FORMULATION OF LEAN SIX SIGMA CRITICAL BUSINESS

PROCESSESS FOR MANUFACTURING

FACILITIES

by

CHAUCEY M. D. CHANDLER

Presented to the Faculty of the Graduate School of

The University of Texas at Arlington in Partial Fulfillment

of the Requirements

for the Degree of

DOCTOR OF PHILOSOPHY

THE UNIVERSITY OF TEXAS AT ARLINGTON

December 2007

ACKNOWLEDGEMENTS

With a grateful heart and sincere appreciation, I take this time to thank those individuals who have given me continuous support during the process of completing my dissertation.

I give, first, all glory and honor to God. Without Him, none of this would be possible.

To the chairman of my dissertation committee, Dr. John Priest, thank you for placing me ‘under your wing’. Your direction, concern, coaching, and motivation guided me through the program and to completion of my dissertation.

To the dissertation committee members, Dr. R.C. Baker, Dr. Sheik Imrhan, and Dr. Donald Liles, you critiqued and pushed me to think beyond boundaries I had set for myself.

Last, but most certainly not least, I thank my family. To my wonderful father, James Chandler, you are a man of few words, but such a big heart. I absolutely appreciate your prayers, your humor, and your loving kindness. To my magnificent mother, Evelyn Chandler, you are the one that kept me grounded, inspired me, prayed for me, and helped me until the very end. All you have done for me in my life, and during the studying for and writing of this dissertation, will never be forgotten. To my spectacular sister, Capré Chandler, you always encouraged me to finish. Because of your warm, kind, and loving spirit, I know you will achieve all of your aspirations. To my remarkable aunt, Precious Evelyne Baldwin, your words, actions, and prayers were powerful. You frequently asked the status of my research and kept me enthused until the very end.

Thanks to fantastic grandmothers, aunts, uncles, and cousins, for their prayers and words of encouragement, and to my marvelous friends for insisting I get out of the house to have some fun so that I could relax, refocus, and continue.

Thanking all of you a million times is not enough, but I will always remember, with a humble spirit, the help you have given as I continue my ‘journey of life’.

November 12, 2007

ABSTRACT

FORMULATION OF LEAN SIX SIGMA CRITICAL BUSINESS

PROCESSESS FOR MANUFACTURING

FACILITIES

Publication No. _______________

Chaucey M. D. Chandler, Ph.D.

The University of Texas at Arlington, 2007

Supervising Professor: Dr. John Priest

The author desired to create a method organizing the concepts from Lean, Six Sigma, critical business processes, and simplifying the usage of these concepts to identify Lean Six Sigma Critical Business Processes. Inspired by Laura Meade (1997) and the author's passion concerning process improvements, this research was created.

Lean activities eliminate waste, Six Sigma activities eliminate variation, critical business processes focus on those areas that need improvement and are critical to the process, and Analytical Network Process (ANP) models problems considering the interactions between levels. There is value for all companies to implement at least one of

these tools. Since the author understands joining these concepts will definitely improve manufacturing facilities, this document identifies Lean Six Sigma Critical Business Processes and its impact to the business.

The objectives of this dissertation are: 1) use Laura Meade's procedure to identify the critical business processes, 2) develop an assessment method for companies to identify high priority Lean Six Sigma processes, and 3) create an evaluation tool for configuring Lean Six Sigma Critical Business Processes.

In order to met these objectives, the following tasks are completed: 1) identify capabilities that support the vision, 2) determine the core ratings, 3) recognize the performance levels, 4) select the critical processes, 5) decide the Lean Six Sigma process rating, 6) place the Lean Six Sigma worthy processes into an Analytical Network Process model to analyze the process enablers, and 7) conduct cost / benefit analysis for Lean Six Sigma Critical Business Process implementation.

From this research, a guide is created for manufacturing companies to identify Lean Six Sigma Critical Business Processes using Analytical Network Process (ANP). This will assist companies in their improvements generating both time and money savings.

TABLE OF CONTENTS

LIST OF FIGURES

Figure

LIST OF TABLES

Table

LIST OF EQUATIONS

Equation

CHAPTER ONE

INTRODUCTION

Lean Six Sigma focuses on eliminating waste and variation within a product. This includes the design of the product, the acquisition of materials or component parts for manufacturing the product, the assembly of the component parts into a final product, the final product tested, the tested product shipped, and the products in the field improved per customer feedback until the product becomes obsolete or is replaced by a new product. This dissertation will support all processes in order to expand knowledge on configuring Lean Six Sigma into critical business processes.

Lean is a technique used to eliminate wasteful activities (Bicheno, 2000, p. 12). This reduces the time needed to make a specific product, which increases the time that can be devoted to making more products or to perform other activities that are value add for the customer and company.

Six Sigma is a technique used to define the capability of any process, and its goal for improvement is to reach near perfection (George, 2002, p.17). In other words, Six Sigma attempts to understand and eliminate variation in processes (Goldsby and Martichenko, 2005, p. 5).

Critical business processes are activities that are related to the vision of the business and company (Meade, 1997, p. 37). These processes are core and need improvement (Meade, 1997, p. 37). By identifying the critical processes, a company can strategically improve areas that have the greatest impact on the business. By identifying those processes that need improvement through eliminating waste and reducing variation, the results can be enormous.

1.1 Dissertation Outline

Chapter 1 creates the incentive and need for the implementation of Lean Six Sigma Critical Business Processes. The objectives, problem statement, and research limitations are provided within this chapter.

Chapter 2 reviews the literature related to this research. This chapter incorporates business processes, critical business processes, history of improvements, Lean, Six Sigma, and Analytical Processes. This documents the background information for theories derived from new ideas or existing concepts, which gives a foundation for using Lean Six Sigma Critical Business Processes to improve a process or product.

Chapter 3 provides an intellectual investigation about Lean Six Sigma Critical Business Processes. This chapter includes gathering and interpreting information for joining these concepts of Lean, Six Sigma, and Critical Business Processes.

Chapter 4 illustrates the knowledge obtained and new ideas proven to assist with the identification of Lean Six Sigma Critical Business Processes. This includes the qualitative analysis of various manufacturing variables, quantitative analysis of manufacturing processes, and cost / benefit analysis evaluated in various case studies used within this research.

Chapter 5 includes the three projects used within this dissertation to test the methodologies. This chapter embodies a detailed description, forecast, and the steps to evaluate each product.

Chapter 6 presents the conclusion of the research. This chapter provides guidelines for Lean Six Sigma Critical Business Processes. This includes the results for various case studies and suggestions for future research.

1.2 Problem Statement

Companies are doing more with less, but not effectively (Campbell, 2007, p. 36). Whether it deals with problems on the production floor (i.e. part shortages, incorrect assemblies, machine breakdowns, etc.), new products created inside or outside the USA (i.e. component parts, completely assembled parts, tooling, etc.), and simple manufacturing (i.e. assembly, test, package, etc.), manufacturers make tough decisions daily (Campbell, 2007, p. 36).

In order to improve the processes, companies have chosen one of these concepts, Lean, Six Sigma, or Critical Business Processes. The first concept is Lean. Companies perform kaizen events to eliminate perceived and identified non-value add tasks (Langer, 2007, p. 71). This increases the value in the product per the customer's viewpoint, while the cost levels out from the manufacturer's viewpoint (Arnheiter, & Maleyeff, 2005, p. 8). This creates a product with minimum non-value add tasks (Womack & Jones, 1996, 38). This is what the customer likes to see.

The second concept is Six Sigma. Companies create teams to eliminate variation within the production process (Nash, Poling, and Ward, 2006, p. 43). This reduces the cost of the product from the manufacturer's viewpoint, while the value of the product levels out from the customer's viewpoint (Arnheiter, & Maleyeff, 2005, p. 8). This creates a product with minimized variation within the process (Nash et al., 2006, p. 38). This is what the manufacturer likes to see.

The third concept is Critical Business Processes that identifies those processes that are key and need improvement (Meade, 1997, 37). This focuses on the processes that affect both the customer and the manufacturer.

Each concept has its benefits, as discussed earlier. Consequently, the author believes that joining these concepts will increase opportunities for improvement. The major challenge is identifying the benefits of joining these concepts, which then will justify the time and the money for implementation.

This research document shows the value of joining Lean, Six Sigma, and Critical Business Processes. In addition, this demonstrates several scenarios with the implementation of Lean Six Sigma Critical Business Processes, and their results.

1.3 Dissertation Objective

The topic of Lean and Six Sigma are widely understood terms and are often heard within manufacturing. The author has chosen to research Lean Six Sigma and its implementation with critical business processes. Lean thinking is a unique way to improve products quickly and effectively, and Six Sigma makes the change consistent and repeatable for the future. Lean and Six Sigma are tools used today in the industry because of their ease of implementation.

From Laura Meade's (1997) research on agile critical business processes, the author chose research that focused on product manufacturing and critical processes for Lean and Six Sigma. This paper will benefit those that support manufacturing facilities, whether it is a manual process or automated process. The determining factors to implement Lean Six Sigma are the resources to make the change, the buy-in from the production floor and management to make the change, the implementation of the change, and sustaining the change until further improvements are implemented.

The objective of this dissertation is to 1) use Laura Meade's procedure to choose the critical business processes, 2) develop an assessment method for companies to identify high priority Lean Six Sigma processes, and 3) create an evaluation tool for configuring Lean Six Sigma Critical Business Processes.

The completion of these objectives can be attained by: 1) identifying capabilities that support the vision, 2) determining the core ratings, 3) recognizing the performance levels, 4) selecting the critical processes, 5) deciding the Lean Six Sigma process rating, 6) placing the Lean Six Sigma worthy processes into an Analytical Network Process model to analyze the process enablers, and 7) conducting cost / benefit analysis for Lean Six Sigma Critical Business Process implementation. This will determine the best Lean Six Sigma Critical Business Process.

1.4 Dissertation Tasks

In all business products, Lean and Six Sigma can be implemented to create improvements. The question business owners and project leaders should ask, "What areas will most benefit the Lean Six Sigma initiative"? This is a critical question. This research assists others in answering this question in both an effective and timely manner because businesses have limited resources

In this Lean Six Sigma Critical Business Processes dissertation, the author achieves the following:

1) Complete Literature Review

2) Identify Lean Six Sigma Critical Business Processes using Analytical Network Process (ANP)

3) Apply and test methodologies

4) Review contributions and suggestions to research

Task 1 - *Literature Review*. This task will incorporate business processes, critical business processes, history of improvements, Lean, Six Sigma, and Analytical Processes. This will provide background information for theories derived from new ideas or existing concepts, which gives a solid structure for using Lean Six Sigma Critical Business Processes to improve a process or product.

Task 2 - *Lean Six Sigma Critical Business Processes using an Analytical Network Process Model (ANP)*. This task will furnish more detailed information about Lean Six Sigma Critical Business Processes collectively, and will conduct a pilot study combining both qualitative and quantitative characteristics to create a Lean Six Sigma Critical Business Process. This study will supply a method to improve the process or product with the use of Lean Six Sigma Critical Business Process model.

Task 3 – *Application and Testing of Methodologies*. This task will present the various case studies used within this research.

Task 4 – *Contributions to research and suggestions for future research.* This task will make available the Lean Six Sigma Critical Business Process tools. In addition, suggestions for future research will be identified. The results will facilitate a complete document that others can use for improving processes or products in the manufacturing facility.

1.5 Limitations of Dissertation

Lean Six Sigma Critical Business Processes are terms and techniques well known to the manufacturing industry. Defining a Lean Six Sigma Critical Business Process is labor intensive. As a result, only those who are properly trained and knowledgeable about quantitative as well as qualitative characteristics should use this methodology.

With the implementation of Lean Six Sigma Critical Business Processes, this methodology offers many different techniques and various statistical calculations. Consequently, the group leader should be knowledgeable about Lean, Six Sigma, and Critical Processes. This includes, but is not limited to, knowing when and where to use each technique, understanding the statistical formulas, and interpreting the output of the data from the calculations.

CHAPTER TWO

LITERATURE REVIEW

2.1 Business Processes

2.1.1 Process Model

A process can best be defined as a set of activities designed to produce a specific output for a particular customer or market from a specific input as described by Gavriel Salvendy. For a process, the emphasis is on how the work is done rather than what is done (Salvendy, 2001, p. 34).

There are three elements that are needed to transform inputs into outputs. These items are 1) data and information, 2) decision making, and 3) implementation and actions (Salvendy, 2001, p. 1243).

The explanation of a process can best be defined with a process model. An example of a process model is Integration Definition for Function Modeling (IDEF0) developed for the US Air Force (Morgan, 2005, p. 23-24).

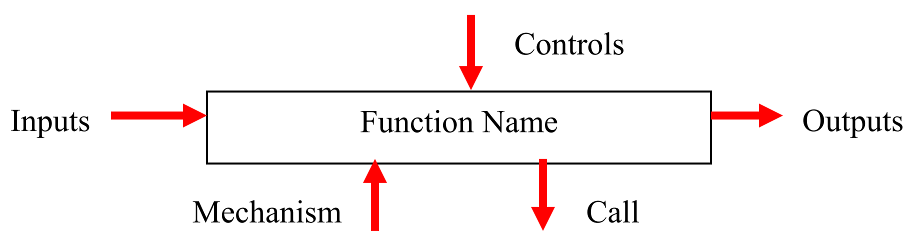

Figure 1: IDEF0 Process Model

This IDEF0 process model has two elements, 1) activities and 2) arrows. The activities are identified with verbiage, while the arrows identify if the items are either added or produced from the activity (Salvendy, 2001, p. 508).

Here is a further explanation of the items identified in the process model described by Laura Meade (1997, pp. 76-77). The function name describes the model function or process.

The inputs are the data and objects that are transformed by the function into outputs (Meade, 1997, p. 76). The inputs for "Formulating a Lean Six Sigma Critical Business Process" are the enterprise assets (i.e. networking, internet, skills, employee knowledge, electronic commerce, computers, and systems), resources (i.e. land, equipment, labor, money, and capital), modularity (i.e. Suppliers combining their expertise for a mutual advantage), and voice of customer (i.e. the expectations and needs of customers given by the customers).

The outputs are the data or objects produced by the function (Meade, 1997, p. 76). One of the outputs to "Formulate a Lean Six Sigma Critical Business Process" is the Lean Six Sigma Critical Business Process. This process will respond positively to change.

The Mechanism is the means used to perform the function (Meade, 1997, p. 77). The mechanisms for this model are the decision maker (who is making the decision) and the technology (technologies available at the time of making the decision).

The call is a type of mechanism that enables sharing of details between models or within a model (Morgan, 2005, p. 24). For this model a database would be a mechanism used to save, search, and compare models.

The controls are used to set the boundaries or standards for the model function or process (Meade, 1997, pp. 76-77). The controls for this model are organization (i.e. innovation, improvement, and participation with measures and controls), planning tools (i.e. flexible tools used to plan for the process), and environment.

*2.1.2 **Categories of Business Processes***

A business process is a logical, related, sequential connected set of activities that takes input from a supplier, adds value to it, and produces output to a customer (Salvendy, 2001, p. 40). In other words, a business process is an activity or set of activities that must be performed to complete a defined process within a business.

According to Gavriel Salvendy (2001), the business process can be placed into the following categories (p. 41):

- Strategic Management Processes - Those processes that develop the value proposition of the enterprise and define the business objectives.
- Core Business Processes - Processes that develop, produce, sell, and distribute products and services.
- Resource Management Processes - Processes that support and provide resources to the value-creating processes of the enterprise.

More discussion of these categories is given below.

2.1.2.1 Strategic Management Processes

Salvendy (2001) documents that Strategic Management is the most difficult activity of an organization (p. 41). Strategic Management focuses on the change in the environment (internal and external) to transition from the demands of today to the requirements of tomorrow (Salvendy, 2001, p. 41). Strategic Management is the process of identifying opportunities to achieve tangible and sustainable success in the marketplace and understanding the risks that threaten achievement of that success (Salvendy, 2001, p. 41).

An illustration of a Strategic Management Process is shown in Figure 2 (Salvendy, 2001, p. 42).

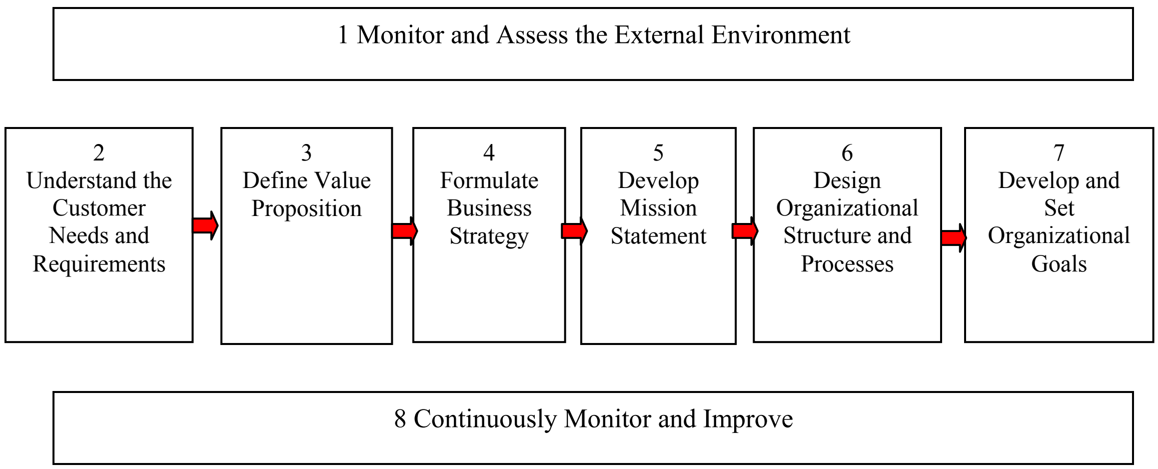

Figure 2: Strategic Management Process

This figure reiterates that the system is a constantly changing entity. For this reason, the processes must be continuously reviewed for opportunities of improvement and enhanced to a constantly changing environment and customer requirements – the entire focus of Lean.

The external forces that affect businesses and their processes are changing so rapidly that organizational structures must be designed so they can respond quickly to changes in the business environment (Salvendy, 2001, p. 41). Once again, this is the focus of this research –Lean Six Sigma Critical Business Processes.

The traditional approach to strategy development involved analytical tools that pushed executives to make fact based decisions about alternatives. This served companies well with a stable business environment (Salvendy, 2001, p. 42).

Due to rapidly changing economies and business environments with increasing uncertainty, unavailable facts, and shorter timeframes to make decisions, the traditional approach is not recommended. Business leaders must make decisions with more imagination and vision – preparing for change (Salvendy, 2001, p. 42). This new approach to strategy development and deployment will incorporate business opportunities and risks that the traditional approach could marginally support (Salvendy, 2001, p. 42).

The key to success is to design business models such that they can respond quickly as economic realities change (Salvendy, 2001, pp. 42-43).

For a quick overview, Figure 3 shows the business process model (Morgan, 2005, p. 27).

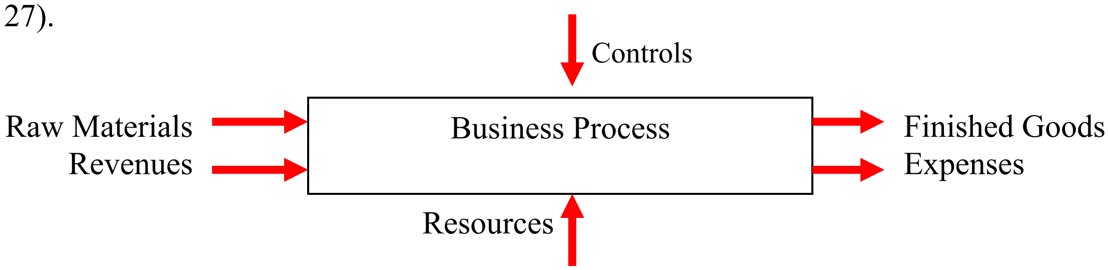

Figure 3: Business Process Model

2.1.2.2 Core Business Processes

In the Industrial Engineering Handbook, it is documented that the core business processes develop, produce, sell, and distribute products and services; this is the system's value chain (Salvendy, 2001, p. 43). These processes reflect the grouping of related business activities (Salvendy, 2001, p. 43). Activities are best defined as work elements that go within a process or sub-process where one person or a team of people performs the activity (Salvendy, 2001, p. 40).

In the past, core business processes pushed product onto customers with the goal of convincing the customer that this product can fit their need (Salvendy, 2001, p. 545). With this focus, the customer would pay for value add tasks and non-value add tasks that were little to no benefit to the customer.

In the present, the core business processes work with the customer such that the customer pulls the product that is needed. Pull means that the product is designed for a customer's need (Salvendy, 2001, p. 545). Once the need is discovered or surfaces, the customer requests the product versus pushing the product on the customer (Salvendy, 2001, p. 545). In addition, this also means that the customer is only willing to pay for the value add tasks. This is a result of more information available to customers, more suppliers available to customers, and reduced economy for purchases (Salvendy, 2001, p. 43).

2.1.2.3 Resource Management Processes

Resource management processes are the processes that support and provide resources to the value-creating processes of the enterprise. In other words, the organization allocates resources to the business and monitors their use (Salvendy, 2001, p. 43).

Resource management processes can be placed in one of the following groupings: information, people, and capital. These resources are used internally and tracked within the business enterprise. These are mandatory to offer the value customers need and provide an effective competitive advantage as stated in the Industrial Engineering Handbook (Salvendy, 2001, p. 43).

2.2 Critical Business Processes

Critical business processes are processes needed for the production of a product or service. These processes are related to the vision, core competence, core processes, and performance level of the business and company (Meade, 1997, p. 37).

2.2.1 Vision

Businesses and companies are focused on managing and anticipating change (Ivancevick, Lorenzi, Skinner, and Crosby, 1997, p. 340). For this reason, leaders create a vision to assist in directing the business and the company. The vision is a clear sense of the organization's future (Ivancevick et al., 1997, p. 340). As stated by Meade (1997), the vision is a focused statement simple to understand and inspirational to the company. In addition, the vision should be validated over time to determine its appropriateness and achievements with the current work environment (Meade, 1997, p. 37 & 38).

The vision contains the mission, strategy, and culture (Meade, 1997, p. 37). The mission is the goal of the company based on its purpose, its values, its distinctive competencies, and its place in the world (Stoner & Freeman, 1992, p. 188). The strategy to meet the organization's broad goals or the vision is identified by top and middle management (Stoner & Freeman, 1992, p. 188). And lastly, the culture is a reflection of the values and beliefs held within the business and company (Meade, 1997, p. 37).

2.2.2 Core Competence

In the article The Core Competence of the Corporation, Prahalad and Hamel (1990) created the terminology of "core competencies" (QuickMBA, 2007). Core competencies are tasks that a firm can do well and meet the following requirements (Wikipedia, 2007, May 4):

1) Provide customer benefits
2) Hard for competitors to imitate
3) Leverage widely to many products and markets

Meade (1997) describes core competence as the knowledge and skills needed by the employees throughout the company (p. 39). The core competencies illustrate excellence and provide a competitive advantage (Meade, 1997, p. 38). This is seen in the core products that represent at least one of the core competencies, which are the components or subassemblies that contribute to the value of the end product (Prahalad & Hamel, 1990, p. 85).

In order to become and sustain the position as a leader in the core competence, the business and the company should seek to maximize their core products (Prahalad & Hamel, 1990, p. 85). This grants the company the power to maintain dominance and shape evolution of end products (Prahalad & Hamel, 1990, p. 85).

2.2.3 Core Process

The core processes express the essential activities of a business (Wikipedia, 2007, January 6). These are needed to meet the goals and objectives through the production of products that are provided for an external customer (Meade, 1997, p. 44).

With the implementation of core processes, the goals and objectives of the company are met, and happy customers are created.

2.2.4 Performance Level

The performance level identifies how well the products meet the demand of the customer. With the use of existing tools and techniques, the team evaluates the performance of the critical processes as it relates to the identified expectations.

The value of each activity in the process must be determined first and this can show which processes need improvement (Meade, 1997, p. 47). Following this activity, the performance indicators must be identified (Meade, 1997, p. 47). These indicators are ways of measuring the performance of the different activities. The results will show if the expectations are being met by the activities performed.

As a team, these core processes are identified and prioritized. This provides the team with a priority list of areas that need improvement (Meade, 1997, p. 47). The key to the success of the team is to identify the appropriate performance metrics to control and improve the process (Meade, 1997, p. 47).

2.3 History of Performance Improvement Initiatives

There have been many different initiatives for businesses to do things better, faster, and increase quality per the Six Sigma Black Belt Handbook (McCarty, Daniels, Bremer, and Gupta, 2005, p. 150). Here are some initiatives.

2.3.1 Quality Circles

Quality circles involve the people because they are a plethora of knowledge (McCarty et al., 2005, p. 150). Per Douglas Montgomery (1991), a quality circle is a motivational program in Japan including a team of workers and supervisors within a single company department whose objective is to conduct studies to improve the effectiveness of work in that department (p. 15). The studies that are performed can include quality, productivity, costs, safety, or other characteristics of the manufacturing environment (Montgomery, 1991, p. 15).

Montgomery (1991) has noted, even though it is estimated that half the workers are involved, the quality circles are voluntary (p. 15). The quality circle begins with a training program, which incorporates data collection and analysis, other successful projects completed by other quality circles, and the completion of an actual project.

Montgomery (1991) writes that this program is extremely successful (p. 15). As of 1991, it is estimated that approximately ten million workers have been trained and participated in Quality Circles, several million projects had been completed averaging approximately $5000 savings per project (Montgomery, 1991, p. 15).

In the Introduction to Statistical Quality Control, Montgomery (1991) points out ”there have been significant effects on product quality” and “training and experience given these workers in preparing them to be better supervisors and managers have also been significant” (p. 15).

