SIX SIGMA IMPLEMENTATION: AN EMPIRICAL ANALYSIS OF CRITICAL SUCCESS FACTORS AND PERFORMANCE OUTCOMES

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ABSTRACT

Using cross-sectional and time series data, this paper analyzes empirically the relationship between Six Sigma implementation and firm Total Sales (TS), Return on Assets (ROA), Return on Sales (ROS), and Sales Growth (SG). A separate analysis examines Six Sigma’s impact on managerial perceptions of financial outcomes (ROI, cost reduction, and revenue enhancement). The key factors that moderate the relationship between Six Sigma implementation and firm performance are also considered. The data pertain to 50 companies (49 American, 1 South African) that have implemented Six Sigma for at least one year and represent nine different industries. The results indicate that a firm’s ability to track the status and financial outcomes of all Six Sigma projects, the maturity of the implementation, the selection of strategically-aligned projects, the integration of Design for Six Sigma (DFSS) into projects, and the breadth of the implementation have a statistically significant impact on subjective and/or objective performance measures.

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1. Introduction

Ever since Motorola gave birth to Six Sigma (6σ) in the late 1980s, the concept has been implemented worldwide in firms striving for quality improvement in their business processes. Six Sigma is defined as a program designed to reduce “the number of defects [in a process] to as low as 3.4 parts per million opportunities” (Henderson and Evans, 2000). To put it simply, Six Sigma uses statistical methods to achieve an almost defect-free process. If the distance between the mean of a process and the closest specification limit (a boundary set by the customer) is six standard deviation units, then the process is considered a “six sigma process.”

The manufacturing sector was the first to integrate 6σ practices into its daily activities, as it involves many highly complex processes that can be easily measured. However, as project managers and Six Sigma leaders became aware of the program’s success in cutting costs in manufacturing, companies began to implement the concept in other areas of business such as information management (IM) and finance. Six Sigma could be applied to these departments without making drastic internal adjustments because of their data-rich, process-oriented environments (Pestorius, 2007).

Not until recently has Six Sigma pushed its way into the transactional process arena: sales and marketing. This delay occurred for several reasons: (1) Six Sigma is much easier to implement in manufacturing, IM, and finance, (2) most Six Sigma professionals had backgrounds in the aforementioned sectors, (3) consumer purchasing has been strong over the past few years, and (4) the current sales culture steers away from systematic processes and considers marketing as an art that could not be integrated with a scientific concept such as 6σ (Pestorius, 2007, xiv-xvi). In spite of this temporary road block, many companies have been able to convince their sales and marketing departments to integrate this tool.

Just as it has been used to improve the measurement and management procedures involved in manufacturing operations, Six Sigma can be applied to sales and marketing processes. The key line of thinking in 6σ for sales and marketing is to visualize activities performed in these departments as one composite process rather than a mere end result (Webb, 2006, 59). Six Sigma takes away the “gut feeling” approach that is too often used in managerial decision-making and replaces it with business decisions based on cold, hard data. In other words, Six Sigma is a process used to improve a process. Although there is not a set formula for Six
Sigma deployment (it varies across companies), the traditional system used by Six Sigma professionals to carry out Six Sigma assignments is called DMAIC (Define, Measure, Analyze, Improve, Control). These represent the five stages of a typical Six Sigma project: (1) Define the problem, (2) Measure the process by gathering data, (3) Analyze the data and look for any cause-effect relationships by paying close attention to key variables (Six Sigma thinking revolves around the equation \( Y = f(x) \)), (4) Improve the process by using the results of the data analysis as a guideline, (5) Control the process through regular monitoring; a control plan should be developed in case the problem reoccurs (Creveling et al., 2006, 9-10). A “roadmap” of the DMAIC process is provided in the Appendix and provides further details on each stage (Exhibit F).

The chart below is a visual representation of how DMAIC is applied to a Six Sigma project. The process itself is very strict, as the project status has to pass a “tollgate” at the end of each stage. For example, after the “Define” stage of the project is complete, the project manager presents the results to the process director who in turn gives a “go” or “no go” signal to either continue with the “Measure” phase or backtrack (Galloway, 2007).

The DMAIC approach is very similar to the modern Stage-Gate process, where projects are strategically selected and must pass a “test” at each gate in order to be eligible to jump to the next project stage (Cooper et al., 2002).
There is a plethora of 6σ tools utilized by both amateurs and experts throughout each stage of DMAIC. Examples of stage-specific tools that can be applied to sales and marketing endeavors are as follows (for visual examples of tools highlighted in bold, refer to Exhibit A in the Appendix):

<table>
<thead>
<tr>
<th>DMAIC STAGE</th>
<th>TOOLS EMPLOYED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Define</td>
<td>Fishbone diagram, project charter, XY matrix, <strong>SIPOC diagram</strong></td>
</tr>
<tr>
<td>Measure</td>
<td>data table, process measurement charts, <strong>Voice of Customer (VOC)</strong></td>
</tr>
<tr>
<td>Analyze</td>
<td>Root cause diagram, <strong>Monte Carlo simulation</strong>, regression analysis, cost-of-poor-quality calculation</td>
</tr>
<tr>
<td>Improve</td>
<td>Quality Function Deployment software, <strong>FMEA</strong></td>
</tr>
<tr>
<td>Control</td>
<td>Documentation, monitoring, response plan, <strong>process sigma calculation</strong></td>
</tr>
</tbody>
</table>

(Creveling et al., 2006; Pestorius, 2007; Webb, 2006; www.isixsigma.com)

An SIPOC (suppliers, inputs, process, outputs, customers) diagram, for example, provides a good map of the process that needs to be assessed and thus assists project leaders in defining the problem at stake (Webb, 2006). A Voice of Customer (VOC) description is an excellent way to measure what the customer values most of the firm’s services/offerings. This method usually involves a sort of survey, focus group, phone interview, etc. that is administered to potential and current customers (Webb, 2006). During the analyze stage, Monte Carlo simulations are a popular project management technique employed in 6σ projects in order to obtain a realistic estimate of the duration of each project task (Creveling et al., 2006). Employment failure modes and effects analysis (FMEA) is often used as a follow-up tool to the Monte Carlo simulation as a method to identify the ways in which potential solutions could fail in addition to the domino effect these possible malfunctions could have on other tasks and results (Webb, 2006). Lastly, as the term Six Sigma denotes, the final goal is to achieve a process that operates at the “6σ” level. A process sigma calculation is therefore a
Logical tool to use during the control phase, as it calculates the sigma level of the process and thus indicates whether the process is remaining on target (www.isixsigma.com). The higher the sigma level, the more standard deviation units can fit between the process average and the closest specification limit. Once again, a process reaches the six sigma level if there are six standard deviations between the mean and the closest specification limit. The specifications limits are set by the customer; therefore anything that falls outside the specification limit translates into a defect. For example, a customer service desk may be required to answer the phone within 20 seconds, and any time later than that would be considered a “defect,” or poor service. The 20 seconds is the upper specification limit (USL) indicated by the customer. There may also be a lower specification limit (LSL), where the product or service delivered cannot go below a certain boundary. The idea is to be as far away as possible from the specification limits. Statistically speaking, the sigma level is equivalent to the “z-score” (Galloway, 2007). In order to calculate the sigma level, the following equation would be employed:

\[ \frac{x - x'}{\sigma} = \text{SIGMA LEVEL} \]

- \(x\) = upper or lower specification limit
- \(x'\) = mean of process
- \(\sigma\) = standard deviation

As mentioned previously, managers strive to achieve the ideal sigma level of 6, however this is rarely accomplished. The graph below provided by NewPage Corporation explains this concept visually using specific industry examples. A further explanation of sigma levels and how they are applied to business processes is provided in Table 2 in the Appendix.
The graph shows that there are large discrepancies in sigma levels according to the industry. The x-axis represents the sigma level and the y-axis represents the defective parts per million opportunities (PPM). The airline industry, for example, requires a six sigma level process, otherwise flying would no longer be a reliable option for transportation. Unfortunately, other business processes such as the shipping of luggage from one airport to the next (luggage is often lost or sent to the wrong destination) and medicine prescriptions (doctors often have sloppy handwriting which is interpreted incorrectly by the pharmacist) hover around the 3 sigma level. To put it simply, at a 3 sigma level, about 60,000 out of every 1 million suitcases are delivered late, to the wrong destination, or lost. The table below gives further examples of specific processes conducted at a 3 sigma level in comparison to a 6 sigma level. Based on these observations, the ultimate goal of managers in charge of processes such as payroll and baggage claims is to reduce overall variation in these processes and thus reduce defects caused by this variation.
Returning to the DMAIC process as a whole, it is important to note that the process itself is very rigid and structured. However, the tools used throughout the process are merely guiding instruments and can be used in more than one phase. For example, regression analysis could be used in the “Measure” or the “Analyze” phase, depending on the project tasks and goals. The abovementioned sigma calculation can also be utilized throughout DMAIC in order to gauge the progress in reducing process defects.

Many critics argue that the tools used throughout DMAIC already existed before the onset of Six Sigma, which essentially makes Six Sigma appear like “old wine in a new bottle” (Antony, 2006; Urdhwareshe, 2000). In other words, the critics want to know what value Six Sigma adds to what was previously available to managers. Six Sigma enthusiasts argue that the DMAIC process provides a foundation for bringing together one or several areas of a business, with the goal of increasing efficiency, reducing defects and waste, and creating a firm culture that embraces a customer-centric perspective. Most importantly, Six Sigma is an instrument that is not only designed to reduce costs (as is seen in the manufacturing sector, i.e.), but also goes hand in hand with boosting firm sales (Webb, 2006). This strong focus on the bottom line is what Six Sigma advocates use as an argument for the program’s value-added
This paper will therefore empirically examine the impact of 6σ implementation on firm financial performance, as this provides insight on the direct effects of the program’s application on profitability and sales growth. This research also addresses the key factors involved in successful, and eventually profitable, Six Sigma implementation. The following sub-section discusses further the specific financial metrics used as dependent variables as well as the importance of this study and its contribution to academia and the business world. Several research questions are also presented.

