003; Larson, 2003).

The last finding to warrant discussion is participant perceptions of organizational performance. Fortunately, mean values indicated that all participants perceive organizational outcomes as "satisfying," which suggests that participants share the organization's desire for the quality improvement results such as improved company operations efficiency, customer satisfaction and business performance. The mean instrumentality ratings for these outcomes indicated that Six Sigma participants felt it likely or near likely that Six Sigma would be instrumental in achieving these organizational outcomes.

In conclusion, the career path of Six Sigma participant requires the establishment of a quality management culture which enables and supports participation, learning, and change. This study focused on the career path of the participants – the promotional possibility, and the job satisfaction. First, it was found that the Six Sigma Black Belts and Green Belts trainings were offered to the employees who were holding an important position in the organization. Their career perspective should be brighter than those non-participants. Second, employees rate Six Sigma as at least somewhat instrumental in their receipt of intrinsic and social rewards, but not of extrinsic rewards.

7.3 The Model Built in the Present Study

The Six Sigma methodology helps the organization to save some man hours, scrap material in the Six Sigma projects; it eventually helps the organization to achieve financial saving. The study result also shows that the organization is customer oriented in that Customer Satisfaction is valued (mean =5.76) the most important issue in the Six Sigma initiative. Six Sigma participants are satisfied with the problem solving tools they learnt in the training. However, to what extent can Six Sigma methodology can contribute it the stakeholders of the organization is depends on various factors, such as the objective of the organization implementing Six Sigma methodology; how experienced the organization is to manage projects; the culture of the organization; how well are the belts trained etc. Simplified from the Path Analytic Model (Table 5.4), the present study found that the Six Sigma Team Management System has the most profound impact on the Business Performance. The Path Analytic Model is simplified as below:



The above diagram shows that Six Sigma Team Management System has the most direct relationship with the constructs. Six Sigma Team Management directly affect the Customer Focus, Process Control and Improvement, Quality System Procedure which helps to improve the Operational Efficiency in the organization, the Business Performance is therefore improved. The Six Sigma Team Management System also has very strong relationship with Customer Satisfaction, which eventually improved the Business Performance.

7.4 General Conclusions of the research results

Although Six Sigma methodology has been playing an increasingly important role in organizational management for more than two decades, little research has been conducted in this area. Motivated by the need to study how the methodology affects organizational performance; an empirical research was carried out in a large international battery manufacturing firm. 42 Six Sigma belts including senior executives of the firm were successfully invited to join the present study.

A wide range of research methodologies was employed and carefully selected for data analysis and model development. Exploratory Factor Analysis (EFA) was the primary technique employed for developing the research instrument and structural equation modeling was used to test the empirical relationships between some performance factors and operational performance.

Identifying and Utilizing the Major Constructs

The present research instrument provides a more comprehensive and systematic measurement on both Six Sigma management practice and organizational performance for the case company. The research constructs were derived not only based on the literature review but also relying on the actual practical knowledge in the industry. The instrument reflects the increasing effects of Six Sigma methodology management standards on the management system.

Building a Six Sigma Management Model

A path analytic model was developed by formulating and testing a series of research hypotheses in the study. The model shows that the Six Sigma Team Management System has the most direct relationship with the constructs. Six Sigma Team Management directly affect the Customer Focus, Process Control and Improvement, Quality System Procedure which helps to improve the Operational Efficiency in the organization, the Business Performance is therefore improved. The Six Sigma Team Management System also has very strong relationship with Customer Satisfaction, which eventually improved the Business Performance.

7.5 Research Contributions

7.5.1 Contributions to the Literature

By focusing on studying the Six Sigma in a large battery manufacturing firm, the present study investigated empirically the association between the Six Sigma management practice and organizational performance, leading to a number of interesting and important findings to both academics and Six Sigma practitioners. The research represents several significant contributions in theory testing building in the field of Six Sigma management practices.

1. An empirical model was developed by using path analytic approach depicting the relationships between Six Sigma management practices and organizational performance. This model is well justified theoretically and represents the most comprehensive model with the best model fit currently available in the literature. It helps to improve the other empirical models and provides an important reference in examining conceptual models in the Six Sigma management practices.

2. An instrument for measuring the Six Sigma management system and organizational performance was developed based on extensive reviews and empirical investigation of the Six Sigma methodology and other quality literature. The present research constructs were derived based on the local Six Sigma professionals' actual practices in their industry. The present study also made comparison with other well-known instruments in the quality field. The present instrument provides a more comprehensive measurement of quality management practices and organizational

performance which helps to serve as a reference for future study in this field.

7.6 Limitation of the Present Study

There were limitations of the study that are appropriate to mention covering the methodology used, generalisability of the findings, and structure of the research questions. Within the quantitative data collection and analysis, random sampling was used to ensure all Six Sigma practitioners were represented in the present study. However, the case company could not provide an updated practitioners name list, the actual number of practitioners were not known. In addition, the questionnaire was sent by the case company via email to the practitioners and also collected by the case company; the researcher could not ensure all the answers provided were under free will. The sample size for the survey was not adequate for most testing, especially in a CCA, which requires a large sample size.

The process of qualitative data collection was also not smooth. Project Charter is considered as the first step in the Six Sigma implementation. Swinney [no date] claimed that

"the project charter can make or break a successful project. It can make it by specifying necessary resources and boundaries that will in turn ensure success; it can break it by reducing team focus, effectiveness motivation".

The case company has had conducted 11 Six Sigma projects, but the organization was not able to provide any of them. Therefore, there was no Start Date and Actual Completion Date of the projects could be tracked. The duration of each project is not known; hence how fast can Six Sigma bring benefit to the organization could not be cross-checked. The names and roles of team members were also not clearly listed in the project summaries, were they all the right persons for the projects is also not known. The financing savings claimed at the project summary might also be misleading. The project teams made the estimation in terms of annual saving, but the effect of a project might not be able to last for a year if the teams could not control the improvement in the right track. Therefore, the real saving from each project could not be verified. In addition, the researcher was intended to interview at least one key informant of each plant, however, only two plants were arranged.

7.7 Recommendations for Future Work

There are recommendations that arise from having undertaken this study. These recommendations are not limited to include topics for exploring other populations or variables or conducting other study.

Other populations that could be explored include other production plants or business units of this large battery manufacturing firms to understand the influence of project management experience on the Six Sigma project performance result. In addition, in the present study, the correlations between Six Sigma tools and techniques with Operational Efficiency, Customer Satisfaction, Business Performance, Job Satisfaction, and Satisfaction with Six Sigma Methodology is very low or even negative (refer to Table 4.6). The researcher believes that it is valuable to have an in-depth study to find out the reason(s). Moreover, almost all of the Predictors in the present study have quite low correlations with Business Performance, even with the aim of Striving for Higher Quality Performance, the correlation value is 0.26 (refer to Table 4.1). What made it this way? What could this organization do to improve the Business Performance?

Chapter 8 Reflective Diary

The researcher's reflective diary includes an account of her experiences during the entire Doctor of Business Administration program and how the program has impacted and improved her work in marketing research and business analysis in her company. The experiential learning in the program helped the researcher to acquire and apply the knowledge and skills learnt in her daily work. These experiences and impacts can be categorised into two main parts: The first part is the reflections based on the taught modules, and the second part is the impacts based on the research components. The overall DBA studies have impacted the researcher's work in her job at the company in the Business Development field and her ability to conduct marketing research and business analysis. The most noticeable improvements are in critical thinking and project management skill. The company which the researcher is working for has several computer systems for recording similar but different data and information. These systems and the information contained always caused confusion to the users; it also wastes users' time on data digging. Through the communication learnt in the programme, researcher is able to redesign the information system with the related departments and users. Her research skill is also improved significantly. She is able to work with the consultancy firm which her company hired for designing and conducting a Customer Satisfaction Survey. The researcher is able to work with the consultancy firm in the questionnaire design and survey conduction work. She is also able to review the analysis results of the consultancy firm. The researcher is also able to review research work of the Hong Kong government and the research reports which her company bought from the research companies in the context of the methods of conducting research, philosophical view of research, epistemology and assumptions associated with methodology, and interpreting the analysis result more effectively now than before starting the DBA studies.

Part I: Impact from Taught Modules

1. Philosophical Underpinnings of Research Methods

This module has the most significant and fundamental impact on the researcher in conducting empirical research because it provides the fundamental knowledge on the research methodologies, research process, research designs, sociology of knowledge, epistemology and ontology, concepts relating to theory building and testing- models, propositions and hypotheses, sample size, scientific data analysis and research ethics.

This module has influenced the researcher's ability to work with the consultancy firm in the customer satisfaction survey in terms of providing a careful overview of the survey method and its appropriateness in questionnaire design, sampling and data analysing. The content of the module has enhanced the researcher on research concepts and techniques, which she is able to present in a more persuading set of survey results.

2. Qualitative and Quantitative Modules

Both of the qualitative and quantitative modules were very insightful for the researcher as it presented information to be connected with the obtaining of knowledge that researcher was not quite familiar with. The qualitative module has the impact on the researcher in communication and text analysis techniques. As a result, she has been able to incorporate philosophical aspects of phenomenological techniques and their description such as text analysis, cognitive mapping and integration of qualitative or quantitative approaches in research design in her plans for investment on a new cruise terminal project. The researcher has also learnt the usefulness of case study planning and analysis techniques, interviews skills and reflective diaries. The researcher has been able to apply both qualitative and quantitative approaches in the study of the possibility of the new cruise terminal investment project in Hong Kong and also be able to develop a research proposal more effectively than before.

The quantitative module was also very helpful for the researcher's dissertation and the analysis works in her company. This module helped the researcher conceptualise the research design and implementation of the DBA research project. It also helps the researcher to examine the Customer Satisfaction Survey result submitted by the consultancy firm. The exposure to the SPSS and Amos were extremely useful for doing the daily data analysis.

The module served as a good preparation for the researcher to be able to use qualitative and quantitative research methods for data collection, and understand the practical problems or issues involved in the use of both approaches.

3. Research Planning and Proposal Writing module

The research planning and proposal writing module is also a very useful module which helped the researcher in developing an academic rigour as well as practical relevance research proposal. It served as a platform to write an acceptable proposal for the dissertation that included objectives, research methodology and proposed analysis methods. This module was particularly useful in helping her understand the overall research project and activities for the rest of the DBA studies. The insights gained from this module have also been useful in her other business proposal writings in her company.

Part II: Impact from Research Components

1. Seminars:

- **Literature Review**

The researcher collected literature relating to various aspects of quality management strategies and Six Sigma Methodology from a variety of secondary sources and acquired knowledge of different quality methodologies and tools and the impacts of introducing quality initiatives to organizations and their stakeholders. During the literature review a large number of quality management methodologies from articles were studied to evaluate the feature of quality management methods and tools for identifying the strengths and weaknesses of them and their impacts on organizations and the stakeholders. In addition to the above mentioned literature review, the researcher has also acquired the knowledge of the research analysis techniques employed in the previous studies. As a result of this experience, this module helps the researcher to select the appropriate statistical analysis techniques in her dissertation.

- **Research Methodology**

The workshop of research methodology provided an opportunity to receive a feedback on the proposed research framework of relationship between Six Sigma Methodology and its impact on organization performance, and as a result the framework was modified. Also, it provided clarity in conceptualising and deciding on the specific statistical techniques, sampling and constraints of the methods. Because of this experience, the researcher is more capable of doing her marketing research by empirical method in her company.

- **Results**

It presented an opportunity to describe results obtained from data analyses in the form of descriptive, hypotheses testing and correlations analyses. The feedback was positive and a good amount of work had been completed in this phase.

2. Dissertation writing

The dissertation writing is one of the most difficult parts of the program that required putting all pieces of the research process together. The university provided in various modules and supervision assistance given by the supervisors, particularly, in terms of providing the structure for the dissertation document and chapters, methodology used and analysis techniques, it turned out to be very useful. The dissertation write up was guided throughout by the supervisors and they have always made very valuable suggestions on the paper. Overall review of the dissertation received positive comments, and the suggestions were incorporated.

The researcher was very thankful for the constructive feedback and efficiency of the supervisors during the write up process. It was a very pleasant learning experience. This has impacted on the researcher's ability to direct advice and supervision of her associate colleagues in a more directive and effective way. It has proved to be an efficient method for directing business analysis and report writing.

3. Summary

Both the taught modules and the research components helped the researcher to develop a business research technique and critical evaluation skills. The experiences have impacted the researcher's proposal and report writing skills, data analysis techniques as well as communication skills in the manner described in sections above. Her job performance reflects this in an appreciation by the peers and supervisors.

The researcher has also found that the research methodologies and analysis methods have been changing and improving during the last past few decades. As a result of this experience, the researcher learnt that there is no perfect method and skill which can be used perpetually; we therefore have to seek for continuous improvement on our knowledge and skills in order to cope with the ever changing environment.

Reference

Adam, E. E., Corbett, L. M. and Flores, B. E., et al. 1997. An international study of quality improvement approach and firm performance. *International Journal of Operations & Production Management*, Vol. 17, No. 9, pp. 842-873.