2.3.2 Total Quality Management

Dr. W. Edwards Deming, Dr. Joseph Juran, and Phil Crosby pushed the concept that better quality is cheaper (McCarty et al., 2005, p. 151). In Total Quality Management, it is documented:

> Total Quality Management (TQM) is an enhancement to the traditional way of doing business. It is a proven technique to guarantee survival in world-class competition. Only by changing the actions of management will culture and actions of an entire organization be transformed. TQM is the art of managing the whole

to achieve excellence. (Besterfield, Besterfield-Michna, Besterfield, and Besterfield-Sacre, 1995, p. 1)

Besterfield et al. (1995, p. 2) noted that there are six concepts for Total Quality Management (TQM). The first concept is that management must be committed and involved (Besterfield et al., 1995, p. 2). By showing their commitment and involvement, management must (Besterfield et al., 1995, p. 2):

- Participate in the program
- Create a quality council with a clear vision
- Set long-term goals
- Direct the program

The second concept is the need for unchanging focus on the internal customer and external customer (Besterfield et al., 1995, p. 2). Per Besterfield, Besterfield-Michna, Besterfield, and Besterfield-Sacre (1995), the key factor to a successfully effective TQM program, it must focus on the customer (p. 2). "We must listen to the voice of the customer and emphasize design quality and defect prevention. Do it right the first time. . . . customer satisfaction is the most important consideration." (Besterfield et al., 1995, p. 2)

The third concept is effective involvement and utilization of the group as stated by Besterfield, Besterfield-Michna, Besterfield, and Besterfield-Sacre (1995, p. 2). Quality is everyone's responsibility, from the internal customers and suppliers to the shipping and receiving departments of the finished product. Besterfield, Besterfield-Michna, Besterfield, and Besterfield-Sacre (1995) believe that TQM is an organizational-wide challenge that is everyone's responsibility (p. 2). The employees should be trained on TQM, Statistical Process Control (SPC), and other appropriate quality improvement skills to effectively participate on the project teams (Besterfield et al., 1995, p. 2). As Besterfield, Besterfield-Michna, Besterfield, and Besterfield-Sacre (1995) emphasize, the author is an advocate that all the people that are affected by the plan should be involved with the development and implementation of the plan (p. 2).

The fourth concept is continuous improvement of not only the production process, but also of the business (Besterfield et al., 1995, p. 2). The TQM projects should focus, but is not limited to, on-time delivery, order entry efficiency, billing error rate, customer satisfaction, cycle time, and scrap reduction (Besterfield et al., 1995, p. 2).

The fifth concept is treating all suppliers as partners (Besterfield et al., 1995, p. 3). Besterfield, Besterfield-Michna, Besterfield, and Besterfield-Sacre (1995) report that on average the purchase product or service constitutes 40% of the sales (p. 3). Given this, the focus should be on the total cost versus the price because both the buyer and seller have much to gain or lose based on the success of the product or service (Besterfield et al., 1995, p. 3). For this reason, the fewer suppliers used, the more partnerships that can be acquired (Besterfield et al., 1995, p. 3).

The sixth concept is establishing process performance measures (Besterfield et al., 1995, p. 3). In Total Quality Management, it declares that up-time, percent nonconforming, absenteeism, and customer service are performance measures that should be identified for each area. This information should be posted in an open area for everyone to see (Besterfield et al., 1995, p. 3).

By following all six of these concepts, TQM will provide quality products to each customer (Besterfield et al., 1995, p. 3). This will result in increased productivity and lower costs (Besterfield et al., 1995, p. 3).

2.3.3 Cost of Quality

Costs are broken down into appraisal, prevention, internal failure, and external failure; the quality cost increases for each of these items, while the cost of quality is free (McCarty et al., 2005, p. 151). However, the cost of poor quality is measured by lost customer bids, declining market share, and declining profit (McCarty et al., 2005, p. 151).

Appraisal costs evaluate a product or service at different stages from design to delivery to determine its acceptability for continuation in the life cycle (Besterfield et al., 1995, p. 144). These costs include (Besterfield et al., 1995, pp. 144-145):

- Purchasing Appraisal Costs – For the inspection and / or test of purchased supplies or services to determine acceptability of usage of the product or service
- Operations Appraisal Costs – Inspections, tests, or audits required to verify acceptability of the product or service
- External Appraisal Costs – Field setup or installation prior to customer acceptance
- Review of Test and Inspection Data – Review test and inspection data prior to the release of the product for shipment
- Miscellaneous Quality Evaluations – Quality evaluations or audits

Prevention costs identify and eliminate failures and their costs to prevent the reoccurrence of a specific failure (Besterfield et al., 1995, p. 143). These costs include (Besterfield et al., 1995, p. 143-144):

- Marketing / Customer / User – Evaluation of customer and user quality needs and perceptions
- Product / Service / Design Development – Translation of needs into quality standards and requirements
- Purchasing – Assuring conformance to requirements
- Operations – Verifying capability and readiness of the operations meeting quality standards and requirements
- Quality Administration – Administration of the quality management function
- Other – Other expenses such as rent, travel, telephone, etc.

Internal failure costs are unscheduled and potentially unbudgeted expenses (Besterfield et al., 1995, p. 145). These costs include (Besterfield et al., 1995, p. 146):

- Product or Service Design Failure – Unplanned costs that result from design inadequacies in the documentation
- Purchasing Failure – Purchased item is rejected
- Operations Failure – Nonconforming product or service is discovered during the operations process

External failure costs are actual or suspected nonconforming products or services that have been delivered to the customer (Besterfield et al., 1995, p. 146). These costs include (Besterfield et al., 1995, pp. 146-147):

- Complaint Investigations of Customer or User Service – Investigation, resolution, and responses to an individual customer or user complaint or inquiry
- Returned Goods – Items returned to the manufacturer or service provider not meeting acceptance by the customer nor used due to quality problems
- Retrofit and Recalls – Modifications or updates of products or field service facilities to a new design or redesign
- Warranty Claims – Covered expenses due to removing, cleaning, or replacing defective products
- Liability Costs – Costs from liability claims
- Penalties – Less than full product or service performance is achieved
- Customer or User Goodwill – Customers are not completely satisfied with the quality of the product or service
- Lost Sales – Profit that is lost due to sales reductions caused by quality problems
- Other – All other external failure costs

2.3.4 Statistical Process Control

Dr. Deming focused on reducing variability; this concept introduced statistics to the common person – not only statisticians (McCarty et al., 2005, p. 151). There are techniques used to monitor product variation while in the production facility (Salvendy, 2001, p. 1857). These techniques require and assume statistical independence with the data, and are known as Statistical Process Control (Salvendy, 2001, p. 1857).

Some of the common terms used are nonconforming, defects, occurrences, variables, and frequency. These terms are used to gather data, document and define the process. A nonconforming item is a product that does not satisfy one or more of the product specifications (Montgomery, 1991, p. 172). Defects or nonconformities are the total points to which a specification is not satisfied (Montgomery, 1991, p. 172). Occurrences are the individual observations (Salvendy, 2001, p. 1857). Variables are the quality characteristics of a product or service (Montgomery, 1991, p. 107). Frequency shows how often different values occur (Rath and Strong Management Consultants, 2003, p. 70). Now the author will discuss the Statistical Process Control (SPC) tools that utilize these terms above.

As stated by Salvendy (2001), there are seven commonly used tools for SPC that are claimed by Ishikawa to resolve 95% of quality related problems (pp. 1857-1875):

- Histogram – Shows the frequency of occurrences
- Check Sheet – Provides types of defects found in a product or service
- Pareto Chart – Observes the types of defects from largest quantity or percentage to the smallest
- Cause and Effect Diagram – Evaluates a defect type and its causes
- Defect Concentration Diagram – Illustrates the part being produced
- Scatter Diagram – Plots the process or product performance and the controllable variable(s)
- Control Chart – Monitors the process variation

2.3.5 Reengineering

In the Six Sigma Black Belt Handbook, it states Hammer took the idea of processes and applied it to the entire business (McCarty et al., 2005, p. 151). This concept had a huge potential for change because it included information technology, business processes, and a clean slate to change (Salvendy, 2001, p. 1700). These concepts together would bring great progress. However, these concepts separately could be dangerous (Salvendy, 2001, p. 1700). For example, by using information technology alone, this could bring institutionalized processes. With the use of business processes solely, this could bring the company only incremental changes. And lastly, with the implementation of using a clean slate to change, this could result in a lack of direction.

In addition to joining the three concepts above, it is mandatory to focus on "growing the top line rather than cutting costs" documented by Salvendy (2001, p. 1701). Consequently, Salvendy (2001) notes that this will (p. 1701):

- Enhance the value for cost to the customer
- Realign the processes and business systems for growth
- Refocus on the soft side of capabilities development

In order to reengineer a process within a business, there are certain tools that can be used for implementation. These tools are as follows (Salvendy, 2001, pp. 1703-1704):

- Benchmarking – "… search for the best practices that will lead to superior performance of a company…"
- Modeling Tools – Show pictures of the business, relationships, and the flow of information

- Analysis Tools – Illustrate different views of results; used to enter, view, and track the process inputs
- Simulation – Allows the user to predict behavior of a system under certain circumstances without actually building the system
- Activity Based Costing – Allocates costs to activities within a process versus to products or services

2.3.6 Six Sigma

Six Sigma is a technique used to evaluate business processes. With the evaluation of the business processes, Statistical Process Control tools are used to make sound unbiased decisions that benefit the business, its customers, associates, and shareholders (McCarty et al., 2005, p. 152).

Six Sigma is an entity birthed from Total Quality Management (TQM) and Statistical Metrics originating at Motorola per Arnheiter and Maleyeff (2005, p. 2). TQM included the focus of the customer satisfaction when making management decisions and investments in statistical education, root cause analysis, and other problem solving methodologies (Arnheiter and Maleyeff, 2005, p. 2). Quality was first, and the main TQM tools used were control charts, histograms, check sheets, scatter plots, flowcharts, cause and effect diagrams, and Pareto charts (Arnheiter and Maleyeff, 2005, p. 2). In conjunction, the management tools used were affinity diagrams, interrelationship diagrams, tree diagrams, matrix diagrams, prioritization matrices, process decision program charts, and activity network diagrams (Arnheiter and Maleyeff, 2005, p. 2).

The main focuses of Six Sigma are changing a culture within an organization and money (Zinkgraf, 2006, pp. 27 & 37). If the implementation of Six Sigma is done well, it will change the thought process of those within the business. Instead of providing information to the group, the group will want to know the origin of data and want to see the data that supports the decision making process (Zinkgraf, 2006, p. 37). In addition, if Six Sigma implementation is successful, the money will be evident through increased productivity, growth, and freed up cash.

2.3.7 Theory of Constraints

Salvendy (2001) documents Goldratt developed the theory of constraints. This effort can be viewed as a philosophy and methodology of improvement (Salvendy, 2001, p. 557). Theory of constraints is used to find and eliminate bottlenecks to increase capacity (McCarty et al., 2005, p. 152). The main focus is that every system has at least one constraint (McCarty et al., 2005, p. 152).

For the success of this technique, the following steps must be followed (Salvendy, 2001, p. 557):

1) Identify the system constraint(s)
2) Decide how to exploit the system constraint(s)
3) Subordinate everything else to the above decision
4) Evaluate the constraints
5) If the constraint has been broken, go back to step 1

2.3.8 Lean Manufacturing

From McCarty, Daniels, Bremer, and Gupta (2005), Womack and Jones focus on Lean Enterprise throughout the company and the way to do business – not just the manufacturing floor. This concept is based on kaizen, continuous improvement, and elimination of waste (McCarty et al., 2005, p. 152).

In order to create a Lean process, Womack and James identify five Lean principles (Bicheno, 2000, pp. 12-13) that should be taken into consideration with the implementation of Lean. These principles are value, value stream, flow, pull, and perfection (Womack & Jones, 1996, pp. 15-25). These principles of Lean Thinking will eliminate waste (Bicheno, 2000, p. 12). This will reduce the time for that individual product, and increase the time to make more products or to do something else that is value add to the customer and company.

2.3.9 Author's Focus

In spite of all the different improvement initiatives, the author is interested in and focused on both Lean and Six Sigma. Lean focuses on removing waste, while Six Sigma focuses on removing variability. By putting these concepts together, Lean Six Sigma will be a very effective and useful tool.

Lean Six Sigma focuses on the projects that are already in existence and can be brought into projects that are in development. The sooner this concept is understood, implemented, and practiced, the more money and time that is saved within a company upfront.

In the end, Lean Six Sigma gives companies more time to focus on new and different things – instead of focusing on and trying to improve existing issues. Due to limited resources, it is in the best interest of companies to implement Lean Six Sigma as soon as possible.

2.4 <u>Lean</u>

2.4.1 Lean Thinking

The focus of Lean thinking is to provide simplicity, flow, visibility, partnership, and value (Bicheno, 2000, p. 8). The end result eliminates waste (Bicheno, 2000, p. 12). This will reduce the time for that individual product, and increase the time to make more products or to do something else that is value add to the customer and company.

This concept can be traced back to Toyota. Toyota had a manufacturing concept called Toyota Production System (TPS) that was created by Taiichi Ohno and Shigeo Shingo based out of Japan (Womack & Jones, 1996, p. 23). TPS was then transformed into Just In Time (JIT) due to Ford's focus to reduce waste and reduce inventories with high throughputs (Arnheiter, 2005, p. 3).

In order to create a Lean process, Bicheno (2000) suggests five Lean principles that should be taken into consideration with the implementation of Lean (pp. 12-13).

First, specify the value from the point of view of the customers, not the viewpoint of the producers (Bicheno, 2000, p. 12). The first question to understand is – what is value? Presently value is defined as either what the producers want to make or are already making, or a slight change to what the customer is already receiving (Womack & Jones, 1996, p. 31). The key to successfully specifying the value is for the producer and the customer to jointly analyze the value of a product and then challenge the old way things are done (Womack & Jones, 1996, p. 31). This will further define what the company should do to create revenue and profits. Customers create business, while a business creates customers. And if the focus leaves from the customer, there will definitely be no business.

Second, identify the value stream (Bicheno, 2000, p. 12). The value stream documents every action needed to design, order, and make a specific product (Womack & Jones, 1996, p. 38). This allows the team to precisely identify, analyze, and link together all the activities that should be challenged, improved or perfected. As an end result, the team can compete against perfection by identifying and eliminating waste, which creates a better flow (Womack & Jones, 1996, p. 37 & 49). The following questions can be asked to determine the value or non-value of an activity or task (George, 2002, pp. 52-53):

<u>Customer Value Add Questions</u>

- Does the task add form or feature to the product?
- Will the task enable competitive advantage?
- Would the customer be willing to pay extra for this task?

<u>Business Value Add Questions</u>

- Is this task required by law or regulation?
- Can this task reduce financial risk of the owner?
- Does this task support financial reporting requirements?
- Would the process break down if this task was removed?

<u>Non-Value Add Questions</u>

- Does this task include counting, handling, inspecting, transporting, moving, delaying, storing, reworking, expediting, or multiple signatures?
- Will the faster lead times and lower costs fill up existing facilities?
- How many distribution centers can be eliminated with faster lead times?

Third, make the product flow (Bicheno, 2000, p. 12). Once the value is defined and the value stream mapped out, the design, order, and product should be looked at (Womack & Jones, 1996, p. 52). Following this activity, how things are normally done is ignored and all obstacles to a continuous flow removed. The last step is to rethink work practices and define tools needed to eliminate scrap, backflows, and stoppages so the design, order, and production will be continuous (Womack & Jones, 1996, p. 52). The focus is now on one piece flow – avoid batching. This will save time and money if any issue is found with a part, and in theory gets more products out of the door to customers. The assembler should only have (1) item to disassemble versus (15) items that are in queue from batching product. In order to have this, Just In Time (JIT) should be in place (Salvendy, 2001, p. 545).

Fourth, the product should be on a pull system (Bicheno, 2000, p. 12). Some companies create a product that does not fit the needs of the customer, and the business tries to convince the customer that this is the best product for their needs (Womack & Jones, 1996, p. 17). Instead of pushing products, products should be pulled by the customer. Customers should have a need for the product and request the product, which reduces inventory of finished goods on the production floor (Womack & Jones, 1996, p. 67). JIT should be in place to make this process go smooth (Salvendy, 2001, p. 545).

And fifth, perfection should be the goal (Bicheno, 2000, p. 12). This means that the business produces only what the customer needs exactly when the customer needs it – at a fair market price with minimum waste (Womack & Jones, 1996, p. 35). In order to do this, start with a vision to pursue. The vision identifies the final destination along the path. Pushing toward perfection provides inspiration and direction, which are both needed to move forward along this path (Womack & Jones, 1996, p. 94). In addition, a timeline should be set for completing tasks along the path. Remember, the goal is to eliminate waste in order to meet your vision (Womack & Jones, 1996, p. 95).

In order to make these activities complete, management should have a Lean policy deployment. This sets improvement targets for a specific area to be completed at a specific time, with the use of specific people and available resources (Womack & Jones, 1996, p. 95). Without this, the above principles are only considered the activities for the month versus a way to do business.

2.4.2 Characteristics

In addition to the five Lean principles, Bicheno (2000, pp. 14-15) also discusses several core characteristics of Lean.

- Customer - The success of the business is based on the customer. The customer must be understood, and there must be a need available. The customer is the starting and ending point to the process making the product.
- Simplicity – The concept of Keep it Simple Sweetie (KISS) should prevail in everything about the product. KISS is focused on the development, manufacturing, assembly, production control, and shipping of the product.
- Visibility – Make all operations as visible as possible; let all operations be known through documentation and training.
- Regularity – Eliminate surprises in the operations. If possible, create the same products at the same time and work with development to reduce the affect of new products on the production floor.

- Synchronization – Let the flow satisfy the demand, and keep the process moving.
- Pull – Let the demand of the product from the customer make the product at the time and not before time. This eliminates excess storage of products and over production; potentially missing dates for other products that are needed by other customers.
- Waste – Eliminate waste. Waste equates to non-value add tasks. Non-value add tasks are tasks that customers are not willing to pay for. For example, if a process requires epoxy, and production wants the epoxy to cure faster, an oven is used. A customer is not willing to pay for the oven, but is willing to pay for the epoxy because the epoxy is part of the product, while the oven is not part of the product.
- Process – This is the order to which a product is made; how the product moves from idea to the finished product.
- Prevention – Create a process that will prevent any problems. Do not plan to fix problems, plan to avoid problems.
- Time – Perform tasks in a timely manner. Save time by performing tasks in parallel or ahead of schedule.
- Improvement – There are always areas to better the product and the process. Never stop improving.
- Partnership – Lean thinking requires teams working together. Goals will never be achieved if individuals do not communicate and remain okay

with the way things are done. There is always room for improvement, and individuals' ideas should be heard.

- Participation / Empowerment – Give the production floor the first opportunities to solve the problems. If the problem cannot be solved on the floor, support the concept of the open door policy. The production floor can come to management with issues, but should have potential solutions also.
- Gemba – Seek the facts, and implement actions on the floor.
- Variation – Seek to reduce or eliminate variation in all processes. This eliminates non-value add tasks.

2.4.3 Time Based Competition

Time to market is so important. The more time required bringing a new or revised product to market, the greater the probability that another company will go to market first. To eliminate a time to market disaster, "second place", here are four rules of response per *The Lean Toolbox* (Bicheno, 2000, p. 19):

- 0.05 to 5 Rule - Value is being added 0.05% to 5% of the total time
- 3/3 Rule - The wait time to which no value is added is split into waiting for completion of batches, waiting for physical and intellectual rework, and waiting for management decisions to send the batch forward
- ¼-2-20 Rule - For every quartering of total competition time, there will be a doubling of productivity and 20% cost reduction
- 3 X 2 Rule - Time based competitors enjoy growth at a rate of three times the average and twice the profit margin for that industry

In addition, here are a few major payoffs to bring a product to market faster (Bicheno, 2000, p. 19):

- Competitive advantage being first to market
- Higher profitability because revenue is realized earlier
- Fewer surprises

Keep in mind, time based competition is important, but quality should never be compromised because of it.

2.4.4 Muda

Muda is a Japanese term for waste (Bicheno, 2000, p. 21). Waste is the opposite of value; it is non-value add to a product or process. Waste must first be identified and then eliminated with the implementation of Lean.

2.4.4.1 Waste Identification

The Lean Toolbox reviews the seven different types of wastes within a system (Bicheno, 2000, p. 21-24):

- Overproduction – Producing more than is needed or requested by the customer; in-other words, making too much, too early, or just in case.
- Waiting – Time is not being used effectively, for example, waiting for work, waiting for a response, bottleneck, watching machines, parts late delivery, etc.
- Transporting – Moving product from one location to another.
- Inappropriate Processing – Pushing production as often as possible versus when needed or machines / processes that are used that are not quality

capable, which produce defects. For example, machines shared between several lines, variation between operators, variation from the standard, etc.

- Unnecessary Inventory – Inventory that is kept and not used in a timely fashion.
- Unnecessary Motions – Non-value add and ergonomically incorrect motions to produce the product.
- Defects – A failure in the process.

In addition to these traditional wastes, John Bicheno (2000) identified some additional wastes (pp. 24-26):

- Untapped Human Potential – Not empowering people to push the envelope with change to improve a process or product. Empowerment requires clear communication, commitment, support, and a culture of trust and mutual respect.
- Inappropriate Systems – Using the incorrect system for the process, making the process more time consuming or cumbersome than it needs to be.
- Energy and Water – Eliminate the wasteful usage of energy and water.
- Materials – Get rid of wasteful usage of materials from the design to manufacturing.
- Service and Office – Do away with wastes created in the offices and services provided to customers.

- Customer Time – Avoid wasting the customers' time, for example customers waiting in queues or customers providing the same information several times.
- Defecting Customers – Loss of existing customers.

These wastes can fall into two categories, either Type One muda or Type Two muda. Type One muda creates no value to the process, but is required to complete the process. Type Two muda creates no value to the process, but can be immediately eliminated from the process (Womack & Jones, 1996, p. 38).

The key to successfully identifying the root causes for these wastes is looking at all the activities involved in creating the product, and understanding how all the machines, people, tools, etc. interact with each other – understanding the entire process (Womack & Jones, 1996, p. 48). Through understanding, the team can challenge the actions that do not collectively create value for the customer (Womack & Jones, 1996, p. 44).

2.4.4.2 Lean Waste Elimination

Eliminating waste requires four steps. Step one identifies the opportunity waste (Nash et al., 2006, pp. 26-27). In this process, all employees are encouraged to help with the implementation of change. As stated by Nash, Poling, and Ward (2006), "buy-in and continued involvement of the employees is an invaluable asset to the project team and the company as a whole" (p. 27). In order for this to be successful, management should provide throughout the company a common understanding of Lean by having team meetings and training (Nash et al., 2006, p. 26). No matter what employment area a person is in, they should be able to see opportunities for Lean implementation.

Step two designs the solution waste (Nash et al., 2006, p. 27). Within this step, the current state and the intended future state of the system are documented. This is completed with the use of value stream mapping and 5S deployment.

Value stream mapping documents all actions required to make or implement a specific product or process (Womack & Jones, 1996, 38). The actions are placed into one of the three categories (Womack & Jones, 1996, 38).

1) Value add tasks as perceived by the customer
2) Non-value add tasks that are required to the process and cannot be eliminated
3) Non-value add tasks that do not create value and can be eliminated immediately).

5S deployment eliminates clutter and promotes order (Nash et al., 2006, p. 28). The 5Ss are sort, set in order, shine, standardize, and sustain (Carreira & Trudell, 2006, 136).

- Sort provides organization. This removes unneeded items from the area and retains needed ones.
- Set in order offers orderliness. This activity defines a specific location for all required items in the area.
- Shine cleans everything. This activity causes employees to regularly clean and inspect everything in the area.
- Standardize brings order. This activity maintains the order and cleanliness of an area.

- Sustain practices discipline. The practices of sorting, setting in order, shining and standardizing continue with this activity.

Step 3 implements change (Nash et al., 2006, p. 29). This provides a constant flow of project work. The focus is to always have projects available that implement improvements within the area. This process allows the area to have just enough projects so that when projects are completed they can also be controlled to follow the results. These projects are selected depending on the customer needs and the criteria created by the organization.

Step four continuously improves (Nash et al., 2006, p. 30). This is the process of sustaining and maintaining the changes that were implemented or making the necessary tweaks to reach the desired results. This looks at the organization as a whole (Nash et al., 2006, p. 30). All improvements are evaluated to determine how the improvement efforts in one area can also be implemented in another area.

The act of improving never ends. It is a continuous cycle for the area and the company. This is the cycle of Plan – Do – Check – Act (Womack & Jones, 1996, p. 242). Plan what will be improved and how it will be improved. Implement the improvements. Check to verify that the implemented changes are working. Act on the changes or do nothing if the changes are good or make modifications if necessary.

2.4.5 R's of Lean

Lean is a process that is usually focused on the internal processes and products of a company (Krar & Gill, 2007, p. 20). In order to make Lean profitable for the company short term and long term, Lean should be extended to outside the manufacturing facility (Womack & Jones, 1996, pp. 35 & 37). The new "Millennium Lean" quoted by John

Bicheno (2000) is noted as lean on internal operations and with a wider impact on society that will be very profitable (p. 27). With the focus on internal and external operations, the 5 R's set the stage (Bicheno, 2000, p. 27):

- Redesign – Design the product for a longer product life for less maintenance with an ease of recycling.
- Reduce – Decrease the energy and materials used in manufacturing and for the life of the product.
- Recover – Recuperate waste materials and energy during product use.
- Recycle – Reuse products and components when their life ends.
- Remanufacture – Remake new products from old products.

2.4.6 Target Cost

In the manufacturing world, the cost is derived from the total cost of the components, labor, and packaging at a fully burden rate (Salvendy, 2001, p. 667). This cost is then, given to Marketing, and Marketing includes the planned profit and creates the price for the product (Salvendy, 2001, p. 667).

Per this document, costs are looked at differently. It is suggested by Bicheno (2000) to start with the price and derive all other information from this (p. 38).

Target Cost = Market Price – Target Profit

What do you gain from this? Well, the target cost can be identified ahead of time. This requires anticipation of what the customer will pay for the product which includes some risk and uncertainty.