1.1 Research Question & Sub-Questions

Although not many theory-based studies have been completed on Six Sigma, numerous analyses have already been performed on other quality management forerunners such as Total Quality Management (TQM) and ISO 9000 methodologies. Various authors have examined the impact of TQM implementation or ISO 9000 certification on business performance. Some focused on operational performance (customer satisfaction, product quality, employee morale), while others concentrated on financial results (market share, ROA, ROI, ROS, sales growth, asset turnover, etc.). The general consensus of these studies indicated a positive relationship between quality management program implementations and firm performance. Therefore, it would be interesting to know if Six Sigma has an impact on performance similar to its quality improvement “cousins.”

The goal of this paper is to explore whether or not a Six Sigma project, with the intentions of improving efficiency and quality, provides enough added value in order to affect the bottom line of the enterprise in a positive and significant manner. In other words, is the investment financially worthwhile in the long-run? The following research question addresses these issues and is the main focus of this paper:

**RQ**: What is the impact of Six Sigma (6σ) implementation on a firm’s financial performance?

*Financial Performance* = Return on Assets (ROA), Return on Sales (ROS), Total Sales (TS), Sales Growth (SG)
There is a multitude of financial indicator variables to choose from in the literature, however this analysis equates financial performance with a combination of return on assets (ROA) and three variations of sales measurements. There are several underlying reasons for the selection of these specific variables: (1) many authors who have performed similar empirical research on TQM or ISO 9000 certification have employed at least one or a combination of these variables as metrics for financial performance (Mohrman et al., 1995; Powell, 1995; Adam et al., 1997; Chenall, 1997; Ittner and Larcker 1997; Easton and Jarrell, 1998; Das et al., 2000; Wilson and Collier, 2000; Douglas and Judge 2001; Kaynak, 2003; Corbett et al., 2005; Feridun and Al-Khadesh, 2006), (2) these four variables together paint a complete financial picture of firm performance by considering long-term growth, return on assets/capital, and the cost of capital (Dobbs and Koller, 2005), and (3) the data for these financial indicators are easily accessible via annual company reports posted online.

Six Sigma is designed to both reduce costs and/or increase sales depending on the goals of the firm. ROA, ROS, TS, and SG represent interesting dependent variables for this study, as they account for both cost reduction and fluctuations in sales over time. Return on Assets (ROA) is measured by dividing the firm’s operating income by its total assets – before depreciation (Corbett et al., 2005). This variable helps to control for the differences in capital intensities among firms. For example, if a manufacturing firm (very asset-based with a lot of very controlled processes) has a 4% growth in sales after Six Sigma implementation and a services firm experiences the same percentage of sales growth, this looks like a perfect fairytale ending for both companies. Unfortunately, this does not tell the whole story, as the manufacturing firm could experience a negative ROA and the services firm a positive ROA despite their identical growth in sales (Hendricks and Singhal, 2000). Return on Sales (ROS) is an excellent metric to couple with ROA due to its power of explaining any changes in the numerator of ROA (operating income) in addition to its ability to measure costs [ROS = 1 - (Cost of Goods Sold + General Expenses (SG&A))/Sales] (Corbett et al., 2005). ROS captures any net profit changes, as it is calculated by dividing operating income (before depreciation) by sales. Thus, although ROS is not needed to complete the financial story per se, its explanatory ability in relation to the ROA variable is invaluable. Lastly, total sales (TS) and sales growth (SG) are key variables because they not only pinpoint Six Sigma’s impact on
pure sales (TS), but sales growth also measures this over time: \( SG = [(S_t - S_{t-1})/S_{t-1}] \) (Corbett et al., 2005). Sales Growth is the only dependent variable used in this analysis that provides more than just a financial “snapshot,” thus complementing the other three “static” variables.

The main goal of this research is to measure the relationship between Six Sigma implementation and the aforementioned financial indicators. However, the second part of this study also takes into account the relationship between Six Sigma implementation and several managerial perception variables (perceived ROI, perceived effectiveness in cost reduction, and perceived effectiveness in increasing revenue). Although perceived performance measures are subjective in nature, they have the advantage of canceling out company-specific characteristics such as differences in accounting conventions, inventory valuations, and size (Powell, 1995). In addition, the use of subjective measures allows for the inclusion of several privately-held companies that participated in the survey, but do not provide public access to their financial information.

Although the implementation of a Six Sigma program is the key phenomenon analyzed in this study, there are various external and internal factors that may moderate the impact of the \( 6\sigma \) program. In the Six Sigma community, a list of critical success factors has been generated over the years based on feedback from companies that have been successful with implementing the program (Porter, 2002; Rees, 2007). Although there is not one universal list of critical success factors, this paper zooms in on the ones that appear most frequently in the literature and thus appear to be the most relevant. The following sub-questions address these factors as well as external factors that may influence the deployment process:

(a) How does the maturity of the Six Sigma program implementation affect a firm’s ROA, ROS, Total Sales, and Sales Growth?

(b) How does the firm’s strategic alignment affect the impact of Six Sigma implementation on ROA, ROS, Total Sales, and Sales Growth?

- Is it an enterprise-wide initiative or are only a few areas of the business applying Six Sigma techniques?
- Are the projects selected in line with the company’s strategic goals?
(c) How does the existing number of employees dedicated both part-time and full-time to Six Sigma projects affect the impact of Six Sigma implementation on ROA, ROS, Total Sales, and Sales Growth?
   ▪ How many Six Sigma experts are in the firm leading projects full-time – (i.e. Master Black Belts, Black Belts)?
   ▪ How many employees are working on Six Sigma projects part-time (i.e. Green Belts)?

(d) How does the firm’s organizational structure and learning ultimately affect the impact of Six Sigma implementation on ROA, ROS, Total Sales, and Sales Growth?
   ▪ Is there effective mentoring and coaching provided for Master Black Belts, Green Belts, Champions, and others working on Six Sigma within the organization?

(e) How does the integration of Lean Six Sigma (LSS) and Design for Six Sigma (DFSS) throughout the organization affect the impact of Six Sigma on financial performance?

(f) How does a firm’s bottom-line focus affect the impact of Six Sigma on ROA, ROS, Total Sales, and Sales Growth?
   ▪ Is the firm able to track the status and measure the financial impact of its Six Sigma projects?
   ▪ Are projects selected specifically for their value creation opportunity (through cost reduction and/or additional revenue)?

(g) How does commitment from top management influence the impact of Six Sigma on ROA, ROS, Total Sales, and Sales Growth?

The aforementioned factors and the subjective performance measures will be discussed in further depth in Chapter 2.

1.2 Study Contribution and Research Approach

The intention of this study is not only to push Six Sigma into the light of theoretical and empirical research, but also to provide managers with an insight on the effectiveness of the program in their firm. This study is also designed to assist sales and marketing managers in making any decisions on Six Sigma implementation, employee training and hiring, etc. Six Sigma has been a powerful tool in manufacturing for years, however its very recent application in service-based business areas and industries is not yet known (Antony, 2006; McAdam and Lafferty, 2004).
This paper will proceed in the following manner. Chapter 2 offers an extensive overview of the many studies already performed on various quality management techniques and describes the theoretical model that links these ideas to the Six Sigma argument. The literature review is succeeded by Chapters 3 and 4, which provide a detailed description of the empirical research design along with the results of the analysis. Chapter 5 discusses the results and their managerial implications, while Chapter 6 provides research limitations and suggestions for further research.

2. Literature Review

Quality management activities receive a lot of hype in the media, where headlines such as “Six Sigma Still Pays Off At Motorola” are not uncommon (Crockett and McGregor, 2006). News like this is appealing to the average manager contemplating the implementation of a Six Sigma program, however there has been a lack of empirical research that can support such statements. What does it mean when Six Sigma activities “pay off” for a firm? What are the stipulations? Because questions like these have been left unanswered, many managers remain skeptical of the added value that any quality management program could bring to their firm (Ittner and Larcker, 1997, Terziovski et al., 2003). The goal of this research is to empirically analyze the impact of Six Sigma implementation on the financial performance of a sample of American firms and examine the key factors related to successful implementation in order to answer these managerial questions.

Several authors have also recently addressed this dilemma in a similar light by researching the impact of ISO 9000 certification, Total Quality Management (TQM), and general process management techniques on business performance. Total Quality Management (TQM), one of the most well-known quality management programs, is a broad way of thinking that extends throughout the firm and focuses principally on customer-centric practices, employee empowerment, planning, improvement, control, and meeting standard performance requirements (Motwani et al., 2004; Brah et al., 2002). The concepts behind TQM and Six Sigma coincide through their shared quality management focus. However, Six Sigma can be seen as the beefed up version of TQM. Using the traditional DMAIC (Define-Measure-Analyze-Improve-Control) procedure as a tool, Six Sigma brings a more solid instrument to
the table through the extensive use of statistical analyses, a leadership-driven atmosphere, problem-solving thinking, and a customer-centric approach (Motwani et al., 2004; Antony, 2004). In spite of the differences between general quality management practices and Six Sigma, the core of both tools is the same. For this reason, empirical studies on these QM techniques are used as a reference for the Six Sigma research model presented in this paper.

The overall consensus of the analyses performed on QM activities is that there are indeed financial returns involved with investing in such programs. More importantly, specific factors that contribute to this success appear consistently throughout the literature: duration of the company’s QM experience, level of implementation (coincides with strategic alignment), employee skill level, top management commitment, firm size, industry, and the extensiveness of training in the firm.

2.1 Maturity of Implementation
When a firm first adopts a quality management tool such as 6σ, a costly investment is made on both the financial and organizational levels. The firm must hire new Six Sigma experts to train current employees and lead projects, invest in statistical technologies and/or software, and above all, see that the entire organization adjusts to a Six Sigma way of thinking (Antony, 2004). It takes time for a company to adapt to these major changes. Therefore, any positive effects on the firm’s bottom line results due to the 6σ implementation may not appear until two or three years after the initial adoption of the tool (Brah et al., 2000). Based on this information, the following hypothesis can be formulated:

H1: The amount of time that has passed since the firm’s implementation of 6σ will increase the impact of Six Sigma on the firm’s financial performance.