Aggogeri, F., and Gentili, E., [no date]. Contribution of Six Sigma methodology to shareholders and stakeholders [online].
Middlesex University. Available from:
http://mubs.mdx.ac.uk/conferences/bpcsr05/05_csr_stakeholder/Francesco%20Aggogeri%20University%20of%20Brescia_ITA.pdf

Afifi, A., Clark, V.A. and May, S., 2004. Computer-Aided Multivariate Analysis (4th ed.). Chapman & Hall/CRC

Ahire, S. L., Golhar, D.Y. and Waller, M.A., 1996. Development and validation of TQM implementation constructs. *Decision Science*, Vol. 27, No. 1, pp. 23-56

Ahmad, R., Kamaruddin, S., Khan, Z. A., Mokthar, M. and Almanar, I. P., 2006. Implementation of dust control system using management and planning tools (MPT): A case study. *Management of Environmental Quality: An International Journal*, Vol. 17, No. 4, pp. 390-408.

Ahmed, N. U., Montagno, R. V. and Firenze, R. J., 1996. Operations strategy and organizational performance: an empirical study. *International Journal of Operations & Production Management*, Vol. 16, No. 5, pp. 41-53.

Ahmed, A., Kayis, B. and Amornsawadwatana, S., 2007. A review of techniques for risk management in projects. *Benchmarking: An International Journal*, Vol. 14, No. 1, pp. 22-36.

Alreck, P. L. and Settle, R. B., 1995. The Survey Research Handbook: Guidelines and Strategies for Conducting a Survey (2nd ed.). The McGraw-Hill Companies, Inc.

Amaratunga, D., Baldry, D., Sarshar, M., and Newton, R., 2002. Quantitative and qualitative research in the built environment: application of "mixed" research approach. *Work Study*, Vol. 51, No. 1, pp. 17-31.

Anbari, F. T. and Kwak, Y. H., 2004. Success Factors in Managing Six Sigma Projects [online]. *Project Management Institute Research Conference*, London, UK, July 11-14. Available from:
http://home.gwu.edu/~kwak/Six_Sigma_PMI_2004.pdf

Anderson, J. C., Rungtusanatham, M., Schroeder, R.G and Devaraj, S. 1995. A path analytic model of a theory of quality management underlying the Deming management method: Preliminary empirical findings. *Decision Sciences*, Vol. 26, No. 5, pp. 637-658.

Anderson, R., Eriksson, H. and Torstensson, H., 2006. Similarities and differences between TQM, six sigma and lean. *The TQM Magazine*, Vol. 18, No. 3, pp. 282-296

Anjard, R. P., 1995. Management and planning tools. *Training for Quality*, Vol. 3, No. 2, pp. 34-37.

Anonymous[1], 2000. How Six Sigma Compares to Other Quality Initiatives [online]. Available from: http://media.wiley.com/product_data/excerpt/37/04713967/0471396737.pdf

Anonymous[2], 2002. A revealing study of Six Sigma: Gains but missed potential. *Strategic Direction*, Vol. 19, No. 8, pp. 34-36.

Antis, D., Creveling, C.M., and Slutsky, J.L., 2003. The Role of Executive and Management Leadership in Design for Six Sigma [online]. Indiana, USA: 2006 Pearson Education, Inc. Prentice Hall PTR. Available from: http://www.phptr.com/articles/printerfriendly.asp?p=30890

Antony, J., 2002. Design for six sigma: a breakthrough business improvement strategy for achieving competitive advantage. *Work Study*, Vol. 51, No. 1, pp. 6-8.

Antony, J., 2004. Some pros and cons of six sigma: an academic perspective. *The TQM Magazine*, Vol. 16 No. 4, pp. 303-306

Antony, J., 2004. Six Sigma in the UK service organisations: results from a pilot survey. *Managerial Auditing Journal*, Vol. 19, No. 8, pp. 1006-1013.

Antony, J., 2006. Six sigma for service processes. *Business Process Management Journal*, Vol. 12, No. 2, pp. 234-248.

Antony, J., 2008. What is the role of academic institutions for the future development of Six Sigma? *International Journal of Productivity and Performance Management*, No. 1, pp. 107-110.

Antony, J. and Bañuelas, R. 2001. Six sigma: a business strategy for manufacturing organisations. *Manufacturing Engineering*, Vol. 8, No.3, pp. 119-21.

Antony, J. and Banuelas, R., 2002. Key ingredients for the effective implementation of Six Sigma program. *Measuring Business Excellence*, Vol. 6 No. 4, pp. 20-27.

Antony, J., Antony, F. J., Kumar, M. and Cho, B. R., 2007. Six sigma in service organisations: Benefits, challenges and difficulties, common myths, empirical observations and success factors. *International Journal of Quality & Reliability Management*, Vol. 24, No. 3, pp. 294-311.

Antony, J. and Fergusson, C., 2004. Six Sigma in the software industry: results from a pilot study. *Managerial Auditing Journal*, Vol. 19, No. 8, pp. 1025-1032.

Antony, J., Kumar, M. and Madu, C. N., 2005. Six sigma in small- and medium-sized UK manufacturing enterprises: Some empirical observations. *International Journal of Quality & Reliability Management*, Vol. 22, No. 8, pp. 860-874.

Antony, J. and Taner, T., 2003. A conceptual framework for the effective implementation of statistical process control. *Business Process Management Journal*, Vol. 9, No. 4, pp. 473-489.

Aravindan, P. and Devadasan, S. R., 1996. A focused system model for strategic quality management. *International Journal of Quality & Reliability Management*, Vol. 13, No. 8, pp. 79-96.

Arthur, J., 2004. The Small Business Guerrilla Guide To Six Sigma – How to Systematically Cut Costs And Boost Profits, Even In Touch Times [online].
Available from:
http://www.qimacros.com/pdf/guerrilla.pdf

Asher, H.B., 1983. Causal Modeling (2nd ed.). Sage Publications, Inc.

Ayeni, F. O., 2003. An Empirical Study of the Impact of Six Sigma methodology on Organizational Financial Performance in the U.S. Thesis (PhD). Regent University.

Babbar, S., Behara, R. and White, E., 2002. Mapping product usability. *International Journal of Operations & Production Management*, Vol. 22, No. 10, pp. 1071-1089.

Badri, M. A., Davis, D. and Davis, D., 1995. A study of measuring the critical factors of quality management. *International Journal of Quality & Reliability Management*, Vol. 12, No. 2, pp. 36-53

Baetke, M., Hammer, L. and Zalesky, S., 2002. Six Sigma [online].
Iowa State University. Available from:
http://www.public.iastate.edu/~vardeman/IE361/f02mini/baetke.pdf

Bagozzi, R. P., Yi, Y., and Phillips L. W., 1991. Assessing Construct Validity in Organizational Research. *Administrative Science Quarterly*, Vol. 36, No. 3. pp. 421-458.

Bailey Jr., J. C., [no date]. Enhanced VOC Data Collection Can Jump Start Projects [online]. *iSixSigma*. Available from:
http://www.isixsigma.com/library/content/c070122a.asp

Bañuelas, R. and Antony, J. 2002. Critical success factors for the successful implementation of six sigma projects in organizations. *The TQM Magazine*, Vol. 14, No.2, pp. 92-9.

Bañuelas, R. and Antony, J. 2003. Going from six sigma to design for six sigma: an exploratory study using analytic hierarchy process. *The TQM Magazine*, Vol. 15, No. 5, pp. 334-344.

Bañuelas, R., Tennant, C., Tuersley, I. and Tang, S., 2006. Selection of Six Sigma project in the UK. *The TQM Magazine*, Vol. 18, No. 5, pp. 514-527.

Baumgartner, H. and Homburg, C., 1996. Applications of structural equation modeling in marketing and consumer research: A review. *International Journal of Research in Marketing*, Vol. 13, Issue 2, pp. 139-161.

Beckford, J., 1998. Quality: A critical introduction. Routledge, London & New York.

Behara, R. S., Fontenot, G. F. and Gresham, A., 1995. Customer satisfaction measurement and analysis using six sigma. *International Journal of Quality & Reliability Management*, Vol. 12, No. 3, pp. 9-18

Bendell, T., 2000. What is Six Sigma? [online]
Qualityworld January 2000 Available from:
http://www.iqa.org/publication/C4-1-3.shtml

Bentler, P. M., 1987. Structural Modeling and the Scientific Method: Comments on Freedman's Critique. *Journal of Educational Statistics*, Vol. 12, No. 2, pp. 151-157.

Bentler, P. M. and Chou, C. P., 1987. Practical Issues in Structural Modeling [online]. *Sociological Methods and Research*, Vol. 16, pp. 78-117.
DOI: 10.1177/0049124187016001004 Available from:
http://smr.sagepub.com/cgi/reprint/16/1/78.pdf

Berdebes, G., 2003. Introduction to Six Sigma — For Internal Service Departments and Professional Services Organizations [online].
VP Professional Services, Tenrox White Paper. Available from:
http://www.tenrox.com/en/downloads/whitepapers/pdf/WhitepaperSixSigmaIntro.pdf

Berryman, M. L., 2002. DFSS and Big Payoffs: Transform Your Organization Into One That's World Class. *Six Sigma Forum Magazine*, November 2002, Vol. 2, No. 1, pp. 23-28.

Bhattacharyya, S.K. and Rahman, Z., 2004. Capturing the customer's voice, the centerpiece of strategy making: A case study in banking. *European Business Review*, Vol. 16, No. 2, pp. 128-138.

Bhote, K. R., 2003. The power of ultimate Six Sigma. New York: American Management Association.

Bititci, U.S., Carrie, A.S. and Mcdevitt, L., 1997. Integrated performance measurement systems: a development guide. *International Journal of Operations & Production Management*, Vol. 17, No.5, pp.522-34.

Black, K. and Revere, L., 2006. Six Sigma arises from the ashes of TQM with a twist. *International Journal of Health Care Quality Assurance*, Vol. 19, No. 3, pp. 259-266.

Black, S. A. and Porter, L. J., 1996. Identification of the critical factors of TQM. *Decision Sciences*, Vol. 27, No. 1, pp. 1-21

Born, L. and Molleman, E., 1996. Empowerment and rewards: a case study, *Empowerment in Organizations*, Vol. 4, No. 3, pp. 30-33.

Bounds, G., Yorks, L., Adams, M. and Ranney, G., 1994. Beyond Total Quality Management: Toward The Emerging Paradigm, McGraw-Hill Series in Management.

Boyer, M., 1998. GE mantra: Six Sigma - Statistics drive quest for aircraft engine excellence [online].
Enquirer Business Coverage. Available from:
http://www.enquirer.com/editions/1998/04/19/sixsigma19.html

Bradley, W. C. and Schaefer, K. C. 1998. The Uses and Misuses of Data and Models. Sage Publications, Thousand Oaks.

Braglia, M., Fantoni, G. and Frosolini, M., 2007. The house of reliability. *International Journal of Quality & Reliability Management*, Vol. 24, No. 4, pp. 420-440.

Brannick, M. T., 1995. Critical Comments on Applying Covariance Structure Modeling. *Journal of Organizational Behavior*, Vol. 16, No. 3, pp. 201-213.

Brassard, M., 1989. The Memory Jogger Plus+. Methuen, MA: GOAL/QPC.

Breyfogle, F. W., 2003. Implementing Six Sigma: Smarter Solutions Using Statistical Methods. Hoboken, NJ: John Wiley & Sons.

Breyfogle, F. W., Cupello, J.M., and Meadows, B., 2001. Managing Six Sigma.
New York: John Wiley & Sons, Inc.

Brown, A., 1994. TQM: Implications for Training. *Training for Quality*, Vol. 2, No. 3, pp. 4-10.

Brown, T., 2002. The Critical List [online]. *Quality World*, August, 2002. Institute of Quality Assurance. Available from:
http://www.thecqi.org/qualityworld/c4-1-71.shtml

Buch, K. and Tolentino, A., 2006. Employee perceptions of the rewards associated with six sigma. *Journal of Organizational Change Management*, Vol. 19, No. 3, pp. 356-364

Burton, T.T., and Sams, J.L., 2004. Six Sigma for Small and Mid-Sized Organizations
J. Ross Publishing, Incorporated

Buthmann, A., [no date]. Creating a Recruiting Process: DFSS for Process Design [online]. iSixSigma. Available from:
http://europe.isixsigma.com/library/content/c070627a.asp

Calabrese, G., 1999. Managing information in product development. *Logistics Information Management*, Vol. 12, No. 6, pp. 439-450.

Carpinetti, L. C. R., Buosi, T. and Gerólamo, M. C., 2003. Quality management and improvement: A framework and a business-process reference model. *Business Process Management Journal*, Vol. 9, No. 4, pp. 543-554.

Carpinetti, L. C. R, Gerólamo, M.C. and Dorta, M., 2000. A conceptual framework for deployment of strategy-related continuous improvements. *The TQM Magazine*, Vol. 12, No. 5, pp. 340-349.

Case, M., Cardella, A. and Toomey, M., [no date]. Project Scoping in Healthcare: An Exploration and Tips [online]. iSixSigma. Available from:
http://www.isixsigma.com/library/content/c040303a.asp

Cenek, R. E., 1995. Why improvement efforts fail and what to do about it [online]. *Journal for Quality and Participation*, January-February. Available from:
http://findarticles.com/p/articles/mi_qa3616/is_199501/ai_n8712270

Chadwick, B. A., Bahr, H. M., and Albrecht, S. L., 1984. Social Science Research Methods. Prentice-Hall, Inc., New Jersey.