With this methodology, the cost begins with the customer in mind, and it is a proactive system. Here is Bicheno's overview (Bicheno, 2000, pp. 38-40).

Target selling price is a result of 1) the perception of value of the product, 2) the loyalty of the customers, 3) competitive offerings of the product, and 4) new markets and market share. And, target profit margin is a result of predecessor products or product line margin.

From the target selling price less the target profit margin, this gives the allowable cost. The allowable cost is then dependent on the following (Bicheno, 2000, pp. 38-40):

- Component Level Target Costing – This is divided into 1) the internal costs for labor at a fully burden rate including packaging, and 2) the supplier costs for the components.
- Design – This is divided into 1) The time, cost, and quality to make a useful and inexpensive functioning product, and 2) The price, functionality, and quality to also make a useful and inexpensive functioning product.

2.4.7 Design For Manufacturing and Assembly

This is a key concept to Lean as described in the Lean Toolbox (Bicheno, 2000, p. 50). The design of the components and the interface of the components with each other are included in the cost. The main factors are 1) the number of parts, 2) the number of types of parts, and 3) the number of interfaces on the parts (Bicheno, 2000, p. 51). These factors are determined by addition, then the factors are multiplied and the cube root is then taken. This provides the complexity of the design.

Manufacturing the product is divided into four activities. The first activity identifies how the components are made. The second activity determines the process used to make the components. The third activity establishes the materials used to make the components. And the fourth activity specifies the tools used to make the components. This is included in the cost of the product.

The assembly of the product identifies 1) how quickly the product is made, 2) how easy the product is made, and 3) how much time it will take to assemble the complete product. This is also included in the cost of the product, so the smaller the costs the better the profit.

2.4.8 Time

Time is always of the essence. With the design of a new product, it must be done in a timely fashion (Bicheno, 2000, p. 41).

2.4.9 Quality Function Deployment

Quality products are no longer an option, it is a need and expected by customers. For this reason, quality products are very important to manufacturers. This identifies the customers' needs which are set against the product characteristics to identify the most important characteristics (Bicheno, 2000, p. 57). These characteristics need to be developed. Remember the customer is the reason to make the product, due to a need.

In laypersons terms, Quality Function and Deployment (QFD) implements quality from all aspects. QFD is a forum for Marketing, Design, Engineering, Manufacturing, Distribution, and others to work together (Bicheno, 2000, p. 57). In the end, this creates a quality product from all aspects.

2.5 Six Sigma

2.5.1 What is Six Sigma?

Six Sigma is a management system to achieve lasting business leadership and top performance to benefit the business and its customers, associates, and shareholders

(McCarty, Daniels, Bremer, Gupta, 2005, p. 22). This system defines the capability of any process, and the goal for improvement is to reach near perfection (George, 2002, p. 17). In simple terms given by Dr. Thomas Goldsby and Robert Matichenko (2005, p. 5), Six Sigma attempts to understand and eliminate the negative effects of variation in processes.

Six Sigma is an entity birthed from Total Quality Management (TQM) and statistical metrics originating at Motorola per Arnheiter (2005, p. 2). TQM included the focus of the customer satisfaction when making management decisions and investments in statistical education, root cause analysis, and other problem solving methodologies (Arnheiter, 2005, p. 2). Quality was first, and the main TQM tools used were control charts, histograms, check sheets, scatter plots, flowcharts, cause and effect diagrams, and Pareto charts (Arnheiter, 2005, p. 2). In conjunction, the management tools used were affinity diagrams, interrelationship diagrams, tree diagrams, matrix diagrams, prioritization matrices, process decision program charts, and activity network diagrams (Arnheiter, 2005, p. 2).

The negative effects of variation in processes create defects. These defects are measured to verify if the processes are in or out of control. The control of the process is based on how far the process deviates from the mean, which is also known as the average (Basu & Wright, 2003, p. 34).

The Sigma level represents the capability of a core business process as it measures in defects per million opportunities (George, 2002, p. 17).

Table 1: Sigma Level

Sigma Level	Defects per Million Opportunities	Yield
6	3	99.9997%
5	233	99.977%
4	6,210	99.379%
3	66,807	93.32%
2	308,537	69.2%
1	690,000	31%

This does not calculate the total defects in the process. Six Sigma identifies the ratio of defects compared to the number of opportunities for defects to occur (Gupta & Walker, 2005, p. 1).

Reference Table 1 for the detailed explanation of two standard deviations, four standard deviations, and six standard deviations. Two standard deviations away from the mean produces 69.2% of the time that a product meets customer requirements, which provides 308,537 defects per million opportunities (Smith, Blakeslee, and Koonce, 2002, p. xxiv). Four standard deviations away from the mean produces 99.37% of the time that a product meets customer requirements, which provides 6210 defects per million opportunities (Smith et al., 2002, p. xxiv). Six standard deviations away from the mean produces 99.9997% of the time that a product meets customer requirements, which provides 3.4 defects per million opportunities (Smith et al., 2002, p. xxiv).

The source of defects is connected with variation, such as materials, procedures, and processes. The goal is to minimize the number of defects. As the standard deviation, also known as Six Sigma, is increased, the process improves.

2.5.2 Critical Success Factors

The critical success factors documented by George (2002) for Six Sigma are listed below (p. 17). The first critical success factor is customer centricity. With this factor, it is important to know what the customer values (George, 2002, p. 17). The goal to any product delivered to any customer is to give the customer what they want, and the vendor must identify these things through several items (George, 2002, pp. 17-18).

- Voice Of the Customer (VOC) is the customer communicating what they want.
- Requirements are specifications and measurable elements communicated from the customer.
- Critical To Quality (CTQ) is the requirement most important to the customer.
- Defects are the products that are not delivered to a customer's CTQ.
- Design for Six Sigma is to design the products and processes based on the customer's requirements.

The difference in what the customer requires and what can be delivered is an area where value can be created for the customer and the supplier. And, this is the focus of Six Sigma. The gaps between the customer and supplier are reduced with Six Sigma while increasing profit (George, 2002, p. 18).

The second critical success factor is financial results. This is the main goal of implementing Six Sigma. Financial performance is the overriding principle (George, 2002, p. 19).

The third critical success factor is management engagement. An infrastructure needed for success must be anchored by strong management involvement (George, 2002, p. 20).

The fourth critical success factor is resource commitment. Personnel are assigned full time to these projects to meet the goals of the identified project (George, 2002, p. 21).

And the last critical success factor is execution infrastructure. Six Sigma possesses an infrastructure that effectively translates the company's agenda into a customer focused set of projects to maximize shareholder value, provide effective management, and monitoring results (George, 2002, p. 21).

2.5.3 DMAIC Process

In order to reduce defects and achieve the goal of perfection, the defects must be eliminated and a structured process must be followed. While Lean focuses on Plan – Do – Check – Act (PDCA) philosophy, Six Sigma follows the Define – Measure – Analyze – Improve – Control (DMAIC) philosophy. It is interesting to note that both philosophies are similar, but each step of the DMAIC process utilizes the PDCA cycle (Nash et al., 2006, p. 41).

In Table 2, it includes the process, activity and tools used for the DMAIC process.

Table 2: Define – Measure – Analyze – Improve – Control (DMAIC) Tool Set

Process	Activity	Tools
Define	Establish Team Charter	Voice of Customer (VOC)
	Identify Sponsor and Team Resources	Supplier, Inputs, Process, Outputs, and Customers (SIPOC)
		Rolled Throughput Yield (RTY)
		Affinity Diagram
Measure	Confirm Team Goal Define Current State Collect and Display Data	Control Charts
		Frequency Plots
		Pareto Charts
		Failure Mode and Effect Analysis (FMEA)
Analyze	Determine Process and Capability and Speed Determine Sources of Variation and Time Bottlenecks	Affinity Diagrams
		Brainstorming
		Cause and Effect Diagrams
		Control Charts
		Regression Analysis
		Hypothesis Tests
		Scatter Plots
		Design of Experiments
Improve	Generate Ideas Conduct Experiments Develop Action Plans Implement	Failure Mode and Effect Analysis (FMEA)
		Pilot
		Implementation
		Solutions
Control	Develop Control Plan Monitor Performance Mistake-Proof Process	Control Charts
		Data Collection
		Standardize
		Monitor
		Evaluate
		Closure

The following gives more details for the different phases of the DMAIC process. The problem or objective is identified by the define phase (Carreira & Trudell, 2006, p. 7). A project charter is created which documents the intent and objective of the project

(Carreira & Trudell, 2006, p. 7). Once the project is reviewed and agreed upon, management signs off on the project and designates a Champion to support the project (Carreira & Trudell, 2006, p. 7).

The measure phase gathers data on the current state of the process identified (Carreira & Trudell, 2006, p. 7). The process is measured, data is collected, and metrics are created (Carreira & Trudell, 2006, p. 7). With this information, the team identifies the current state of the process. After discussing and evaluating the present state of the process, the team then decides what part of the process should be reviewed further and what results identify an improved process.

The analyze phase reviews the data to identify the root causes of the defects, which develops solutions and improvements for the next phase (Carreira & Trudell, 2006, p. 8). With this information, the defects that are produced can now be eliminated with the suggested solutions and improvements.

The improve phase pushes to eliminate defects in the process by testing or implementing solutions from the prior phase (Carreira & Trudell, 2006, p. 8). With this phase, the output is a plan to improve, creating little to no defects.

The control phase ensures the desired results and prevents future occurrences of defects by using mistake proofing, monitoring the process, and getting feedback. (Carreira & Trudell, 2006, p. 9). With this phase, the process is under control, creating little to no defects.

2.6 Lean Six Sigma

2.6.1 What is Lean Six Sigma?

James Schutta described Lean Six Sigma as a combination of Lean which eliminates wastes and Six Sigma which reduces variation. The focus is to use the knowledge of the workers with the proper tools to design, improve, and control the key processes of the product manufactured (Schutta, 2006, p. 1). In addition, management must provide a business process involving planning and strategic thinking (Schutta, 2006, p. 2).

Looking at Lean and Six Sigma separately, each gives priority to different items of organizational performance resulting in diminishing returns (Arnheiter, & Maleyeff, 2005, p. 8). However, with the implementation of both Lean and Six Sigma together, the returns can be on-going as shown in Figure 4 (Arnheiter, & Maleyeff, 2005, p. 8&11).

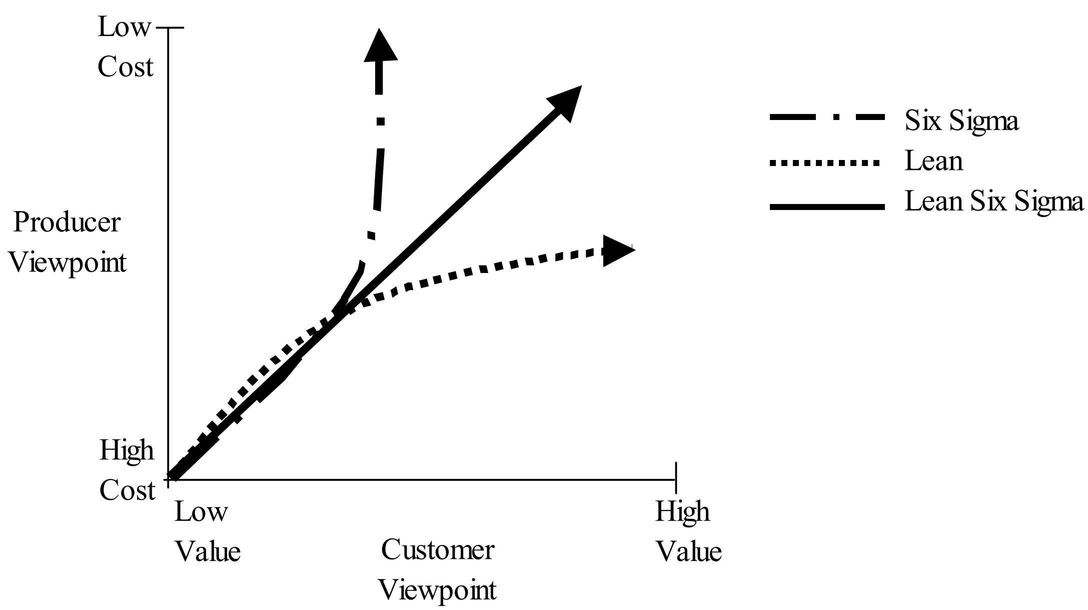

Figure 4: Competitive Advantage

Lean Six Sigma can grow with the strengths of both Lean and Six Sigma which can be combined to develop a synergy as shown in Table 3 (Gore, 2003, pp. 5-6).

Table 3: Batch Synergy of Lean and Six Sigma

Lean	Six Sigma
Establish a methodology for improvements	Policy deployment methodology
Focus on customer value stream	Customer requirements measurement, cross functional management
Use project-based implementation	Black-Belt project management skills
Understand current conditions	Knowledge discovery
Collect product and production data	Data collection and analysis tools
Document current layout and flow	Process mapping and flowcharting
Time the process	Data collection tools and techniques (SPC)
Calculate process capability and takt times	Data collection tools and techniques (SPC)
Create standard work combination sheets	Process control planning
Evaluate the options	Cause-and-effect FMEA
Plan new layouts	Team skills, project management
Test to confirm improvement	Statistical methods for valid comparison
Reduce cycle times, product defects, changeover time, equipment failures, etc.	Seven management tools, seven quality control rules, design of experiments

The Lean concepts that would be used are (Arnheiter & Maleyeff, 2005, p. 8):

1) Maximize the value-added content of all operations

2) Ensure the incentive systems result in global optimization

3) Base all decisions on the impact to the customer

The Six Sigma concepts that would be used are (Arnheiter & Maleyeff, 2005, p. 8):

1) Stress data driven methodologies in all decisions

2) Promote methodologies that minimize variation of quality characteristics

3) Design and implement a company wide and highly standard education and training system

In order to make this Lean Six Sigma concept successful, the company must focus on processes and problem areas that will affect the company's strategic plan and vision for leadership (Schutta, 2006, p. 1).

2.6.2 Paradigm Shift

As the author has learned, it is insane to expect different results if you continue the same actions. In order for Lean Six Sigma to be effective and last, there must be a paradigm shift – change in thought, actions, and tools.

As stated by Schutta, Lean Six Sigma is a new level of running business. It is a cultural change which supports the idea of businesses focusing on the customer, key processes, and steps to continuously deliver a product that satisfies existing and new customers (Schutta, 2006, p. 1).

2.6.3 Knowledge Worker

The knowledge worker is the future worker's capability to solve process variation problems (Schutta, 2006, p. 2). The knowledge worker is in the process of change due to process know-how, knowledge of problem solving, and knowledge of how to handle statistical data to solve problems and improve capability of the process (Schutta, 2006, p. 2).

With this new knowledge worker, Schutta (2006) states the focus will be on customers' needs, process measures, and improving the process. The only way companies will be successful for the future is developing and empowering the knowledge worker (Schutta, 2006, p. 2).

2.6.4 Malcolm Baldridge National Quality Award

In Business Performance Through Lean Six Sigma by Schutta (2006), the Malcolm Baldridge National Quality Award (MBNQA) recognizes, rewards, and shares ideas of companies that are performing well. If the company and worker understand the MBNQA criteria, the worker can implement change, drive the organization into the right direction while Lean Six Sigma can provide the tools to get there (Schutta, 2006, p. 2).

2.6.5 Customer Needs

As discussed earlier, in order for the company to be successful, the focal point of any business providing a service or product to a customer should be the needs of the customer. Businesses should center their attention on the market, the end users, the customers' expectations, the regulatory environment, and the customers' specific needs per Schutta (2006, p. 2).

If time is not spent doing the above, businesses will make products that are pushed on versus pulled by the customer. In reality, it is much easier to sell products that have a demand than try to make a demand for a product where there is little to no need. This is why it is so important to understand the voice of the customer (discussed earlier) and build upon this for a successful and lasting business.

2.6.6 Management Involvement

The success of any project within any business is based on the involvement from Management. The top down push for improvements is more effective, productive, and easier for others to buy-in versus the down to the top push. It can be done, but the load is very heavy and can become overwhelming, hard to implement, and much more work.

Management must assemble key business indicators that monitor the performance of the organization and determining the status of the processes, customer satisfaction, and operational performance (Schutta, 2006, p. 3).

Here are a few examples of items to monitor per Schutta (2006, p. 3):

Table 4: Management Items to Monitor

Customer needs analysis report
Customer level of satisfaction
Market effects
Key business processes
Key performance processes
Financial indicators of performance
Sales per employee
Employee satisfaction
Community Needs
Key product performance
Key service performance
Supplier performance level
Project status level
Costs of non-conformances
Maintenance costs
Manufacturing and assembly costs

2.6.7 Strategic Planning

The business managers must plan to be successful. If time is not spent to create a strategic plan, that business is definitely planning to fail.

The main strategic planning guidelines per Schutta (2006, pp. 4-5) are shown in Table 5.

Table 5: **Strategic Planning Guidelines**

Leadership involvement is crucial in the success of a project
Drivers of change must be in the business
Strategic planning process requires planning, executing the plan, checking the results, and acting on the findings
Planning documentation
Plan-Do-Check-Act (PDCA) process

2.6.8 Twelve Pillars

Per the author James Schutta, one of the weaknesses of Six Sigma processes is that it started in the retrospective approach without proper support (Schutta, 2006, p. 6).

In addition, the author of this document sees an opportunity of improvement because both Six Sigma and Lean are implemented after the product and process are designed, prototyped, and available to the customer. There is a better way to run the business without designing to improve later. If businesses design to improve now, this would save lots of time and money. Work on the front end when the product is in the design phase.

At this point, have a team of people work to create a functioning, meet the needs of the customer, process improvement implemented, variation reduced, design for simple manufacturing, and assembly type of product. All the necessary changes and implementations are completed at the front end. This will require more time initially. However, after this becomes a way to do business, the time line will become shorter with more experience and better products at the beginning of a product life cycle.

Given this background, there are fifteen fundamentals that must be followed to make Lean Six Sigma victorious (Schutta, 2006, p. 6). See Table 6.

Table 6: **Lean Six Sigma Fundamentals**

1	Top management involvement
2	Top management knowledge of the key processes
3	Strategic plan completed
4	Integration of project selection with the strategic plan
5	Project selection process developed
6	Greenbelt and Blackbelt selection process developed
7	Adequate training
8	Adequate consulting
9	Resources
10	Sufficient time to solve problems
11	Problem definition and Six Sigma Champions
12	Proper process measures and company key business indicators
13	Financial results measures
14	Reward system and recognition process
15	Promotional path for Greenbelts and Blackbelts

Taking a look at Lean Six Sigma, twelve steps are mandatory for its success and must be implemented for process improvement (Schutta, 2006, p. 7). Reference Figure 5.

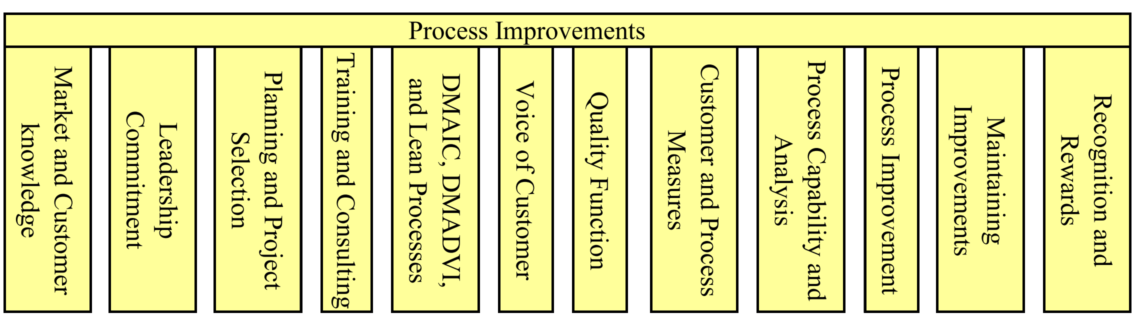

Figure 5: Twelve Pillars to Process Improvements

2.7 Analytical Processes

2.7.1 Analytical Hierarchy Process

Analytical Hierarchy Process (AHP) is a decision aiding tool for dealing with complex, unstructured and multiple attribute decisions (Dweiri, 1995, p. 22). AHP was developed by Thomas Saaty during the 1970's, and is very useful because it considers the inconsistencies of the developer (Dweiri, 1995, p. 22). AHP is a flexible model that allows people to shape their ideas and define their problems by making their own assumptions and deriving the desired solution (Saaty, 1982, p. 22).

As stated earlier, Analytical Hierarchy Process (AHP) models complex, unstructured, and multiple attribute decisions. This has its benefits and drawbacks. The benefits of AHP are (Meade & Presley, 2002, p. 60):

- Provides a structure to the complex issues of the manufacturing company
- Deals with comprehensive framework that deals with the intuitive, rational, and irrational
- Easy to use

There is one main disadvantage of AHP. Analytical Hierarchy Process (AHP) does not consider important interactions between decision levels (Meade & Presley, 2002, p. 61). For this reason, the user of this model must be very careful to use scenarios with unidirectional hierarchy relationships between decision levels (Meade & Presley, 2002, p. 60).

Here are the basic steps to using AHP (Dweiri, 1995, p. 22). 1) Describe the complex decision problem as a hierarchy. 2) Use pairwise comparisons to estimate the relative importance of the elements of the hierarchy. 3) Integrate pairwise comparisons to develop the overall evaluation of the decision alternatives.

Per Saaty (2005), hierarchies are a fundamental tool of the mind. It involves identifying elements of the problem, grouping the elements into homogeneous sets, and arranging these sets into different levels. Hierarchies can be divided into 1) structural and 2) functional. In structural hierarchies, complex systems are structured into their constituent parts in descending order according to priorities. While functional hierarchies break down complex systems into their constituent parts to their essential relationships (Saaty, 1982, p. 28).

Analytical Hierarchy Process (AHP) is based on exhaustive pairwise comparison. This can be very time consuming if there are a lot of attributes in the problem (Olcer & Odabasi, 2005, p. 97). This comparison is useful in research to find the weight factors of each reason or attribute affecting the decision (Dweiri, 1995, p. 22). In addition, this comparison only allows one way hierarchical arcs that show dominance or control over one level of attributes over sub-components or attributes (Meade, 1997, p. 64).

In other words, the decision maker assigns an importance number to each reason that represents the true preference of each reason. See Table 7 (Dweiri, 1995, p. 23).

Table 7: **AHP Intensity Importance Factors for Pairwise Comparisons**

Intensity Number a_{ij}	**Definition of the Comparisons**
1	Equal importance of i and j
2	Between equal and weak importance of i over j
3	Weak importance of i over j
4	Between weak and strong importance of i over j

Table 7 - continued

5	Strong importance of i over j
6	Between strong and demonstrated importance of i over j
7	Demonstrative importance of i over j
8	Between demonstrated and absolute importance of i over j
9	Absolute importance of i over j

The intensity importance of factor i over factor j is equal to a_{ij}, while the intensity importance of factor j over i is equal to $a_{ji} = 1/ a_{ij}$ (Dweiri, 1995, p. 23).

If there are n factors to compare, use Table 7 to develop a matrix resembling Equation 1 to represent the importance of these factors (Dweiri, 1995, p. 23).

$$A_{nxn} \begin{Bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{Bmatrix} \quad ; \text{where } a_{ij} = 1, \text{ iff } i=j, i=1,\ldots, n; j=1,\ldots, n$$

Equation 1: Matrix

Dweiri (1995, p. 24) documents Saaty's steps for AHP.

1) Find the priorities (P_i) of the factors.

   a) Multiply the n elements in each row in the matrix by each other, resulting in X_i

   b) Take the nth root of X_i for each row, resulting in Y_i

   c) Normalize by dividing each number Y_i by the sum of all the numbers SUM OF ALL Y_i, resulting in vector P_i

Equation 2: P_i

2) Find the vector Fi by multiplying A_{nxn} by P_i

Equation 3: F_i

3) Divide F_i by P_i to find the vector Z_i

Equation 4: Z_i

4) Sum Z_i and divide by n to find the maximum eigenvalue = SIGMA SIGN $_{max}$, which is the average

Equation 5: Maximum Eigenvalue

5) Find the Consistency Index (CI) = (SIGMA SIGN $_{max}$ – n) / (n-1)

Equation 6: Consistency Index

6) Find the Random Index (RI) from the Random Index Table below

n	1	2	3	4	5	6	7	8	9	10	11	12
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.58

Table 8: **The Random Index**

7) Find the Consistency Ratio (CR) = (CI) / (RI) – any value of CR that is less than or equal to 0.1 is considered an acceptable ratio of consistency

Equation 7: Consistency Ratio

As documented by Dweiri (1995), the benefits to using AHP are as follows (p. 25):

1) Formalizes making a decision
2) Makes the decision making process non-subjective
3) Provides management with information about the weights of each factor
4) Uses computers for the sensitivity analysis

5) Generates better communication, understanding, and concerns that are addressed with the decision makers

2.7.2 Analytical Network Process

Analytical Network Process (ANP) represents relationships with a hierarchy, but does not use the strict structure like Analytical Hierarchy Process (AHP). Meade stated that ANP is a non-linear network that allows for more complex interrelationships among decision levels and attributes (Meade, 1997, p. 62).

Analytical Network Process (ANP) models problems of systems between levels known as "systems-with-feedback" (Yurdakul, 2003, p. 2503). In summary, this means that a level may both dominate and be dominated, directly or indirectly, by other decision attributes and levels (Meade, 1997, p. 62).

As stated earlier, Analytical Network Process (ANP) models different levels of a manufacturing system. This has its benefits and drawbacks. The benefits of ANP are (Yurdakul, 2003, pp. 2522-2523):

- Provides a structure to the manufacturing company
- Takes the human out - it reduces human judgments and expertise, similar to AHP
- Presents a more accurate and realistic long-term performance score

There is one main disadvantage of ANP. Analytical Network Process (ANP) requires more calculations and the creation of more pairwise comparison matrices (Yurdakul, 2003, p. 2523). For this reason, the user of this model must be very careful with the creation of the matrices, comparisons, and calculations.