2.2 Strategic Alignment
Although strategic alignment is not a variable that is emphasized in the quality management literature, it is considered in the Six Sigma literature as a critical success factor with regards to Six Sigma deployment in a firm. Strategic alignment has two components: (1) level of Six Sigma integration throughout the company and (2) project alignment with company’s
strategic goals (Porter, 2002). Certified Black Belt and research manager for iSixSigma, Michael Marx (2007), devised the following levels of Six Sigma implementation in a firm:

- **Corporate**: 6σ is deployed on an enterprise-wide level and thus integrated throughout the entire organizational culture.
- **Business unit**: 6σ is implemented in a single business area (i.e. finance department) of the firm and supported by the general manager of that unit or a corporate executive.
- **Pilot**: the 6σ initiative is present in and supported by one or more business units in the company, but it is in a trial phase.
- **Belt**: Several Black Belts or Green Belts (trained Six Sigma professionals) are working within the company, but they are not working on a specific project (lack of organization).

It is also important to note that broadening the Six Sigma scope in a corporation to include not only manufacturing processes, but also transactional processes (sales- and marketing-oriented activities) is considered a step closer to achieving the best value from Six Sigma deployment (Hahn, 2005). Creveling et al. (2006) also indicate that the combination of cost control in manufacturing with the creation of sustainable growth through 6σ sales and marketing efforts is the ultimate recipe for positive performance results after Six Sigma deployment. Therefore, the amount of presence Six Sigma has in the overall firm structure coupled with its application to a diverse range of activities (from manufacturing to marketing) comprises the degree at which an enterprise has implemented Six Sigma. This study focuses on the specific business areas in which Six Sigma has been implemented.

In addition to a firm’s degree of implementation, strategic alignment is determined by the specific projects that are adopted and the extent to which they fall in line with the firm’s strategic goals (Porter, 2002). Hahn (2005) emphasizes the importance of this factor particularly in the beginning stages of Six Sigma deployment. The ability to demonstrate the project’s alignment with key strategic measures will motivate employees by revealing its relevance to firm goals. This aspect, along with the integration level of the program, leads to the second hypothesis:
**H2**: The degree of Six Sigma strategic alignment in a firm will have a positive effect on the impact of Six Sigma on financial performance.

2.3 Cadre of Change Leaders

This variable is simple but crucial during Six Sigma deployment. There must be a strong cadre of change leaders (i.e. Master Black Belts, Black Belts) who are expert Six Sigma practitioners dedicated full-time to deployment (for Six Sigma leader titles and their definitions, refer to Table 1 in the Appendix). Master Black Belts (MBBs) are certified, trained experts specialized in Six Sigma practices and represent the top of the Six Sigma hierarchy. Black Belts (BBs) also possess extensive Six Sigma knowledge through rigorous training and an exam and lead projects within the organization (www.isixsigma.com). MBBs and BBs almost always play a full-time Six Sigma role, meaning that 100% of their time and energy is dedicated to Six Sigma endeavors within the company. Companies will most likely see a direct impact on bottom line results through investment in Black Belt training, as the average Black Belt project is claimed to save around £100,000 (Porter, 2002). It is equally important to have a large group of employees trained in basic Six Sigma methodologies leading projects on a part-time basis (Green Belts). Their knowledge of Six Sigma tools is not as extensive as that of the MBBs and BBs, however they still play a key role in executing Six Sigma projects. This hierarchy of expertise, coupled with a large percentage of employees dedicated full-time to Six Sigma deployment, represents yet another critical success factor (Goh, 2002; Porter, 2002; Rees, 2007). The hypothesis is formulated as follows:

**H3**: There will be a positive relationship between the percentage of employees dedicated full-time and part-time to Six Sigma deployment and the impact of Six Sigma on firm performance.

2.4 Organizational Structure and Learning

In this context, organizational structure and learning encompasses the extent of training, mentoring, and coaching provided to all Six Sigma leaders within the company. Several quality management authors emphasize the importance of training and expertise within the organization in order to ensure a strong foundation of “know-how.” Kaynak (2003) examined
the relationship between TQM initiatives and firm performance and found that training had a positive and significant indirect effect on process management.

Although some authors hypothesized a positive relationship between training and company performance (in a TQM or ISO 9000 context) and received statistically insignificant results (Powell, 1995; Terziovski and Samson, 1999), the results of an identical analysis in a Six Sigma setting may differ completely. According to Six Sigma experts, it remains a key element in the Six Sigma implementation process, therefore it is not excluded from the analysis. Training also goes hand-in-hand with consistent mentoring and coaching of Six Sigma project participants at all levels of the hierarchy (Rees, 2007). Lastly, Henderson and Evans (2000) point out that whether training is outsourced or provided in-house, it is a crucial success factor regarding Six Sigma implementation. The Six Sigma strategy requires a wide variety of expertise from mathematicians to statisticians to quality specialists. In 1998, General Electric (one of the Six Sigma pioneers) invested almost $400 million in Six Sigma training and realized around $1.2 billion in returns on this investment. In fact, becoming a trained Black Belt is a requirement for promotion in management at GE (Porter, 2002). As Henderson and Evans (2000) state so eloquently, “besides hardware and software, the ‘human-ware’ side is needed to make productivity work [in Six Sigma].” The fourth hypothesis is derived from these observations:

\[ H4: \text{There is a positive relationship between organizational structure and learning and the impact of Six Sigma on firm financial performance.} \]

2.5 Lean Six Sigma (LSS) and Design for Six Sigma (DFSS)

“Lean Six Sigma (LSS) is the combination of two proven methodologies for improving total organization performance through systematic and continuous process improvement” (NewPage Corporation, 2007). “Lean” is a method often combined with Six Sigma, as the two concepts go hand-in-hand. The main goal is to reduce waste and increase the speed of a process, thereby increasing overall efficiency. Waste includes things like rework (any repair), motion (any motion of the worker that does not add value), overproduction, waiting, etc. The main difference between Six Sigma and Lean is that Lean focuses on speed and efficiency and
Six Sigma focuses on precision and quality. Lean applies tools like “kaizen” events, where a diverse project team (composed of employees ranging from assembly line workers to senior executives) spends one week examining a specific defect in a process (Smith, 2003). This is a very short-term results-driven procedure. Also, lean often does not possess the extensive amount of statistical tools and analysis used in Six Sigma. In essence, Lean and Six Sigma are interconnected because they feed into each other. The faster, more efficient cycles derived from Lean produce the quality inherent in Six Sigma. This Six Sigma quality (reduction of variation → reduction of defects) in turn reduces the time spent trying to reduce waste through Lean processes. Nancy Rees, Senior Vice President of Xerox Corporation, mentioned the integration of LSS into daily operations as a critical success factor in Six Sigma deployment (Six Sigma Leadership Conference, 2007).

Design for Six Sigma (DFSS), on the other hand, is an approach (rather than a methodology) to Six Sigma that does not focus on reducing defects in an already-existing process (through DMAIC). Instead, it is used to design a completely new product or service based on the customer’s needs and/or desires (www.isixsigma.com). DFSS does not have a specific set of stages; this varies between companies depending on their goals. It is very customer-driven, proactive, and innovative. The goal is to define a specific set of customer-oriented attributes in the very beginning of the new product development process that can be defined, measured, analyzed, optimized, and verified [DMAOV] (UGS PMC Software). Once the customer requirements have been defined, a product design can be derived from these findings. The table below provides a general comparison of Six Sigma and DFSS.

<table>
<thead>
<tr>
<th>Differences between Six Sigma and Design For Six Sigma</th>
<th>Design for Six Sigma</th>
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<tr>
<td><strong>Six Sigma</strong></td>
<td><strong>Design for Six Sigma</strong></td>
</tr>
<tr>
<td>• DMAIC: Define, Measure, Analyze, Improve, Control</td>
<td>• DMADV: Define, Measure, Analyze, Design and Verify</td>
</tr>
<tr>
<td></td>
<td>• DMADOV: Define, Measure, Analyze, Design, Optimize, and Verify</td>
</tr>
<tr>
<td>Looks at existing processes and fixes problems</td>
<td>Focuses on the up-front design of the product and process.</td>
</tr>
<tr>
<td>More reactive</td>
<td>More proactive</td>
</tr>
</tbody>
</table>
| Dollar benefits obtained from Six Sigma can be quantified rather quickly. | Benefits are more difficult to quantify and tend to be more long-term. It can take six to 12 months after the launch of the new product before you will obtain proper accounting on the impact.

(UGS PMC Software)
Both LSS and DFSS are seen as value-adding supplements to the Six Sigma repertoire within the Six Sigma community and are therefore seen as critical success factors that will ultimately affect the firm’s financial statement (Hahn, 2005). Thus, the following hypothesis can be stated:

**H5**: Integration of Lean Six Sigma (LSS) and/or Design for Six Sigma (DFSS) methodologies will positively affect the impact of Six Sigma on ROA, ROS, Total Sales, and Sales Growth.

### 2.6 Bottom-line Focus

Although this variable is not prevalent in the TQM literature, Six Sigma professionals stress the importance of high-impact projects. A firm is considered to have a “bottom-line focus” with regards to Six Sigma implementation when it purposely hand picks projects that will eventually reduce costs and/or bring in additional revenue (Porter, 2002). Rees (2007) also indicated that one of Xerox’s critical success factors is the selection of projects for value creation opportunity, particularly those that yield a healthy ROIC (Return on Investment Capital). More specifically, the Sales and Marketing department is expected to adopt Six Sigma projects that provide value to the customer, and that value is eventually reciprocated: “a company must create value for its customers and be paid for that value” (Webb, 2006, p. 52). Lastly, value creation must also be coupled with the firm’s ability to track the financial status of the project throughout all stages: creation until realization. The combination of value creation and rigorous financial tracking and measurement comprises an overall bottom-line focus and thus leads to the following hypothesis:

**H6**: A firm’s bottom-line focus will have a positive effect on the impact of Six Sigma on ROA, ROS, Total Sales, and Sales Growth.

### 2.7 Top Management Commitment

The final and one of the most widely used variables in the quality management literature is the level of commitment that top management invests before, during, and after implementation. Ittnier and Larcker (1997) state that without commitment and support from management, the adoption of process management techniques is bound for failure, as this
project dedication ensures teamwork and induces continuous improvement efforts. Managers have the power to create enthusiasm and motivation among employees and see that the implementation process runs smoothly and effectively at all times. Executive commitment has also shown to have a direct or indirect link with financial or operating performance in relation to quality management endeavors (Kaynak, 2003; Powell, 1995, Adam et al., 1997).