Chang, C. L., Wei, C.C. and Lee, Y. H., 1999. Failure mode and effects analysis using fuzzy method and grey theory. *Kybernetes*, Vol. 28, No. 9, pp. 1072-1080.

Chen, S.C., Chen, K.S., and Hsia, T.C., 2005. Promoting Customer Satisfactions by Applying Six Sigma: An Example from the Automobile Industry. *Quality Progress*, Vol. 12, No. 4, pp. 21-33

Chowdhury, S., 2001. Power of Six Sigma: An Inspiring Tale of How Six Sigma Is Transforming the Way We Work [online].
Chicago, IL, USA: Dearborn Trade, A Kaplan Professional Company. Available from:
http://site.ebrary.com/lib/surreyuniv/Doc?id=10025997&ppg=11

Chua, C. H., 2002. What You Need to Know About Six Sigma [online].
Productivity Digest. Available from:
http://www.spring.gov.sg/newsarchive/epublications/pd/2001_12/index9.html

Churchill, G A., Jr. 1979. A Paradigm for Developing Better Measures of Marketing Constructs. *Journal of Marketing Research*, Vol. 16, No. 1, pp. 64-73.

Collins, D., 1995. Rooting for empowerment? *Empowerment in Organizations*, Vol. 3, No. 2, pp. 25-33.

Collins, D., 1996. Control and isolation in the management of empowerment. *Empowerment in Organizations*, Vol. 4, No. 2, pp. 29-39.

Combe, I.A. and Botschen, G., 2004. Strategy paradigms for the management of quality:dealing with complexity. *European Journal of Marketing*, Vol. 38, No. 5/6, 2004

Comrey, A. L. and Lee, H. B., 1992. A First Course in Factor Analysis (2nd ed.). Lawrence Erlbaum Associates, Publishers, New Jersey.

Cook, S., 1994. The Cultural Implications of Empowerment. *Empowerment in Organizations*, Vol. 2, No. 1, pp. 9-13.

Coronado, R. B. and Antony, J., 2002. Critical success factors for the successful implementation of six sigma projects in organizations. The TQM Magazine, Vol.14 No. 2, pp. 92-99

Costa, A. C., 2003. Work team trust and effectiveness. *Personnel Review*, Vo. 32 No. 5, pp. 605-622.

Creswell, J. W., 2003. Research design: Qualitative, quantitative, and mixed methods approaches (2nd ed.). Thousand Oaks, CA: SAGE

Cua, K.O., Mc Kone, K.E., Schroeder, R.G., 2001. Relationships between implementation of TQM, JIT, and TPM and manufacturing performance. *Journal of Operations Management*, Vol. 19, pp.675-94.

Curtis, D. and Dean, H., 2004. Impact and performance measurement in library services. *Performance Measurement and Metrics*, Vol. 5, No. 3, pp. 90-95.

Dahlgaard, J. J. and Dahlgaard-Park, S. M., 2006. Lean production, six sigma quality, TQM and company culture. *The TQM Magazine*, Vol. 18, No. 3, pp. 263-281.

Dale, B. G., 1996. Sustaining a process of continuous improvement: definition and key factors. *The TQM Magazine*, Vol.8, No. 2, pp. 49-51.

Daniels, S., 1997. Back to basics with productivity techniques. *Work Study*, Vol. 46, No. 2, pp. 52-57.

Darke, P., Shanks, G., and Broadbent, M., 1998. Successfully completing case study research: combining rigor, relevance and pragmatism. *Information Systems Journal* 8, 273-289.

Daya, M. B. and Raouf, A. R., 1996. A revised failure mode and effects analysis model. *International Journal of Quality & Reliability Management*, Vol. 13, No. 1, pp. 43-47.

Dean, J. W. and Bowen, D. E., 1994. Management Theory and Total Quality: Improving Research and Practice through Theory Development. *The Academy of*

Management Review, Vol. 19, No. 3, Special Issue: "Total Quality". pp. 392-418.

Delisle, C.L.G., 2001. Success and communication in virtual teams. Thesis (PhD). The University of Calgary.

Deming, W.E., 1986. Out of the Crisis. MIT Center for Advanced Engineering Study, Cambridge, MA.

Devadasan, S.R., Muthu, S., Samson, R. N. and Sankaran, R. A., 2003. Design of total failure mode and effects analysis programme. *International Journal of Quality & Reliability Management*, Vol. 20, No. 5, pp. 551-568.

Dhilon, B.S., 2003. Methods for performing human reliability and error analysis in health care. *International Journal of Health Care Quality Assurance*, Vol. 16, No. 6, pp. 306-317.

DiGiacomo, G., King, R. and Nordquist, D., 2003. Building a Sustainable Business: A Guide to Developing a Business Plan for Farms and Rural Businesses. Minnesota Institute for Sustainable Agriculture.

Dobbin, B., 2003. Kodak's 3Q profits tumble 63%. The world's largest photography company, which is betting heavily on digital imaging, is wrestling with a three-year drop in film sales [online].
Information Week, October 22, 2003. Available from:
www.informationweek.com/story/showArticle.jhtml?articleID=15500520

Doran, C., 2004. Using Six Sigma in the Credit Department [online].
onesixsigma.com. Available from:
http://www.onesixsigma.com/Sponsors/Paloma%20Consulting/Articles%20and%20White%20Papers/Using%20Six%20Sigma%20in%20the%20Credit%20Department.aspx

Dorsch, J. J., Yasin, M. M. and Czuchry, A. J., 1997. Application of root cause analysis in a service delivery operational environment: A framework for implementation. *International Journal of Service Industry Management*, Vol. 8, No. 4, pp. 268-289.

Duffuaa, S. O. and Ben-Daya, M., 1995. Improving maintenance quality using SPC tools. *Journal of Quality in Maintenance Engineering*, Vol. 1, No. 2, pp. 25-33.

Dusharme, D., 2001. Six Sigma Survey: Breaking Through the Six Sigma Hype. Quality Digest. Available from:
http://www.qualitydigest.com/nov01/html/sixsigmaarticle.html

Dusharme, D., 2006. Six Sigma Survey: Big success ... but what about the other 98 percent? Quality Digest. Available from:
http://www.qualitydigest.com/feb03/articles/01_article.shtml

Dwivedi, Y. K., Choudrie, J. and Brinkman, W. P., 2006. Development of a survey instrument to examine consumer adoption of broadband, *Industrial Management & Data Systems*, Vol. 106, No. 5, pp. 700-718.

Eckhouse, J., 2003. In Pursuit of Perfection [online]. Bechtel Briefs. Available from: http://www.bechtel.com/Briefs/0803/Perfection.htm

Eggli, Y. and Halfon, P., 2003. A conceptual framework for hospital quality management. *International Journal of Health Care Quality Assurance*, Vol. 16 No. 1, pp. 29-36

Eighteen, R., 1999. Training needs analysis for IT training. *Industrial and Commercial Training*, Vol. 31, No. 4, pp. 149-153.

Eisenhardt, K. M., 1989. Building Theories from Case Study Research. *Academy of Management Review*, Vol. 14, No. 4, pp. 532-550.

Eriksson, H., 2003. The impact of TQM on financial performance. *Measuring Business Excellence*, Vol. 7, No. 1, pp.-36-50.

Erwin, J., 1998. The SIX SIGMA focus on TOTAL CUSTOMER SATISFACTION. *Measuring Business Excellence*, Vol. 2, Issue 4, pp. 16-22.

Erwin, J., 1998. Achieving Total Customer Satisfaction Through Six Sigma [online]. QCI International. Available from:
http://www.qualitydigest.com/july98/html/sixsigma.html

Fellenstein, S.J., [no date]. Dishing up success: Six Sigma helps create GE's latest dishwasher [online].
Quality in Manufacturing. Available from:
http://www.manufacturingcenter.com/qm/archives/1099/dish.asp

Field, A., 2005. Discovering Statistics Using SPSS (2nd ed.). Sage Publications

Filippini, R., 1997. Operations management research: some reflections on evolution, models and empirical studies in OM. *International Journal of Operations and Production Management*, Vol. 17, No. 7, pp. 655-670.

Finlow-Bates, T., 1998. The root cause myth. *The TQM Magazine*, Vol. 10, No. 1, pp. 10-15.

Finlow-Bates, T., Visser, B. and Finlow-Bates, C., 2000. An integrated approach to problem solving: linking K-T, TQM and RCA to TPM. *The TQM Magazine*, Vol. 12, No. 4, pp. 284-289.

Flynn, B.B., Sakakibara, S., Schroeder, R.G., Bates, K.A. and Flynn, E.J., 1990. Empirical research methods in operations management. *Journal of Operations Management*, Vol. 9 No. 2, pp. 250–284.

Flynn, B. B., Schroeder, R.G. and Sakakibara, S., 1995. The impact of quality management practices on performance and competitive advantage. *Decision Sciences*, Sep/Oct 1995.

Forza, C., 2002. Survey research in operations management: a process-based perspective. *International Journal of Operations & Production Management*, Vol. 22 No. 2, pp. 152-194.

Franco-Santos, M., Kennerley, M. and Micheli, P., et al. 2007. Towards a definition of a business performance measurement system. *International Journal of Operations & Production Management*, Vol. 27, No. 8, pp. 784-801.

GAO, 1990. Case Study Evaluation.
United States General Account Office, Program Evaluation and Methodology Division, November 1990.

García-Cebrián, L. and López-Viñegla, A., 2002. The use of the scorecard in the management of production-operations. *Industrial Management & Data Systems*, Vol. 102, No. 1, pp. 39-46.

Garvin, D. A., 1983. Quality on the line. *Harvard Business Review*, September-October, pp. 65-75.

Gattiker, T.F. and Parente, D. H., 2006. Introduction to the special issue on innovative data sources for empirically building and validating theories in Operations Management. *Journal of Operations Management*, doi:10.1016/j.jom.10.001

Germain, R., Spears, N. and Stephen, F., 1999. Quality management and its relationship with organizational context and design. *International Journal of Quality & Reliability Management*, Vol. 16, No. 4, pp. 371-392

Geroy, G., Wright, P. C. and Anderson, J., 1998. *Strategic performance empowerment model. Empowerment in Organizations*, Vol. 6, No. 2, pp. 57-65.

Ghauri, P., Gronhaug, K., and Kristianslund, I., 2005. Research Methods in Business Studies: A Practical Guide (3rd ed.). Prentice Hall

Ginn, D. M., Jones, D.V., Rahnejat, H. and Zairi, M. 1998. The "QFD/FMEA interface". *European Journal of Innovation Management*; Vol. 1, No. 1, pp. 7-20.

Ginn, D. and Zairi, M., 2005. Best practice QFD application: an internal/external benchmarking approach based on Ford Motors' experience. *International Journal of Quality & Reliability Management*, Vol. 22, No. 1, pp. 38-58.

Glaser, B. G and Strauss, A. L., 1967. The Discovery of Grounded Theory-strategies for qualitative research. Aldine de Gruyter, New York

Gluckman, A., 2003. Quality in, workers out? Companies adopt Six Sigma [online] AllBusiness.com Inc. Available from:
http://www.allbusiness.com/periodicals/article/677106-1.html

Goffnett, S. P., 2004. Understanding Six Sigma: Implications for Industry and Education. *Journal of Industry Technology*, Vol. 20, No.4, pp. 1-10.

Goh, T. N., 1999. Perspectives on statistical quality engineering. The TQM Magazine, Vol. 11, No. 6, pp. 461-466

Goh, T. N., 2004. Improving on the six sigma paradigm. The TQM Magazine, Vol. 16 No. 4, pp. 235-240

Greg, B., 2002. Six Sigma for Managers
Ohio: McGraw-Hill Professional

Grover, S., Agrawal, V. P. and Khan, I. A., 2006. Role of human factors in TQM: a graph theoretic approach. *Benchmarking: An International Journal*, Vol. 13, No. 4, pp. 447-468.

Haikonen, A., Savolainen, T. and Savolainen, P., 2004. Exploring Six Sigma and CI capability development: preliminary case study findings on management role. *Journal of Manufacturing Technology Management*, Vol. 15, No. 4, pp. 369-378.

Hair, J. F., Anderson, R.E., Tatham, R. L. and Black, W. C., 1998. Multivariate Data Analysis (4th ed.). Pearson Higher Education.

Hammer, M., 2002. Process Management and the Future of Six Sigma [online]. MIT SLOAN Management Review. Available from:
http://content.ebscohost.com/pdf10/pdf/2002/EW4/01Jan02/5982676.pdf?T=P&P=AN&K=5982676&S=R&D=buh&EbscoContent=dGJyMNXb4kSeprY4zOX0OLCmrk6eqK5SsK%2B4S7SWxWXS&ContentCustomer=dGJyMPGqr0qvp7ZOuePfgeyx44Dt6fIA

Harry, M. J., 1998. Six Sigma: A Breakthrough Strategy for Profitability. *Quality Progress*, Vol. 31, No. 5, May 1998, pp. 60-64.