Analytical Network Process (ANP) is used to demonstrate product life cycles in replacement decisions (Meade, 1997, pp. 65). ANP handles multiple attributes and multiple periods as well as interdependence among attributes. Here are the five steps (Meade, 1997, 65-73):

1) *Model Construction and Problem Structuring:* The problem should be structured into its important components, including topmost elements, sub-components, and attributes.

2) *Pairwise Comparisons Matrices of Interdependent Component Levels:* Components and attributes require a pairwise comparison.

a. The matrix value assigned to the relationship of component i to component j is equal to a_{ij}, while the intensity importance of factor j over i is equal to $a_{ji} = 1/ a_{ij}$.

b. Once the pairwise comparisons are complete, the local vector *w* is computed:

$$Aw = \text{GAMMA SIGN}_{max} w$$

Equation 8: Vector W

c. From this, a two stage algorithm will involve forming a new n x n matrix by dividing each element in a column by the sum of the elements. After this, sum the elements in each row and divide by the n elements in the row. See Equation 9.

$$w = \frac{\underset{i=1}{\overset{I}{\text{SUMMATION SIGN}}} \left(\frac{a_{ij}}{\text{SUMMATION SIGN } a_{ij}} \right)}{J}$$

Equation 9: Weighted Priority

where: w_i = weighted priority for component i

J = index number of columns (components)

I = index number of rows (components)

3) *Consistency Ratio Calculation:* This provides a numerical assessment of the evaluations. First, calculate the Consistency Index (CI) - see the AHP section for more details. Then, identify the random index from the Random Index (RI) table - see the AHP section for more details. From the Consistency Index and the Random index, the Consistency Ratio (CR) can be calculated.

$$CR = CI / RI$$

Equation 10: Random Index

If the calculated ratio is ≤ 0.10, consistency is considered satisfactory.

4) *Supermatrix Formation:* This allows a resolution of the effects of interdependence that exists between elements in the system. See Figure 6 and Figure 7.

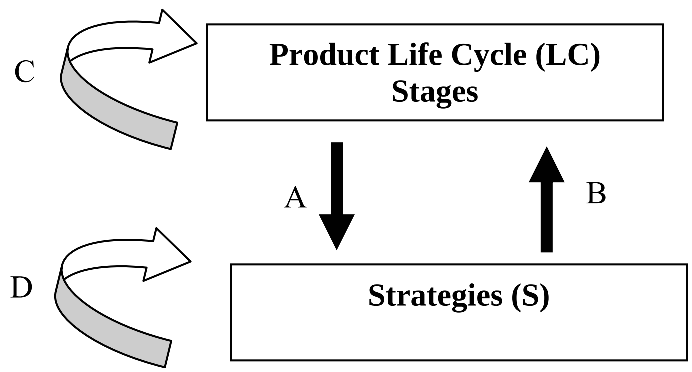

Figure 6: Network Model

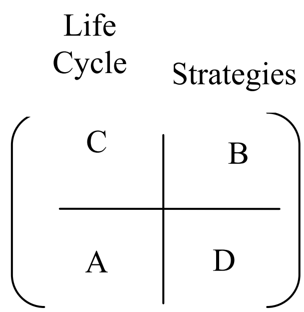

Figure 7: Matrix Model

Figures 6 and 7 are pictorial views of these three types of relationships in a supermatrix:

a. Independence from succeeding components

b. Interdependence among components

c. Interdependence between levels of components

5) Selection of Best Alternative: The selection of the best alternative should depend on the calculation of the desirability index (D_i) for alternative i. See Equation 11.

$$D_i = \sum_{j=1}^{J} \sum_{k=1}^{K} P_j A_{kj} S_{ikj}$$

Equation 11: D_i

where: P_j = relative importance weight of principle j

A_{kj} = relative importance weight for attribute k of principle j

S_{ikj} = relative impact of alternative i on attribute k of principle j

K_j = index set of attributes for principle j

J = index set of principles

2.7.3 Author's Focus for Analytical Processes

Analytical Hierarchy Processes (AHP) and Analytical Network Processes (ANP) both have their positive attributes and some areas of improvement. The author has chosen Analytical Network Processes (ANP) as the tool for this research. This is due to the nature of the observed environments. There are complex interrelationships within varies levels for varies attributes. As a result, ANP would provide the more realistic representation of the present environment.

CHAPTER THREE

OVERVIEW OF LEAN SIX SIGMA CRITICAL BUSINESS PROCESSES

In the prior chapter, the literature review was given of Lean, Six Sigma, Critical Business Processes, and Analytical Processes. It was imperative for the reader to understand each piece in order to make the conundrum complete. From this information, this dissertation will now provide detailed information supporting the use of Lean Six Sigma Critical Business Processes.

3.1 Concepts in Action

3.1.1 Lean

James Womack and Daniel Jones (1996) documented the concept of lean thinking in their book entitled Lean Thinking: Banish Waste and Create Wealth in Your Corporation. The strategy of Lean thinking is to eliminate wastes (Womack & Jones, 1996, p. 15). As stated by Womack and Jones (1996), "lean thinking . . . provides a way to do more and more with less and less", "provides a way to make work more satisfying", and it "provides a way to create new work rather than simply destroying jobs in the name of efficiency" (p. 15).

The author is very experienced with Lean. She has participated in at least three projects per year over the last twelve years focused on Lean. From her experiences, Lean is an excellent tool to use in order to eliminate waste.

Through the experiences of the author, team involvement is one of the keys to a successful Lean implementation. Projects that did not include team involvement were often misrepresented. Consequently, the Lean activities did not last and often ended during the first quarter of implementation. However, projects that incorporated the team concept demonstrated sustainable success. Because there is a shift in the paradigm, the team takes ownership of the changes. The team becomes change coordinators instigating Lean and eliminating waste.

The second key to successful Lean implementation is management involvement. Projects that did not engage management, management was too busy, or management did not see the value of participating sent a strong message to the employees. This message implied that, "change is not important". Conversely, with management participation, employees put forth an effort to execute and maintain the change. Lean is employed and waste is eliminated.

And the third key to successful Lean implementation is tracking the affects of the changes. Management provides goals for the group. This helps to sustain and improve the area. Tracking progress identifies if we are not meeting, meeting, or exceeding the set goals. Through tracking progress, activities that hinder and / or promote victory can be identified.

I have two factual project examples to illustrate unsuccessful and successful implementations of Lean. In the first project, quality and output are the main concerns. In view of that, a team gathered to discuss a Lean activity. The team consisted of eight people – Production Supervisor, two Production Associates, Manufacturing Engineer (the author), Engineering Technician, Development Engineer, Test Engineering, and Quality

Engineer. The majority of the group had heard Lean before, and had not participated in a Lean activity. The Manufacturing Engineer (the author) briefly reviewed Lean and its purpose within an hour workshop. After the workshop, the enthusiastic team plunged in and identified the wasteful activities. These wasteful activities were:

- Looking for tools
- Transporting the product
- Retesting products
- Reapplying tape to products
- Reattaching parts to the product

Process improvements were implemented which created a cost avoidance of $84K. In this project, the team was included, management was involved for a short period of time, and the changes were tracked. Due to decreased management involvement and no verification that changes were sustained, the cost avoidance was not maintained and began to slip.

The second project was also concerned with quality and output. The team consisted of eight people – Production Supervisor (the author), Production Associate, Manufacturing Engineer, Engineering Technician, Development Engineer, and Quality Engineer. The team gathered to discuss removing waste from the line. The majority of the group had heard and participated in a Lean activity. The Supervisor (the author) reviewed Lean and its purpose within an hour seminar. The seminar helped inform and reinforce their understanding of the concept. After the seminar, the team identified the wasteful activities. These activities included:

- Not effective tools

- Transporting the product
- Failed units
- Retesting products
- Reattaching parts to the product

Process improvements were implemented which created a cost avoidance of $32K. In this project, the team and management were involved. The Production Associate was familiar with the concepts, so she reported regularly any issues or ways to remove waste from the line. In addition, she was eager to try new things to help the productivity of the line. Because of the team effort, management was involved with tracking progress and cost avoidance was sustained.

3.1.2 Six Sigma

The focus of Six Sigma is to understand and eliminate the negative effects of variation in processes (Goldsby and Martichenko, 2005, p. 5). As stated by Nash, Poling, and Ward (2006), “the goal is to create near perfection through continuous improvement that aligns ‘the voice of the process’ with ‘the voice of the customer’” (p. 38).

The author is well educated on Six Sigma. She has involved herself in at least two projects per year over the last nine years. Six Sigma is an outstanding tool to eliminate variation. According to the author, Six Sigma can be influential in implementing sustainable changes when 1) the concepts are understood, 2) the tools are used correctly, and 3) changes are tracked.

The first item for success is to understand the Six Sigma concept. Six Sigma is more complex than Lean. Six Sigma is based on statistics that focuses on conformity – how many items meet the standards and how many items do not meet the standards. This can be a difficult concept to comprehend, but it is imperative that the team understands it. Once, the user of this concept grasps the idea of variation and defects, this is the first step to a victorious project. In the activities that the team did not understand the concepts, the team members only did what was asked of them. Subsequently, sustaining change was a challenge.

The second item is that the data collection and tracking tools must be used correctly. As discussed in Chapter 2, there are many tools. These tools are used at different times of the DMAIC process. The author has learned from work experience, all the data collection and tracking tools are very helpful, and should be used whenever needed. However, all the tools are not necessary to use all the time. It depends on the type of data being analyzed, the product being reviewed, and where you are in the process. Whenever projects used all assessment tools, it was a challenge to identify variability in a suitable timeframe. For instance, if projects spent more time trying to force the data into every tool, the true meaning of using the tools to identify variability was missed. The other projects where the team thought through the tools that worked for that scenario, there was a smooth transition from data collection to problem identification to problem resolution.

And the third item is tracking change. Similar to Lean, it is imperative to identify the affects of the changes on the process. Tracking the changes makes sure that the modifications improve the area.

Once more, the author provides two realistic models to exemplify unsuccessful and successful implementations of Six Sigma. In the first model, the number one concern was quality. The team consisted of four people – Supervisor (the author), Production

Associate, Production Technician, and Manufacturing Engineer. The entire team was not familiar with Six Sigma and had not participated in a Six Sigma activity. For this reason, the Supervisor (the author) had an hour session discussing Six Sigma. After the session, the team met and identified the variation in the process. The process was changed and the variation was minimized from a 25% failure rate to less than 5% failure rate. The team understood the concepts, used the tools correctly, and tracked the changes for a little while. Once the tracking diminished, so did the likelihood of keeping things changed. Unfortunately, the variation began to increase and at least six months later, the old process was back in place.

The second project was focused on improving quality and delivery, yet this project was a little different. The Supervisor, Manufacturing Engineer (the author), Test Engineering, Development Engineer, and Production Associate compiled the team. The majority of the team was familiar with Six Sigma, yet had not participated in a Six Sigma activity. For this reason, Six Sigma was reviewed for an hour. Following the refresher and learning session, the team actively looked for the item that caused the variation on the production line. The main item was identified and corrected. This reduced the failure rate from 20% to less than 1%. The understanding of the concepts, correct usage of the tools, and tracking the changes has maintained the failure rate at 3%.

3.1.3 Critical Business Processes

Critical business processes are necessary, and in need of change. In the end, this change will improve the overall process that either creates or produces a product or service.

The author is knowledgeable about critical business processes. With every project that she has either led or participated in over the last fourteen years, the author 's team had to identify the critical processes. These processes were mandatory because each project required improvement. The processes were reviewed, the critical path items were identified, and the bottlenecks were recognized. The team decided the item that provided the largest output with the most affordable investment – this was our critical process.

From the author's experiences, the identification of the critical process is essential. In all events, the critical processes were exposed, improvements were selected, and implementation was completed. As a consequence, a new critical process was established or the same critical process needed more work as the overall process was improved.

The author will review two true-life cases that identify the critical business processes. In the first case, the area of development was delivery. The team consisted of the Industrial Engineer (the author), five Production Associates, and Supervisor. Six out of the seven people were not familiar with critical processes. During a two hour colloquium, the Industrial Engineer (the author) trained the team. The assembly process was assessed and documented. From this class, the team revealed the critical business processes and the process improvements for the product. Initially, the assembly process required 24 days. After uncovering and revamping the critical business processes, the assembly time was condensed to 11 days.

The second case is presently being evaluated. The push is for better delivery and quality. Consequently, a team was created. The team was consisted of a Supervisor, one

Manufacturing Engineer, two Development Engineers, two Production Associates, Quality Engineer, one Greenbelt (the author), three Black Belts, Black Belt Champion, and Production Planner. Half the team was familiar with critical processes, and no training was provided. The process required the individuals learn from their teammates. With much review of the assembly process, the critical business process has been identified. The present process only allows the assembly of 60 units per day. However, demand requires as few as 10 units and as many as 115 units per day. Now the team is in the process of deciding the corrective action needed to improve the processes in order to meet the demand.

3.1.4 Analytical Network Process

Analytical Network Process (ANP) is a modeling tool that represents complex interrelationships among decision levels and attributes (Meade, 1997, p. 62). The author has learned that this process is a definite representation of the real world today. There are so many layers, each layer interacts, and each layer affects the other layers when it comes to making decisions.

The author has utilized ANP within this research. The results can be seen in Chapter 4.

*3.1.5 **Author's Focus for Lean Six Sigma Critical Business Processes Using an Analytical Network Process***

As discussed in Chapter 2 and 3, Lean activities eliminate waste, Six Sigma activities eliminate variation, critical business processes focus on those areas that need improvement and are critical to the process, and Analytical Network Process (ANP) models problems considering the interactions between levels. There is value for all companies to implement at least one of these tools.

The author has not been on a team, lead a team, or gotten feedback about a team that has joined and implemented all four concepts together. These concepts are Lean, Six Sigma, critical business processes, and Analytical Network Process (ANP). The feedback received and gathered by the author is that two concepts have been linked together. For example, Lean and Six Sigma, Lean and critical business processes, or Six Sigma and critical business processes. Yet all four tools, Lean, Six Sigma, critical business processes, and ANP, are not implemented together.

Since the author has participated on teams that have successfully implemented Lean, Six Sigma, or critical business processes, the author sees enormous value in joining these concepts with the ANP modeling tool. For this reason, the author has chosen to research and identify a technique that will combine all these concepts and tools; thereby, creating Lean Six Sigma Critical Business Processes using ANP.

3.2 Create Lean Six Sigma Critical Business Processes

As discussed in Chapter 2, a process model has inputs, mechanisms, calls, controls, and outputs. The author's experiences show that the purpose of this model is to visually explain the process. All activities are identified in a picture. The author used this format to model a quick overview of the Lean Six Sigma Critical Business Process in Figure 8.

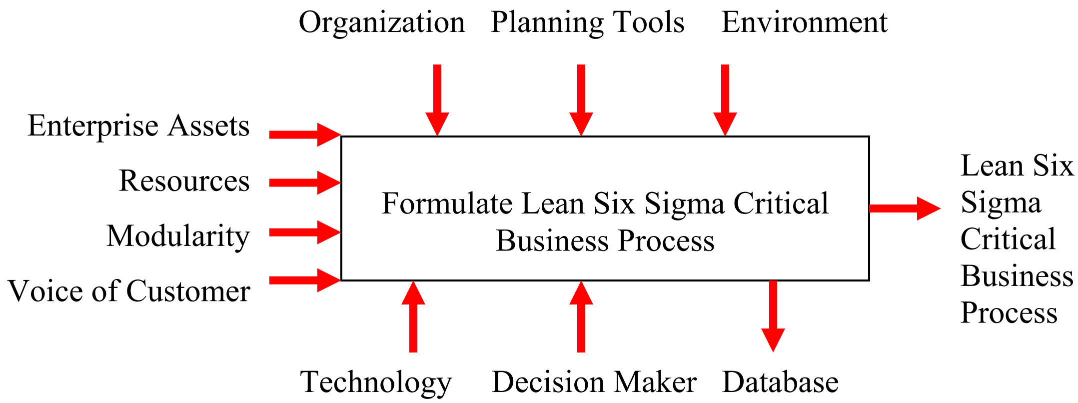

Figure 8: Formulate Lean Six Sigma Critical Business Process

The inputs for formulating a Lean Six Sigma Critical Business Process are the enterprise assets, resources, modularity and voice of the customer as documented by the author. The enterprise assets are the items available to pay debts – the opposite of debt. The resources are the tools (i.e. people, money, equipment, etc.) available for the process evaluation and improvement implementation. The modularity is the process consisting of many smaller units making up one large unit. The theory behind this is that there are a lot of small parts that make up the whole. The voice of the customer is what is important and value-add to the customer. This is what the customer is willing to pay for.

The mechanisms for developing a Lean Six Sigma Critical Business Process are the technology and decision maker. The technology consists of the expertise, machinery, and tools available to create the Lean Six Sigma Critical Business Process. The decision maker is the person involved with making the decisions in this process.

The call for this process is the database. The database holds, modifies, or creates the information for identifying the Lean Six Sigma Critical Business Process.

The controls are the organization, planning tools, and environment. These items are used to set the boundaries for devising a Lean Six Sigma Critical Business Process. The organization is the institution that makes up the business. The planning tools are the materials used to plan for the future or modifications. The environment is the atmosphere that surrounds the process.

The output is the Lean Six Sigma Critical Business Process. From the evaluation of the enterprise assets, resources, modularity, voice of the customer by the decision maker with the technology and databases available, the organization, planning tools, and environment are used to identify the Lean Six Sigma Critical Business Process.

This model should be utilized for the evaluation of other processes to identify its Lean Six Sigma Critical Business Process.

3.3 Lean Six Sigma Critical Business Process Selection

The author will articulate in writing the detailed review of selecting the Lean Six Sigma Critical Business Process.

From Meade's model of formulating an agile business process (1997, pp. 90-111), the author modified the model to relate to formulating a Lean Six Sigma Critical Business Process. This can be reviewed in Figure 9.

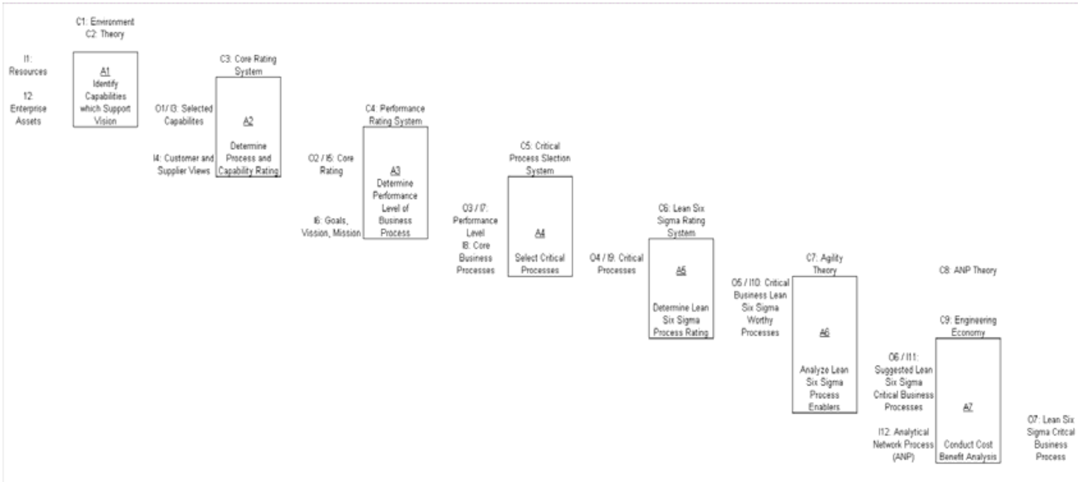

Figure 9: Formulate Lean Six Sigma Critical Business Process

Here is a review of the abbreviations in the different steps shown in this figure:

I = Input

C = Control

O = Output

A = Function Name

In summary, there are (12) inputs, (9) controls, (7) outputs, and (7) functional names, which are I1 through I12, C1 through C9, O1 through O7, A1 through A7 respectively.

The steps shown in Figure 9 identify how to improve the Lean Six Sigma Critical Business Process and provide a greater focus toward the vision and mission for the enterprise. This selection process is needed to distinguish the areas that are most critical to the process and in need of the most improvement. Ultimately, promoting a more effective and efficient change in business and enterprise.

In this chapter, the author will 1) identify capabilities which support the vision, 2) determine the process and capability rating, 3) establish the performance level of the business process, 4) select the critical processes, 5) produce the Lean Six Sigma process rating, 6) analyze the Lean Six Sigma process enablers, determinants, dimensions, and alternatives, and 7) conduct the cost / benefit analysis. These are all the steps to formulating a Lean Six Sigma Business Process shown in Figure 9.

*3.3.1 **Identify Capabilities which Support the Vision***

In order for the identification of Lean Six Sigma Critical Business Processes to benefit the enterprise, there must be a link between the company and its customers, the vision, and your process improvement. As the initiator of change, the company's capabilities, resources, goals, and objectives must be established and verified by the company and its customers. This verification can be found in employee knowledge, employee skills, management systems, and standards of the company while using resources such as land, labor, capital, equipment, and money. (Meade, 1997, p. 80).

Similar to Meade, the author surveyed each group for each project to identify the capabilities. The capabilities were defined and explained to each group as the requirements and objectives of the business process. Reference Table 9 for the survey and Figure 10 for the process model identifying the capabilities. The results from this survey can be found in Chapter 4 and Appendix D.

Table 9: **Survey for Capabilities**

	(Insert Company's Vision)
BP 1	*Insert Company's Business Process*
C1	Insert Company's Business Process Capability
C2	Insert Company's Business Process Capability
C3	Insert Company's Business Process Capability
BP 2	*Insert Company's Business Process*
C4	Insert Company's Business Process Capability
C5	Insert Company's Business Process Capability
C6	Insert Company's Business Process Capability
BP 3	*Insert Company's Business Process*
C7	Insert Company's Business Process Capability
C8	Insert Company's Business Process Capability
C9	Insert Company's Business Process Capability

(BP = Business Process; C = Capability)

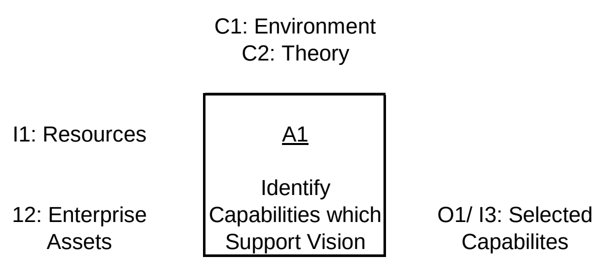

Figure 10: Process Model to Identify Capabilities

3.3.2 ***Determine Process and Capability Core Rating***

A core business process is difficult to imitate, provides competitive advantage, is perceived as a value by customers, and is mandatory to a process (Meade, 1997, p. 37). The core process can be performed effectively and efficiently to improve the overall process. The core business process is reviewed and receives a core rating. The core rating is simplifying a complex concept of what is essential to the enterprise, and there is a high probability that whatever is essential to the enterprise needs to be improved first (Meade, 1997, pp. 82-83).

Similar to Meade, the author collected data from each group for each project to determine the core ratings. The survey and the process model for identifying the core ratings are below. The results from this survey can be found in Chapter 4 and Appendix D.

Table 10: Survey for Process and Capability Core Rating

	Managerial System	Difficult to Imitate (1/0)	Provide Competitive Advantage (1/0)	Extendable to New Markets (1/0)	Customer Perceived Value (1/0)	Support (1)	Basic (2)	Critical (3)	Cutting Edge (4)	Total Score	Normalized Business Process Score
BP 1											
C1											
C2											
C3											
BP 2											
C4											
C5											
BP 3											
C6											
C7											

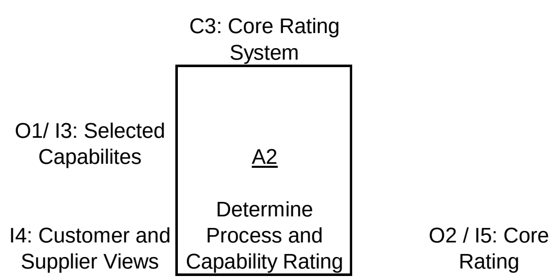

Figure 11: Process Model to Determine Process and Capability Core Rating

Here are the tasks that must be completed to get the core capability rating from the survey. First, identify the core capability criteria per capability by providing a score of 0 or 1. 0 means poor, while 1 means excellent. The options are:

- Difficult to imitate – Hard to duplicate
- Provide a competitive advantage – Gives the company an advantage in this market
- Extendable to new markets – Data gathered can be used in new or different markets
- Customer perceived value – Customer perceives value in this activity or product/process

After the core criteria are set, the second task is to categorize the capabilities by providing a score of 1 to 4. The options are as follows:

- Support – For internal customer usage (i.e. HR, legal, etc.); score of 1
- Basic – Skills and systems used that are common to business; necessary to do business; score of 2
- Critical – Skills and systems needed to provide business with a competitive advantage today; score of 3
- Cutting Edge – Skills and systems needed to provide business with competitive advantage tomorrow; score of 4

After the capabilities are categorized, total the scores at the capabilities level. Then, total the scores at the business process level. Finally, normalize the scores. Normalization is an average and is used to take into account the various quantities of capabilities per business process level. This normalized business process score is known as the core rating of each business process.

3.3.3 ***Determine Performance Level of Business Process***

In determining the performance level, the strategies, vision, and mission of the organization are compared to the performance of the process (Meade, 1997, p. 49). The evaluation is a result of how the process is achieving its goals. This step will answer the questions, 1) "Is it possible that the process can perform better?", and 2) "Is there room for improvement?"

The author gathered facts from each group for each project to determine the performance level of the business processes. Table 11 and Figure 12 show the survey and process model respectively. The results from this survey can be found in Chapter 4 and Appendix D.