In addition, Six Sigma literature specifically conveys commitment from top management as the most critical success factor of 6σ deployment (Henderson and Evans, 2000; Hahn, 2005). Kuei and Madu (2003) argue that quality leadership among top managers is one of the key drivers of successful completion of the DMAIC project cycle. Support from leaders within the company represents the foundation of a Six Sigma project, and without this, there would be no grounds to build the project implementation upon. With this being said, the following hypothesis can be suggested:

\textbf{H7: Commitment from Top Management throughout Six Sigma implementation will have a positive relationship with the impact of Six Sigma on a firm’s financial performance.}

\section*{2.8 Firm Size and Industry}

Firm size is introduced as a control variable in numerous studies on quality management endeavors and their link to organizational or financial performance (Ittner and Larcker, 1997; Powell 1995; Terziovski et al., 2003; Brah et al., 2002). For example, larger companies may have a higher sales growth in comparison to smaller companies, irrespective of the Six Sigma implementation. Many TQM and ISO 9000 studies also included firm industry/sector as a control variable, as performance can vary significantly depending on the specific industry (Brah et al., 2000; Brah et al., 2002; Powell, 1995).

\section*{2.9 Model of Key Success Factors and Performance Outcomes of Six Sigma Implementation}

The goal of this paper is to discover to what extent Six Sigma impacts the bottom line of the firm and through which key deployment success factors the company sees the most positive financial outcomes. Return on Assets (ROA), Return on Sales (ROS), Total Sales, and Sales Growth are the objective financial indicators used to measure firm performance. Perceived ROI, perceived effectiveness in cost reduction, and perceived effectiveness in increasing
revenues represent the subjective measures of Six Sigma effectiveness. Furthermore, the seven abovementioned hypotheses correspond to the key success factors that will ultimately influence the end results of Six Sigma deployment. Lastly, firm size and industry are placed in the model in order to control for any variance in Six Sigma effectiveness between small, medium, and large firms and the industries to which they belong.

The model below summarizes the theoretical foundation of this study and represents the basis of the empirical model which is elaborated upon in the subsequent section.

3. Research Methodology

3.1 Sample

Only managers currently working with Six Sigma tools in a company that has implemented Six Sigma for at least one year were invited to participate in the research. Contacts were obtained from a list of Six Sigma Leadership Council members and through solicitation of Six Sigma forums (iSixSigma, www.lean.org) and networking communities (www.xing.com, www.linkedin.com). Requests to participate in this research were sent out via e-mail and snail mail to potential candidates. A total of 50 companies agreed to participate out of 120
companies that were contacted, yielding a response rate of about 42%. Among these 50 companies, 41 of them are publicly traded, 8 of them are privately held, and only one of them is based outside the United States (South Africa). All other responses were from American companies or United States-based subsidiaries. The following industries were represented in the sample: Health, Manufacturing, Finance, Energy, Engineering, Retail, Transportation, High Tech, and Other. Every questionnaire was filled out by a range of top managers such as performance engineers, Six Sigma deployment directors, business excellence leaders, and Master Black Belts. All respondents are knowledgeable key informants about information pertaining to Six Sigma; the majority is responsible for Six Sigma activities in their respective company.

3.2 Data
The empirical analysis of the impact of Six Sigma implementation on firm performance employed data gathered from an online survey (administered via www.zoomerang.com), several online databases, and company annual reports. A short survey of 21 questions addressed all seven characteristics referred to in the hypotheses mentioned in Chapter 2. A specific reliable and valid scale has not yet been developed for Six Sigma-related research, therefore the questions were constructed based upon scales already applied in quality management research (Iltner and Larcker, 1997; Kaynak, 2003) and an in-depth discussion with a Six Sigma expert. The list of questions presented in the questionnaire and the variables to which they correspond are presented in the Appendix (Exhibit G). The types of questions are mixed in nature; some contain a 5-point Likert Scale and ask the respondent to indicate his/her level of agreement with the statement, while some ask the respondent to select from a list of options (i.e. level of Six Sigma implementation, industry), and others require the respondent to type in a numerical answer (i.e. number of full-time Black Belts, number of employees).

For the dependent variables, financial data (ROA, ROS, Total Sales, Sales Growth) was gathered for all 41 public companies from various online sources (Google Finance, Morning Star, company annual reports, Osiris). The remaining 9 private/foreign companies were included only in the subjective analysis. This objective financial data were retrieved in
attempt to balance the potentially biased subjective financial measures (perceived ROI, perceived effectiveness in reducing costs, and perceived effectiveness in increasing revenue).

3.3 Model Specification and Estimation
The empirical model below attempts to identify the key determinants involved in successful Six Sigma implementation as well as the financial impact of Six Sigma program implementation. This is a cross-sectional analysis for the year 2006. Variables are grouped into Six Sigma characteristics ($\beta$s) and control variables ($\gamma$s). The control variables in this econometric model consist of two dummy variables for industry effects and a firm size variable (number of employees). In order to conserve degrees of freedom, the nine industries prevalent in the data set were grouped into two categories based on their degree of similarity. Manufacturing and energy were paired to create the INDUSTRY dummy to control for any differences between the “manufacturing” and “other” sectors. However subjective this industry categorization may be, it is crucial that industry is somehow controlled for in such an analysis.

Financial Performance (ROA, ROS, TS, or SG) = $\alpha + \beta_1\text{MATURITY} + \beta_2\text{SCOPE} + \beta_3\text{STRATEGIC} + \beta_4\text{LEADER} + \beta_5\text{BELTS} + \beta_6\text{COACHING} + \beta_7\text{TRACKING} + \beta_8\text{DFSS} + \beta_9\text{LSS} + \gamma_1\text{SIZE} + \gamma_2\text{INDUSTRY} + \epsilon \tag{1}$

Return on Assets (ROA), Return on Sales (ROS), Total Sales (TS), and Sales Growth (SG) serve as the dependent variables in this equation and represent the overall financial performance of the firm. The first two independent variables are MATURITY and SCOPE, where MATURITY is the number of years Six Sigma has been implemented in the company, and SCOPE corresponds to the number of business areas in which Six Sigma has been implemented (i.e. only engineering and manufacturing or all business areas including sales, marketing, planning, and R&D). Both of these variables are expected to carry a positive coefficient, as the longer Six Sigma has been implemented and the more widespread the implementation is across the firm, the better the bottom line performance.
The remaining independent variables are a blend of key success factors derived from quality management and Six Sigma literature (Powell, 1997; Kaynak, 2003; Antony, 2007). The STRATEGIC variable refers to the extent to which a firm selects Six Sigma projects in line with the company’s strategic goals. LEADER measures the amount of top management commitment to Six Sigma projects within the firm, and the BELTS variables refers to the percentage of employees dedicated both part-time and full-time to Six Sigma projects within the company. The COACHING variable indicates whether or not there is a strong presence of effective mentoring and coaching in the company for all employees involved in Six Sigma projects. All four of these variables are expected to have a positive relationship with the dependent variables. TRACKING refers to Six Sigma leaders’ ability to consistently track the status and financial outcomes of all Six Sigma projects. This variable is expected to carry a positive coefficient estimate. Lastly, LSS and DFSS measure the extent to which a firm has implemented Lean Six Sigma (a tool designed to reduce waste in a process) and Design for Six Sigma (an advanced innovation-oriented tool, usually implemented after LSS). The expected sign for both variables is expected to be positive.

The last two variables in the equation are the control variables. SIZE controls for firm size and is measured by the number of employees in 2006, and the INDUSTRY variable controls for all firms in the manufacturing and energy sectors only. These control variables are consistent with the quality management literature (Powell, 2005; Ittnner and Larcker, 1997; Hendricks and Singhal, 2000).

Two additional equations employed subjective managerial data as dependent variables: COSTS, and REVENUE. A Chi-square test was performed for the subjective analysis using the PERCROI dependent variable. PERCROI refers to whether or not the manager believes Six Sigma was good investment for his/her respective company. COSTS and REVENUE refer to the level of the company’s effectiveness in reducing costs and/or increasing revenue streams through Six Sigma projects. This second subjective cross section analysis has two purposes: (1) to compare managerial perceptions of Six Sigma success with actual bottom line results and (2) to include the private and foreign companies who completed the survey. Both equations mirror the first model, except the subjective variables mentioned above replace the objective financial dependent variables (ROA, ROS, Total Sales, and Sales Growth).
Chi-Square test examines each independent variable and its relationship to managers’ perceptions of Six Sigma as an investment. The results of this test are discussed in the following chapter. The two COSTS and REVENUE equations are formulated as follows:

\[
\text{COSTS} = \alpha + \beta_1\text{MATURITY} + \beta_2\text{SCOPE} + \beta_3\text{STRATEGIC} + \beta_4\text{LEADER} + \beta_5\text{BELTS} + \beta_6\text{COACHING} + \beta_7\text{TRACKING} + \beta_8\text{DFSS} + \beta_9\text{LSS} + \gamma_1\text{SIZE} + \gamma_2\text{INDUSTRY}1 + \gamma_3\text{INDUSTRY}2 + \epsilon
\]

\[
\text{REVENUE} = \alpha + \beta_1\text{MATURITY} + \beta_2\text{SCOPE} + \beta_3\text{STRATEGIC} + \beta_4\text{LEADER} + \beta_5\text{BELTS} + \beta_6\text{COACHING} + \beta_7\text{TRACKING} + \beta_8\text{DFSS} + \beta_9\text{LSS} + \gamma_1\text{SIZE} + \gamma_2\text{INDUSTRY}1 + \gamma_3\text{INDUSTRY}2 + \epsilon
\]

Lastly, a third analysis using the objective financial data examined the impact of Six Sigma over time, more specifically over the years 1996-2007. This analysis is meant to be a supplement to the first cross-section model, as it takes into account year-to-year fluctuations opposed to just a snapshot in time. The historical financial data could not be utilized in the first model because the data obtained for the explanatory variables (via the survey) were only representative of current company characteristics. The first industry-specific equation utilizes Total Sales (TS) as a dependent variable and is multiplicative in nature:

\[
\text{TS} = \alpha \cdot \beta^\text{SIXSIG} \cdot \gamma^\text{INDUSTRY}_{(a,b,...,z)} \cdot \delta^\text{TREND} \cdot \text{SIZE}^\epsilon \cdot \exp(\epsilon)
\]

The equation is linearized by taking the natural log on both sides. This leads to the following expression:

\[
\ln(\text{TS}) = \ln(\alpha) + \ln(\beta)^\text{SIXSIG} + \ln(\gamma)^\text{INDUSTRY}_{(a,b,...,z)} + \ln(\delta)^\text{TREND} + \ln(\epsilon)^\text{SIZE} + \epsilon
\]

The key explanatory variable is SIXSIG, a variable indicating how many years Six Sigma has been implemented in the considered company. For example, if a company has been practicing Six Sigma for five years, the company would receive a 1 for the dummy variable SIXSIG1 for the year 2002 and a 0 for all other years. SIXSIG2 would receive a 1 for the
second year of implementation in 2003 and a 0 for all other years. Finally, SIXISIG5 would receive a 1 for the year 2006 and a 0 for the remaining years. This variable is accompanied by nine industry dummies (Health, Manufacturing, Finance, Retail, Energy, Engineering, Transportation, High Tech, and Other), a TREND variable which attempts to counterbalance any trends in the dependent variables not associated with Six Sigma implementation, and a SIZE variable which controls for firm size.