Harry, M. and Schroeder, R., 2000. Six Sigma: The Breakthrough Strategy Revolutionizing the World's Top Corporations. Doubleday, New York, NY.

Hatice, C. A., 2007. Total quality management through six sigma benchmarking. Benchmarking: An International Journal, Vol. 14, No. 2, pp. 186-201.

He, Z., Staples, G, Ross, M. and Court, I. 1996. Fourteen Japanese quality tools in software process improvement. *The TQM Magazine*, Vol. 8, No. 4, pp. 40-44.

Hefner, R., Grumman, N. and Siviy, J., 2006. Six Sigma Tools for Early Adopters [online].
Carnegie Mellon University. Available from:
http://www.sei.cmu.edu/sema/presentations/siviy/sigma-tools.pdf

Heise, D.R., 1969. Path Analysis, Causal Inferences, and the Measurement of Change
Problems in Path Analysis and Causal Inference. *Sociological Methodology*, Vol. 1, pp. 38-73.

Hendricks, C.A., Kelbaugh, R., 1998. Implementing Six Sigma at GE. *The Journal of Quality and Participation*, Vol. 21, No.4, pp.48-53.

Henderson, K. M. and Evans, J. R., 2000. Successful implementation of Six Sigma: benchmarking General Electric Company. Benchmarking: *An International Journal*, Vol. 7, No. 4, pp. 260-282.

Hensley, R. L. and Dobie, K., 2005. Assessing readiness for six sigma in a service setting. Managing Service Quality, Vol. 15 No.1, pp. 82-101

Hild, C., Sanders, D. and Ross, B., 1999. The Thought Map. *Quality Engineering*, Vol. 12, No. 1, pp. 21-27.

Hoerl, R.W., 1998. Six Sigma and the Future of the Quality Profession [online]. *Journal of Quality Progress*, p. 35- 42, June 1998 Available from:
http://www.asq.org/data/subscriptions/qp/1998/0698/qp0698hoerl.pdf

Hoerl, R.W., 2001. Six Sigma Black Belts: What Do They Need to Know? *Journal of Quality Technology*, Available from:
http://www.asq.org/pub/jqt/past/vol33_issue4/qtec-391.pdf

Hoerl, R., Snee, R.D., Czarniak, S., Parr, W.C., 2004. The future of Six Sigma. ASQ Six Sigma Forum Magazine, Vol. 3 No.4, pp.38-43

Honold, L., 1997. A review of the literature on employee empowerment. *Empowerment in Organizations*, Vol. 5, No. 4, pp. 202-212.

Howell, J., Miller, P., Hyun, H.P., Sattler, D., Schack, T., Spery, E., Widhalm, S., and Palmquist, M., 2005. Reliability and Validity.
Writing@CSU. Colorado State University Department of English. Available from: http://writing.colostate.edu/guides/research/relval/.

Ingle, S., and Roe, W., 2001a. GE and Motorola belt up for Six Sigma success [online]. The TQM Magazine, Vol. 13 No. 4, pp.273-80.

Ingle, S. and Roe, W., 2001. Six sigma black belt implementation. The TQM Magazine, Vol. 13, No. 4, pp. 273-280

Ingram, H., Teare, R., Scheuing, E. and Armistead, C., 1997. A systems model of effective teamwork. *The TQM Magazine*, Vol. 9, No. 2, pp. 118-127.

Ishikawa, K., 1985. What is Total Quality Control? The Japanese Way. Prentice-Hall, Inc., Englewood Cliffs, NJ.

Ishikawa, K., 1986. Guide to Quality Control. Tokyo: Asian Productivity Organization.

Iverson, W., 2003. Cat Cashes In on Six Sigma [online].
Automation World. November 2003 (p.18). Available from:
www.automationworld.com/cds_print.html?rec=id=302

James, J., 2003. Demystifying Six Sigma [online]. Integrated Quality Solutions. Available from:
http://72.14.235.104/search?q=cache:Pzua7iwNRs4J:www.sixsigmagulf.com/pdf/Demystifying%2520Six%2520Sigma.pdf+Demystifying+Six+Sigma+Integrated+Quality+Solutions+Jeremy+James&hl=zh-TW&gl=hk&ct=clnk&cd=1

Janes, J., 2001. Survey research design. *Library Hi Tech*, Vol. 19, No. 4, pp. 419-421.

Jiang, Shiu and Tu 2007. Quality function deployment (QFD) technology designed for contract manufacturing. *The TQM Magazine*, Vol. 19, No. 4, pp. 291-307.

Johnson, A. and Swisher, B., 2003. How Six Sigma Improves R&D (Managers At Work) [online]. Industrial Research Institute Inc. Available from:
http://www.allbusiness.com/periodicals/article/487953-1.html

Johnson, R. A. and Wichern, D. W., 2002. Applied Multivariate Statistical Analysis (5th ed.). Prentice Hall, New Jersey.

Jones Jr., M. H., 2004. Six Sigma at a bank? [online].
Six Sigma Forum Magazine, February 2004, p.13-17

Jones, R., Arndt, G. and Kustin, R., 1997. ISO 9000 among Australian Companies - Impact of Time and Reasons for Seeking Certification on Perceptions of Benefits Received. *International Journal of Quality and Reliability Management*, Vol. 14, No. 7, pp. 650-660.

Judd, C. M., Smith, E. R. and Kidder, L. H., 1991. Research Methods in Social Relations (6th ed.).

Juran, J. M., 1979. Quality Control Handbook (3rd ed.). McGraw-Hill Book Company.

Juran, J. M., 1986. The Quality Trilogy—A Universal Approach to Managing for Quality [online]. ASQC 40th Annual Quality Congress in Anaheim, California. Access available from:
http://72.14.235.104/search?q=cache:cXodriMY79EJ:www.forum.johnson.cornell.edu/faculty/Juran/trilogy1.doc+The+Quality+Trilogy+by+Juran&hl=zh-TW&ct=clnk&cd=8&gl=hk

Karapetrovic, S., and Willborn, W., 1998. Connecting internal management systems in service organizations. *Managing Service Quality*, Vol. 8, No. 4, pp. 256-271.

Kaynak, H., 2003. The relationship between total quality management practices and their effects on firm performance. *Journal of Operations Management*, Vol. 21, No. 4, pp. 405-435

Keller, P., [no date]. Common Questions on Six Sigma [online]
Quality America Inc. Available from:
http://www.qualityamerica.com/six_sigma/faq.htm

Kerlinger, F. N. and Lee, H. B., 2000. Foundations of Behavioral Research. Wadsworth Publishing (4th ed.).

Kiemele, M.J., 2003. Using the Design for Six Sigma (DFSS) Approach to Design, Test, and Evaluate to Reduce Program Risk [online]. Available from:
http://www.dtic.mil/ndia/2003test/kiemele.pdf

Kim, S. H., Yoon, Y. H. and Zeon, G. T., 2004. Combine Quality and Speed to Market. *Six Sigma Forum Magazine*, August 2004, Vol. 3, No. 4, pp. 26-31.

Klefsjö, B., Wiklund, H., Edgeman, R.L., 2001. Six sigma seen as a methodology for total quality management. Measuring Business Excellence, Vol. 5 No.1, pp. 31-35.

Kline, P., 1994. An Easy Guide to Factor Analysis. Routledge, New York.

Kumar, U. D., Saranga, Ramírez-Márquez, J. E. and Nowicki, D., 2007. Six Sigma project selection using data envelopment analysis. *The TQM Magazine*, Vol. 19, No. 5, pp. 419-441.

Knowledge@Wharton, 2005. TQM, ISO 9000, Six Sigma: Do Process Management Programs Discourage Innovation? [online]
Wharton School of the University of Pennsylvania. Available from:
http://knowledge.wharton.upenn.edu/article/1321.cfm

Kolarik, W. J., 1995. Creating Quality: Concepts, Systems, Strategies, and Tools. McGraw-Hill, Inc.

Koning, H. and Mast, J., 2006. A rational reconstruction of Six-Sigma's breakthrough cookbook. *International Journal of Quality & Reliability Management*, Vol. 23, No. 7, pp. 766-787.

Kullmann, J., 2005. Introduction to Six Sigma for Small to Mid-Sized Companies [online].
Six Sigma Qualtec. Available from:
http://www.ssqi.com/whitepaper-pdfs/Midsize_WP.pdf

Kumar, U. D., Saranga, H., Ramírez-Márquez, J. E. and Nowicki, D., 2007. Six sigma project selection using data envelopment analysis. *The TQM Magazine*, Vol. 19, No. 5, pp. 419-441.

Kuwaiti, M. E. and Kay, J. M., 2000. The role of performance measurement in business process re-engineering. *International Journal of Operations & Production Management*, Vol. 20, No. 12, pp. 1411-1426.

Kwak, Y.H., Anbari, F.T., 2004, Benefits, obstacles and future of six sigma approach, *Technovation*, Vol. 20, pp.1-8.

Labib, A. W. and Shah, J., 2001. Management decisions for a continuous improvement process in industry using the analytical hierarchy process. *Work Study*, Vol. 50, No. 5, pp. 189-194.

Lagrosen, S. and Lagrosen Y., 2006. A dive into the depths of quality management. European Business Review. Volume 18 No. 2, 2006 pp.84-96

Lakhal, L., 2006. Quality management practices and their impact on performance. *International Journal of Quality & Reliability Management*, Volume 23 Number 6 2006 pp. 625-646

Lazarus, I. and Butler, K., 2001. The Promise of Six Sigma: Getting Better Faster [online]. BetterManagement.com. Available from:
http://www.bettermanagement.com/library/library.aspx?pagetype=1&libraryid=7722

Lee, C., 2001. Why you can safely ignore Six Sigma: The management fad gets raves from Jack Welch, but it hasn't boosted the stocks of other devotees [online].
http://www.kellogg.northwestern.edu/faculty/savaskan/OPNSQuality/Why%20you%20can%20safely%20ignore%20Six%20Sigma%20%20Fortune%20%202001.pdf

Lee, R., 2004. ISSSP Session: Innovation and Six Sigma Go Hand in Hand [online]. iSixSigma. Available from:
http://www.isixsigma.com/library/content/c040617a.asp

Lee-Mortimer, A., 2006. Six Sigma: a vital improvement approach when applied to the right problems, in the right environment. *Assembly Automation*, Vol. 26, No. 1, pp. 10-17.

Leung, H., Liao, L. and Qu, Y., 2007. Automated support of software quality improvement. *International Journal of Quality & Reliability Management*, Vol. 24, No. 3, pp. 230-243.

Linderman, K., Schroeder, R.G., Zaheer, S. and Choo, A. S., 2002. Six Sigma: a goal-theoretic perspective. *Journal of Operations Management*, Vol. 21, No. 2, pp. 193-203

Loehlin, J. C., 1998. Latent Variable Models: An introduction to factor, path and structural analysis (3rd ed.). Mahwah, NJ: Lawrence Erlbaum Associates, Publishers

Love, P. E. D. and Holt, G. D., 2000. Construction business performance measurement: the SPM alternative. *Business Process Management Journal*, Vol. 6, No. 5, pp. 408-416.

Lunde, K., 2003. Ensuring system safety is more efficient. *Aircraft Engineering and Aerospace Technology*, Vol. 75, No. 5, pp. 477-484.

Lynch, D. P. and Cloutier, E. T., 2003. 5 Steps to Success. *Six Sigma Forum Magazine*, February 2003, Vol. 2, No. 2, pp. 27-33.

Lyons, P., 2005. A robust approach to employee skill and knowledge development. *Industrial and Commercial Training*, Vol. 37, No. 1, pp. 3-9.

Madu, C. N., Kuei, C. H. and Liu, C. H. 1995. A comparative analysis of quality practice in manufacturing firms in the U.S. and Taiwan. *Decision Sciences*, Vol. 26, No. 5, pp. 621-635. Available from:
http://findarticles.com/p/articles/mi_qa3713/is_199509/ai_n8725849

Mann, R. and Kehoe, D., 1994. An Evaluation of the Effects of Quality Improvement Activities on Business Performance. *International Journal of Quality & Reliability Management*, Vol. 11 No. 4, pp. 29-44

Marr, B., Schiuma, G., 2003. Business performance measurement – past, present, and future, *Management Decision*, Vol. 41, No.8, pp.680-7.

Maruyama, G. M., 1998. Basic of Structural Equation Modeling. Thousand Oaks: Sage Publications, Inc.

Marx, M., [no date]. ROI on Six Sigma Programs Directly Related to Investment Size. iSixSigma Magazine. Available from:
http://www.marketwire.com/mw/release_html_b1?release_id=100040

Marx, M., 2006. No Change in Six Sigma Salaries Worldwide, Survey Shows; Certification Apparently Not a Factor [online]. Available from:
http://www.marketwire.com/mw/release_html_b1?release_id=111596&category=

Mast, J. D., 2004. A methodological comparison of three strategies for quality improvement. *International Journal of Quality & Reliability Management*, Vol. 21, No. 2, pp. 198-213.

McAdam, R. and Bannister, A., 2001. Business performance measurement and change management within a TQM framework. *International Journal of Operations & Production Management*, Vol. 21, No. 1/2, pp. 88-108.

McAdam, R., and Lafferty, B., 2004. A multilevel case study critique of six sigma: statistical control or strategic change? *International Journal of Operations & Production Management*, Vol. 24, No. 5, pp. 530-549.