Table 11: **Survey to Determine Performance Level of Business Processes**

	Capability	Cost	Time	Quality	Value	Ease of Implementation	Total Score	Normalized Business Process Score
	Weight							
BP 1								
C1								
C2								
C3								
BP 2								
C4								
C5								
BP 3								
C6								
C7								

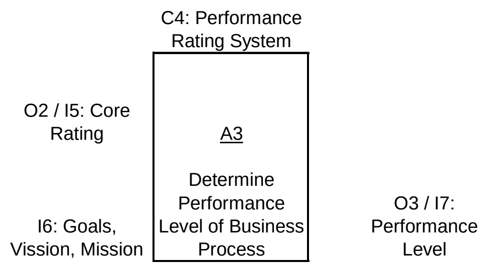

Figure 12: Process Model to Determine Performance Level of Business Process

The weights for the categories are determined. Each capability is graded using a ranking system of 1 to 5, with 1 meaning poor and 5 meaning excellent. And then, the weighting and scoring should be multiplied together, summed, and divided by the total number of performance categories to obtain the total score. Next, total the capabilities at the business process level. Lastly, normalize the scores per business process. This brings the data to a common scale.

*3.3.4 **Select Critical Processes***

The critical processes are the activities that are necessary to the process and require improvement. These critical processes are determined from the process and capability core rating and performance levels.

The author compiled the data from each group for each project to calculate the critical processes. The survey and process model is shown in Table 12 and Figure 13 respectively. The results from this survey can be found in Chapter 4 and Appendix D.

	Business Process	Core Rating	Core Rating Converted	Performance Indicators	Performance Indicator Converted	Total Score
BP 1						
BP 2						
BP 3						

Table 12: **Data form to Calculate Critical Processes**

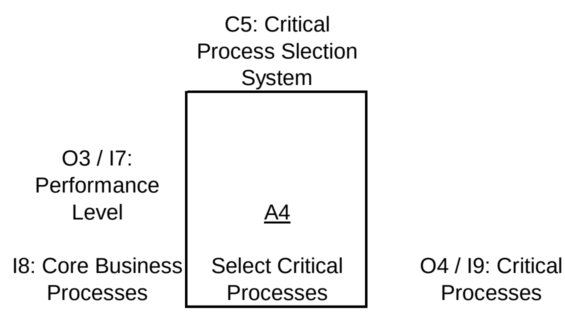

Figure 13: Process Model to Determine Critical Processes

If the core rating scores are calculated on a different scale than the performance level indicator scores, the values must be placed on the same scale by 1) identifying the least common multiple, 2) multiplying the core ratings by the highest possible number on the performance level indicators scale, and 3) multiplying the performance level indicators by the highest possible number on the core ratings scale. These new values will provide the converted core rating and performance indicators. As designated by Meade (1997), the total score is the subtraction of the core rating converted less performance indicator converted, and the highest score is the most critical process (p. 110).

3.3.5 Determine Lean Six Sigma Process Rating

After determining the critical business processes, use the Lean Six Sigma table shown below that was created by the author to determine the Lean Six Sigma Rating for the most critical business process and its capabilities.

The author received data from each group for each project to determine the Lean Six Sigma process ratings. The survey and the process model employed are below. The results from this survey can be found in Chapter 4 and Appendix D.

Table 13: Survey for Lean Six Sigma Process Rating

Description	Market and Customer Knowledge	Leadership Commitment	Planning and Project Selection	Training and Consulting	DMAIC and Lean Processes	Resources	Voice of Customer	Quality Function	Customer and Process Measures	Process Capability and Analysis	Process Improvement	Maintaining Improvements	Financial Results Measures	Recognition and Rewards	Total LSS Score	Item	LSS Priority Rating
BP																	
C																	
C																	
BP																	
C																	
C																	

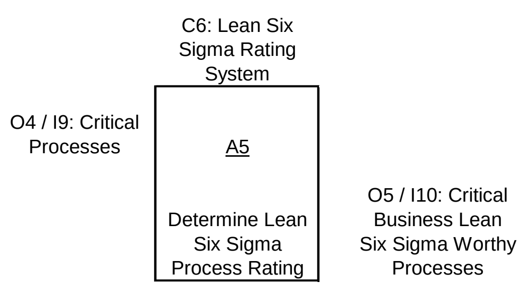

Figure 14: Process Model for Lean Six Sigma Process Rating

For the use of the survey shown in Table 13, rate each business process capability (C) from this rating system.

1	=	Little to No Relevance
2	=	Sometimes Relevant
3	=	Relevant
4	=	Very Relevant
5	=	Definite Relevance

After rating each capability, sum the values in the rows. After this, calculate the value for the business process by summing all the scores for each capability, sum all the capability values for the specific business process, divide by the total number of Lean Six Sigma characteristics, and take an average using the total number of capabilities. This will give the Lean Six Sigma (LSS) priority rating.

3.3.6 Analyze Lean Six Sigma Process Determinants, Dimensions, Enablers, and Alternatives

Now that the processes that are in most need of Lean Six Sigma improvements have been identified from the Lean Six Sigma rating process, a discussion of Analytical Network Process (ANP) is needed to understand the Lean Six Sigma process enablers.

As discussed earlier, the Analytical Network Process (ANP) model is used to represent dependencies and feedback that assists in making complex decisions with benefits, opportunities, costs, and risks, and combining them to obtain an overall outcome (Wikipedia, 2007, January 14). ANP is a non-linear network that allows for more complex interrelationships among decision levels and attributes (Meade, 1997, p. 62).

For this dissertation, the ANP model for Lean Six Sigma Critical Processes was created. The information was compiled from the groups for each project. Here are the figures for the Lean Six Sigma Critical Business Process and its process model.

Determinants of Lean Six Sigma

Cost (C)	Delivery (D)	Robustness (R)	Scope (S)	Risk (RI)

Dimensions of Lean Six Sigma

Relationships (Input)	Knowledge, training, and empowered workers (Mechanism)	Databases and Environment (Call)	Uncertainty, Change Agent, and Management (Control)	More effective and efficient company at a minimal cost, and happy customer (Output)

Lean Six Sigma Attribute Enablers

CEC	CCSP	D	PC	SDP
CB	PI	E	ROS	MCP
	ECCK		MM	PC
			AI	FCS

Lean Six Sigma Implementation Alternatives

Customer Demand (CD)	Current System (CS)	Implementation of Process / Product Improvements (II)

Figure 15: ANP Model of Lean Six Sigma Critical Business Process

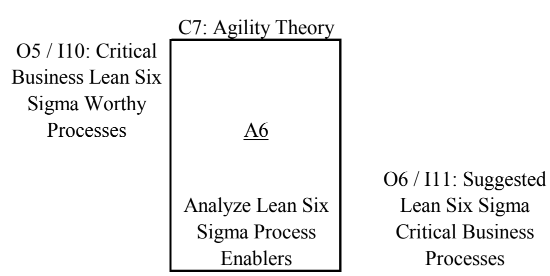

Figure 16: Process Model for Analyze Lean Six Sigma Process Enablers

This ANP model of the Lean Six Sigma Critical Business Process is similar to the ANP model for agile critical business processes (Meade, 1997, pp. 112-146). More details of Lean Six Sigma Critical Business Processes are explained in the following sections.

3.3.6.1 ***Determinants of Lean Six Sigma***

The determinants of Lean Six Sigma Critical Business Processes are the key factors that support the vision of the business and determine the present state of the business. From the evaluation of the group, the most important determinants for Lean Six Sigma Critical Business Processes are 1) cost (C), 2) delivery (D), 3) robustness (R), 4) scope (S), and 5) risk (RI). Listed below is a section of the ANP model of Lean Six Sigma Critical Business Processes showing these determinants.

Determinants of Lean Six Sigma

Cost (C)	Delivery (D)	Robustness (R)	Scope (S)	Risk (RI)

Figure 17: Process Determinants of Lean Six Sigma Critical Business Process

3.3.6.2 ***Dimensions of Lean Six Sigma***

The dimensions of Lean Six Sigma Critical Business Processes are features that affect and can be affected by the determinants. These items are direct inputs for the pairwise comparisons for the ANP model. In addition, these dimensions are needed to make the business flow smoothly, when utilized to their full potential and used properly.

The focus group used for this dissertation identified the following dimensions for the Lean Six Sigma Critical Business Process model:

- Relationships
- Knowledge, Training, and Empowered Workers
- Databases and Environment
- Uncertainty, Change Agent, and Management

- More effective and efficient Company at Minimal Cost

Here is a portion of the ANP model showing the dimensions of Lean Six Sigma Critical Business Processes.

Dimensions of Lean Six Sigma

Relationships (Input)	Knowledge, training, and empowered workers (Mechanism)	Databases and Environment (Call)	Uncertainty, Change Agent, and Management (Control)	More effective and efficient company at a minimal cost, and happy customer (Output)

Figure 18: Process Dimensions of Lean Six Sigma Critical Business Process

3.3.6.3 ***Lean Six Sigma Enablers***

The enablers of Lean Six Sigma Critical Business Processes are detailed descriptors for each dimension of Lean Six Sigma Critical Business Processes. The team, that was used to gather data for this dissertation, identified every enabler.

Here is a portion of the ANP model showing the enablers of Lean Six Sigma Critical Business Processes.

Lean Six Sigma Attribute Enablers

CEC	CCSP	D	PC	SDP
CB	PI	E	ROS	MCP
	ECCK		MM	PC
			AI	FCS

Figure 19: Enablers of Lean Six Sigma Critical Business Process

Each abbreviation shown in Figure 19 is identified in detailed in Table 14. This table gives the detailed description of the enablers for each dimension, and it also provides an applicable code. This code shown in the table is the abbreviation that will be used throughout this document for simplicity purposes.

Table 14: **Lean Six Sigma Attribute Enablers**

***Business Process*: Attribute Enablers**	**Code**
Relationships:	
Communication with Employees and Customers	CEC
Collaboration with other Businesses	CB
Knowledge, training, and empowered workers:	
Core Capability Strategic Planning	CCSP
Usage of Performance Information	PI
Captured Employee, Customer, and Competitor Knowledge	ECCK
Databases and Environment:	
Useful Database	D
Non-bias Environment	E
Uncertainty, Change Agent, and Management:	
Proficient at Change	PC
Reconfigurable Organizational Structure	ROS
Motivational Management	MM
Adaptable Information	AI
More effective and efficient company at a minimal cost, and happy customer:	
Sales (Cost / Savings) Documentation Process	SDP
Maintain Change Process	MCP
Greater Product Customization	GPC
Flexible Change System	FCS

3.3.6.4 Lean Six Sigma Implementation Alternatives

The implementation alternatives complete the ANP model for Lean Six Sigma Critical Business Processes. The alternatives are the best described by Meade as the specific projects to evaluate the different levels of the ANP model (Meade, 1997, pp. 125-126). In addition, the decision makers, used for this dissertation, described the Lean Six Sigma Implementation Alternatives as the options considered for successful implementation of activities that support the vision.

The determinants, dimensions, and enablers are compared in the ANP model. The results show the impact of the determinants, dimensions, and the enablers to the implementation alternatives. For a review, here is the final section of the ANP Model showing the alternatives of Lean Six Sigma Critical Business Processes.

Lean Six Sigma Implementation Alternatives

Customer Demand (CD)	Current System (CS)	Implementation of Process / Product Improvements (II)

Figure 20: Alternatives of Lean Six Sigma Critical Business Process

3.3.7 Conduct Cost / Benefit Analysis

After the ANP model is used to evaluate the relationships of the determinants, dimensions, enablers, and alternatives, a cost / benefit analysis is performed (Ostwald, 1992, pp. 369 & 375). This analysis shows the cost or benefit of implementing changes to the present system. Once again, these changes should support the vision and mission of the company and the business.

The author and the group, used to examine the different projects, analyzed the options to determine the cost or benefit to executing change. As with other companies, the standard return on investment and payback period are used to evaluate if the changes are worthwhile. Here is the process model employed, return on investment equation, and payback period equation used to evaluate the suggested changes.

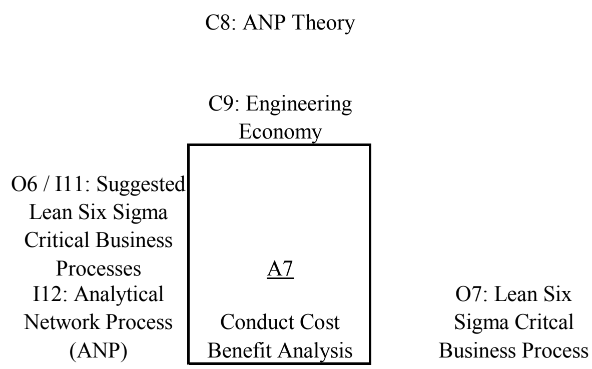

Figure 21: Process Model for Conduct Cost / Benefit Analysis

Return On Investment (ROI) = (Dollar Return / Initial Investment) X 100

Equation 12: Return on Investment

Payback Period = Net Investment / Annual Earnings

Equation 13: Payback Period

This chapter provided an overview of the Lean Six Sigma concepts, how to create a Lean Six Sigma Critical Business Process, and how to select the Lean Six Sigma Critical Business Processes that will have the most impact on improving the business.

From this information, the author will now provide specific project information utilizing the surveys, equations, and process models discussed in Chapters 2 and 3.

CHAPTER FOUR

GUIDE FOR IDENTIFYING LEAN SIX SIGMA CRITICAL BUSINESS PROCESSES

Three projects are used to test and apply the Lean Six Sigma Critical Business Process methodologies. For purposes of simplicity, only Project 1 is discussed in detail. More information concerning Projects 1, 2, and 3 can be found in Appendix D.

4.1 Listing of Capabilities

In Project 1, the author evaluates the development and product release strategy for a signaling product. The purpose of the product is to reduce downtime by signaling breakdowns and material shortages. In addition, this product improves safety by alerting the operator immediately of any hazards (Rockwell Automation, 2007). Through efficient control and automatic monitoring, safety and minimal downtime is brought to the manufacturing process.

Here is Table 15 that provides the capabilities of the department that affect the vision.

Table 15: Worksheet 1 – List of Capabilities

	Company ABC's vision is focused on being the most valued global provider of power, control and information solutions.
BP 1	*Create Business Plan*
C1	Excel in the vision strategy
C2	Create a niche or better value with existing product / process for customer
C3	Identify market opportunities

Table 15 - continued

BP 2	*Identify Needed Resources*
C4	Educate the product / process provider
C5	Gather costs for resources
BP 3	*Implement and Manage Business Plan and Performance*
C6	Track sales
C7	Track financial impact to department
BP 4	*Market to Others*
C8	Grab market opportunities
BP 5	*Design Products / Processes*
C9	Create plan from concept to Available For Sale (AFS)
C10	DFMA and PDFMA
BP 6	*Acquire , Develop, and Maintain Human Assets, Property, and Equipment*
C11	Relationship with vendors and business
BP 7	*Get Orders*
C12	Identify catalog specific items
C13	Acquire component parts
C14	Identify process
BP 8	*Assemble Product / Complete Process to Existing and Future Orders*
C15	Create at production facility
C16	Customer training
C17	Trouble shooting
C18	Train production facility
BP 9	*Manage Product*
C19	Process for accessing product
C20	Process for accessing financial impact to department

(BP = Business Process; C = Capability)

Business processes (BP) are the activities needed for the development and release of Product 1. These business processes are listed above as items BP1 through BP9. The capabilities (C) are the requirements and objectives of each business process. These capabilities are listed above as items C1 through C20.

4.2 <u>Process and Capability Core Rating</u>

As a team, the group rated each capability per business plan collectively using the survey discussed in Chapter 3. From this survey, the results for Project 1 are in Table 16.

Table 16: **Worksheet 2 – Process and Capability Core Rating**

	Managerial System	Difficult to Imitate (1/0)	Provide Competitive Advantage (1/0)	Extendable to New Markets (1/0)	Customer Perceived Value (1/0)	Support (1)	Basic (2)	Critical (3)	Cutting Edge (4)	Total Score	Normalized Business Process Score
BP 1	*Create Business Plan*									21	7
C1	Excel in the vision strategy	1	1	1	0				4	7	
C2	Create a niche or better value with existing product / process for customer	1	1	1	1				4	8	
C3	Identify market opportunities	0	1	1	0				4	6	
BP 2	*Identify Needed Resources*									6	3
C4	Educate the product / process provider	0	0	1	0		2			3	
C5	Gather costs for resources	0	0	1	0		2			3	
BP 3	*Implement and Manage Business Plan and Performance*									6	3
C6	Track sales	0	0	1	0		2			3	
C7	Track financial impact to department	0	0	1	0		2			3	
BP 4	*Market to Others*									5	5
C8	Grab market opportunities	0	1	1	0			3		5	
BP 5	*Design Products / Processes*									7	4
C9	Create plan from concept to Available For Sale (AFS)	0	1	1	0		2			4	
C10	DFMA and PDFMA	0	1	1	0	1				3	
BP 6	*Acquire , Develop, and Maintain Human Assets, Property, and Equipment*									3	3
C11	Relationship with vendors and business	0	0	1	0		2			3	
BP 7	*Get Orders*									11	4
C12	Identify catalog specific items	0	1	0	1		2			4	
C13	Acquire component parts	0	1	0	0		2			3	
C14	Identify process	0	1	1	0		2			4	
BP 8	*Assemble Product / Complete Process to Existing and Future Orders*									19	5
C15	Create at production facility	0	1	0	1		2			4	
C16	Customer training	0	1	0	1			3		5	
C17	Trouble shooting	0	1	1	0				4	6	
C18	Train production facility	0	1	1	0		2			4	
BP 9	*Manage Product*									10	5
C19	Process for accessing product	0	1	1	0			3		5	
C20	Process for accessing financial impact to department	0	1	1	0			3		5	

(BP = Business Process; C = Capability)

Discussed in Chapter 3, the core capability criteria from Table 16 were identified by rating each capability with a score of 0 or 1. This includes “Difficult to Imitate”, “Provide Competitive Advantage”, “Extendable to New Markets” and “Customer Perceived Value”. Then, the core criteria set was identified with a score of 1 to 4. This is incorporated for “Support”, Basic”, “Critical”, and “Cutting Edge”.

From this activity, the business processes with the highest scores are BP1 - Create Business Plan, BP4 - Market to Others, BP8 - Assemble Product / Complete Process to Existing and Future Orders, and BP9 - Manage Product.

4.3 Performance Level

After identify the core ratings, the performance level is evaluated. This step will answer these questions, “Is it possible that the process can perform better?”, and “Is there room for improvement?”

The decision makers, evaluated for this dissertation, selected cost, time, quality, value, and ease of implementation as the criteria that are important to both the business and the vision of the company. These items are used to rate how the process is performing within the business.

Here are the categories of performance and their weighting factors. See Table 17 and Table 18.

Table 17: **Categories of Performance**

Cost (C)	Time (T)	Quality (Q)	Value (V)	Ease of Implementation (E)
C1: Development	T1: Development	Q1: Product Performance	V1: Perceived	E1: Simple
C2: Manufacturing	T2: Manufacturing	Q2: Product Features	V2: Actual	E2: Difficult
C3: Tooling	T3: Lead Time	Q3: Product Reliability	V3: Usable	E3: Loss / Profit
C4: Value Add	T4: Repeatability	Q4: Manufacturing Process	V4: Needed	
C5: Selling Price	T5: Promise Date Delivery	Q5: Delivery Process	V5: Extra	
C6: Advertisement		Q6: Components	V6: Add to product	
C7: Distribution		Q7: Serviceability	V7: Loss / Profit	
C8: Service		Q8: Aesthetics		
C9: Loss / Profit				

Table 18: **Worksheet 3 – Performance Measure Weights**

Dimension	Weight
Cost (C)	0.2
Time (T)	0.2
Quality (Q)	0.2
Value (V)	0.2
Ease of Implementation (E)	0.2
Total	**1.00**

The author only uses the main categories for performance. The subcategories are provided for more details. In addition, the categories are equally weighted. This shows that there is equivalent importance of each category to the business. Overall, these categories reiterate the vision of the company, "focused on being the most valued global provider of power, control and information solutions".

Now, the performance level can be calculated from the categories and their applicable weighting factors. From the survey used in Chapter 3, here are the results for Project 1.

Table 19: **Worksheet 4 – Performance Indicators**

	Capability	Cost	Time	Quality	Value	Ease of Implementation	Total Score	Normalized Business Process Score
	Weight	0.2	0.2	0.2	0.2	0.2	1.00	
BP 1	*Create Business Plan*						11.6	3.9
C1	Excel in the vision strategy	4	4	5	5	4	4.4	
C2	Create a niche or better value with existing product / process for customer	3	3	5	3	3	3.4	
C3	Identify market opportunities	4	3	4	5	3	3.8	
BP 2	*Identify Needed Resources*						8.6	4.3
C4	Educate the product / process provider	4	4	5	5	5	4.6	
C5	Gather costs for resources	4	4	4	4	4	4	
BP 3	*Implement and Manage Business Plan and Performance*						7.4	3.7
C6	Track sales	4	4	4	4	4	4	
C7	Track financial impact to department	4	3	4	3	3	3.4	
BP 4	*Market to Others*						3.2	3.2
C8	Grab market opportunities	2	3	4	5	2	3.2	
BP 5	*Design Products / Processes*						6	3.0
C9	Create plan from concept to Available For Sale (AFS)	2	2	4	4	3	3	
C10	DFMA and PDFMA	2	2	3	4	4	3	
BP 6	*Acquire , Develop, and Maintain Human Assets, Property, and Equipment*						4.6	4.6
C11	Relationship with vendors and business	5	4	5	5	4	4.6	
BP 7	*Get Orders*						12.4	4.1
C12	Identify catalog specific items	5	4	5	5	5	4.8	
C13	Acquire component parts	4	3	5	4	4	4	
C14	Identify process	3	4	3	4	4	3.6	
BP 8	*Assemble Product / Complete Process to Existing and Future Orders*						14	3.5
C15	Create at production facility	2	4	2	2	2	2.4	
C16	Customer training	3	4	5	5	4	4.2	
C17	Trouble shooting	4	2	5	5	3	3.8	
C18	Train production facility	2	3	4	5	4	3.6	
BP 9	*Manage Product*						6	3.0
C19	Process for accessing product	3	3	3	3	3	3	
C20	Process for accessing financial impact to department	3	3	3	3	3	3	

(BP = Business Process; C = Capability)

As reviewed in Chapter 3, the weights are used, the capabilities are scored, and the overall score is calculated. Here are the details behind calculating the performance levels in Table 19.

First, the weights from Table 18 are used for the performance measure and added to the performance indicator Table 19.

Second, the capabilities are then scored on a scale of 1 to 5, with 1 meaning poor and 5 meaning excellent. For Project 1, the capability C1 "Excel in the Vision Strategy" scored a "5" because it has a direct tie or is an excellent supporter for "Quality". All the scores for the capabilities are shown in Table 19.

Third, the weighting and scoring should be multiplied together then added and divided by the total number of categories to obtain the total score. However, if the weights are equal, you can use the scores as they are identified. Here is an example of both scenarios.

Table 20: **Performance Indicators with Equal Weights**

	Capability	Cost	Time	Quality	Value	Ease of Implementation	Total Score
	Weight	0.2	0.2	0.2	0.2	0.2	1.00
BP 1	*Create Business Plan*						11.6
C1	Excel in the vision strategy	4	4	5	5	4	4.4
C2	Create a niche or better value with existing product / process for customer	3	3	5	3	3	3.4
C3	Identify market opportunities	4	3	4	5	3	3.8

In Project 1, the weighted values were 0.2 for the categories of performance - cost, time, quality, value, and ease of implementation, as shown in Table 20. For this reason, the author used the scores given by the group, summed these scores, and divided by the total performance categories to get the total score for each capability. For example, capability C1 “Excel in the Vision Strategy” scored 4 for cost, 4 for time, 5 for quality, 5 for value and 4 for ease of implementation. The sum of these scores is 22. Since there are 5 categories of performance – cost, time, quality, value, and ease of implementation, the score 22 is divided by 5 which gives a score of 4.4.

Table 21: **Performance Indicators with Unequal Weights**

	Capability	Cost	Time	Quality	Value	Ease of Implementation	Total Score
	Weight	**0.4**	**0.05**	**0.4**	**0.05**	**0.1**	**1.00**
BP 1	*Create Business Plan*						2.43
C1	Excel in the vision strategy	4	4	5	5	4	0.89
C2	Create a niche or better value with existing product / process for customer	3	3	5	3	3	0.76
C3	Identify market opportunities	4	3	4	5	3	0.78

For all projects used for this dissertation, the weights were equal. For assistance with future projects whose performance categories that are not rated equal, Table 21 provides an example. In Table 21, the weights are 0.4 for cost, 0.05 for time, 0.4 for quality, 0.05 for value, and 0.1 for ease of implementation. Using capability C1 “Excel in the Vision Strategy”, it was scored 4 for cost, 4 for time, 5 for quality, 5 for value and 4 for ease of implementation. The sum of the scores multiplied by the applicable weights is 4.45. Since there are 5 categories of performance – cost, time, quality, value, and ease of implementation, the score 4.45 is divided by 5 which gives a score of 0.89.

Fourth, normalize the scores per business process. As discussed in Chapter 3, normalization takes into account various quantities of capabilities per business process by taking an average.

Table 22: **Performance Indicators with Normalized Scores**

	Capability	Total Score	Normalized Business Process Score
	Weight	**1.00**	
BP 1	*Create Business Plan*	11.6	3.9
C1	Excel in the vision strategy	4.4	
C2	Create a niche or better value with existing product / process for customer	3.4	
C3	Identify market opportunities	3.8	

The total score for Project 1 business process BP1 "Create Business Plan" capability C1, C2, and C3 was 4.4, 3.4, and 3.8 respectively. After calculating the total scores for each capability, sum the total scores. This provides a total score of 11.6 for business plan BP1. For each business plan, divide the total score by the number of capabilities available per business plan. For BP1, there are 3 capabilities. As a result, the normalized score is 11.6 divided by 3 that gives a normalized score of 3.9.

The business processes with the lowest scores are BP4 - Market to Others, BP5 - Design Products / Processes, and BP9 - Manage Product. Review Table 19 for details.