The second series of equations includes ROA, ROS, and SG as dependent variables instead of Total Sales, eliminates the TREND variable and is additive rather than multiplicative due to the nature of the dependent variables:

\[
\text{ROA, ROS, SG} = \alpha + \beta \text{SIXSIG} + \gamma \text{INDUSTRY}_{(a,b,...z)} + \epsilon 
\]

The table below lists all variables and their definitions. The following section provides an overview of key descriptive statistics for the considered variables.

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dependent Variables</strong></td>
<td></td>
</tr>
<tr>
<td><strong>ROA</strong></td>
<td>Return on Assets = operating income (before taxes)/total assets</td>
</tr>
<tr>
<td><strong>ROS</strong></td>
<td>Return on Sales = operating income (before taxes)/total sales</td>
</tr>
<tr>
<td><strong>Total Sales (TS)</strong></td>
<td>Total Sales before any deductions</td>
</tr>
<tr>
<td><strong>Sales Growth (SG)</strong></td>
<td></td>
</tr>
<tr>
<td><strong>PERCROI</strong></td>
<td>Managerial perception on Six Sigma investment (Dummy)</td>
</tr>
<tr>
<td><strong>COSTS</strong></td>
<td>Managerial perception on the effectiveness of Six Sigma projects in reducing costs</td>
</tr>
<tr>
<td>*<em>REVENUE</em></td>
<td>Managerial perception on the effectiveness of Six Sigma projects in increasing revenue</td>
</tr>
<tr>
<td><strong>Six Sigma Characteristics</strong></td>
<td></td>
</tr>
<tr>
<td><strong>MATURITY</strong></td>
<td>Number of years Six Sigma has been implemented in the company</td>
</tr>
<tr>
<td><strong>SCOPE</strong></td>
<td>Year-to-year change in the number of non-Westerners in the region divided by the total regional population in 1995</td>
</tr>
<tr>
<td><strong>STRATEGIC</strong></td>
<td>Managerial perception on strategic alignment of Six Sigma projects</td>
</tr>
<tr>
<td><strong>LEADERSHIP</strong></td>
<td>Managerial perception on the commitment of top management to Six Sigma endeavors</td>
</tr>
<tr>
<td><strong>BELTS</strong></td>
<td>Percentage of part-time and full-time employees dedicated to Six Sigma projects (Master Black Belts, Black Belts, Green Belts, etc.)</td>
</tr>
<tr>
<td><strong>COACHING</strong></td>
<td>Managerial perception on the availability/quality of coaching and mentoring for all employees working with Six Sigma tools</td>
</tr>
<tr>
<td><strong>COSTS</strong></td>
<td>Managerial perception on the effectiveness of Six Sigma projects in reducing costs</td>
</tr>
<tr>
<td><strong>REVENUE</strong></td>
<td>Managerial perception on the effectiveness of Six Sigma projects in increasing revenue</td>
</tr>
<tr>
<td><strong>TRACKING</strong></td>
<td>Managerial perception on the firm’s ability to track the status and financial outcomes of all Six Sigma projects</td>
</tr>
</tbody>
</table>
3.4 Descriptive Statistics

The data gathered from the 41 publicly traded companies indicated that the average company size of the sample was 40,381 employees. When adding the private companies to the sample (N=50), this number dropped to 34,736. The most prevalent industries in the data set were Manufacturing (14/50 = 28%) and Health (10/50 = 20%). The number of years of Six Sigma implementation (MATURITY) for both samples averaged around 5 years, while the extentiveness of the integration of Lean Six Sigma (LSS) and Design for Six Sigma (DFSS) in the firm for both samples averaged at 3.5 and 2.7 on a 5-point scale, respectively. On this scale, a 1 is equivalent to no implementation of the tool whatsoever, and a 5 represents very extensive integration of the methodology throughout the company. The ability to track the status and financial outcomes of projects (TRACKING), the level of effectiveness in cost reduction (COSTS), and the level of effectiveness in increasing revenue (REVENUE) for both samples was approximately 4.1, 3.8, and 3.1 on a 5-point scale. For the COSTS and REVENUE scale, a 1 = ineffective (no measurable cost/revenue improvements) and a 5 = extremely effective (a key productivity tool for cost improvements/a key revenue enhancement). The respondent was asked to indicate his/her level of agreement of tracking effectiveness for the TRACKING variable; 1 = strongly disagree, 5 = strongly agree). On the same five-point scale, both samples ranked their companies’ Six Sigma mentoring and coaching activities (COACHING) around 4.2 and the strategic alignment (STRATEGIC) of Six Sigma projects around 3.7.

There were some discrepancies among the two samples with regards to top management commitment (LEADER), the percentage of employees dedicated part-time and full-time to Six Sigma projects (BELTS), and the breadth of the program implementation (SCOPE, a dummy variable, where 0 = Six Sigma implemented in less than five business areas within the company, and 1 = five or more business areas). The sample of public companies yielded the following descriptive statistics for these variables: LEADER = mean (3.97), standard
deviation (0.935); BELTS = mean (10.09%), standard deviation (16.85%); and SCOPE = mean (0.78), standard deviation (0.42). The larger sample including the private and foreign companies yielded the following statistics for the same variables: LEADER = mean (4.02), standard deviation (0.915); BELTS = mean (12.97), standard deviation (21.88); and SCOPE = mean (0.74), standard deviation (0.44). Lastly, among all 50 respondents, 45 agreed that Six Sigma was a good investment for their company. Two managers responded negatively and three indicated that they were “undecided” as to whether or not the program was a good investment. Descriptive statistics for all dependent and explanatory variables are presented in further detail in Table 3 in the Appendix.

4. Estimation Procedure and Empirical Results

4.1 Model 1

Model 1 (4 separate equations) was estimated using the Ordinary Least Squares (OLS) technique, with adjustments taken for heteroskedasticity in the ROA, ROS, and Sales Growth equations. The results of Breusch-Pagan tests indicated that heteroskedasticity was present in these three equations; this is the preferred test used by econometricians for cross-sectional analyses (Studenmund, 2006). The White heteroskedasticity robust covariance matrix was used to obtain heteroskedasticity-consistent standard errors.

The Total Sales (TS) equation yielded an adjusted $R^2$ of 0.347 and three statistically significant moderator variables: MATURITY, at the 0.10 level according to the t-statistic, SCOPE at the 0.10 level, and TRACKING, at the .01 level. The sign for the MATURITY variable was also positive, which falls in line with theory. The longer the firm has been working with Six Sigma, the more likely it is to see bottom line results with regards to the implementation (Hendricks and Singhal, 2000). In addition, there is a positive relationship between the number of business areas in which Six Sigma has been implemented (SCOPE) and Total Sales. The TRACKING variable carried a negative coefficient estimate, which was an unexpected result. According to theory, if a firm is consistently able to track the status of their projects and the financial outcomes of each one, positive financial returns should result. However, since TRACKING is significant and positive in the ROA and SG equations, this unexpected result may just be due to the nature of the dependent variable and not necessarily an indication that tracking Six Sigma projects is financially detrimental. The control variable
SIZE was also positive and significant, which corresponds with logic; the larger the company, the larger the total influx of revenue. A number of the Six Sigma constructs were not statistically significant. This outcome is also consistent with the quality management literature. In their study which examines the performance effects (ROA, ROS) of process management techniques, Ittner and Larcker (1997) found similar results with regards to the automotive and computer industries. They express the extreme difficulty involved in capturing all of the dynamics within an organization through the use of linear additive models. They explain that they “suppress complex forms of interactions and ignore likely nonlinear relationships…[which] can yield misleading conclusions, particularly when addressing the determinants of organizational performance” (pp. 529-30). I attempted to address this problem by using a multiplicative model for the Total Sales equation (the Total Sales equation is the only one to which a multiplicative model can be applied, as the ROA, ROS, and SG variables all contain negative numeric values throughout the sample, thus hindering the calculation of natural logarithms). However, the results of the regression yielded an overall fit significantly less than that of the additive model; the f-statistic and adjusted r-squared decreased, and the Akaike criterion increased. Therefore, only the results of the additive model are reported.

The ROA equation rendered a very low adjusted $R^2$ and only one significant determinant. As mentioned previously, the TRACKING variable carried a positive sign and was significant at the .10 level. Once again, this outcome falls in line with the Six Sigma literature.