McLean, D., 2006. The operational efficiency of passenger aircraft. Aircraft Engineering and Aerospace Technology: *An International Journal*, Vol. 78, No. 1, pp. 32-38.

McQuater, R. E., Scurr, C. H., Dale, B. G and Hillman, P. G., 1995. Using quality tools and techniques successfully. *The TQM Magazine*, Vol. 7, No. 6, pp. 37-42.

Meegan, S.T. and Taylor, W. A., 1997. Factors Influencing a Successful Transition from ISO 9000 to TQM. *International Journal of Quality and Reliability Management*, Vol. 14, No. 2, pp. 100-117.

Mehra B., 2002. Bias in qualitative research: Voices from an online classroom. The Qualitative Report, 7(1). Retrieved [December 18, 2006], from http://www.nova.edu/ssss/QR/QR7-1/mehra.html

Melnyk, S.A., Handfield, R.B., 1998. May you live in interesting times...the emergence of theory-driven empirical research. *Journal of Operations Management*, Vol.16, No. 4, pp. 311-319.

Meredith, J. R., Raturi, A., Amoako-Gyampah, K. and Kaplan, B., 1989. Alternative Research Paradigms in Operations. *Journal of Operations Management*, Vol. 8, No. 4, pp. 297-326.

Meredith, J. R., 1998. Building operations management theory through case and field research. *Journal of Operations Management*, Vol. 16, No. 4, pp. 441-454.

Mersha, T., 1997. TQM implementation in LDCs: driving and restraining forces. *International Journal of Operations & Production Management*, Vol.17, No. 2, pp. 164-183

Miles, M. B., and Huberman, A. M., 1994. Qualitative Data Analysis: An Expanded Sourcebook. Thousand Oaks, CA: SAGE.

Mill, H., 1994. Enhanced Quality Functional Deployment. *World Class Design to Manufacture*, Vol. 1, No. 3, pp. 23-26.

Mizuno, S., 1995. Management for Quality Improvement: The 7 New QC Tools. Cambridge, MA: Productivity Press.

Morgan, S. J. and Symon, G., 2004. Electronic Interviews in Organizational Research. In: Cassell C. and Symon G.. (eds.), Essential Guide to Quantitative Methods in Organizational Research, London: Sage, p. 23-33.

Motwani, J., 2001. Critical factors and performance measures of TQM. The TQM Magazine, Vol. 13, No. 4, pp. 292-300

Motwani, J., Kumar, A. and Antony J., 2004. A business process change framework for examining the implementation of six sigma: a case study of Dow Chemicals. *The TQM Magazine*, Vol. 16, No. 4, pp. 273-283.

Muir, A., [no date]. Design of Experiments/Conjoint Analysis in Marketing [no date]. iSixSigma. Available from:
http://www.isixsigma.com/library/content/c051031a.asp

Narasimhan, R. and Jayaram, J., 1998. An empirical investigation of the antecedents and consequences of manufacturing goal achievement in North American, European and Pan Pacific firms. *Journal of Operations Management,* Vol. 16, Issues 2-3, pp. 159-176.

Naumann E., and Hoisington S., 2001. Customer Centered Six Sigma: Linking Customers, Process Improvement, and Financial Results
Wisconsin, USA: ASQ Quality Press

Neely, A.D., Gregory, M.J. and Platts, K., 2005. Performance measurement system design: a literature review and research agenda. *International Journal of Operations & Production Management*, Vol. 25, No. 12, pp. 1228-1263.

Neely, A.D., Gregory, M.J. and Platts, K., 2005. Performance measurement system design: a literature review and research agenda. *International Journal of Operations & Production Management*, Vol. 25, No. 12, pp. 1228-1263.

Nilsson-Witell, L., 2005. Dynamics of service attributes: a test of Kano's theory of attractive quality. *International Journal of Service Industry Management*, Vol. 16, No. 2, pp. 152-168.

Nonthaleerak, P. and Hendry, L., 2008. Exploring the Six Sigma phenomenon using multiple case study evidence. *International Journal of Operations & Production Management*, Vol. 28, No. 3, pp. 279-303.

Norusis, M. J., 2006. SPSS 15.0 Guide to Data Analysis. Prentice Hall Inc.

Nykodym, N., Simonetti, J. L., Nielsen, W. R. and Welling, B., 1994. Employee Empowerment. *Empowerment in Organizations*, Vol. 2, No. 3, pp. 45-55.

Olson, P. C., 2005. The impact of multiple improvement strategies on organizational effectiveness: A case study of team-based. Thesis (PhD). Capella University.

Omar, T. A. and Kleiner, B. H., 1997. Effective decision making in the defence industry. *Aircraft Engineering and Aerospace Technology*, Vol. 69, No. 2, pp. 151-159.

Pallant, J., 2005. SPSS Survival Manual: A step by step guide to data analysis using SPSS for Windows (Version 12) (2nd ed.). Open University Press

Pallant, J., 2007. SPSS Survival Manual: A Step by Step Guide to Data Analysis using SPSS for Windows (Version 12) (3rd ed.). McGraw Hill

Pande, P., Neuman, R. and Cavanagh, R. 1999. The Six Sigma Way. Sigma Press, New York.

Pande, P. and Holpp, L., 2001. What Is Six Sigma?
New York: McGraw-Hill Professional

Pande. P. S., Neuman, R. P., and Cavanagh, R.R., 2000. The Six Sigma way: How GE, Motorola, and other top companies are honing their performance. New York: McGraw-Hill.

Pandey, A., 2007. Strategically focused training in Six Sigma way: a case study. *Journal of European Industrial Training*. Vol. 31, No. 2, pp. 145-162.

Pastor, J., 1996. Empowerment: what it is and what it is not. *Empowerment in Organizations*, Vol. 4, No. 2, pp. 5-7.

Patton, M.Q., 2002. Qualitative Research & Evaluation Methods (3rd ed.). Thousand Oaks, CA: SAGE.

Pedhazur, , E. J., 1982. Multiple Regression in Behavioral Research: Explanation and Prediction (2nd ed.). Harcourt College Publisher.

Pedhazur, E., J. and Schmelkin, L. P., 1991. Measurement, Design, and Analysis, An Integrated Approach, Lawrence Erlbum Associates, Publishers, Hillsdale, NJ.

Pfeifer, T., Reissiger, W. and Canales, C., 2004. Integrating six sigma with quality management systems. *The TQM Magazine*, Vol. 16, No. 4, pp. 241-249.

Platt, M.M., 2005. Choosing the best quality tools for a non-manufacturing environment: ISO 9001:2000 CMMI or Six Sigma? Thesis (MSc.). California State University Dominguez Hills.

Pries, K. H., 2006. Six Sigma for the Next Millennium: A CSSBB Guidebook
Wisconsin, USA: ASQ Quality Press

Przekop, P., [no date]. Black Belt Not Required: Don't Wait for Six Sigma to Come to You [online]. PharmaManufacturing.com. Available from:
http://www.pharmamanufacturing.com/articles/2005/168.html

Pun, K. F., Chin, K.S. and Lau, H., 2000. A QFD/ approach for service quality deployment: a case study. *Managing Service Quality*, Vol. 10, No. 3, pp. 156-170.

Pyzdek, T., 1999. The Value of Six Sigma [online].
Quality Digest. Available from:
http://www.pyzdek.com/PDF/1999-12.pdf

Pyzdek, T., [no date[1]]. The Evolution of Six Sigma [online].
Process Quality Associates Inc. Available from:
http://www.pqa.net/ProdServices/sixsigma/W06002009.html

Pyzdek, T., [no date[1]]. The Six Sigma Revolution [online].
Quality America Inc. Available from:
https://www.qualityamerica.com/knowledgecente/articles/PYZDEKSixSigRev.htm

Pyzdek, T., [no date[2]]. Why Six Sigma is not TQM [online].
Available from:
http://www.pyzdek.com/six_sigma_vs_tqm.htm

Pyzdek, T., 2003. The Six Sigma Handbook: Revised and Expanded. McGraw-Hill, New York, NY.

Raisinghani, M.S., Ette, H., Pierce, R., Cannon, G. and Daripaly, P., 2005. Six Sigma: concepts, tools, and applications. *Industrial Management & Data Systems*, Vol. 105, No. 4, pp. 491-505.

Ramberg, J. S., 2000. Six Sigma: Fad or Fundamental? [online]
QCI International. Available from:
http://www.qualitydigest.com/may00/html/sixsigmapro.html

Recker, R., and Bolstorff, P., 2003. Integration of SCOR with Lean & Six Sigma [online]. Advanced Integrated Technologies Group. Available from:
http://www.scelimited.com/sitebuildercontent/sitebuilderfiles/scorsixsigmaconvergence.pdf

Rho, B. H. and Yu, Y.M., 1998. A comparative study on the structural relationships of manufacturing practices, lead time and productivity in Japan and Korea. *Journal of Operations Management*. Vol. 16, Issues 2-3, pp. 257-270.

Robinson, H. S., Anumba, C. J. A. and Carrillo, P. M., et al. 2005. Business performance measurement practices in construction engineering organisations. *Measuring Business Excellence*, Vol. 9, No. 1, pp. 13-22.

Roos, G., Fernström, L. and Pike, S., 2004. Human resource management and business performance measurement. *Measuring Business Excellence*, Vol. 8, No. 1, pp. 28-37.

Rozgus, A., 2003. Using the sixth sense: by implementing the Six Sigma approach, companies can move ahead of the pack - E-Concrete - concrete industry [online]. FindArticles™. Available from:
http://www.findarticles.com/p/articles/mi_m0NSY/is_8_21/ai_106585458

Rungtusanatham, M., Forzab, C., Filippinib, R. and Anderson, J. C., 1998. A replication study of a theory of quality management underlying the Deming management method: insights from an Italian context. *Journal of Operations Management*, Vol. 17, Issue 1, pp. 77-95.

Sakakibara, S., Flynn, B. B., Schroeder, R. G. and Morris, W. T., 1997. The Impact of Just-in-Time Manufacturing and Its Infrastructure on Manufacturing Performance. *Management Science*, Vol. 43, No. 9, pp. 1246 – 1257.

Sankar, N. R. and Prabhu, B. S., 2001. Modified approach for prioritization of failures in a system failure mode and effects analysis. *International Journal of Quality & Reliability Management*, Vol. 18, No. 3, pp. 324-336.

Savolainen, T. and Haikonen, A., 2007. Dynamics of organizational learning and continuous improvement in six sigma implementation. *The TQM Magazine*, Vol. 19, No. 1, pp. 6-17.

Schalkwyk, J. C., 1998. Total quality management and the performance measurement barrier. The TQM Magazine, Vol. 10, No. 2, pp. 124-131

Schmidt, W. H., and Finnigan, J. P., 1992. The Race Without a Finish Line, Jossey-Bass Publishers, San Francisco.

Selltiz, C., Kidder, L. H. and Judd, C.M., 1986. Research Methods in Social Relations (5th ed.). Thomson Learning.

Senapati, N.R., 2004. Six Sigma: myths and realities. *International Journal of Quality & Reliability Management*, Vol. 21, No. 6, pp. 683-690.

Shahin, A., 2004. Integration of FMEA and the Kano model: An exploratory examination. *International Journal of Quality & Reliability Management*, Vol. 21, No. 7, pp. 731-746.

Shen, X.X., Tan, K.C. and Xie, M., 2000. An integrated approach to innovative product development using Kano's model and QFD. *European Journal of Innovation Management*, Vol. 3, No. 2, pp. 91-99.

Simon, K., [no date]. What Is DFSS? And how does Design For Six Sigma compare to DMAIC? [online]. Available from:
http://www.isixsigma.com/library/content/c020722a.asp?action

Singleton, R. A. and Straits, B. C., 1999. Approaches to Social Research (3rd ed.). Oxford University Press, New York.

Siviy, J., 2001. Six Sigma [online].
Carnegie Mellon University. Available from:
http://www.sei.cmu.edu/str/descriptions/sigma6_body.html

Small, M. H. and Yasin, M. M., 1997. Advanced Manufacturing Technology: Implementation Policy and Performance. *Integrated Manufacturing Systems*, Vol. 15, No. 4, pp. 349-370.

Smart, A. and Dudas, A., 2007. Developing a decision-making framework for implementing purchasing synergy: a case study. *International Journal of Physical Distribution & Logistics Management*, Vol. 37, No. 1, pp. 64-89.

Smith, B., 1997. Empowerment - the challenge is now. *Empowerment in Organizations*, Vol. 5, No. 3, pp. 120-122.

Smith, D., Blakeslee, J. and Koonce, R., 2002. Strategic Six Sigma: Best Practices from the Executive Suite. NJ: John Wiley & Sons, Inc.

Snee, R.D., 1999. Why Should Statisticians Pay Attention to Six Sigma? [online] *Quality Progress*, September 1999. Available from:
http://www.asq.org/data/subscriptions/qp/1999/0999/100statistics_sept99.html

Sokovic, M., Pavletic, D and Fakin, S., 2005. Application of Six Sigma methodology for process design. *Journal of Materials Processing Technology*, Vol. 162-163, pp. 777-783

Sousa, R. and Voss, C.A., 2002. Quality management re-visited: a reflective review and agenda for future research. *Journal of Operations Management*, Vol. 20 pp.91-109.