4.4 Critical Processes

From the prior sections, get the normalized business process scores, which are the core ratings for Worksheet 2 and the performance indicators for Worksheet 4. Record this information onto Worksheet 5. See Table 23.

Since the Core Rating score is calculated from 1 to 8 and the Performance Indicator score is calculated from 1 to 5, these values must be placed on the same scale by normalizing the scores. The least common multiple is 40, so multiply the Core Ratings by 5 and the Performance Indicators by 8. This will provided the converted Core Rating and converted Performance Indicators.

The end result is the total score. This score is the subtraction of the Core Rating Converted less Performance Indicator Converted, and the highest score is the most critical process.

Table 23: **Worksheet 5 – Critical Process Determination**

	Business Process	Core Rating	Core Rating Converted	Performance Indicators	Performance Indicator Converted	Total Score
BP 1	Create Business Plan	7	35	3.9	31	4
BP 2	Identify Needed Resources	3	15	4.3	34	-19
BP 3	Implement and Manage Business Plan and Performance	3	15	3.7	30	-15
BP 4	Market to Others	5	25	3.2	26	-1
BP 5	Design Products / Processes	4	18	3.0	24	-7
BP 6	Acquire , Develop, and Maintain Human Assets, Property, and Equipment	3	15	4.6	37	-22
BP 7	Get Orders	4	18	4.1	33	-15
BP 8	Assemble Product / Complete Process to Existing and Future Orders	5	24	3.5	28	-4
BP 9	Manage Product	5	25	3.0	24	1

(BP = Business Process)

For further explanation, here is a review of business plan BP1 – Create Business Plan from Table 23. From Worksheet 2, the core rating is 7. From Worksheet 4, the performance indicator is 3.9. To normalize the scores, the core rating of 7 is multiplied by 5 giving a converted core rating of 35 and the performance indicator of 3.9 is multiplied by 8 giving a converted performance indicator of 31. From these calculations, the performance indicator converted score of 31 is subtracted from the core rating converted score of 35, giving a total score of 4 which is the critical process score.

In calculating the scores shown in Table 23, it is determined that the most critical process is BP1 - Create Business Plan - with a total score of 4.

4.5 Lean Six Sigma Process Rating

From the group, the author collected data for each project to determine the Lean Six Sigma rating. The ratings for each business process capability were recorded into Worksheet 6 – see Table 24.

After rating each capability, the scores were normalized. Each value in the rows was totaled for each capability. Each value in the column was averaged for each business plan by taking the sum of the capabilities for the business plan and dividing by the number of Lean Six Sigma rating categories. Each business plan value was averaged per the number of capabilities. This is the Lean Six Sigma (LSS) priority rating presented in Table 24.

Table 24: **Worksheet 6 – Lean Six Sigma Rating**

Description	Market and Customer Knowledge	Leadership Commitment	Planning and Project Selection	Training and Consulting	DMAIC and Lean Processes	Resources	Voice of Customer	Quality Function	Customer and Process Measures	Process Capability and Analysis	Process Improvement	Maintaining Improvements	Financial Results Measures	Recognition and Rewards	Total LSS Score	Item	LSS Priority Rating
Create Business Plan															10		3.3
Excel in the vision strategy	3	5	1	3	1	4	4	4	4	1	4	4	3	1	42	1	
Create a niche or better value with existing product / process for customer	3	4	3	3	3	2	5	4	5	1	4	4	4	1	46	1	
Identify market opportunities	3	5	4	5	2	3	4	4	5	1	4	4	4	1	49	1	
Manage Product															7		3.4
Process for accessing product	2	4	4	4	4	4	2	4	2	4	4	4	5	1	48	1	
Process for accessing financial impact to department	1	5	4	4	4	3	2	4	2	3	4	4	5	1	46	1	

Here is a review of business plan BP9 – Manage Product. The ratings are given in Table 24 for the capabilities. The total score for the capability C19 "Process for Accessing Product" is 48 and for capability C20 "Process for Accessing Financial Impact to Department" is 46. The total score for the business process BP9 "Manage Product" is rounded up to 7, which is the total score 48 for C19 plus the total LSS score 46 for C20 divided by 14 rating characteristics for this project. The final LSS priority rating is 3.4, which is the total LSS score rounded up to 7 for the business plan divided by the 2 capabilities.

From Worksheet 6, it is identified that BP1 "Create Business Plan" is most important to the team and the enterprise because it has the lowest score. This is the business process that is in need of most Lean Six Sigma improvement.

4.6 Lean Six Sigma Process Determinants, Dimensions, and Enablers

The Analytical Network Process (ANP) model used to identify Lean Six Sigma Critical Business Processes is shown in Chapter 3 on Figure 15. The decision makers used for this dissertation produced this model.

In this model, it shows the relationship of Lean Six Sigma determinants, Lean Six Sigma dimensions, Lean Six Sigma enablers, and Lean Six Sigma alternatives. As in any

ANP model, it represents problems of systems between levels known as "systems-with-feedback" (Yurdakul, 2003, p. 2503). This means that a level may both dominate and be dominated, directly or indirectly, by other decision attributes and levels (Meade, 1997, p. 62). From the author's observations, the relationships can be from the determinants down to the alternatives (top down) and from the alternatives to the determinants (bottom up).

In addition, this ANP process model requires the documentation of the relationships of one level to another. Here are the relationships of the determinants, dimensions, and enablers for the business process BP1 "Create Business Plan" in Table 25. For the Lean Six Sigma Relationships of the determinants, dimensions, and enablers for the other business processes, see Appendix A.

Table 25: **Lean Six Sigma Relationships of Determinants, Dimensions, and Enablers**

	Create Business Plan	**Development of Short and Long Term Goals**	**Already In Place**	**Interested in Cost (C), Delivery (D), Robustness (R), Scope (S), or Risk (RI)**	**Disregard**
Input	Relationships				
	Communication with Employees and Customers	Is there communication between the employee, customers, and business to discuss the needs of customers and the business capabilities?		C/D/R/S/RI	
	Collaboration with other Businesses	Is there a system in place to easily work with other businesses to enhance your business?		C/D/R/S/RI	

Table 25 - continued

Mechanism	Knowledge, training, and empowered workers				
	Core Capability Strategic Planning	Is the company meeting its capability?		C/S	
	Usage of Performance Information	How well is the business performing?		C/D/R/S	
	Captured Employee, Customer, and Competitor Knowledge	Is this knowledge captured? If so, how?		C/D/R/S/RI	
Call	Databases and Environment				
	Useful Database	Are there databases available that has this information or can acquire it?		C/D/R/S	
	Non-bias Environment	Is the environment conducive to change?		C/D/R	
Control	Uncertainty, Change Agent, and Management				
	Proficient at Change	How well does the business handle change?		C/D/R/S/RI	
	Reconfigurable Organizational Structure	How agile is the business to change?		C/D/R	
	Motivational Management	How prepared is management for change?		R/RI	
	Adaptable Information	How adaptable is the data and data collection with change?		C/D/R/S/RI	
Output	More effective and efficient company at a minimal cost, and happy customer				
	Cost Savings Documentation Process	Is there are documentation process in place for tracking savings?		C/S	
	Maintain Change Process	Is there a system in place to maintain the changes?		S	
	Greater Product Customization	Is there a system in place to handle high product customization?		C/D/R/S/RI	
	Flexible Change System	Is there a system in place to change quickly due to customization?		C/D/R/S/RI	

In Chapter 2 and 3, there were detailed discussions about process models. Each process model has an input, mechanism, call, control, and output. Each dimension is related to the process model to identify the Lean Six Sigma Critical Business Processes. This can be seen on the left side of Table 25. Now, let's discuss the relationships between the process model, determinants, dimensions, and enablers.

Refer to the section entitled "Mechanism". The mechanism for this process is the dimension "Knowledge, Training, and Empowered Workers". This dimension has the capabilities "Core Capability Strategic Planning (CCSP)", "Usage of Performance Information (PI)", and "Captured Employee, Customer, and Competitor Knowledge (ECCK)". In order to identify the short and long term goals, questions are asked for each enabler. For these enablers, it is important to identify "is the company meeting its goals", "how well is the business is performing", and "is the knowledge captured". These questions were posed to the group. The answers to these questions let the decision makers know there is no system in place. For this reason, no items are disregarded. When analyzing other groups for other projects, the results will depend on the business and the processes.

As seen above in Table 25, all enablers are identified, should be in place, and should not be disregarded because each item is important to the process. After identifying all characteristics that will remain, the affects of the determinants on the enablers are rated. Here are the ratings from the group. For the enabler "Core Capability Strategic Planning (CCSP)", this item has an affect on cost (C) and scope (S) of this business process. For the enabler "Usage of Performance Information (PI)", this item has an affect on cost (C), delivery (D), robustness (R), and scope (S). For the enabler "Captured Employee, Customer, and Competitor Knowledge (ECCK)", this item has an affect on cost (C), delivery (D), robustness (R), scope (S), and risk (RI).

All of the above ratings specify if there is a connection between the Lean Six Sigma determinants, dimensions, and enablers. After their relationships are determined in the ANP model, the detailed comparisons begin.

4.6.1 Conduct Pairwise Comparisons

The Analytical Network Process (ANP) model is used to determine the best Lean Six Sigma Critical Business Process that will provide the largest impact to the business, similar to the agile business process identified by Meade (1997, pp. 127-140). For simplicity, the author will focus on the Lean Six Sigma dimension “Uncertainty, Change Agent, and Management”.

As discussed in Chapter 2, creating a comparison matrix must be done first. This matrix includes the intensity importance of factor i over factor j. For the dimension “Uncertainty, Change Agent, and Management (UCAM)” in support of the business process “Create Business Plan”, it has four enablers. The four enablers are “Proficient at Change (PC)”, “Reconfigurable Organizational Structure (ROS)”, “Motivational Management (MM)”, “and “Adaptable Information (AI)”.

The author has worked with comparing factors and evaluating data for thirteen years. For this reason, the author uses techniques to eliminate redundancies, discrepancies, and inconsistencies. Some of the successful techniques used with various projects are normalizing, ranking, weighting, averaging, control charting, and plotting.

The author and the group ranked the enablers by their importance and weighted each enabler in order to eliminate inconsistent ratings, including the sum of the rankings. The largest numbers are used to rank the most important factor(s). See Table 26.

Table 26: **Enabler Ranking**

	Ranking by Order
PC	4
ROS	3
MM	2
AI	1
TOTAL	10

where PC = Proficient at change
ROS = Reconfigurable organizational structure
MM = Motivational management
AI = Adaptable information

Here is an overview of Table 26 for the dimension "Uncertainty, Change Agent, and Management (UCAM)" with the enablers ranked. There are four enablers - "Proficient at Change (PC)", "Reconfigurable Organizational Structure (ROS)", "Motivational Management (MM)", "and "Adaptable Information (AI)". Since there are four enablers, there will only be a ranking from 1 to 4. In this grouping of enablers, PC is most important (rated 4), ROS is next important (rated 3), MM is next important (rated 2), and AI is least important (rated 1) for the dimension UCAM. The sum of these values (4+3+2+1) is 10.

Given the rankings, the weighted values can be calculated by dividing each enabler value by the sum of the enabler rankings. Verify that the total of these weighted values is 1.00. See Table 27.

Table 27: **Weighted Values**

	Weighted Value
PC	0.4
ROS	0.3
MM	0.2
AI	0.1
TOTAL	1.0

This is a summary of Table 27 for the dimension UCAM with its enabler weighted values. There are four enablers – PC, ROS, MM, and AI. As shown in Table 26, the total for the enablers is 10. The weighted values are calculated as such, PC is the ranking of 4 divided by the total of 10 (which gives a total of 0.4), ROS is the ranking of 3 divided by the total of 10 (which gives a total of 0.3), MM is the ranking of 2 divided by the total of 10 (which gives a total of 0.2), and AI is the ranking of 1 divided by the total of 10 (which gives a total of 0.1) for the dimension UCAM. The sum of these values (0.4+0.3+0.2+0.1) is 1.0 confirming all enablers are ranked correctly and included. The result to this activity is the weighted values for all the enablers.

From the weighted values, compare each enabler. This can be accomplished by dividing the weighted value of the enabler identified on the far left column by the enabler at the top row. See Table 28.

Table 28: **Favorability**

Favorability	PC	ROS	MM	AI
PC	1.00	1.33	2.00	4.00
ROS	0.75	1.00	1.50	3.00
MM	0.50	0.67	1.00	2.00
AI	0.25	0.33	0.50	1.00

Here is a rundown of Table 28 for the dimension UCAM with the favorability ratings of the enablers. There are four enablers – PC, ROS, MM, and AI. As shown in Table 27, the weighted values for enabler PC is 0.4, ROS is 0.3, MM is 0.2, and AI is 0.1 for the dimension UCAM. For simplicity, let's review the row PC. PC is 0.4 divided by PC which is 0.4, giving a favorability rating of 1.0. PC is 0.4 divided by ROS which is 0.3, giving a favorability rating of 1.33. PC is 0.4 divided by MM which is 0.2, giving a favorability rating of 2.00. PC is 0.4 divided by AI which is 0.1, giving a favorability rating of 4.00. The outcome to this activity is the favorability ratings for all the enablers to each other.

The favorability rating facilitates the identification of the intensity rating values. Listing the ratings from high to low and providing an intensity number to each rating can fulfill this. To increase accuracy, the values in Table 28 that are 1.0 or greater will be recorded via the intensity number rating key, while the inverse values will be recorded for those items that are less than 1.0 on the comparison matrix. See Table 29 for the intensity number rating key.

Table 29: **Intensity Number Rating Key**

Score	Intensity Number
4	5
3-3.99	4
2-2.99	3
1-1.99	2

Here is a review of Table 29 for the dimension UCAM with the intensity rating values for the enablers. There are four enablers – PC, ROS, MM, and AI. In Table 29, there are several ranges of values. The highest value is 4.0, which gives an intensity value of 5 (one greater than its lowest value 4). The next values range from 3.0 to 3.99, which gives an intensity value of 4 (one greater than its lowest value 3). The next values range from 2.0 to 2.99, which gives an intensity value of 3 (one greater than its lowest value 2). The next values range from 1.0 to 1.99, which gives an intensity value of 2 (one greater than its lowest value 1). The values that are less than 1 are evaluated as an inverse value that can be seen in Table 30. The product of this activity is the intensity number rating key for the enablers.

As a result of Table 28 and Table 29, Table 30 is configured.

Table 30: **Comparison Matrix**

Uncertainty, Change Agent, and Management	PC	ROS	MM	AI
PC	1.00	2.00	3.00	5.00
ROS	0.50	1.00	2.00	4.00
MM	0.33	0.50	1.00	3.00
AI	0.20	0.25	0.33	1.00
TOTAL	2.03	3.75	6.33	13.00

To maximize the understanding of the reader, let's review the row PC from Table 30. As discussed earlier, the values that are 1.0 or greater are compared to the intensity number rating key Table 29, and the values that are less than 1.0 are the inverse values recorded onto Table 30. Additionally, any value compared to itself is always 1.0. Here are the details.

PC compared to PC is 1.0 from Table 28. Given the rules identified for this dissertation, the value placed into the comparison matrix is 1.00. PC compared to ROS is 1.33 from Table 28. On Table 29, the value for the comparison matrix is 2.00. PC compared to MM is 2.0 from Table 28. On Table 29, the value to input onto the comparison matrix is 3.00. PC compared to AI is 4.0 from Table 28. On Table 29, 5.00 is the value for the comparison matrix. Here is an example of the inverse. ROS compared to PC is 0.75 from Table 28. Since ROS compared to PC is the inverse of PC compared to ROS, this value is 0.50, 1 divided by 2.00, which is the comparison matrix value for PC compared to ROS.

These comparisons must be completed for every Lean Six Sigma dimension and its enablers. The result to this activity is the comparison matrix.

4.6.2 Verify Consistencies of Pairwise Comparisons

After calculating the comparisons matrix, it is suggested that the consistency ratio is calculated (Meade, 1997, p. 70). This verifies the ratings are consistent and satisfactory. The author used a different approach to calculating consistent and satisfactory values for the comparison matrices. However, the author used the following process to validate this new approach used for this dissertation.

Using the calculated comparison matrix, find the Xi vector by multiply the n elements in each row by each other. For example, the first value in the X_i vector is 30, which is 1.00 x 2.00 x 3.00 x 5.00. These are the comparison matrix values found in Table 30 for the row PC. See Table 31 for the calculated vector.

Table 31: $X_{i.}$ Vector

X_1	30.0000
	4.0000
	0.5000
	0.0167

From the $X_{i.}$ vector, calculate the nth root of $X_{i.}$ for each row. This results in the Y_i vector. For example, the first value in the Y_i vector is 2.3403, which is the 4^{th} root of 30.00. The fourth root is used because there are 4 enablers. The number of elements involved in the comparison is used for the Y_i calculation. See Table 32.

Table 32: $Y_{i.}$ Vector

Y_1	2.3403
	1.4142
	0.8409
	0.3593
Total	4.9548

With the Y_i vector, find the P_i vector by dividing each number by the sum of all the numbers. For example, the first value in the P_i vector is 0.4723, which is 2.3403 divided by 4.9548. See Table 33.

Table 33: $P_{i.}$ Vector

P_1	0.4723
	0.2854
	0.1697
	0.0725

After identifying the P_i vector, multiply the comparison matrix by the P_i vector. This results in the F_i vector. For example, the first value in the F_i vector is 1.9149, which is (1.00 x 0.4723) + (2.00 x 0.2854) + (3.00 x 0.6874) + (5.00 x 0.0725). See Table 34.

Table 34: $F_{i.}$ Vector

1.9149
1.1511
0.6874
0.2949

Following the F_i vector, calculate the Z_i vector. The Z_i vector can be found by dividing F_i vector by P_i. For example, the first value of the Z_i vector is 4.0541 which is 1.9149 divided by 0.4723. See Table 35.

Table 35: $Z_{i.}$ Vector

4.0541
4.0329
4.0505
4.0668

By the means of the Z_i vector, compute the maximum eigenvalue which is the SIGMA SIGN max. The eigenvalue can best be described as the average. For example, this value is 4.0511, which is (4.0541 + 4.0329 + 4.0505 + 4.0688) divided by 4. See Table 36.

Table 36: Maximum Eigenvalue

4.0511

As a result of the maximum eigenvalue, determine the Consistency Index (CI). The consistency index is the maximum eigenvalue minus the number of n elements divided by the number of n elements minus 1. For example, CI is 0.0170 which is (4.0511-4) divided by (4-1). See Table 37.

Table 37: Consistency Index (CI)

0.0170

Given the random index table and the number of n elements, identify the random index (Dweiri, 1995, p.24). Since the number of n elements is 4, then the Random Index (RI) is 0.9. See Table 38.

Table 38: Random Index (RI)

n	1	2	3	**4**	5	6	7	8	9	10	11	12
RI	0	0	0.58	**0.9**	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.58

From the CI and RI, the Consistency Ratio (CR) can be determined. The CR is the CI divided by the RI. For example, CR is 0.0189 which is 0.170 divided by 0.9. See Table 39.

Table 39: Consistency Ratio

0.0189

Since the CR is less than 0.1 in Table 39, this is considered an acceptable ratio of consistency. This confirms that the new approach to calculating consistent and satisfactory values for the comparison matrices is valid.

4.6.3 Conduct Pairwise Comparisons with Interdependencies

There are two types of interdependence amongst elements in a hierarchy. The interdependence is either additive or synergistic (Saaty, 1982, pp. 86-90). Additive interdependence has each element contributing a share that is uniquely its own and also contributes indirectly by overlapping or interacting with other elements (Saaty, 1982, p. 87). In other words, the total impact is a result of the independent elements and the overlapping.

Synergistic interdependence is the total impact of the interaction of the elements (Saaty, 1982, p. 89). As a result, the total impact from element interaction is greater than totaling each element's individual impact (Saaty, 1982, p. 90). For this dissertation, synergistic independence applies to this research.

As discussed earlier, ANP demonstrates complex relationships between decision levels and attributes. This portion of the dissertation will show the synergistic interdependence of enablers to the determinants, dimensions, and other enablers.

To show the interdependencies, pairwise comparisons were formed for the attribute enablers. For example, looking at the Lean Six Sigma determinant "Robustness (R)" for the dimension "Uncertainty, Change Agent, and Management (UCAM)", it is seen that there are four attribute enablers. When analyzing the enabler "Reconfigurable Organizational Structure (ROS)" as the controlling attribute to the other enablers, the result is Table 40 and Table 41.

Table 40: Pairwise Comparison Matrix for Lean Six Sigma Attribute Enablers to Reconfigurable Organizational Structure (ROS) under Uncertainty, Change Agent, and Management (UCAM)

Uncertainty, Change Agent, and Management	PC	MM	AI
PC	1.00	3.00	5.00
MM	0.33	1.00	3.00
AI	0.20	0.33	1.00
TOTAL	1.53	4.33	9.00

Table 41: New Pairwise Comparison Matrix for Lean Six Sigma Attribute Enablers to Reconfigurable Organizational Structure (ROS) under Uncertainty, Change Agent, and Management (UCAM)

	PC	MM	AI	Total
PC	0.6522	0.6923	0.5556	1.9000
MM	0.2174	0.2308	0.3333	0.7815
AI	0.1304	0.0769	0.1111	0.3185

In Table 40, this shows the relationships of the enablers PC, MM, and AI to enabler ROS under the dimension UCAM for the determinant Robustness (R). This calculation process is the same as was implemented for Table 30.

With the comparison of enablers to enablers for each dimension and determinant, the interdependencies are established. Each item in the comparison matrix is divided by the sum of the values for that column. This provides the values for the new comparison matrix. For the example used in Table 41, ROS is removed, and PC, MM, and AI are compared to each other. Using the row PC from Table 40 as an example, here is an explanation. PC is 1.00 divided by the total 1.53 for the column, which gives a value of 0.6522. MM is 3.00 divided by the total 4.33 for the column, which gives a value of

0.69232. AI is 5.00 divided by the total 9.00 for the column, which gives a value of 0.5556. The end result is the new comparison matrix for each enabler compared to another enabler.

From the new pairwise comparison matrix, the vector is calculated in Table 42.

Table 42: Vector from the Pairwise Comparison Matrix

PC	0.6333
MM	0.2605
AI	0.1062

The vector is calculated using the values and totals from Table 41. Using PC as the example, the total for PC is 1.9000. The average is calculated by dividing 1.9000 by 3 (which represents the number of enablers compared in the new pairwise comparison matrix), giving an average of 0.6333. This computation is completed for each enabler for each dimension and each determinant.

4.6.4 Supermatrix Formulation and Analysis

As a result of the new pairwise comparisons and vectors completed per the prior section, additional matrices were created. These matrices are all grouped together in one large matrix called a supermatrix. The supermatrices include all the interdependencies between enablers per the determinants. Reference Table 43.

Table 43: Supermatrix for Robustness Lean Six Sigma Enablers

ROBUSTNESS	R		KTEW			DE		UCAM				MEEC			
Relationships (R)	CEC	CB	CCSP	PI	ECCK	D	E	PC	ROS	MM	AI	SDP	MCP	GPC	FCS
CEC	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
CB	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Knowledge, training, and empowered workers (KTEW)															
CCSP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PI	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
ECCK	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Databases and Environment (DE)															
D	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
E	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Uncertainty, Change Agent, and Management (UCAM)															
PC	0	0	0	0	0	0	0	0	0.6333	0.5679	0.5390	0	0	0	0
ROS	0	0	0	0	0	0	0	0.5571	0	0.3339	0.2973	0	0	0	0
MM	0	0	0	0	0	0	0	0.3202	0.2605	0	0.1638	0	0	0	0
AI	0	0	0	0	0	0	0	0.1226	0.1062	0.0982	0	0	0	0	0
More effective and efficient company at a minimal cost, and happy customer (MEEC)															
SDP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MCP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GPC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
FCS	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0

Each vector from the pairwise comparisons of the enablers is placed into each supermatrix per the Lean Six Sigma determinant. Using UCAM dimension and ROS enabler, here are the particulars for the results. The vector from Table 42 is 0.6333 for PC, 0 for ROS (when comparing an enabler to itself the value is always 0), 0.2605 for MM, and 0.1062 for AI. These values are placed into the supermatrix. This is completed for all the vectors for the entire process model. See Appendix D for more details per each determinant, dimension, and enabler for each project.

4.6.5 Converged Supermatrix Formulation and Analysis

Now that the supermatrix has been calculated, the author will now demonstrate how to create the converged supermatrix for each Lean Six Sigma determinant. A converged supermatrix is a large matrix that has each value approaching a common center. In other words, the supermatrices can be raised to a very large number. The result is that the supermatrix allows convergence of the interdependent relationships between the Lean Six Sigma enablers and its dimensions.

$$M^{2k+1}$$

where M = Supermatrix

K = Number of attributes

Equation 14: Converged Supermatrix

In other words, this large matrix has interdependencies, uncertainty, and randomness between the columns and rows (Meade, 1997, p. 133). In order to predict the effect of change in an existing system, a stochastic system must be created (Salvendy, 2001, p. 2146). The creation of a stochastic system is shown in Table 44.