The ROS and Sales Growth (SG) regressions demonstrated slightly different results in comparison to the first two equations. The more extensively the company integrates Design for Six Sigma into its practices, the higher the profit margins (ROS). This corresponds to the Six Sigma literature. Design for Six Sigma is an advanced technique usually implemented by companies who have already been using Six Sigma in the firm for a while and are looking to combine the reduction of defects in a process with designing completely new, innovative, and equally efficient processes (Bañuelas and Antony, 2003). Based on its concept alone, it is no surprise that DFSS has a direct, positive impact on sales growth in this equation. The number of business areas in which Six Sigma has been implemented in a company (SCOPE) and the extent to which the firm has integrated “lean” into its projects (LSS) have significant but
negative relationships with ROS. These results may not necessarily imply that Lean is not a useful tool, or that Six Sigma as a company-wide initiative is not beneficial. Instead, these negative outcomes may be an indication of the way that Six Sigma has been implemented in the firm. For example, if Lean has been adopted too rapidly and the company culture is not ready for such an undertaking, the outcome may be negative when it should have been the opposite. Also, the same outcome could take place if a company rushes to implement Six Sigma in all business areas, whether or not they are prepared for such an organizational change. The SCOPE variable, however, should be interpreted with caution, as it is also positive and significant in the Total Sales equation. Lastly, the TRACKING variable carries a positive and significant (.05 level) coefficient in the Sales Growth equation. This implies that the company’s ability to track the status and financial outcomes of its Six Sigma projects has a direct impact on sales growth. The table below provides a detailed overview of the OLS results for Model 1.

**OLS RESULTS: MODEL 1**

<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>Model 1.1 (TS)</th>
<th>Model 1.2(ROA)*</th>
<th>Model 1.3(ROS)*</th>
<th>Model 1.4(SG)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONSTANT</td>
<td>66085.38</td>
<td>6.4025</td>
<td>15.08305</td>
<td>14.6066</td>
</tr>
<tr>
<td></td>
<td>(1.592)</td>
<td>(0.913)</td>
<td>(1.145)</td>
<td>(0.828)</td>
</tr>
<tr>
<td>MATURITY</td>
<td>4755.251*</td>
<td>-0.20361</td>
<td>0.45066</td>
<td>-1.4655</td>
</tr>
<tr>
<td></td>
<td>(1.839)</td>
<td>(-0.478)</td>
<td>(0.414)</td>
<td>(-0.977)</td>
</tr>
<tr>
<td>SCOPE</td>
<td>25481.66*</td>
<td>0.35795</td>
<td>-15.086*</td>
<td>-6.5561</td>
</tr>
<tr>
<td></td>
<td>(1.753)</td>
<td>(0.138)</td>
<td>(-1.821)</td>
<td>(-0.696)</td>
</tr>
<tr>
<td>STRATEGIC</td>
<td>-120.413</td>
<td>0.24944</td>
<td>1.3408</td>
<td>-0.57651</td>
</tr>
<tr>
<td></td>
<td>(-0.017)</td>
<td>(0.270)</td>
<td>(0.629)</td>
<td>(-0.164)</td>
</tr>
<tr>
<td>LEADER</td>
<td>1564.509</td>
<td>-2.7867</td>
<td>-0.73231</td>
<td>-2.7559</td>
</tr>
<tr>
<td></td>
<td>(0.153)</td>
<td>(-1.027)</td>
<td>(-0.252)</td>
<td>(-0.408)</td>
</tr>
<tr>
<td>BELTS</td>
<td>-124.728</td>
<td>0.62303 x 10^-3</td>
<td>-0.15011</td>
<td>-0.196707 x 10^-1</td>
</tr>
<tr>
<td></td>
<td>(-0.339)</td>
<td>(0.928)</td>
<td>(-1.319)</td>
<td>(-0.120)</td>
</tr>
<tr>
<td>COACHING</td>
<td>-5567.184</td>
<td>-0.32313</td>
<td>-2.4255</td>
<td>-3.2812</td>
</tr>
<tr>
<td></td>
<td>(-0.576)</td>
<td>(-0.169)</td>
<td>(-0.548)</td>
<td>(-0.467)</td>
</tr>
<tr>
<td>TRACKING</td>
<td>-15803.84***</td>
<td>2.2557*</td>
<td>4.8245</td>
<td>6.9581**</td>
</tr>
<tr>
<td></td>
<td>(-2.725)</td>
<td>(1.828)</td>
<td>(1.537)</td>
<td>(2.410)</td>
</tr>
<tr>
<td>DFSS</td>
<td>-4993.176</td>
<td>1.0267</td>
<td>4.01618**</td>
<td>1.5722</td>
</tr>
<tr>
<td></td>
<td>(-0.999)</td>
<td>(1.022)</td>
<td>(2.087)</td>
<td>(0.494)</td>
</tr>
<tr>
<td>LSS</td>
<td>2990.426</td>
<td>0.21084</td>
<td>-3.86055**</td>
<td>1.0324</td>
</tr>
<tr>
<td></td>
<td>(0.577)</td>
<td>(0.297)</td>
<td>(-2.071)</td>
<td>(0.340)</td>
</tr>
<tr>
<td>INDUSTRYb</td>
<td>-6261.549</td>
<td>-0.914426</td>
<td>-6.18955</td>
<td>3.68569</td>
</tr>
<tr>
<td></td>
<td>(-0.520)</td>
<td>(-0.435)</td>
<td>(-1.580)</td>
<td>(0.433)</td>
</tr>
<tr>
<td>SIZE</td>
<td>0.24068*</td>
<td>-0.73603 x 10^-2</td>
<td>0.109634 x 10^-3**</td>
<td>0.232189 x 10^-2</td>
</tr>
<tr>
<td></td>
<td>(1.843)</td>
<td>(-0.376)</td>
<td>(2.477)</td>
<td>(0.347)</td>
</tr>
<tr>
<td>Adjusted R-squared</td>
<td>0.368</td>
<td>-0.159</td>
<td>0.278</td>
<td>-0.189</td>
</tr>
<tr>
<td>F-Statistic</td>
<td>3.12</td>
<td>0.50</td>
<td>2.40</td>
<td>0.42</td>
</tr>
</tbody>
</table>

*a*Significant at the 10% level, **Significant at the 5% level, ***Significant at the 1% level.

^t-^statistics in parentheses are based on White heteroskedasticity-consistent standard errors.

^b^Industry = manufacturing and energy
4.2 Models 2-3

OLS remains the estimator for models two and three. An additional analysis is performed using a Chi-square test for the PERCROI dependent variable. Models two and three regress the same set of independent variables used in model one against subjective managerial perception variables instead of variables derived from financial statement data. The sample size increases from N=41 to N=50 in this analysis, because the private companies and the South African company are included.

Models 2 and 3 employ the variables COSTS and REVENUE as dependent variables. COSTS refers to the perceived effectiveness of Six Sigma projects in reducing overall costs for the firm. REVENUE refers to the perceived effectiveness of Six Sigma projects in enhancing revenue. The results reveal two different sets of statistically significant variables. In the COSTS equation, TRACKING is the sole significant variable at the .01 level. On the other hand, SCOPE, STRATEGIC, and TRACKING are positive and significant (.01, .01, and .10 levels) in the REVENUE equation. COACHING, however, is significant and carries an unexpected negative sign. Thus, it seems that if managers are able to consistently track the status and financial outcomes of Six Sigma projects, the success of Six Sigma implementation increases through both cost reduction and revenue enhancement. In addition, the level of effectiveness in increasing revenue through Six Sigma projects rises if managers focus on strategically aligning their projects with the strategic goals of the firm and integrating Six Sigma into as many business areas as possible to make it a company-wide initiative.

Apparently, thorough mentoring and coaching for employees working with Six Sigma is not one of the key success factors in this sample that leads to increased revenue streams. The table below provides an overview of the OLS results for Models 2 and 3.

<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>Model 2 (COSTS)</th>
<th>Model 3 (REVENUE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONSTANT</td>
<td>0.643 (0.760)</td>
<td>0.165 (0.157)</td>
</tr>
<tr>
<td>MATURITY</td>
<td>0.037 (0.132)</td>
<td>0.060 (1.099)</td>
</tr>
<tr>
<td>SCOPE</td>
<td>0.122 (0.513)</td>
<td>1.090*** (3.716)</td>
</tr>
<tr>
<td>STRATEGIC</td>
<td>0.130 (1.073)</td>
<td>0.405*** (2.708)</td>
</tr>
<tr>
<td>LEADER</td>
<td>0.006 (0.036)</td>
<td>0.022 (0.102)</td>
</tr>
</tbody>
</table>
The last subjective analysis examined the key determinants of perceived performance of Six Sigma within the firm. Respondents were asked whether or not they thought Six Sigma was a good investment for their respective companies. Based on an answer of “yes,” “no,” or “undecided” (yes = 1; no = 0; undecided = 0), the PERCROI variable was formulated. A Chi-Square test revealed only one statistically significant relationship (p = 0.007): the scope of the Six Sigma implementation and its relationship with perceived return on investment.

According to the results, quality managers working in companies that have implemented Six Sigma in less than five business areas tend to see the program as a poor investment for their company. The results are displayed in the table below:

### Results Chi-Square Test

<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>PERCROI</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCOPE</td>
<td>$\chi^2 = 7.153$, p-value = 0.007</td>
</tr>
</tbody>
</table>

4.3 Models 4-5

The last two time series models utilize the financial data obtained for each company for the years 1997-2006. This analysis, although rather rough in its estimation technique due to the lack of managerial perception data for 10 years, is designed to complement the various cross-sectional analyses. This model zooms in on the Six Sigma implementation itself and attempts
to observe Six Sigma’s progress over a 10-year time span, rather than just a snapshot of 2006. As mentioned in the previous chapter, the models employ industry-specific intercepts and all four financial measures as dependent variables (TS, ROS, ROA, SG). A SIZE variable is added to the equation to account for firm size within each industry. A multiplicative model is used for the Total Sales equation, while additive models are employed for the ROS, ROA, and SG equations. OLS remains the estimating technique for all equations.

The TS and SG equations revealed the most interesting results. In the TS equation, there are no statistically significant coefficient estimates. The trend in the estimates, however, indicates that Six Sigma does not positively impact Total Sales until around the sixth year of implementation, as this is the first year that reveals a coefficient value greater than 1.