Stamatis, D.H., 2000. Who Needs Six Sigma, Anyway? [online]
Quality Digest. Available from:
http://www.qualitydigest.com/may00/html/sixsigmacon.html

Stephens, K.S., Aubrey, C.A. and Smith, L.R., 2001. What is the future of Six Sigma? Six Sigma Forum Magazine, November 2001 P. 47-49.

Stevens, J. P., 2002. Applied Multivariate Statistics For The Social Sciences (4th ed.). Mahwah, NJ: Lawrence Erlbaum Associates, Publishers

Stone-Romero, E. F., Weaver, A. E. and Glenar, J. L., 1995. Trends in research design and data analytic strategies in organizational research. *Journal of Management*, Vol. 21, No. 1, 141-157.

Swamidass, P. M. and Newell, W. T., 1987. Manufacturing Strategy, Environmental Uncertainty and Performance: A Path Analytic Model. *Management Science*, Vol. 33, No. 4. pp. 509-524.

Swenson, D. X., 1997. Requisite conditions for team empowerment. *Empowerment in Organizations*, Vol. 5, No. 1, pp. 16-25.

Swinney, Z., [no date]. Project Charter [online]. iSixSigma. Available from: http://www.isixsigma.com/library/content/c010218a.asp

Tague, N. R., 2004. The Quality Toolbox (2nd ed.). ASQ Quality Press, pp. 444-446.

Tam, W. H., 2000. Quality management theory and practice: some observations of practices in Australian academic libraries. Library Management, Volume 21 Number 7 2000 pp. 349-356.

Tan, C. M. and Raghavan, N., 2007. Root cause analysis based maintenance policy. *International Journal of Quality & Reliability Management*, Vol. 24, No. 2, pp. 203-228.

Tan, C. M., 2003. Customer-focused build-in reliability: a case study. *International Journal of Quality & Reliability Management*, Vol. 20, No. 3, pp. 378-397.

Tan, K.C. and Pawitra, T. A., 2001. Integrating SERVQUAL and Kano's model into QFD for service excellence development. *Managing Service Quality*, Vol. 11, No. 6, pp. 418-430.

Taría, J. J., Molina, J. F. and Castejon, J. L., 2006. The relationship between quality management practices and their effects on quality outcomes.
European Journal of Operational Research (2006), doi:10.1016/j.ejor.2006.10.016

Taylor, W. A. and Meegan, S.T., 1997. Senior executives and the ISO 9000-TQM transition - A framework and some empirical data. *International Journal of Quality and Reliability Management*, Vol. 14, No. 7, pp. 669-686.

Taylor, W. A. and Wright, G. H., 2003. A longitudinal study of TQM implementation: Factors influencing success and failure. *Omega International Journal of Management Science*, Vol. 31, Issue 2, .pp. 97-111

Tellis, W., 1997. Application of a Case Study Methodology (online). Available from: http://www.nova.edu/ssss/QR/QR3-3/tellis2.html

Teng, S. H. and Ho, S. Y., 1996. Failure mode and effects analysis: An integrated approach for product design and process control. *International Journal of Quality & Reliability Management*, Vol. 13, No. 5, pp. 8-26.

Teng, S. G. and Liu, P. C., 2006. Implementing FMEA in a collaborative supply chain environment. *International Journal of Quality & Reliability Management*, Vol. 23, No. 2, pp. 179-196.

Tennant, G. 2002. Design for six sigma: launching new products and services without failure. *The TQM Magazine*, Vol. 14, No.4, pp.264-5.

The Juran Institute, Inc., 2003. A revealing study of Six Sigma: Gains but missed potential. Strategic Direction, Vol. 19, No. 8, pp. 34-36.

Thietart, R. A., et al. 2001. Doing Management Research: A comprehensive guide. Sage Publications Ltd.

Thomas, A. and Barton, R., 2006. Developing an SME based six sigma strategy. *Journal of Manufacturing Technology Management*, Vol. 17, No. 4, pp.417-434.

Tontini, G. and Silveira, A., 2007. Identification of satisfaction attributes using competitive analysis of the improvement gap. *International Journal of Operations & Production Management*, Vol. 27, No. 5, pp. 482-500.

Vaus, de D.A., 1996. Surveys in Social Research (4th ed.). UCL Press, London.

Villarreal, M. and Kleiner, B. H., 1997. Analytical tools for facilitating task group performance. *Journal of Workplace Learning*, Vol. 9, No. 3, pp. 94-97.

Wan, H.D. and Chen, F.F., 2004. A Framework For Performance-Driven Web-Based Manufacturing. *Journal of the Chinese Institute of Industrial Engineers*, Vol. 21, No. 6, pp. 527-534.

Watson, R. M., 1998. Implementing self-managed process improvement teams in a continuous improvement environment. *The TQM Magazine*, Vol. 10, No. 4, pp. 246-257.

Waxer, C., [no date]. Six Sigma Black Belt Curriculum and Body of Knowledge [online]. iSixSigma. Available from: http://www.isixsigma.com/library/content/c010618d.asp

Wee, Y. S., 2005. Development and validation of critical factors of environmental management. *Industrial Management & Data Systems*, Vol. 105, No. 1, pp. 96-114.

Wickisier, E. L., 1997. The paradox of empowerment - a case study. *Empowerment in Organizations*, Vol. 5, No. 4, pp. 213-219.

Wiele, T. and Brown, A., 2002. Quality management over a decade: A longitudinal study. *International Journal of Quality & Reliability Management*, Vol. 19, No. 5, pp. 508-523.

Wilkinson, A. and Willmott, H., 1996. Quality management, problems and pitfalls: a critical perspective. *International Journal of Quality & Reliability Management*, Vol. 13, No. 2, pp. 55-65.

Witell, L. and Löfgren, M., 2007. Classification of quality attributes. *Managing Service Quality*, Vol. 17, No. 1, pp. 54-73.

Wright, L.T., 1996. Exploring the in-depth interview as a qualitative research technique with American and Japanese firms. *Marketing Intelligence & Planning*, Vol. 14, No. 6, pp. 59-64.

Yang, K. and Trewn, J., 2004. Multivariate Statistical Method in Quality Management. McGraw-Hill

Yavas, U. and Yasin, M., 2001. Enhancing organizational performance in banks: a systematic approach. *Journal of Services Marketing*, Vol. 15, No. 6, pp. 444-453.

Yeh, Y.J., 2003. Implementing a sustainable TQM system: employee focus. *The TQM Magazine*, Vol. 15, No. 4, pp. 257-265.

Yeung, C. L., 1999. Quality Management System and Its Association with Organizational Performance. Thesis (PhD). Hong Kong University.

Yin, R. K., 2003[1]. Case Study Research: Design and Methods (3rd ed.). Sage Publications

Yin, R. K., 2003[2]. Applications of case study research (2nd ed.). Sage Publications

Zimmerman, J.P., and Weiss, J., 2005. Six Sigma's Seven Deadly Sins [online]. Kepner-Tregoe, Inc. Available from: http://www.kepner-tregoe.com/pdfs/articles/SixSigma.cfm?ID=7#

Zu, X. X., 2005. A Study of the Impact of Six Sigma on Firm Performance: Theoretical Analysis and Empirical Investigation. Thesis (PhD). Clemson University.

(APPENDIX I)

Interview Questions

For

Measure the Values of Six Sigma

Appendix 1. General Information of the Six Sigma Practices.

Interview Questions

Section 1. Record the following demographic information

1. Date, place, and time of interview
2. Name and position of Key Information
3. Organizational area represented (Function, IPT, or Program)
4. Number of staff in area of responsibility
5. Gender :
6. Years of Experience in the industry:
7. Years of Experience in implementing Six Sigma methodology
8. Telephone and email (ask how contact is preferred for follow-up questions)

Section 2. Questions about the organization and the improvement strategy.

A. What is Six Sigma?

1. What is the reason(s) for using Six Sigma methodology?

2. How long has this organization been implementing Six Sigma methodology?

3. How does your organization see Six Sigma?

   a. As a process improvement tool

   b. As a business strategy driver

4. What is the purpose of implementing Six Sigma methodology?

a. To formulate, integrate, and execute new business strategies and missions

b. Deal with constantly changing customer requirements.

c. To Accelerate globalization

d. To improve profitability and corporate performance.

e. Accelerate innovation

f. Improve marketing channels.

g. To enhance and shorten the corporate learning cycle – the time it takes to translate market intelligence and competitive data into new business practices

h. To maintain the relationship with your employees, customers, suppliers and shareholders etc.

i. Manage and mitigate business risk.

j. Others (please specify)

5. At which level do you implement Six Sigma methodology?

   a. Process level

   b. Corporate level

   c. Others (please specify)

6. What problem is the Six Sigma methodology that your organization intended to address?

7. How does it link to this organization's mission, vision or strategic objectives?

8. How many Six Sigma Black Belts do you have in this company?

9. Is the number of Black Belts and Green Belts increasing or decreasing?

10. To what extent your employees are trained in the use of Six Sigma tools?

B. Deployment

11. What projects including Six Sigma Projects, if any, have been undertaken in supporting of your strategy/initiative from 2003 to 2007?

12. How many Six Sigma Projects have ever been implemented?

    a. From 2004 to 2007 in total.

    b. Who leads each project by job title?

    c. Who were on each project team?

    d. What was the extent of your involvement with the project?

13. Which Six Sigma tool is/are mostly used in the organization?

14. Will you keep using Six Sigma methodology in the next 10 years?

C. Results

15. What are the results of the projects (for example, completed successfully, completed unsuccessfully, not completed, etc.) and how those results are measured (Cumulative ROI, Net Present Value (NPV), productivity, etc.)

16. How fast can Six Sigma bring benefit to this organization?

D. Others

17. Is Six Sigma methodology able to help this organization to develop new products in lesser time and for lesser money?

18. Has this organization ever laid off any employee because of the improved organization effectiveness?

19. What is/are the unique value(s) of Six Sigma which is not found in the other quality approach (es)?

E .Lessons Learned

Single Strategy (Six Sigma)

20. What, if any, problems are you aware of that were encountered in regards to this particular strategy/initiative?

21. What would your assessment of Six Sigma methodology be as far as its strengths or weaknesses?

    a. What made it that way?
    b. What could have helped more?
    c. What could help more now?

Multiple Strategies

22. What other improvement strategy or strategies were implemented prior to Six Sigma methodology that helped or hurt?

23. What other improvement strategy or strategies are implementing concurrently with Six Sigma methodology that helped or hurt?

24. What other improvement strategy or strategies would be leveraged (the basis for future strategies)?

Organization

25. Compared with other improvement initiatives, do you think that Six Sigma methodology has the largest contribution on business results? Why?

Weaknesses of Six Sigma

26. What weaknesses of Six Sigma you consider are important that you would like to share with the companies which are planning to introduce it into their companies?

(APPENDIX II)

Survey Instrument

For

Measure the Values of Six Sigma

Part A. General Information

1 How many employees do you have in this organization now? ____________

2 Please indicate that which quality improvement program is/are employing now?

☐ ISO 9001 ☐ TQM ☐ Six Sigma ☐ Other (Please specify) ____________

3 Which of the following quality improvement programs has your organization implemented from the year of 2004 to 2007?

☐ ISO 9001 ☐ TQM ☐ Six Sigma ☐ Other (Please specify) ____________

4 How many trained Black Belt does this organization have? ____________

5 How many trained Green Belts does this organization have? ____________

6 How long have you been working for this organizations? ____________

7 What is your job position in this organizaton?

☐ Quality Manager ☐ Engineer ☐ Managers[1]

☐ Management Team Members ☐ Other (Please specify) ____________

8 How long have you been working in this position? ____________

9 Which of the following title is best description of your role in the Six Sigma team?

☐ Champion/Sponsor ☐ Master Black Belt ☐ Black Belt

☐ Green Belt ☐ Other (Please specify) ____________

10 How many hours of training have you received in each of the following?

ISO 9001	TQM	Six Sigma	Other (Please specify) ____________
☐ 0-under 10	☐ 0-under 10	☐ 0-under 10	☐ 0-under 10
☐ 10- under 50	☐ 10- under 50	☐ 10- under 50	☐ 10- under 50
☐ 50- 100 hours	☐ 50- 100 hours	☐ 50- 100 hours	☐ 50- 100 hours
☐ more than 100 hours	☐ more than 100 hours	☐ more than 100 hours	☐ more than 100 hours

11 Where did you get your Six Sigma training?

☐ The company provides in house training ☐ American Society for Quality

☐ Other (Please specify) ____________________

12 How did you be qualified as a Six Sigma belt?

☐ After finished the training

☐ Passed the written examination

☐ Passed the written examination and finished a Six Sigma project.

☐ Other (Please specify) ____________________

Remarks:

1. Who lead a team to execute tasks or ideas assigned by Management Team members.

2. Who can make important decisions for the company

Part B. Survey On Six Sigma Practices

Please answer the following questions based on the Six Sigma practices in your company since the year of 2004 by using the 7-points Scales shown below.