Table 44: Converged Supermatrix for Robustness Enablers

ROBUSTNESS	R		KTEW			DE		UCAM				MEEC			
Relationships (R)	CEC	CB	CCSP	PI	ECCK	D	E	PC	ROS	MM	AI	SDP	MCP	GPC	FCS
CEC	0.500	0.500	0	0	0	0	0	0	0	0	0	0	0	0	0
CB	0.500	0.500	0	0	0	0	0	0	0	0	0	0	0	0	0
Knowledge, training, and empowered workers (KTEW)															
CCSP	0	0	0.000	0.000	0.000	0	0	0	0	0	0	0	0	0	0
PI	0	0	0.333	0.333	0.333	0	0	0	0	0	0	0	0	0	0
ECCK	0	0	0.333	0.333	0.333	0	0	0	0	0	0	0	0	0	0
Databases and Environment (DE)															
D	0	0	0	0	0	0.500	0.500	0	0	0	0	0	0	0	0
E	0	0	0	0	0	0.500	0.500	0	0	0	0	0	0	0	0
Uncertainty, Change Agent, and Management (UCAM)															
PC	0	0	0	0	0	0	0	0.435	0.435	0.435	0.435	0	0	0	0
ROS	0	0	0	0	0	0	0	0.297	0.297	0.297	0.297	0	0	0	0
MM	0	0	0	0	0	0	0	0.186	0.186	0.186	0.186	0	0	0	0
AI	0	0	0	0	0	0	0	0.082	0.082	0.082	0.082	0	0	0	0
More effective and efficient company at a minimal cost, and happy customer (MEEC)															
SDP	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000
MCP	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000
GPC	0	0	0	0	0	0	0	0	0	0	0	0.250	0.250	0.250	0.250
FCS	0	0	0	0	0	0	0	0	0	0	0	0.250	0.250	0.250	0.250

Each calculated value from the supermatrices is placed into each converged supermatrix per the Lean Six Sigma determinant. Using UCAM dimension and ROS enabler from Table 43, here are the details for the outcome shown in Table 44. Referencing UCAM dimension and ROS enabler, the values are 0.5571, 0, 0.3339, and 0.2973. These values are summed which gives a value of 1.188. After identifying the sum of these values, the average is calculated. This is 1.188 divided by 4 (because there are 4 enablers being compared) is 0.297. This value is used for the UCAM determinant and ROS enabler row for the converged supermatrix. This is completed for all the supermatrix values for the entire process model. See Appendix D for more details per each determinant for each project.

4.6.6 Calculation of the Desirability Indices

At this point, there have been many calculations concerning the Lean Six Sigma determinants, dimensions, and enablers. All this information can be reviewed prior to this section. Now, it is time to bring in the relationship of the Lean Six Sigma alternatives to its determinants, dimensions, and enablers. This will tie the entire ANP model together.

4.6.6.1 Ranking and Weighting of Enablers

Similar to agile critical business processes, the desirability index is a method to select the best alternative for Lean Six Sigma Critical Business Processes (Meade, 1997, pp. 137-140). This index ranks the dimensions of Lean Six Sigma given the determinants. From the data collection of the decision makers used for this document, here are the results in Table 45.

Table 45: Ranking of Enablers given the Determinants

Business Plan: Attribute Enablers	Cost Ranking for Lean Six Sigma	Delivery Ranking for Lean Six Sigma	Robustness Ranking for Lean Six Sigma	Scope Ranking for Lean Six Sigma	Risk Ranking for Lean Six Sigma
Relationships (R)	1	3	2	2	1
Knowledge, training, and empowered workers (KTEW)	4	4	4	3	3
Databases and Environment (DE)	5	5	5	1	4
Uncertainty, Change Agent, and Management (UCAM)	3	1	3	5	5
More effective and efficient company at a minimal cost, and happy customer (MEEC)	2	2	1	4	2

As agreed upon by the group for Table 45, the rankings are based on the following ratings:

5 = Absolutely Important to Lean Six Sigma

4 = Strong Importance to Lean Six Sigma

3 = Importance to Lean Six Sigma

2 = Somewhat Important to Lean Six Sigma

1 = Little Importance to Lean Six Sigma

Looking at "Cost Ranking for Lean Six Sigma", the group decided DE was absolutely important (ranked 5), KTEW had strong importance (ranked 4), UCAM was important (ranked 3), MEEC was somewhat important (ranked 2), and R had little importance (ranked 1). This is completed for every determinant and its dimension.

After receiving the rankings, the weights of each dimension for the determinants were calculated from the rankings. See Table 46.

Table 46: Weights of Enablers given the Determinants

Business Plan: Attribute Enablers	Cost Weight	Delivery Weight	Robustness Weight	Scope Weight	Risk Weight
Relationships (R)	0.067	0.200	0.133	0.133	0.067
Knowledge, training, and empowered workers (KTEW)	0.267	0.267	0.267	0.200	0.200
Databases and Environment (DE)	0.333	0.333	0.333	0.067	0.267
Uncertainty, Change Agent, and Management (UCAM)	0.200	0.067	0.200	0.333	0.333
More effective and efficient company at a minimal cost, and happy customer (MEEC)	0.133	0.133	0.067	0.267	0.133

The weights for Table 46 are calculated as follows:

1) Total all the columns of the rankings in Table 45
2) Divide the ranking value by the total value of that column from Table 45
3) Complete this for each enabler given the determinants to create Table 46

Looking at "Cost Ranking for Lean Six Sigma" from Table 45, the group decided DE was absolutely important (ranked 5), KTEW had strong importance (ranked 4), UCAM was important (ranked 3), MEEC was somewhat important (ranked 2), and R had little importance (ranked 1). The total of these values in this column is 15 (which is 1 + 4 + 5 + 3 + 2). The new value for R is 0.067 (which is 1 divided by 15), for KTEW is 0.267 (which is 4 divided by 15), for DE is 0.333 (which is 5 divided by 15), for UCAM is 0.200 (which is 3 divided by 15), and for MEEC is 0.133 (which is 2 divided by 15).

This is completed for every determinant and its dimension. The final calculations are in Table 46.

4.6.6.2 Conduct Pairwise Comparisons for Alternatives

In addition to completing the pairwise comparison in section 4.6.1 for the Lean Six Sigma determinants, dimensions, and enablers as they interact one to another, the pairwise comparison is also completed for the alternatives as they relate to the determinants, dimensions, and enablers.

The decision makers ranked the implementation alternatives and calculated the comparison matrices. The comparison matrices for UCAM given PC are shown in Table 47 and Table 48.

Table 47: Pairwise Comparison Matrix for Lean Six Sigma Alternatives to Proficient at Change (PC) under Uncertainty, Change Agent, and Management (UCAM)

Uncertainty, Change Agent, and Management	CD	CS	II
CD	1.00	0.33	4.00
CS	3.00	1.00	5.00
II	0.25	0.20	1.00
TOTAL	4.25	1.53	10.00

Table 48: New Pairwise Comparison Matrix for Lean Six Sigma Alternatives to Proficient at Change (PC) under Uncertainty, Change Agent, and Management (UCAM)

Uncertainty, Change Agent, and Management	CD	CS	II	Total
CD	0.2353	0.2174	0.4000	0.8527
CS	0.7059	0.6522	0.5000	1.8581
II	0.0588	0.1304	0.1000	0.2893

where CD = Customer demand

CS = Current system

II = Implementation of improvements

In Table 47, this shows the relationships of the alternatives under the dimension UCAM for the enabler PC. This calculation process is the same as was implemented for Table 30.

With the comparison of alternatives to enablers for each dimension and determinant, the interdependencies are established. Each item in the pairwise comparison matrix is divided by the sum of the values for that column. This provides the values for the new pairwise comparison matrix. For the example used in Table 48, "Customer Demand (CD)", "Current System (CS)", and "Implementation of Improvements (II)" are compared to each other for the enablers and their dimensions. Using the row CD from Table 47 as an example, here is an overview. CD is 1.00 divided by the total 4.25 for the column, which gives a value of 0.2353. CS is 0.33 divided by the total 1.53 for the column, which gives a value of 0.2174. II is 4.00 divided by the total 10.00 for the column, which gives a value of 0.4000. The end result is the new comparison matrix for each alternative compared to another alternative, which created Table 48.

After the formation of the comparison matrices, the vector concerning the alternatives can be configured. See Table 49.

Table 49: Alternatives Vector from the Pairwise Comparison Matrix

CD	0.2842
CS	0.6194
II	0.0964

This vector is constructed using the values and totals from Table 48. Using CD as the example, the total for CD is 0.8527. The average is calculated by dividing 0.8527 by 3 (which represents the number of alternatives compared in the new pairwise comparison matrix), giving an average of 0.2842. This computation is completed for each enabler for each dimension and each determinant.

For simplicity, the vectors for UCAM are shown in Table 50.

Table 50: Vector Matrix for Alternatives

	PC	ROS	MM	AI
CD	0.2842	0.6194	0.0964	0.6194
CS	0.6194	0.0964	0.6194	0.0964
II	0.0964	0.2842	0.2842	0.2842

After comparing the alternatives to each other, the alternatives must be compared to the enablers. From Table 30, the new comparison matrices are created. In Table 51, it shows details for UCAM enablers.

Table 51: New Comparison Matrix for Enablers

	PC	ROS	MM	AI	Total
PC	0.4918	0.5333	0.4737	0.3846	1.8834
ROS	0.2459	0.2667	0.3158	0.3077	1.1361
MM	0.1639	0.1333	0.1579	0.2308	0.6859
AI	0.0984	0.0667	0.0526	0.0769	0.2946

With the comparison of all enablers for each dimension and determinant, the comparison matrices are generated. Similar to the comparison matrices for the enablers compared to other enablers and for the alternatives, this computation is the same. The comparison matrix is divided by the sum of the values for that column. This provides the values for the new comparison matrix. For the example used in Table 51, the enablers

PC, ROS, MM, and AI are compared to each other for each dimension. Using the row PC as an example from Table 30, here is an overview. PC is 1.00 divided by the total 2.03 for the column, which gives a value of 0.4918. ROS is 2.00 divided by the total 3.75 for the column, which gives a value of 0.5333. MM is 3.00 divided by the total 6.33 for the column, which gives a value of 0.4737. AI is 5.00 divided by the total 13.00 for the column, which gives a value of 0.3846. The end result is the new comparison matrix for each enabler compared to another enabler, which created Table 51.

From the comparison matrices, vectors for each determinant are produced. See Table 52.

Table 52: Vector Matrix for Enablers

PC	ROS	MM	AI
0.4709	0.2840	0.1715	0.0736

This vector is constructed using the values and totals from Table 51. Similar to the vectors for the enablers and for the alternatives, this process is the same. Using PC as the example, the total for PC is 1.8834. The average is calculated by dividing 1.8834 by 4 (which represents the number of enablers compared in the new pairwise comparison matrix), giving an average of 0.4709. This computation is completed for each enabler for each dimension.

Subsequent to calculating the vectors for the enablers and alternatives, the alternatives must now be compared to the enablers to accomplish all the comparisons within the ANP model. This is accomplished by multiplying the alternative vector matrix by the enabler vector matrix. This will create the overall priorities.

Table 53: Priorities for each Enabler and Alternative Matrices

	PC	ROS	MM	AI	Total
CD	0.1338	0.1759	0.0165	0.0456	0.3719
CS	0.2916	0.0274	0.1062	0.0071	0.4323
II	0.0454	0.0807	0.0487	0.0209	0.1958

For clarification, here is a review using CD row. In Table 50, CD and PC is 0.2842. In Table 52, PC is 0.4709. These two values are multiplied together to provide an entry into the matrix of 0.1338. This is completed for all the enablers and alternatives.

Given all this data from the above matrices, a supermatrix can be created. The person that will make the decision on the Lean Six Sigma project can calculate the scores for each alternative and the desirability indices. The desirability index for alternative i is D_i.

$$D_i = \sum_{j=1}^{J} \sum_{k=1}^{K} P_j A_{kj} S_{ikj}$$

Equation 15: D_i

where: P_j = relative importance weight of principle j

A_{kj} = relative importance weight for attribute k of principle j

S_{ikj} = relative impact of alternative i on attribute k of principle j

K_j = index set of attributes for principle j

J = index set of principles

This equation is used to identify the correlation of the determinants, dimensions, and enablers on the alternatives. In other words, this process will help identify the alternative that is most impacted by the interrelationships of the determinants, dimensions, enablers, and alternatives as evaluated, ranked, and rated by the decision makers noted on the ANP model.

Equation 15 is used to build supermatrices for each determinant. See Table 54 for the desirability matrix for Robustness.

Table 54: Desirability Index

ROBUSTNESS									
Relationships (R)	Weight (Business Plan)	eVector (Lean Six Sigma Enablers)	Converged Supermatrix	eVector (Customer Demand Implementation Alternative)	eVector (Current System Implementation Alternative)	eVector (Improvements Implementation Alternative)	Customer Demand Score	Current System Score	Improvements Score
CEC	0.067	0.750	0.500	0.080	0.195	0.475	0.00199	0.00488	0.01188
CB	0.067	0.250	0.500	0.163	0.024	0.064	0.00136	0.00020	0.00053
Knowledge, training, and empowered workers (KTEW)									
CCSP	0.267	0.000	0.000	0.158	0.345	0.054	0.00000	0.00000	0.00000
PI	0.267	0.250	0.333	0.080	0.012	0.031	0.00177	0.00026	0.00069
ECCK	0.267	0.750	0.333	0.034	0.083	0.203	0.00227	0.00556	0.01352
Databases and Environment (DE)									
D	0.333	0.750	0.500	0.488	0.071	0.191	0.06099	0.00892	0.02384
E	0.333	0.250	0.500	0.163	0.024	0.064	0.00678	0.00099	0.00265
Uncertainty, Change Agent, and Management (UCAM)									
PC	0.200	0.471	0.435	0.134	0.292	0.045	0.00548	0.01195	0.00186
ROS	0.200	0.284	0.297	0.176	0.027	0.081	0.00297	0.00046	0.00136
MM	0.200	0.171	0.186	0.017	0.106	0.049	0.00011	0.00068	0.00031
AI	0.200	0.074	0.082	0.046	0.007	0.021	0.00005	0.00001	0.00003
More effective and efficient company at a minimal cost, and happy customer (MEEC)									
SDP	0.133	0.000	0.000	0.046	0.021	0.007	0.00000	0.00000	0.00000
MCP	0.133	0.000	0.000	0.292	0.045	0.134	0.00000	0.00000	0.00000
GPC	0.133	0.667	0.250	0.176	0.027	0.081	0.00391	0.00061	0.00179
FCS	0.133	0.333	0.250	0.106	0.017	0.049	0.00118	0.00018	0.00054
						Desirability Indices	**0.08885**	**0.03471**	**0.05900**

From Table 54, row PC under UCAM will be reviewed. The weight (Business Plan) of 0.200 was calculated in Table 46. The eVector (Lean Six Sigma Enabler) of 0.471 was calculated in Table 52. The converged Supermatrix value 0.435 was calculated in Table 44. The eVectors (Customer Demand Implementation Alternative, Current System Implementation Alternative, and Improvements Implementation Alternatives) numbered 0.134, 0.292, and 0.045 respectively are shown in Table 53.

From these values the scores are determined. The Customer Demand Score is the weight multiplied by eVector (Lean Six Sigma Enablers) multiplied by Converged Supermatrix multiplied by eVector (Customer Demand Implementation Alternative) which is 0.200 X 0.471 X 0.435 X 0.134 giving a value of 0.00548. The Current System Score is the weight multiplied by eVector (Lean Six Sigma Enablers) multiplied by Converged Supermatrix multiplied by eVector (Customer Demand Implementation Alternative) which is 0.200 X 0.471 X 0.435 X 0.292 giving a value of 0.01195. The Improvements Score is the weight multiplied by eVector (Lean Six Sigma Enablers) multiplied by Converged Supermatrix multiplied by eVector (Improvements Implementation Alternative) which is 0.200 X 0.471 X 0.435 X 0.045 giving a value of 0.00186.

These computations are completed for every enabler per dimension per determinant. After this multiplication process, the values under the scores are summed. For example, the Customer Demand Score is the sum of all the values from 0.00199 through 0.00188. The total is 0.08885. The summing all the data for the Customer Demand Score, Current System Score, and Improvements Score provides the desirability index. As discussed above, the desirability index correlates all items of the ANP model.

From this supermatrix, it is identified that the impact on the robustness of the manufacturing process is most impacted by the customer demand. For more details about the other determinants in project 1 and the other projects, refer to Appendix D.

4.7 <u>Conduct Cost / Benefit Analysis</u>

Each entity of the ANP model has been ranked and evaluated. The end results build the desirability indices. The final step is to determine if there is a cost or benefit to making modifications to the product or process. This is accomplished with a cost /

benefit analysis. This shows the cost or benefit of creating Lean Six Sigma Critical Business Processes to the team. Once again, this should support the vision and mission of the company.

*4.7.1 **Calculation of the Lean Six Sigma Weighted Indices***

Similar to the agile critical process, the weighted index is calculated from the desirability indices and weighted values (Meade, 1997, p. 141). For this documentation, this final weighted index will be called Lean Six Sigma Weighted Index (LSSWI). The LSSWI identifies which Lean Six Sigma alternative will have the most impact on the business by using the values that interpret the relationships of the Lean Six Sigma determinants, dimensions, enablers, and alternatives. Therefore, the alternative with the highest score is the alternative that should be evaluated for Lean Six Sigma Critical Business Process implementation. See Table 55 for details.

Table 55: Lean Six Sigma Weighted Index (LSSWI)

Manage Product	Cost	Delivery	Robustness	Scope	Risk	LSSWI
Weight	*0.315*	*0.431*	*0.058*	*0.196*	*0.132*	
Customer Demand	0.097	0.089	0.089	0.028	0.016	0.082
Current System	0.056	0.035	0.035	0.036	0.023	0.013
Implementation of Process / Product Improvements	0.055	0.059	0.059	0.028	0.018	0.009

The weighted values for the determinants are the resulting priority vectors. In sections 4.6.1 through 4.6.3, there are more details on how to compute the final vector. As a quick review, here are the six steps to identify the priority:

1) Rank the determinants

2) Configure weighted values from the ranked values

3) Create the favorability matrix and a numbering system

4) Develop pairwise comparison matrix

5) Generate new pairwise comparison matrix

6) Determine the priority vector

From the LSSWI shown in Table 55, it is identified that the customer demand will most impact the business because it has the highest score. Therefore, customer demand is the alternative to have the biggest impact on the business in regards to Lean Six Sigma improvements.

*4.7.2 **Determine Labor, Material, and Capital Requirements***

As a result of computing the Lean Six Sigma Weighted Index (LSSWI) in section 4.7.1, the identification of the alternatives that will have a Lean Six Sigma process improvement impact on business process is complete. Referencing Table 55, this LSSWI identifies the largest impact is the alternative "Customer Demand", the alternative "Current System" has the second greatest impact to the business, and the alternative "Implementation of Improvements" is third in its impact to the business.

Starting with the alternative that has the largest impact to the business, the process improvement evaluation takes place in order to decide if this is the alternative that is most cost and time effective. Brainstorming, contacting other internal businesses for feedback, or contacting external businesses for feedback, can complete this activity.

For additional feedback, this section used alternative "Customer Demand" from Table 55 for the business plan "Manage Product". The team evaluates the labor, materials, and capital needed to improve this business process. The suggested changes are as follows:

- More sales and marketing people in the field
- Better system to track requests, orders, and sales
- Consolidate the territories

These suggestions support the capabilities "Process for Accessing Product" and "Process for Accessing Financial Impact to Department" for the business process "Manage Product".

4.7.3 Calculate Costs and Savings

From the suggested improvements in the prior section, the total costs and savings can be assessed. For each business process selected for Lean Six Sigma improvements, the team must specify the costs, annual savings, annual cost avoidance, and total dollar return per improvement. The decision maker involved in the process improvement can then construct the cost / benefit analysis.

There are various financial equations that can be used to justify improvements to a business, such as inventory turn over, fixed-asset turnover, debt-equity ratio, profit margin, return on investment, payback period, and many others. The financial equations that are customary with the decision makers involved in this dissertation, and throughout the author's thirteen years in the industry, are Return On Investment (ROI) and Payback Period. As noted by Ostwald, these financial equations are as follows (1992, pp. 369 & 375):

Return On Investment (ROI) = (Dollar Return / Initial Investment) X 100

Equation 16: Return on Investment

Payback Period = Net Investment / Annual Earnings

Equation 17: Payback Period

The ROI calculates the money that will be returned from the investment and divides that by the total cost of the investment. This value multiplied by 100 provides you with a percentage. For the businesses reviewed for this document, it is acceptable to have an ROI of 33% or better.

The payback period divides the total cost of the investment by the annual earnings received from this implementation. These earnings can be cost avoidance, cost savings, and others. For the businesses included in this dissertation, it was agreed that a payback period should be no more than 2.5 years.

Depending on the scenario and the business, these equations or others can be used. The decision maker must identify which financial evaluation is the best fit for the situation.

4.7.4 Implement Changes

The areas of improvement are now identified, along with the cost or benefit to the implementation of the changes. From this information, it can be decided if the change is justified. In other words, the benefits of the process improvement must out way the cost according to the standards set by the business and company.

From detailed assessment, the process improvements are executed if the enhancements are justified. If the modifications are not justified, these steps are repeated with the next highest Lean Six Sigma Weighted Index (LSSWI). After identifying the LSSWI with next highest score, the labor, material, and capital requirements are identified. Then, the costs and savings are calculated. And lastly, this information is evaluated. This process is repeated until a process improvement is chosen that is cost justifiable.

CHAPTER FIVE

TESTING METHODOLOGY

This chapter summarizes the various projects used for Company ABC. This name is fictitious to secure the anonymity of the company.

The first project evaluated the development and product release strategy for Product 1. This product is a signaling product. It is used to notify those in and surrounding the manufacturing area of any changes with the equipment or the process.

Product 1 had a forecast of 6,800 units sold per year, and the plan was to have it available for sale by the end of the fiscal year. The steps to evaluate this strategy are as follows:

- Identify manufacturing and marketing strategy processes
- Determine the critical business processes using Laura Meade's methodology
- Decide the high priority Lean Six Sigma processes
- Calculate the cost /benefit analysis
- Evaluate the process that is most critical to the manufacturing strategy

For more details see Appendix D.

The second project is improving the existing Product 2. Product 2 is a soft starter motor control. This product is used because of its innovative starting and stopping solutions for motors, and its conservation of power.

Product 2 had a forecast of 28,800 units sold per year. The steps to evaluate this process were as follows:

- Identify supply chain, order processing chain, and manufacturing processes
- Determine the critical business processes using Laura Meade's methodology
- Decide the high priority Lean Six Sigma processes
- Calculate the cost / benefit analysis
- Evaluate the process that is most critical to manufacturing this product

For more details see Appendix D.

The third project is improving the existing Product 3. Product 3 is a larger controller for motors. This product is similar to Product 2. The main difference is that it is configured into an enclosure for industrial usage.

Product 3 had a forecast of 1,248 units sold per year. The steps to evaluate this process were as follows:

- Identify supply chain, order processing chain, and manufacturing processes
- Determine the critical business processes using Laura Meade's methodology
- Decide the high priority Lean Six Sigma processes
- Calculate the cost / benefit analysis
- Evaluate the process that is most critical to the development of this product

For more details see Appendix D.

CHAPTER SIX

SUMMARY AND CONCLUSION

This chapter summarizes the guide for Lean Six Sigma Critical Business Processes. It is divided into three sections: 1) Summary of Chapters, 2) Contributions to Research, and 3) Future Research.

6.1 Summary of Chapters

Chapter 1 creates the incentive and need for the implementation of Lean Six Sigma Critical Business Processes. This chapter explains the objective of this research is to identify the areas that need Lean Six Sigma implementation the most by 1) selecting the critical business process, 2) choosing the high priority Lean Six Sigma processes, and 3) using the evaluation tool to configure the Lean Six Sigma Critical Business Processes.

Chapter 2 reviews the literature related to this research. This chapter incorporates business processes, critical business processes, history of improvements, Lean, Six Sigma, and analytical processes. The focus is placed on Lean Six Sigma and Analytical Network Process (ANP) modeling. Lean Six Sigma focuses on new or existing projects to eliminate waste and reduce variation, while ANP modeling focuses on complex interrelationships within varies levels for varies attributes. These concepts are the foundation for using Lean Six Sigma Critical Business Processes to improve any process or product.

Chapter 3 provides an intellectual investigation about Lean Six Sigma Critical Business Processes. This chapter provides the background information for determining the Lean Six Sigma Critical Business Process. First, this chapter provides a detailed description of Lean, Six Sigma, Critical Business Processes, and Analytical Network Process. Second, the process of determining Lean Six Sigma Critical Business Processes is shown step by step. This includes the surveys used to collect data and the models used to evaluate data.

Chapter 4 illustrates the knowledge obtained and new ideas proven to assist with the identification of Lean Six Sigma Critical Business Processes. This chapter utilizes project 1 to demonstrate the steps in the process. The first step identifies the capabilities. The second step specifies the core ratings. The third step denotes the performance levels. The fourth step exhibits the critical processes. The fifth step indicates the Lean Six Sigma process rating. The sixth step reviews the ANP model, which includes the Lean Six Sigma Determinants, Dimensions, Enablers, and Alternatives. The seventh step analyzes the cost and benefit to implementing improvements.

Chapter 5 embodies a detailed description, forecast, and the steps to evaluate each product. The results for each project can be found in the appendices.

6.2 Contributions to Research

This dissertation creates a methodology to identify Lean Six Sigma Critical Business Processes. This approach is compared to Lean, Six Sigma, and Critical Process techniques.

There are four major contributions that are made from this research. The first contribution is confirming the critical business process identification method by Laura Meade. The second contribution is proving there is a need for a simple system to determine projects based on Lean Six Sigma Critical Business Processes. The third contribution is the use of a factor rating system to identify processes that have the highest priority for Lean Six Sigma improvements. The fourth contribution is proving that ANP is a good model to identify Lean Six Sigma Critical Business Processes.

*6.2.1 **Methodology of Critical Business Process Selection by Laura Meade***

The first contribution is confirming the methodology documented by Laura Meade to identify critical business processes. Seven steps were taken to compute the Lean Six Sigma Critical Business Process.

- Step 1 – Identify the capabilities
- Step 2 - Determine the core ratings
- Step 3 - Recognize the performance levels
- Step 4 Select the critical business processes
- Step 5 – Decide the Lean Six Sigma process rating
- Step 6 – Place Lean Six Sigma worthy processes into ANP model
- Step 7 – Conduct the cost / benefit analysis

Laura Meade provided the groundwork to complete these steps which allowed the author to calculate the critical business processes.

With the purpose of minimizing the time and justifying the usability of Meade's critical business process selection, the methodology of Meade was employed in Projects 1, 2, and 3. Incorporating Meade's critical business process selection in these projects, the author was able to prove that methods used by Meade and the present system produced identical results.