SIXSIG1 and SIXSIG2 are significant at the .02 level in the SG equation, while SIXSIG3-6 are significant at the .05 level. Sales Growth increases by 0.2% after one year of implementation (87.9% to 88.1%) and by another 2% after the second year (88.1% to 90.1%), ceteris paribus. Stagnation occurs in years three and four (Six Sigma still has a positive impact on sales in these years, however there is no incremental impact on sales in comparison to the previous years), while year five climbs back up to a 0.37% increase from year two. There is an even larger increase in sales growth between years five and six of 5.7%. The output of these two models shows that there is a noticeable increase in Total Sales and Sales Growth the longer Six Sigma is implemented in the firm. The brief “plateau” that appears around years three and four may be attributed to the newness of the implementation wearing off. In the beginning, results come easily since the Six Sigma tools are new to the organization and its culture. However, after a few years, greater efforts need to be invested into applying new tools and methodologies and thinking outside the box in order to maintain such results. For more detailed information on the statistical output of the Industry models (4-5), see the table below.
5. Discussion

The goal of the current study was threefold: (1) to determine whether the implementation of Six Sigma is positively linked to firm financial performance (2) to identify some key moderators of the relationship between Six Sigma implementation and performance, and (3) to compare managerial perceptions on Six Sigma performance with actual financial statement performance data. The results of this empirical analysis produced several notable findings.

First, two determinants were pinpointed as being key moderators of the relationship between Six Sigma implementation and firm financial performance: the breadth of Six Sigma implementation and the company’s ability to track the status and financial outcomes of all Six Sigma projects. Kaynak (2003) emphasizes the importance of quality data and reporting in his research, which entails capabilities such as the ability to track quality measures. Also, one of the critical factors tied to the success of Six Sigma at General Electric is the use of a project tracking system (Henderson and Evans, 2000). The scope of Six Sigma implementation
throughout the company is equally important as tracking capabilities. Goh (2002) states in his strategic assessment of Six Sigma that “extending the horizon of statistical thinking” to all business areas within a company is a critical success factor linked to Six Sigma implementation. Implementing Six Sigma as a company-wide endeavor creates a quality culture throughout the organization which involves all employees, regardless of their background or position in the company. Part of General Electric’s bottom line success with Six Sigma is most likely attributed to their policy that all employees desiring a promotion within the company must be a certified Six Sigma Green Belt (Henderson and Evans, 2000).

Not only is the scope of Six Sigma implementation directly related to bottom line results, but the maturity of the implementation has demonstrated a positive relationship with Total Sales. That is, the longer Six Sigma is implemented in a company, the more impact the program will have on financial results. Hendricks and Singhal (2000) and Brah et al. (2002) also found a positive relationship between the maturity of the TQM program and financial and quality performance, respectively. On the other hand, this “maturity effect” appears to reach a plateau after about three years after the adoption of the Six Sigma program, according to the results of the industry model. This is most likely due to the increased amount of effort required for a company to continuously improve after three or four years of working with Six Sigma tools. In the beginning, results come quickly in response to such a drastic organizational transformation. However, “peeling the next layer of the onion requires a different set of investigative tools and new methodology” in addition to much more intense effort (Murphy, 1998; quoted by Henderson and Evans, 2000).

Design for Six Sigma (DFSS) is an example of a new methodology that companies undertake to work towards continuous improvement. This innovative tool which focuses on value creation revealed a significant impact on Sales Growth and Six Sigma’s ability to increase revenue (managerial perception). DFSS is an advanced tool usually adopted by companies that have already implemented Six Sigma and/or “lean.” Instead of DMAIC, it applies the IDOV approach (Identify-Design-Optimize-Validate) in order to design a brand new product or process design with the intention of delighting the customer (Gupta, 2001; Goh, 2002). With this objective in mind, it is no surprise that DFSS contributes to the company’s bottom line.
In addition to the factors that contributed directly to firm financial measures, two other variables proved to be crucial in either reducing costs or increasing revenues in the eyes of Six Sigma managers: the ability to track the status and financial outcomes of all Six Sigma projects and the selection of strategically aligned projects. If a company does not have a formal, organized tracking system for its projects, evaluating the progress of the projects and therefore eliminating any non-value-adding ones from the agenda becomes more difficult (Hahn, 2005). This coincides with the selection of projects that align with company strategic goals. If the company invests its resources in the “wrong projects,” the company will have a hard time achieving the “pay-off” for its Six Sigma investment.

Overall, the results emphasize the importance of the role of tracking projects and maintaining a strategic, bottom-line focus. If companies implement Six Sigma without selecting the right projects and without being able to consistently track their financial benefits, their efforts are likely to be disappointing. This may partially explain the negative relationship between the breadth of Six Sigma implementation and Return on Sales, for example. A company may rush to make Six Sigma a company-wide initiative without first taking the time to select and keep track of only the value-adding projects.

### 6. Conclusion

#### 6.1 Theoretical Implications

Numerous empirical analyses have been performed in the past decade on various quality management endeavors and their relationship to financial performance. However, minimal empirical research has been done on Six Sigma implementation and its impact on bottom line indicators. This study contributes to this gap in Six Sigma research. In addition, this study presents two different sets of analyses: one based on managerial perception data gathered from a diverse pallet of public and private American companies, and the other based on financial data. Many quality management studies focus on one aspect or the other instead of combining both. Last of all, this study includes an analysis which takes into account the effectiveness of Six Sigma implementation over a 10-year time span. The rich, multi-faceted nature of this research alone contributes to the very limited line of Six Sigma empirical research.
6.2 Managerial Implications

The results of this study have several important implications for managers. First, this research took the critical success factors identified within the Six Sigma community and tied them directly to financial measures and managerial perceptions. The results brought to light the importance of selecting strategically aligned projects, tracking the status and financial outcomes of these projects, and receiving the utmost support and commitment from top management. Thus, a company could use this input as a guide when first implementing a Six Sigma program or when attempting to pinpoint the reasons why the already implemented program is not working up to par.

Second, managers should expect Six Sigma to reach a point of “stagnation” after 3 or 4 years (where Six Sigma projects will still bring in positive absolute results, but no positive incremental impact on the bottom line in comparison to the previous years). This means managers should constantly look for ways to apply new tools and methodologies to not only maintain the performance of Six Sigma within the company, but also better results year after year. Design for Six Sigma is a good example of this innovate behavior and strongly encouraged based on the output derived from this study. Most importantly, Six Sigma should be viewed as a long-term investment and not as a “quick fix,” as dividends are not realized until later on in the game.

Third, one of the questions in the survey asked the respondent to identify his/her top three critical success factors with regards to Six Sigma implementation. This question was not analyzed empirically, but the results are worth noting. A large percentage of respondents indicated that having full-time Black Belts and Master Black Belts on staff is critical to Six Sigma success. Interestingly, none of the analyses performed revealed any significance for the BELTS variable. Although this does not imply that full-time Six Sigma experts are not an important asset to implementation, it does suggest that managers should focus more on the strategy of their Six Sigma projects rather than the number of experts that need to be hired or trained.

Lastly, another question on the survey that was not empirically analyzed asked the respondent to identify in which business areas in their respective companies Six Sigma has seen the
most/least success. Not surprisingly, finance, engineering, and manufacturing reigned as the most successful sectors. Six Sigma was first implemented in these more structured, process-oriented areas, as was mentioned in the first chapter of this paper. Forty-five percent of the companies that implemented Six Sigma in their sales and marketing departments, however, indicated that these two business areas saw the least improvement. This outcome very well could be related to the fairly novel integration of Six Sigma into sales and marketing. Nevertheless, managers should hone in on their sales and marketing processes and try to pinpoint what exactly is going wrong in these business areas.

6.3 Limitations and Suggestions for Further Research
Although this study produced useful and interesting findings, there are several limitations to discuss as well as possible avenues for future research. First of all, this study examined a fairly small sample size of only companies that have implemented Six Sigma. Future researchers could look at a larger sample of companies that have implemented Six Sigma and those that haven’t. The benefits/downfalls of Six Sigma may shine through more clearly when employing such a comparative study.

Second, this study examined a “snapshot” of the key success factors and bottom line impact of Six Sigma for the year 2006. This is valuable information, however it would be even more interesting to gather managerial perception data over time and perform a panel analysis across various years and companies. A longitudinal analysis examining one company over time (before and after Six Sigma implementation) would be equally interesting.

Third, it was very difficult to account for industry effects in this study since nine different industries were involved. Many quality management studies focus on just a few industry sectors and examine trends within those industries only. For example, it may be more thorough to analyze a sample of companies in manufacturing and health (the two most prominent sectors in this study’s sample) and compare the results. Six Sigma is a continuously-evolving tool, and this will most likely open even more doors for future research opportunities in the field.
References


Pestorius, Michael J. (2006, Nov. 30). “Six Sigma as Catalyst for Revenue Growth: How sanofi-aventis has Applied Six Sigma to Sales & Marketing.” Web Seminar (Microsoft Live Meeting), 2:00 PM EST, 60 minutes.


Appendix

Exhibit A: SIPOC Diagram

Exhibit B: VOC matrix
Exhibit C: Monte Carlo Simulation

![Monte Carlo Simulation applied to a Project Schedule](Source: www.maxwideman.com)

S-curve shows cumulative probability of completion by a given date. Below 145, less likely, i.e. higher risk. Above, more likely, i.e. less risk.

(Source: www.maxwideman.com)

Exhibit D: FMEA matrix

| Item/Function | Potential Failure Modes | Failure Node Effects | S E V | Potential Failure Causes | P F | Current Controls | D E T | R P N | Actions Req'd | Owner/Target Date | Actions Taken | S E V | P F | D E T | R P N |
|---------------|-------------------------|----------------------|------|--------------------------|-----|------------------|------|------|---------------|-----------------|--------------|------|-----|------|------|------|
|               |                         |                      |      |                          |     |                  |      |      |               |                 |              |      |     |      |      |      |
|               |                         |                      |      |                          |     |                  |      |      |               |                 |              |      |     |      |      |      |
|               |                         |                      |      |                          |     |                  |      |      |               |                 |              |      |     |      |      |      |

(Source: www.siliconfareast.com)
Exhibit E: Process Sigma Calculation

Table 1: Six Sigma Certified Titles and Definitions

<table>
<thead>
<tr>
<th>TITLE</th>
<th>DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Master Black Belt</strong></td>
<td>Six Sigma Quality Experts responsible for the strategic implementations within an organization. Their main responsibilities include training and mentoring Black Belts and Green Belts, helping to prioritize, select and charter high-impact projects; maintaining the integrity of the Six Sigma measurements, improvements and tollgates; and developing, maintaining and revising Six Sigma training materials. The Master Black Belt should be qualified to teach other Six Sigma facilitators the methodologies, tools, and applications in all functions and levels of the company, and should be a resource for utilizing statistical process control within processes.</td>
</tr>
<tr>
<td><strong>Black Belt</strong></td>
<td>Six Sigma team leaders responsible for implementing process improvement projects (DMAIC or DFSS) within the business -- to increase customer satisfaction levels and business productivity. Black Belts are knowledgeable and skilled in the use of the Six Sigma methodology and tools. Black Belts have typically completed four weeks of Six Sigma training, and have demonstrated mastery of the subject matter through the completion of project(s) and an exam.</td>
</tr>
</tbody>
</table>
Black Belts coach Green Belts and receive coaching and support from Master Black Belts.