Circle the Appropriate Number							
	Strongly Disagree			Neutral			Strongly Agree
e.g.	1	2	3	(4)	5	6	7

Section 1. Quality Management System and Philosophy

	Quality Practices since the year of 2004	Degree of Agreement: Strongly Disagree 1	2	3	Neutral 4	5	6	Strongly Agree 7	
1	We have a formal systems of acquiring the voice of customer (e.g. opinion or expections) in our company.	1	2	3	4	5	6	7	N/A
2	We have been carrying out analyses of our customer complaints or feedback in order to improve our product quality.	1	2	3	4	5	6	7	N/A
3	We have been reviewing and analyzing the customer satisfaction surveys in order to seek for the opportunities for improving the product quality.	1	2	3	4	5	6	7	N/A
4	We have been working closely with our customers in designing our products or improving the product design.	1	2	3	4	5	6	7	N/A
5	Our Research and Development Department always has sound knowledge on the customers requirement and market	1	2	3	4	5	6	7	N/A
6	Loss of market share due to bad quality has always been studied and evaluated as an important part of the total quality costs.	1	2	3	4	5	6	7	N/A
7	Our marketing staff are fully aware of and responsible for the quality of product and services they provide to our customers.	1	2	3	4	5	6	7	N/A
8	Our Six Sigma Teams have always been rewarded by management for the improvements of product quality they	1	2	3	4	5	6	7	N/A
9	Our Six Sigma teams always involve all departments in order to minimize departmental barriers.	1	2	3	4	5	6	7	N/A

10	We have been encouraging all of our Belts to develop their own quality improvement tools.	1	2	3	4	5	6	7	N/A
11	We have been providing continous counseling for skill enhancement in order for Six Sigma Belts to be even more competent at their job.	1	2	3	4	5	6	7	N/A
12	Six Sigma Belts have always been encourage to form a team to solve or fix the production related problems they discovered.	1	2	3	4	5	6	7	N/A
13	Six Sigma Teams have always been given the necessary support on their projects.	1	2	3	4	5	6	7	N/A
14	All Six Sigma Belts' improvement suggestions have always been evaluated by management and implemented if appropriate.	1	2	3	4	5	6	7	N/A
15	Six Sigma teams have always been formed in our company as working teams for solving production related problems.	1	2	3	4	5	6	7	N/A
16	We have been analyzing all relevant quality records, such as service reports, customer complaints, work instructions to detect and eliminate potential causes of non-conforming products.	1	2	3	4	5	6	7	N/A
17	We have always recorded the scrap and rework rates of our products or processes for the reference of management and workers.	1	2	3	4	5	6	7	N/A
18	We have been making use of quality cost information as a tool to reduce the overall production costs.	1	2	3	4	5	6	7	N/A
19	Our senior management has been committed in Six Sigma Practices.	1	2	3	4	5	6	7	N/A
20	Managers of all departments have always been involved in Six Sigma Projects.	1	2	3	4	5	6	7	N/A
21	We are striving to reach the Six Sigma level.	1	2	3	4	5	6	7	N/A
22	Our company has been trying to accomplish continuous improvement throughout all domains from planning through operations.	1	2	3	4	5	6	7	N/A

23	Multidisciplinary Six Sigma teams across different departments have been organized and functioning to improve quality.	1	2	3	4	5	6	7	N/A
24	Six Sigma teams handled almost all quality problems.	1	2	3	4	5	6	7	N/A
25	We use Six Sigma methodology for solving every quality related problem.	1	2	3	4	5	6	7	N/A
26	There is a Sponsor in each Six Sigma team to provide resources and overseeing each Six Sigma project.	1	2	3	4	5	6	7	N/A
27	We have been studying the variations in our production processes, identifying the undesirable variations, and acting on its sources to achieve greater consistency of product.	1	2	3	4	5	6	7	N/A
28	We have always been considering the potential quality problems in manufacturing processes in the product design stage.	1	2	3	4	5	6	7	N/A
29	We study the root causes and take corrective actions every time after a problem is found.	1	2	3	4	5	6	7	N/A
30	We study every process in order to eliminate any problem before it happened.	1	2	3	4	5	6	7	N/A
31	We have been trying to find out the causes for high operational costs, identifying and solving them to reduce the unit cost of manufacturing.	1	2	3	4	5	6	7	N/A
32	We have not been satisfied with just meeting the required specifications in our production processes, we are making efforts to minimize the deviations from the target points.	1	2	3	4	5	6	7	N/A
33	Our Senior Management has been highly involved in developing quality policy as they have always treated quality as an important strategy for long-term growth of our	1	2	3	4	5	6	7	N/A
34	We have been developing trust and working closely with our suppliers.	1	2	3	4	5	6	7	N/A
35	We have been cooperating with our suppliers on a long term basis.	1	2	3	4	5	6	7	N/A
36	There have been formal supplier rating systems to evaluate our suppliers' quality performance.	1	2	3	4	5	6	7	N/A

37	We selecting our suppliers, the quality of products they provided is the most important consideration than the prices.	1	2	3	4	5	6	7	N/A
38	We have been providing clear specifications and requirements to our suppliers.	1	2	3	4	5	6	7	N/A
39	We have been providing training on Six Sigma techniques to all suppliers to improve their quality performance.	1	2	3	4	5	6	7	N/A
40	Our organization has been providing training on Six Sigma techniques to all employees.	1	2	3	4	5	6	7	N/A
41	Our Senior Management has been highly involved in quality management projects.	1	2	3	4	5	6	7	N/A
42	We have been reviewing our quality policy and strategy regularly in order to identify their strengths and weaknesses.	1	2	3	4	5	6	7	N/A
43	Our senior management is full of visionary, they have planned for long-term development of our company instead of focusing on short-term profits.	1	2	3	4	5	6	7	N/A
44	Six Sigma becomes a common language in our company for different business units to talk to one another.	1	2	3	4	5	6	7	N/A
45	The Six Sigma language creates a closer bond between different business units.	1	2	3	4	5	6	7	N/A

Section 2. Use of Six Sigma methodology and tools

Please indicate your level of use of following Six Sigma methodology and tools since the year of 2004 by using the 7-points Scales shown below.

Circle the Appropriate Number							
	Never Use			Sometimes			Extensive Use
e.g.	1	2	3	(4)	5	6	7

Level of Use

	Never Use			Sometimes			Extensive Use	
1 Suppliers-Inputs-Process-Outputs-Customers (SIPOC)	1	2	3	4	5	6	7	N/A
2 Failure Modes and Effects Analysis (FMEA)	1	2	3	4	5	6	7	N/A
3 Root Cause Analysis	1	2	3	4	5	6	7	N/A
4 Brainstorming & Affinity Group Tool	1	2	3	4	5	6	7	N/A
5 Thought Map Relations Diagram	1	2	3	4	5	6	7	N/A
6 Customer Segmentation Worksheet	1	2	3	4	5	6	7	N/A
7 Voice of the Customer Data Collection Worksheet	1	2	3	4	5	6	7	N/A
8 Voice of the Customer Requirements Translation and Kano Analysis	1	2	3	4	5	6	7	N/A
9 House of Quality - Quality Functional Deployment Matrix	1	2	3	4	5	6	7	N/A
10 Cause and Effect Matrix	1	2	3	4	5	6	7	N/A
11 Critical to Quality CTQ Tree Diagram	1	2	3	4	5	6	7	N/A

12 DMAIC Measurement Selection Matrix	1	2	3	4	5	6	7	N/A
13 Design For Six Sigma (DFSS)	1	2	3	4	5	6	7	N/A
14 Measurement Assessment Tree Diagram	1	2	3	4	5	6	7	N/A
15 Quality Data Checklist & Scorecard	1	2	3	4	5	6	7	N/A
16 Production Schedule to Actual Scorecard	1	2	3	4	5	6	7	N/A
17 Pareto Chart	1	2	3	4	5	6	7	N/A
18 Six Sigma Team Roles	1	2	3	4	5	6	7	N/A
19 Team Empowerment Boundaries	1	2	3	4	5	6	7	N/A
20 Six Sigma Project Charter	1	2	3	4	5	6	7	N/A

Part C. Company Performance Survey

On a scale from 1 to 7, please indicate how strongly you Disagree or Agree with each statement below.

Circle the Appropriate Number							
	Strongly Disagree			Neutral			Strongly Agree
e.g.	1	2	3	(4)	5	6	7

Section 1. Operational Efficiency

		Degree of Agreement							
		Strongly Disagree			Neutral			Strongly Agree	
1	Six Sigma methodology helps us to reduce defect and rework rates.	1	2	3	4	5	6	7	N/A
2	Six Sigma methodology helps us to reduce the Total Quality Costs.	1	2	3	4	5	6	7	N/A
3	Six Sigma methodology helps us to reduce the unit cost of product.	1	2	3	4	5	6	7	N/A
4	Six Sigma methodology helps us to reduces inventory turnover rate.	1	2	3	4	5	6	7	N/A
5	Six Sigma methodology helps us to reduce employee turnover rate.	1	2	3	4	5	6	7	N/A
6	Six Sigma methodology helps us to improve the delivery speed and reliablity.	1	2	3	4	5	6	7	N/A
7	Six Sigma methodology helps us to improve manufacturing lead time (Product Cycle Time).	1	2	3	4	5	6	7	N/A

Section 2. Customer Satisfaction

		Degree of Agreement							
		Strongly Disagree			Neutral			Strongly Agree	
1	Six Sigma methodology helps us to improve product reliability.	1	2	3	4	5	6	7	N/A
2	Six Sigma methodology helps us to reduce customer complaints.	1	2	3	4	5	6	7	N/A

3 Six Sigma methodology helps us improve the reputation of our products.	1	2	3	4	5	6	7	N/A
4 Six Sigma methodology helps us to improve the overall corporate image.	1	2	3	4	5	6	7	N/A
5 Six Sigma methodology helps us to improve the customer relationship.	1	2	3	4	5	6	7	N/A

Section 3. Business Performance

Degree of Agreement

	Strongly Disagree			Neutral			Strongly Agree	
1 Six Sigma methodology helps us to improve the Return on Investment.	1	2	3	4	5	6	7	N/A
2 Six Sigma methodology helps us to increase Sales Volume.	1	2	3	4	5	6	7	N/A
3 Six Sigma methodology helps us to improve Profit Margins.	1	2	3	4	5	6	7	N/A
4 Six Sigma methodology helps us to improve Overall Profitability.	1	2	3	4	5	6	7	N/A
5 Six Sigma methodology helps us to improve market share.	1	2	3	4	5	6	7	N/A
6 Six Sigma methodology helps us to improve stock price.	1	2	3	4	5	6	7	N/A

Section 4. Participants' comments

Degree of Agreement

	Strongly Disagree			Neutral			Strongly Agree	
1 I am honored to be a member of a Six Sigma team.	1	2	3	4	5	6	7	N/A
2 Six Sigma team members are well respected in the company.	1	2	3	4	5	6	7	N/A
3 I have ownership of each Six Sigma Project I participated in.	1	2	3	4	5	6	7	N/A
4 Six Sigma improved our team spirits.	1	2	3	4	5	6	7	N/A
5 Six Sigma methodology training improved my problem solving skills.	1	2	3	4	5	6	7	N/A

6	Six Sigma Project(s) increased my sense of belonging to this company.	1	2	3	4	5	6	7	N/A
7	Six Sigma Project(s) bring me even better job satisfaction.	1	2	3	4	5	6	7	N/A
8	Six Sigma Project team members will have a better career path than those non-team members.	1	2	3	4	5	6	7	N/A
9	There is always a reward for the Six Sigma team who successfully finished the project.	1	2	3	4	5	6	7	N/A
10	Six Sigma methodology creates permanent change through altering the organizational paradigm.	1	2	3	4	5	6	7	N/A
11	Six Sigma projects mainly come in on schedule.	1	2	3	4	5	6	7	N/A
12	Six Sigma projects mainlycome in on budget.	1	2	3	4	5	6	7	N/A
13	Six Sigma methodology is a valuable apprach which will bring benefits to the stakeholders in the future.	1	2	3	4	5	6	7	N/A

Page 9

Part D. Attitude and Commitment to Six Sigma

Please answer the following questions by using the 7-points Scales shown below.