**Green Belt**

An employee of an organization who has been trained on the improvement methodology of Six Sigma and will lead a process improvement or quality improvement team as *part* of their full time job. Their degree of knowledge and skills associated with Six Sigma is less than that of a Black Belt or Master Black Belt. Extensive product knowledge in their company is a must in their task of process improvement. The green belt employee plays an important role in executing the Six Sigma process at an organization level.

**Champion**

Business leaders and senior managers who ensure that resources are available for training and projects, and who are involved in project tollgate reviews.

(Definitions taken directly from [www.isixsigma.com](http://www.isixsigma.com))

Exhibit F: DMAIC Roadmap

<table>
<thead>
<tr>
<th>Define</th>
<th>Measure</th>
<th>Analyze</th>
<th>Improve</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initiate the Project</td>
<td>Understand the Process</td>
<td>Analyze Data to Prioritize Key Input Variables</td>
<td>Verify Critical Inputs Using Planned Experiments</td>
<td>Finalize the Control System</td>
</tr>
<tr>
<td>Define the Process</td>
<td>Evaluate Risks on Process Inputs</td>
<td>Identify Waste</td>
<td>Design Improvements</td>
<td>Verify Long Term Capability</td>
</tr>
<tr>
<td>Determine Customer Requirements</td>
<td>Develop and Evaluate Measurement Systems</td>
<td></td>
<td>Pilot New Process</td>
<td></td>
</tr>
<tr>
<td>Define Key Process Output Variables</td>
<td>Measure Current Process Performance</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(Source: NewPage Corporation, 2007)
Table 2: Sigma Levels and Process Capabilities

<table>
<thead>
<tr>
<th>Sigma</th>
<th>Monthly Statements</th>
<th>Application Processing</th>
<th>Response Time</th>
<th>DPMO</th>
<th>% Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>3σ</td>
<td>3,660 Statements With Wrong Balance Every Day</td>
<td>770 Application Errors Every Day Require Correction</td>
<td>257 Calls Each Day Exceed The Two Minute On-Hold Time</td>
<td>66,800</td>
<td>93.32000%</td>
</tr>
<tr>
<td>4σ</td>
<td>340 Statements With Wrong Balance Every Day</td>
<td>72 Application Errors Every Day Require Correction</td>
<td>24 Calls Each Day Exceed The Two Minute On-Hold Time</td>
<td>6,210</td>
<td>99.3490%</td>
</tr>
<tr>
<td>5σ</td>
<td>12 Statements With Wrong Balance Every Week</td>
<td>13 Application Errors Every Week Require Correction</td>
<td>5 Calls Each Week Exceed The Two Minute On-Hold Time</td>
<td>230</td>
<td>99.97700%</td>
</tr>
<tr>
<td>6σ</td>
<td>6 Statements With Wrong Balance Every Month</td>
<td>During The Year, Only 10 Application Errors Require Correction</td>
<td>During The Year, 3 Calls Exceed The Two Minute On-Hold Time</td>
<td>3.4</td>
<td>99.99966%</td>
</tr>
</tbody>
</table>

DPMO = Defect Parts Per Million Opportunities
(NewPage Corporation, 2007)

Exhibit G: Zoomerang Questionnaire

1. Introduction

Six Sigma Deployment Effectiveness

Hi,

My name is Rebecca Galloway and I am a master’s student at the University of Maastricht in the Netherlands. I am currently working on my master’s thesis which explores the impact of Six Sigma implementation on certain company financial measures (ROA, ROS, and sales growth). To date, not much research has been done to explore the impact on the financial performance of the company with regards to Six Sigma.

To investigate this I need to obtain data on your perceptions of the effectiveness of Six Sigma implementation in your company. I need your help and would greatly appreciate your sparing 10 minutes of your time to complete this short questionnaire concerning Six Sigma practices in your company. The results will be used to help expand my knowledge and understanding of the effectiveness of Six Sigma projects and the key factors that drive their success in a company. All answers will be kept strictly confidential and only aggregate results will be reported. In addition, as a “thank you” for your participation, you will receive a copy of my thesis paper along with results of the survey when it is published.

Thank you in advance for your help!

START SURVEY!

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2. Questions 1-5

**Corresponding variables:**
Q1-2: Contact information
Q3: MATURITY
Q4-5: BELTS

---

3. Questions 6-8

**Corresponding variables:**
Q6: COACHING
Q7: LEADERSHIP
Q8: TRACKING
4. Questions 9-10

Corresponding variables:
Q9: omitted from analysis
Q10: STRATEGIC

5. Questions 11-12

Corresponding variables:
Q11: SCOPE
Q12: extra information – not included in analysis
6. Questions 13-15

Corresponding variables:
Q13: extra information – not included in analysis
Q14: COSTS
Q15: REVENUE

7. Questions 16-19

Corresponding variables:
Q16: DFSS
Q17: LSS
Q18: extra information – not included in analysis
Q19: PERCROI
8. Questions 20-21

Corresponding variables:
Q20: INDUSTRY
Q21: SIZE

Table 3: Descriptive Statistics

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>MEAN</th>
<th>STANDARD DEV</th>
<th>MINIMUM</th>
<th>MAXIMUM</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROA*</td>
<td>6.75365854</td>
<td>6.11981444</td>
<td>-4.60000000</td>
<td>31.53000000</td>
</tr>
<tr>
<td>ROS*</td>
<td>15.1080488</td>
<td>15.7044343</td>
<td>-5.10000000</td>
<td>71.93000000</td>
</tr>
<tr>
<td>TS*</td>
<td>31103.7829</td>
<td>36600.8642</td>
<td>997.000000</td>
<td>163391.0000</td>
</tr>
<tr>
<td>SG*</td>
<td>13.2817073</td>
<td>20.0920264</td>
<td>-23.40000000</td>
<td>76.74000000</td>
</tr>
<tr>
<td>PERCROI</td>
<td>0.90000000</td>
<td>0.303045763</td>
<td>0.00000000</td>
<td>1.00000000</td>
</tr>
<tr>
<td>COSTS</td>
<td>3.84000000</td>
<td>0.791794655</td>
<td>2.00000000</td>
<td>5.00000000</td>
</tr>
<tr>
<td>REVENUE</td>
<td>3.12000000</td>
<td>0.982292196</td>
<td>1.00000000</td>
<td>5.00000000</td>
</tr>
<tr>
<td>MATURITY</td>
<td>5.08000000</td>
<td>2.85599977</td>
<td>1.00000000</td>
<td>12.00000000</td>
</tr>
<tr>
<td>SCOPE</td>
<td>0.74000000</td>
<td>0.443087498</td>
<td>0.00000000</td>
<td>1.00000000</td>
</tr>
<tr>
<td>STRATEGIC</td>
<td>3.70000000</td>
<td>0.974155835</td>
<td>1.00000000</td>
<td>5.00000000</td>
</tr>
<tr>
<td>LEADERSHIP</td>
<td>4.02000000</td>
<td>0.914508901</td>
<td>1.00000000</td>
<td>5.00000000</td>
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<tr>
<td>BELTS</td>
<td>12.97260000</td>
<td>21.8772323</td>
<td>6.00000000 x 10^-1</td>
<td>100.000000</td>
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<tr>
<td>COACHING</td>
<td>4.20000000</td>
<td>0.857142857</td>
<td>1.00000000</td>
<td>5.00000000</td>
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<tr>
<td>TRACKING</td>
<td>4.06000000</td>
<td>1.03824813</td>
<td>1.00000000</td>
<td>5.00000000</td>
</tr>
<tr>
<td>DFSS</td>
<td>2.68000000</td>
<td>1.39151950</td>
<td>1.00000000</td>
<td>5.00000000</td>
</tr>
<tr>
<td>LSS</td>
<td>3.50000000</td>
<td>1.12938488</td>
<td>1.00000000</td>
<td>5.00000000</td>
</tr>
<tr>
<td>INDUSTRY</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Health</td>
<td>0.20000000</td>
<td>0.404061018</td>
<td>.00000000</td>
<td>1.00000000</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>0.292682927</td>
<td>0.460646417</td>
<td>.00000000</td>
<td>1.00000000</td>
</tr>
<tr>
<td>High Tech</td>
<td>0.975609756 x 10^-1</td>
<td>0.300406229</td>
<td>.00000000</td>
<td>1.00000000</td>
</tr>
<tr>
<td>Energy</td>
<td>0.731707317 x 10^-1</td>
<td>0.263651655</td>
<td>.00000000</td>
<td>1.00000000</td>
</tr>
<tr>
<td>Finance</td>
<td>0.975609756 x 10^-1</td>
<td>0.300406229</td>
<td>.00000000</td>
<td>1.00000000</td>
</tr>
<tr>
<td>Retail</td>
<td>0.243902439 x 10^-1</td>
<td>0.156173762</td>
<td>.00000000</td>
<td>1.00000000</td>
</tr>
<tr>
<td>Engineering</td>
<td>0.243902439 x 10^-1</td>
<td>0.156173762</td>
<td>.00000000</td>
<td>1.00000000</td>
</tr>
<tr>
<td>Transportation</td>
<td>0.243902439 x 10^-1</td>
<td>0.156173762</td>
<td>.00000000</td>
<td>1.00000000</td>
</tr>
<tr>
<td>Other</td>
<td>0.170731707</td>
<td>0.380948751</td>
<td>.00000000</td>
<td>1.00000000</td>
</tr>
<tr>
<td>SIZE</td>
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<td>40242.9918</td>
<td>10.000000</td>
<td>200000.0000</td>
</tr>
</tbody>
</table>

*The statistics corresponding to these variables are for N=41 (publicly traded companies only); for the remaining variables, N=50 (public and private companies included)