Circle the Appropriate Number

	Very Unimportant			Average			Very Important
e.g.	1	2	3	(4)	5	6	7

Section 1. The main objective(s) of implementing Six Sigm

	Degree of Agreement							
	Very Unimportant			Average			Very Important	
1 To pursue even higher quality standard.	1	2	3	4	5	6	7	N/A
2 To increase customer confidence.	1	2	3	4	5	6	7	N/A
3 To increase the consistency of product quality.	1	2	3	4	5	6	7	N/A
4 To increase the financial benefits.	1	2	3	4	5	6	7	N/A
5 To promote the company image.	1	2	3	4	5	6	7	N/A

Section 2. Attitude:

	Degree of Agreement							
	Strongly Disagree			Neutral			Strongly Agree	
1 Our management cares about how Six Sigma can improve the efficiency of the entire company.	1	2	3	4	5	6	7	N/A
2 We have been always reviewing the documented Six Sigma practices to see whether they are the most efficient ways and try to improve them.	1	2	3	4	5	6	7	N/A
3 We see Six Sigma initiative as a marketing tool.	1	2	3	4	5	6	7	N/A
4 We believe that Six Sigma is just another business overhead, it will not improve our product quality.	1	2	3	4	5	6	7	N/A

Section 3. Understanding:

		Degree of Agreement							
		Strongly Disagree			Neutral			Strongly Agree	
1	We understand the objectives and functions of Six Sigma well.	1	2	3	4	5	6	7	N/A
2	We understand the contents of Six Sigma well.	1	2	3	4	5	6	7	N/A
3	We understand the philosophy and techniques of Six Sigma well.	1	2	3	4	5	6	7	N/A

(APPENDIX III)

The Refined Research Instrument

For

Measure the Values of Six Sigma

The Refined Research Instrument

Section 1. Quality Management Practices

Name of Constructs	KMO	Reliability	Variance Explained	Abbreviation of Indicator	Indicators	Factor Loadings
Senior Management Commitment and Involvement	0.882	0.903	67.597	Part_B_1 Q42	We have been reviewing our quality policy and strategy regularly in order to identify their strengths and weaknesses.	0.914
				Part_B_1 Q41	Our Senior Management has been highly involved in quality management projects.	0.909
				Part_B_1 Q19	Our senior management has been committed in Six Sigma Practices.	0.818
				Part_B_1 Q43	Our senior management is full of visionary, they have planned for long-term development of our company instead of focusing on short-term profits.	0.816
				Part_B_1 Q20	Managers of all departments have always been involved in Six Sigma Projects.	0.799
				Part_B_1 Q40	Our organization has been providing training on Six Sigma techniques to all employees.	0.742
				Part_B_1 Q33	Our Senior Management has been highly involved in developing quality policy as they have always treated quality as an important strategy for long-term growth of our organization.	0.739
Customer Focus	0.732	0.816	52.888	Part_B_1 Q03	We have been reviewing and analyzing the customer satisfaction surveys in order to seek for the opportunities for improving the product quality.	0.825
				Part_B_1 Q05	Our Research and Development Department always has sound knowledge on the customers requirement and market trends.	0.784
				Part_B_1 Q04	We have been working closely with our customers in designing our products or improving the product design.	0.749

				Part_B_1 Q06	Our marketing staff are fully aware of and responsible for the quality of product and services they provide to our customers.	0.672
				Part_B_1 Q01	We have a formal systems of acquiring the voice of customer (e.g. opinion or expectations) in our company.	0.669
				Part_B_1 Q02	We have been carrying out analyses of our customer complaints or feedback in order to improve our product quality.	0.646
Supplier Management	0.799	0.910	70.825	Part_B_1 Q35	We have been cooperating with our suppliers on a long term basis.	0.937
				Part_B_1 Q34	We have been developing trust and working closely with our suppliers.	0.911
				Part_B_1 Q38	We have been providing clear specifications and requirements to our suppliers.	0.909
				Part_B_1 Q37	We selecting our suppliers, the quality of products they provided is the most important consideration than the prices.	0.872
				Part_B_1 Q36	There have been formal supplier rating systems to evaluate our suppliers' quality performance.	0.75
				Part_B_1 Q39	We have been providing training on Six Sigma techniques to all suppliers to improve their quality performance.	0.626
Six Sigma Team Management System	0.873	0.935	66.704	Part_B_1 Q10	We have been encouraging all of our Belts to develop their own quality improvement tools.	0.907
				Part_B_1 Q12	Six Sigma Belts have always been encourage to form a team to solve or fix the production related problems they discovered.	0.903
				Part_B_1 Q13	Six Sigma Teams have always been given the necessary support on their projects.	0.889
				Part_B_1 Q15	Six Sigma teams have always been formed in our company as working teams for solving production related problems.	0.827
				Part_B_1 Q11	We have been providing continous counseling for skill enhancement in order for Six Sigma Belts to be even more competent at their job.	0.809

				Part_B_1 Q09	Our Six Sigma teams always involve all departments in order to minimize departmental barriers.	0.776
				Part_B_1 Q14	All Six Sigma Belts' improvement suggestions have always been evaluated by management and implemented if appropriate.	0.774
				Part_B_1 Q23	Multidisciplinary Six Sigma teams across different departments have been organized and functioning to improve quality.	0.757
				Part_B_1 Q26	There is a Sponsor in each Six Sigma team to provide resources and overseeing each Six Sigma project.	0.68

Internal Implementation of Six Sigma initiative

Process Control and Improvement	0.824	0.922	62.633	Part_B_1 Q30	We study every process in order to eliminate any problem before it happened.	0.893
				Part_B_1 Q27	We have been studying the variations in our production processes, identifying the undesirable variations, and acting on its sources to achieve greater consistency of product.	0.838
				Part_B_1 Q16	We have been analyzing all relevant quality records, such as service reports, customer complaints, work instructions to detect and eliminate potential causes of non-conforming products.	0.810
				Part_B_1 Q24	Six Sigma teams handled almost all quality problems.	0.796
				Part_B_1 Q22	Our company has been trying to accomplish continuous improvement throughout all domains from planning through operations.	0.793
				Part_B_1 Q32	We have not been satisfied with just meeting the required specifications in our production processes, we are making efforts to minimize the deviations from the target points.	0.788
				Part_B_1 Q25	We use Six Sigma methodology for solving every quality related problem.	0.786
				Part_B_1 Q29	We study the root causes and take corrective actions every time after a problem is found.	0.774

				Part_B_1 Q17	We have always recorded the scrap and rework rates of our products or process for the reference of management and workers.	0.617
Quality System Procedure	0.817	0.892	71.209	Part_B_1 Q45	The Six Sigma language creates a closer bond between different business units.	0.912
				Part_B_1 Q28	We have always been considering the potential quality problems in manufacturing processes in the product design stage.	0.889
				Part_B_1 Q44	Six Sigma becomes a common language in our company for different business units to talk to one another.	0.865
				Part_B_1 Q18	We have been making use of quality cost information as a tool to reduce the overall production costs.	0.801
				Part_B_1 Q07	Our marketing staff are fully aware of and responsible for the quality of product and services they provide to our customers.	0.741
Striving for Higher Quality Performance	0.562	0.548	52.611	Part_B_1 Q31	We have been trying to find out the causes for high operational costs, identifying and solving them to reduce the unit cost of manufacturing.	0.82
				Part_B_1 Q08	Our employees have always been rewarded by management for the improvements of product quality they produce.	0.738
				Part_B_1 Q21	We are striving to reach the Six Sigma level.	-0.601

Section 2. Use of Six Sigma methodology and tools

Name of Constructs	KMO	Reliability	Variance Explained	Abbreviation of Indicator	Indicators	Factor Loadings
Quality Management & Six Sigma Analytical Tools	0.857	0.932	55.086	Part_B_2 Q07	Voice of the Customer Data Collection Worksheet	0.883
				Part_B_2 Q13	Design For Six Sigma (DFSS)	0.868
				Part_B_2 Q12	DMAIC Measurement Selection Matrix	0.845
				Part_B_2 Q08	Voice of the Customer Requirement Translation and Kano Analysis	0.844
				Part_B_2 Q15	Quality Data Checklist & Scorecard	0.835
				Part_B_2 Q14	Measurement Assessment Tree Diagram	0.812
				Part_B_2 Q05	Thought Map Relations Diagram	0.77
				Part_B_2 Q09	House of Quality - Quality Functional Deployment Matrix	0.768
				Part_B_2 Q01	Suppliers-Inputs-Process-Outputs-Customers (SIPOC)	0.745
				Part_B_2 Q11	Critical to Quality CTQ Tree Diagram	0.711
				Part_B_2 Q02	Failure Modes and Effects Analysis (FMEA)	0.587
				Part_B_2 Q06	Customer Segmentation Worksheet	0.572
				Part_B_2 Q10	Cause and Effect Matrix	0.521

				Part_B_2 Q16	Production Schedule to Actual Scorecard	0.457
Basic 7 QC (New/Old) Tools	0.701	0.768	69.326	Part_B_2 Q03	Root Cause Analysis	0.845
				Part_B_2 Q04	Brainstorming & Affinity Group Tool	0.834
				Part_B_2 Q17	Pareto Chart	0.818
General Project Management Tools	0.644	0.824	74.071	Part_B_2 Q20	Six Sigma Project Charter	0.922
				Part_B_2 Q18	Six Sigma Team Roles	0.871
				Part_B_2 Q19	Team Empowerment Boundaries	0.783

Section 3. Organizational Performance

Name of Constructs	KMO	Reliability	Variance Explained	Abbreviation of Indicator	Indicators	Factor Loadings
Operational Efficiency	0.853	0.908	66.844	Part_C_1 Q01	Six Sigma methodology helps us to reduce defect and rework rates.	0.876
				Part_C_1 Q02	Six Sigma methodology helps us to reduce the Total Quality Costs.	0.874
				Part_C_1 Q03	Six Sigma methodology helps us to reduce the unit cost of product.	0.867
				Part_C_1 Q07	Six Sigma methodology helps us to improve manufacturing lead time (Product Cycle Time).	0.864
				Part_C_1 Q04	Six Sigma methodology helps us to reduce inventory turnover rate.	0.834
				Part_C_1 Q06	Six Sigma methodology helps us to improve the delivery speed and reliability.	0.758

				Part_C_1 Q05	Six Sigma methodology helps us to reduce employee turnover rate.	0.615
Customer Satisfaction	0.681	0.823	59.691	Part_C_2 Q03	Six Sigma methodology helps us to improve the reputation of our products.	0.920
				Part_C_2 Q04	Six Sigma methodology helps us to improve the overall corporate image.	0.879
				Part_C_2 Q05	Six Sigma methodology helps us to improve the customer relationship.	0.794
				Part_C_2 Q01	Six Sigma methodology helps us to improve product reliability.	0.632
				Part_C_2 Q02	Six Sigma methodology helps us to reduce customer complaints.	0.580
Business Performance	0.745	0.918	71.278	Part_C_3 Q03	Six Sigma methodology helps us to improve Profit Margins.	0.934
				Part_C_3 Q04	Six Sigma methodology helps us to improve Overall Profitability.	0.927
				Part_C_3 Q05	Six Sigma methodology helps us to improve market share.	0.895
				Part_C_3 Q06	Six Sigma methodology helps us to improve stock price.	0.780
				Part_C_3 Q02	Six Sigma methodology helps us to increase Sales Volume.	0.757
				Part_C_3 Q01	Six Sigma methodology helps us to improve the Return on Investment.	0.751
Participant Comment						
Job Satisfaction	0.773	0.887	61.555	Part_C_4 Q04	Six Sigma improved our team spirits.	0.949

				Part_C_4 Q02	Six Sigma team members are well respected in the company.	0.820
				Part_C_4 Q01	I am honored to be a member of a Six Sigma team.	0.795
				Part_C_4 Q03	I have ownership of each Six Sigma Project I participated in.	0.769
				Part_C_4 Q06	Six Sigma Project(s) increased my sense of belonging to this company.	0.735
				Part_C_4 Q05	Six Sigma methodology training improved my problem solving skills.	0.718
				Part_C_4 Q08	Six Sigma Project team members will have a better career path than those non-team members.	0.677
Satisfactionwith Six Sigma methodology	0.842	0.859	59.631	Part_C_4 Q09	There is always a reward for the Six Sigma team who successfully finished the project.	0.859
				Part_C_4 Q12	Six Sigma projects mainly come in on budget.	0.849
				Part_C_4 Q10	Six Sigma methodology creates permanent change through altering the organizational paradigm.	0.820
				Part_C_4 Q07	Six Sigma Project(s) bring me even better job satisfaction.	0.748
				Part_C_4 Q13	Six Sigma methodology is a valuable approach which will bring benefits to the stakeholders in the future.	0.681
				Part_C_4 Q11	Six Sigma projects mainly come in on schedule.	0.650

Section 4. Attitudes and Commitments To Six Sigma

Name of Constructs		Reliability	Variance Explained	Abbreviation of Indicator	Indicators	Factor Loadings
Continuous Improvement Objectives	0.794	0.800	61.691	Part_D_1 Q02	To increase customer confidence.	0.874
				Part_D_1 Q01	To pursue even higher quality standard.	0.821
				Part_D_1 Q03	To increase the consistency of product quality.	0.811
				Part_D_1 Q04	To increase the financial benefits.	0.708
				Part_D_1 Q05	To promote the company image.	0.697

Attitudes towards Six Sigma methodology

Application and Practice of Six Sigma Methodology	0.500	0.190	55.252	Part_D_2 Q03	We see Six Sigma initiative as a marketing tool.	0.743
				Part_D_2 Q02	We have been always reviewing the documented Six Sigma practices to see whether they are the most efficient ways and try to improve them.	0.743
Treating Six Sigma as another business model	0.500	0.244	58.97	Part_D_2 Q01	Our management cares about how Six Sigma can improve the efficiency of the entire company.	0.768
				Part_D_2 Q04	We believe that Six Sigma is just another business overhead, it will not improve our product quality.	0.768
Understanding	0.636	0.895	83.680	Part_D_3 Q02	We understand the contents of Six Sigma well.	0.966
				Part_D_3 Q01	We understand the objectives and functions of Six Sigma well.	0.919
				Part_D_3 Q03	We understand the philosophy and techniques of Six Sigma well.	0.856