6.2.2 Lean Six Sigma Rating System

The second contribution is proving there is a need for a simple system to determine projects based on Lean Six Sigma Critical Business Processes. Meade presented a methodology to determine critical business processes. This was combined with Lean Six Sigma in this research to identify Lean Six Sigma Critical Business Processes.

The author has participated and led many teams that use a "gut feeling" to eliminate waste, and use various matrices (i.e. Failure Mode and Effect Analysis (FMEA), Cause and Effect (C&E), Prioritization, etc.) to reduce variation. In order to simplify this process, the author created a Lean Six Sigma rating system.

Presently, Lean and Six Sigma activities are based on issues that have been surfaced through tester failures, duplicate activities, and product returns to name a few issues. These issues are then rated using various matrices, and the score with the largest impact is the activity to address.

To shorten the evaluation process, the Lean Six Sigma rating system created by the author incorporates specific Lean and Six Sigma characteristics. For this research, the decision maker is asked to rate the business processes based on the Lean Six Sigma characteristics. The lower the score, the business process has little to no relevance to that characteristic. The higher the score, the business process has definite relevance to that characteristic. After rating all the business processes, the process with the lowest score is in need of the most Lean Six Sigma improvement. From this evaluation, it is then determined which area is addressed first for process improvements. The details can be found in Chapter 4.

Projects 1, 2, and 3 used the present system and the Lean Six Sigma rating system created by the author. The present system and the Lean Six Sigma rating system both identified the same business processes in most need of improvement. The main difference is that the present system averaged 12 hours to collect and evaluate the data to identify the processes to focus Lean and Six Sigma efforts, while the Lean Six Sigma rating system averaged 2 hours to collect and evaluate the data to identify the processes to focus Lean and Six Sigma efforts.

6.2.3 ***Factor Rating System***

The third contribution is the use of a factor rating system to identify processes that have the highest priority for Lean Six Sigma improvements. In order to conduct the pairwise comparisons, each determinant, dimension, attribute enabler, and alternative must be rated to other determinants, dimensions, attribute enablers, and alternatives.

With any rating system, there is the possibility for inconsistencies depending on the decision maker. From prior evaluations, rating processes or products can vary depending on the day of week, the time of day, and the activities going on in the day. In order to eliminate inconsistent ratings, the author utilized a factor rating system.

The decision maker is asked to rank the determinants from greatest importance to least importance, rank the attribute enablers from greatest importance to least importance, and rank the alternatives from greatest importance to least importance. From these rankings, the resulting comparison matrices are calculated. The details can be found in Chapter 4.

Projects 1, 2, and 3 used the factor rating system and the consistency ratio evaluation. The consistency ratios proved that the factor rating system eliminated inconsistencies.

*6.2.4 **Analytical Network Process Modeling***

The fourth contribution is proving that Analytical Network Process (ANP) is a good model to identify Lean Six Sigma Critical Business Processes. Meade presented a methodology to determine agile critical business processes using ANP. This technique is modified to determine Lean Six Sigma Critical Business Processes.

As stated above, the author has participated and led many teams that used a "gut feeling" and various matrices to eliminate waste and reduce variation. In order to accurately represent the processes, the author uses ANP to determine the Lean Six Sigma Critical Business Process that will provide the largest impact to the business.

Presently, Lean and Six Sigma activities are based on the decision levels and attributes. The present process evaluates decisions and their attributes as unidirectional. With the use of ANP, all scenarios and affects are evaluated between levels. This evaluation is more realistic and accurate performance score. The details can be found in Chapter 4.

Projects 1, 2, and 3 used the present system and the ANP model. The present system showed challenges with multidirectional relationships among each determinant, dimension, attribute enabler, and alternative. The first challenge was rating each determinant, dimension, attribute enabler, and alternative to other determinants, dimensions, attribute enablers, and alternatives accordingly. The second challenge was identifying all the relationships between determinants, dimensions, attribute enablers, and alternatives.

With this research, the decision maker is asked to identify all the relationships for the determinants, dimensions, attribute enablers, and alternatives to other determinants, dimensions, attribute enablers, and alternatives. With the implementation of the ANP model, there were no challenges with the interactions. The ANP model shows the multidirectional relationships.

The ANP model and the present modeling process identified areas of improvement for all three projects within this research. The main difference is that the present system averaged 28 hours to collect and evaluate the data to identify the processes to focus Lean and Six Sigma efforts, while the ANP model averaged 10 hours to collect and evaluate the data to identify the processes to focus Lean and Six Sigma efforts.

6.3 <u>Future Research</u>

Lean Six Sigma Critical Business Processes are terms and techniques well known to the manufacturing industry. As a result, more companies see the value to Lean, Six Sigma, and Critical Business Processes. It is important to make sure that the methods used are accurate and consistent.

Because more companies are identifying their critical processes and implementing Lean Six Sigma, many opportunities exist for the future. The first suggestion to further research is to gather more data. The technique used in this research should be evaluated on other scenarios. This will provide additional data about the affects of Lean Six Sigma Critical Business Processes for other companies and projects.

The second suggestion to further research is to incorporate user friendly software. Microsoft Excel is used for this research. The evaluation of Lean Six Sigma Critical Business Process data employing user friendly software may prove to save more time and provide greater flexibility. This would increase the likelihood of more decision makers using this system to identify their Lean Six Sigma Critical Business Processes.

The opportunities for improvement and exposure are great. With the implementation of these two suggestions, this can definitely further research for Lean Six Sigma Critical Business Processes.

APPENDIX A

ATTRIBUTE ENABLERS FOR LEAN SIX SIGMA CRITICAL BUSINESS PROCESSES

This appendix contains data for the evaluation of Lean Six Sigma Critical Business Processes. Each process will be 1) evaluated using the ANP model, 2) assessed using the attribute enablers, and 3) related to the determinants.

A.1.1 <u>Analytical Network Process Model</u>

Each project uses the same Analytical Network Process (ANP) model. This model was originally used by Meade and determines which business process should be reviewed for the betterment of the business.

A.1.1.1 Lean Six Sigma Business Process

Determinants of Lean Six Sigma

Cost (C)	Delivery (D)	Robustness (R)	Scope (S)	Risk (RI)

Dimensions of Lean Six Sigma

Relationships (Input)	Knowledge, training, and empowered workers (Mechanism)	Databases and Environment (Call)	Uncertainty, Change Agent, and Management (Control)	More effective and efficient company at a minimal cost, and happy customer (Output)

Lean Six Sigma Attribute Enablers

CEC	CCSP	D	PC	SDP
CB	PI	E	ROS	MCP
	ECCK		MM	PC
			AI	FCS

Lean Six Sigma Implementation Alternatives

Customer Demand (CD)	Current System (CS)	Implementation of Process / Product Improvements (II)

Here is a quick overview of Lean Six Sigma determinants, dimensions, attribute enablers, and implementation alternatives that are shown in the business process above.

A.1.1.1.1 Determinants of Lean Six Sigma

The determinants of Lean Six Sigma are modeled after the agility determinants (Meade, 1997, p. 118). The determinants are used to determine the present situation of the business.

A.1.1.1.2 Dimensions of Lean Six Sigma

The dimensions of Lean Six Sigma are also modeled from the dimensions of agility (Meade, 1997, p. 123). The Lean Six Sigma dimensions are used as the decision maker's input for pairwise comparisons (Meade, 1997, p. 123).

A.1.1.1.3 Attribute Enablers of Lean Six Sigma

Lean Six Sigma attribute enablers are characteristics of agility enablers (Meade, 1997, pp. 124-125). These enablers are detailed descriptors of the dimensions.

A.1.1.1.4 Implementation Alternatives of Lean Six Sigma

Lean Six Sigma implementation alternatives are characteristics that support the vision of the business. These items represent proactive options the decision maker considers implementing in the current business (Meade, 1997, p. 125).

A.1.1.2 Attribute Enablers

***Business Process*: Attribute Enabler**	**Code**	**Definition**
Relationships:		
Communication with Employees and Customers	CEC	Gathering data by communicating with employees and customers to focus the business plan
Collaboration with other Businesses	CB	Gathering data with past experiences (successes and failures) within other business groups
Knowledge, training, and empowered workers:		
Core Capability Strategic Planning	CCSP	Core focus of the business plan including the strategic plan to accomplish needed goals
Usage of Performance Information	PI	Use prior performance infromation to verify the progress (increase or decrease) of success
Captured Employee, Customer, and Competitor Knowledge	ECCK	Use knoledge that is documented or in storage from employees, customers, and competitors to assist in creating the best plan with the most success
Databases and Environment:		
Useful Database	D	Database that can be helpful with gathering information
Non-bias Environment	E	Environment that is willing to change or try new things without any push back of "that's not how we used to do that"
Uncertainty, Change Agent, and Management:		
Proficient at Change	PC	Company that is change saavy, and looks for opportunites of improvement from change
Reconfigurable Organizational Structure	ROS	Organizational structure is changeable to improve the business
Motivational Management	MM	Management that is motivated by change and pushes to motivate others to improve the business
Adaptable Information	AI	Infromation is easily modified to improve the process, documentation, and plan
More effective and efficient company at a minimal cost, and happy customer:		
Sales (Cost / Savings) Documentation Process	SDP	A specific process is in place to document the costs / savings from the implementation of change
Maintain Change Process	MCP	A specific process is in place to maintain or monitor results of the change
Greater Product Customization	GPC	Opportunities to customize products with minimum time needed for development
Flexible Change System	FCS	Opportunities to change products or systems with minimum time needed for development due to a flexible system

A.1.2 Lean Six Sigma Relationships of the Determinants, Dimensions, and Enablers

The attribute enablers are evaluated to determine which enablers are most important to the determinants. The determinants for Projects 1, 2, and 3 are cost, delivery, robustness, scope, and risk. Each enabler is evaluated by completing this document per business process. As with any decision, the evaluation results are very dependent on the decision maker.

With the three projects for this dissertation, the relationships of the determinants, dimensions, and enablers were determined to be the same. This was a result of the three projects being a part of the same company. The vision for the company identifies the priorities for each business. Here is the completed form for Project 3 using Business Process 2.

	Engineering	**Development of Short and Long Term Goals**	**Already In Place**	**Interested in Cost (C), Delivery (D), Robustness (R), Scope (S), or Risk (RI)**	**Disregard**
Input	Relationships				
	Communication with Employees and Customers (CEC)	Is there communication between the employee, customers, and business to discuss the needs of customers and the business capabilities?		C/D/R/S/RI	
	Collaboration with other Businesses (CB)	Is there a system in place to easily work with other businesses to enhance your business?		C/D/R/S/RI	
Mechanism	Knowledge, training, and empowered workers				
	Core Capability Strategic Planning (CCSP)	Is the company meeting its capability?		C/S	
	Usage of Performance Information (PI)	How well is the business performing?		C/D/R/S	
	Captured Employee, Customer, and Competitor Knowledge (ECCK)	Is this knowledge captured? If so, how?		C/D/R/S/RI	

Section A.1. 2 Table - continued

Call	Databases and Environment				
	Useful Database (D)	Are there databases available that have this information or can acquire it?		C/D/R/S	
	Non-bias Environment (E)	Is the environment conducive to change?		C/D/R	
Control	Uncertainty, Change Agent, and Management				
	Proficient at Change (PC)	How well does the business handle change?		C/D/R/S/RI	
	Reconfigurable Organizational Structure (ROS)	How agile is the business to change?		C/D/R	
	Motivational Management (MM)	How prepared is management for change?		R/RI	
	Adaptable Information (AI)	How adaptable is the data and data collection with change?		C/D/R/S/RI	
Output	More effective and efficient company at a minimal cost, and happy customer				
	Cost Savings Documentation Process (SDP)	Is there are documentation process in place for tracking savings?		C/S	
	Maintain Change Process (MCP)	Is there a system in place to maintain the changes?		S	
	Greater Product Customization (GPC)	Is there a system in place to handle high product customization?		C/D/R/S/RI	
	Flexible Change System (FCS)	Is there a system in place to change quickly due to customization?		C/D/R/S/RI	

APPENDIX B

RANKING AND WEIGHTING ENABLERS FOR LEAN SIX SIGMA CRITICAL BUSINESS PROCESSES

This appendix contains data that assists the decision maker in calculating the desirability index. The enablers are ranked and weighted given the determinants. As with any decision, the evaluation results are very dependent on the decision maker.

B.1.1 Ranking of Enablers

Business Plan: Attribute Enablers	Cost Ranking for Lean Six Sigma	Delivery Ranking for Lean Six Sigma	Robustness Ranking for Lean Six Sigma	Scope Ranking for Lean Six Sigma	Risk Ranking for Lean Six Sigma
Relationships	1	3	2	2	1
Knowledge, training, and empowered workers	4	4	4	3	3
Databases and Environment	5	5	5	1	4
Uncertainty, Change Agent, and Management	3	1	3	5	5
More effective and efficient company at a minimal cost, and happy customer	2	2	1	4	2

B.1.2 Weights of Enablers

Business Plan: Attribute Enablers	Cost Weight	Delivery Weight	Robustness Weight	Scope Weight	Risk Weight
Relationships	0.067	0.200	0.133	0.133	0.067
Knowledge, training, and empowered workers	0.267	0.267	0.267	0.200	0.200
Databases and Environment	0.333	0.333	0.333	0.067	0.267
Uncertainty, Change Agent, and Management	0.200	0.067	0.200	0.333	0.333
More effective and efficient company at a minimal cost, and happy customer	0.133	0.133	0.067	0.267	0.133

APPENDIX C

COMPARISON MATRIX CALCULATIONS FOR LEAN SIX SIGMA CRITICAL BUSINESS PROCESSES

This appendix contains data that assists the decision maker to rate factors consistently. From this rating, the comparison matrix is calculated and begins the evaluation process using the ANP model. As with any decision, the evaluation results are very dependent on the decision maker.

C.1.1 **Ranking of Enablers**

Each enabler must be placed into a ranking order by 1) identifying how many enablers are available, 2) rank each enable from the highest number (as the most important) to the lowest number of one (as the least important).

Here is an example from Project 1 for the Dimension "More Effective and Efficient Company at a Minimal Cost, and a Happy Customer (MEEC)".

	Ranking by Order
SDP	1
MCP	4
GPC	3
FCS	2
TOTAL	10

There are (4) enablers within this dimension. The most important factor is Maintain Change Process (MCP), so it is rated with a 4. While the least important factor is Cost Savings Documentation Process (SDP), so it was rated with a 1.

C.1.2 Weighted Values for Enablers

In order to find the weighted values, take the ranking number for the enabler and divide by the total. This identifies the enablers with the heaviest to lightest weight when determining the affect of the enablers on the determinants.

Continuing from the example above, here is Project 1 for the Dimension "More Effective and Efficient Company at a Minimal Cost, and a Happy Customer (MEEC)".

	Weighted Value
SDP	0.1
MCP	0.4
GPC	0.3
FCS	0.2

For this example, let's use Cost Savings Documentation Process (SDP). This has a factor rating of 1. The total for all the factor rankings is 10. As a result, the weighted value for SDP is 1 divided by 10, which is 0.1. Complete this weight calculation for each enabler.

C.1.3 Favorability Ratings for Enablers

In order to calculate the comparison matrix, the favorability matrix must be calculated. This matrix compares one enabler to another.

Continuing from the example above, here is Project 1 for the Dimension "More Effective and Efficient Company at a Minimal Cost, and a Happy Customer (MEEC)".

Favorability	SDP	MCP	GPC	FCS
SDP	1.00	0.25	0.33	0.50
MCP	4.00	1.00	1.33	2.00
GPC	3.00	0.75	1.00	1.50
FCS	2.00	0.50	0.67	1.00

For this example, let's use Cost Savings Documentation Process (SDP) under "Favorability". SDP, as is anything compared to itself, has a rating of 1.0. SDP compared to MCP is 0.1 divided by 0.4, which is 0.25. This means that SDP is a rating of 0.25 favorable to MCP. While the inverse is that MCP is a rating of 4.0 favorable to SDP.

C.1.4 <u>Intensity Number Rating Key</u>

The intensity number rating key is used to calculate the comparison matrix. This key is used with the favorability matrix and creates the pairwise comparison matrix.

Continuing from the example above, here is Project 1 for the Dimension "More Effective and Efficient Company at a Minimal Cost, and a Happy Customer (MEEC)".

Score	Intensity Number
4	5
3-3.99	4
2-2.99	3
1-1.99	2

Always start with the lowest intensity number of 2. This is the rating provided for any favorability value that is between 1 and 1.99. And the highest intensity number depends on the highest number in the favorability rating matrix. For example, if the largest number in the favorability matrix is 6, the score would be 6 and the intensity number would be 7.

C.1.5 Comparison Matrix Calculation

With the intensity number rating key and the favorability matrix, the comparison matrix can be calculated. Continuing from the example above, here is Project 1 for the Dimension "More Effective and Efficient Company at a Minimal Cost, and a Happy Customer (MEEC)".

More effective and efficient company at a minimal cost, and happy customer	SDP	MCP	GPC	FCS
SDP	1.00	0.20	0.25	0.33
MCP	5.00	1.00	2.00	3.00
GPC	4.00	0.50	1.00	2.00
FCS	3.00	0.33	0.50	1.00
TOTAL	13.00	2.03	3.75	6.33

For example, looking at MCP compared to SDP from the favorability matrix. Its value is 4. Compare this to the intensity number rating, and anything that is a 4 gets a value of 5. This is placed into the comparison matrix.

APPENDIX D

CASE STUDIES FOR LEAN SIX SIGMA CRITICAL BUSINESS PROCESSES

This appendix contains data from the case studies. Each case study will have 1) completed worksheets to determine the process that is most in need Lean Six Sigma improvement, 2) Lean Six Sigma enabler worksheets, and 3) ANP matrices.

D.1.1 Case Study 1: Project 1

Project 1 is a small project. It will create approximately $297 thousand in annual sales and utilizes two people from the manufacturing facility. This item is a signaling product that brings safety to a manufacturing process through efficient control and automatic monitoring. (Rockwell Automation, 2007)

The person involved in this case study is the Marketing Engineer, and can contribute to both the development of the product and the manufacturing process for the product. As with any decision, the evaluation results are very dependent on the decision maker.

D.1.1.1 Case Study 1: Worksheet 1

	Company ABC's vision is focused on being the most valued global provider of power, control and information solutions.
BP 1	*Create Business Plan*
C1	Excel in the vision strategy
C2	Create a niche or better value with existing product / process for customer
C3	Identify market opportunities
BP 2	*Identify Needed Resources*
C4	Educate the product / process provider
C5	Gather costs for resources

Section D.1.1.1 Table - continued

BP 3	*Implement and Manage Business Plan and Performance*
C6	Track sales
C7	Track financial impact to department
BP 4	*Market to Others*
C8	Grab market opportunities
BP 5	*Design Products / Processes*
C9	Create plan from concept to Available For Sale (AFS)
C10	DFMA and PDFMA
BP 6	*Acquire , Develop, and Maintain Human Assets, Property, and Equipment*
C11	Relationship with vendors and business
BP 7	*Get Orders*
C12	Identify catalog specific items
C13	Acquire component parts
C14	Identify process
BP 8	*Assemble Product / Complete Process to Existing and Future Orders*
C15	Create at production facility
C16	Customer training
C17	Trouble shooting
C18	Train production facility
BP 9	*Manage Product*
C19	Process for accessing product
C20	Process for accessing financial impact to department

D.1.1.2 <u>Case Study 1: Worksheet 2</u>

	Managerial System	Difficult to Imitate (1/0)	Provide Competitive Advantage (1/0)	Extendable to New Markets (1/0)	Customer Perceived Value (1/0)	Support (1)	Basic (2)	Critical (3)	Cutting Edge (4)	Total Score	Normalized Business Process Score
BP 1	*Create Business Plan*									21	7
C1	Excel in the vision strategy	1	1	1	0				4	7	
C2	Create a niche or better value with existing product / process for customer	1	1	1	1				4	8	
C3	Identify market opportunities	0	1	1	0				4	6	
BP 2	*Identify Needed Resources*									6	3
C4	Educate the product / process provider	0	0	1	0		2			3	
C5	Gather costs for resources	0	0	1	0		2			3	
BP 3	*Implement and Manage Business Plan and Performance*									6	3
C6	Track sales	0	0	1	0		2			3	
C7	Track financial impact to department	0	0	1	0		2			3	
BP 4	*Market to Others*									5	5
C8	Grab market opportunities	0	1	1	0			3		5	
BP 5	*Design Products / Processes*									7	4
C9	Create plan from concept to Available For Sale (AFS)	0	1	1	0		2			4	
C10	DFMA and PDFMA	0	1	1	0	1				3	
BP 6	*Acquire , Develop, and Maintain Human Assets, Property, and Equipment*									3	3
C11	Relationship with vendors and business	0	0	1	0		2			3	
BP 7	*Get Orders*									11	4
C12	Identify catalog specific items	0	1	0	1		2			4	
C13	Acquire component parts	0	1	0	0		2			3	
C14	Identify process	0	1	1	0		2			4	
BP 8	*Assemble Product / Complete Process to Existing and Future Orders*									19	5
C15	Create at production facility	0	1	0	1		2			4	
C16	Customer training	0	1	0	1			3		5	
C17	Trouble shooting	0	1	1	0				4	6	
C18	Train production facility	0	1	1	0		2			4	
BP 9	*Manage Product*									10	5
C19	Process for accessing product	0	1	1	0			3		5	
C20	Process for accessing financial impact to department	0	1	1	0			3		5	

D.1.1.3 <u>Case Study 1: Worksheet 3</u>

Dimension	Weight
Cost	0.2
Time	0.2
Quality	0.2
Value	0.2
Ease of Implementation	0.2

D.1.1.4 Case Study 1: Worksheet 4

	Capability	Cost	Time	Quality	Value	Ease of Implementation	Total Score	Normalized Business Process Score
	Weight	0.2	0.2	0.2	0.2	0.2	1.00	
BP 1	*Create Business Plan*						11.6	3.9
C1	Excel in the vision strategy	4	4	5	5	4	4.4	
C2	Create a niche or better value with existing product / process for customer	3	3	5	3	3	3.4	
C3	Identify market opportunities	4	3	4	5	3	3.8	
BP 2	*Identify Needed Resources*						8.6	4.3
C4	Educate the product / process provider	4	4	5	5	5	4.6	
C5	Gather costs for resources	4	4	4	4	4	4	
BP 3	*Implement and Manage Business Plan and Performance*						7.4	3.7
C6	Track sales	4	4	4	4	4	4	
C7	Track financial impact to department	4	3	4	3	3	3.4	
BP 4	*Market to Others*						3.2	3.2
C8	Grab market opportunities	2	3	4	5	2	3.2	
BP 5	*Design Products / Processes*						6	3.0
C9	Create plan from concept to Available For Sale (AFS)	2	2	4	4	3	3	
C10	DFMA and PDFMA	2	2	3	4	4	3	
BP 6	*Acquire , Develop, and Maintain Human Assets, Property, and Equipment*						4.6	4.6
C11	Relationship with vendors and business	5	4	5	5	4	4.6	
BP 7	*Get Orders*						12.4	4.1
C12	Identify catalog specific items	5	4	5	5	5	4.8	
C13	Acquire component parts	4	3	5	4	4	4	
C14	Identify process	3	4	3	4	4	3.6	
BP 8	*Assemble Product / Complete Process to Existing and Future Orders*						14	3.5
C15	Create at production facility	2	4	2	2	2	2.4	
C16	Customer training	3	4	5	5	4	4.2	
C17	Trouble shooting	4	2	5	5	3	3.8	
C18	Train production facility	2	3	4	5	4	3.6	
BP 9	*Manage Product*						6	3.0
C19	Process for accessing product	3	3	3	3	3	3	
C20	Process for accessing financial impact to department	3	3	3	3	3	3	

D.1.1.5 Case Study 1: Worksheet 5

	Business Process	Core Rating	Core Rating Converted	Performance Indicators	Performance Indicator Converted	Total Score
BP 1	Create Business Plan	7	35	3.9	31	4
BP 2	Identify Needed Resources	3	15	4.3	34	-19
BP 3	Implement and Manage Business Plan and Performance	3	15	3.7	30	-15
BP 4	Market to Others	5	25	3.2	26	-1
BP 5	Design Products / Processes	4	18	3.0	24	-7
BP 6	Acquire , Develop, and Maintain Human Assets, Property, and Equipment	3	15	4.6	37	-22
BP 7	Get Orders	4	18	4.1	33	-15
BP 8	Assemble Product / Complete Process to Existing and Future Orders	5	24	3.5	28	-4
BP 9	Manage Product	5	25	3.0	24	1

D.1.1.6 Case Study 1: Worksheet 6

Description	Market and Customer Knowledge	Leadership Commitment	Planning and Project Selection	Training and Consulting	DMAIC and Lean Processes	Resources	Voice of Customer	Quality Function	Customer and Process Measures	Process Capability and Analysis	Process Improvement	Maintaining Improvements	Financial Results Measures	Recognition and Rewards	Total LSS Score	Item	LSS Priority Rating
Create Business Plan															10		3.3
Excel in the vision strategy	3	5	1	3	1	4	4	4	4	1	4	4	3	1	42	1	
Create a niche or better value with existing product / process for customer	3	4	3	3	3	2	5	4	5	1	4	4	4	1	46	1	
Identify market opportunities	3	5	4	5	2	3	4	4	5	1	4	4	4	1	49	1	
Manage Product															7		3.4
Process for accessing product	2	4	4	4	4	4	2	4	2	4	4	4	5	1	48	1	
Process for accessing financial impact to department	1	5	4	4	4	3	2	4	2	3	4	4	5	1	46	1	

D.1.1.7 Case Study 1: Supermatrix for Cost

COST	R		KTEW			DE		UCAM				MEEC			
Relationships (R)	CEC	CB	CCSP	PI	ECCK	D	E	PC	ROS	MM	AI	SDP	MCP	GPC	FCS
CEC	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
CB	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Knowledge, training, and empowered workers (KTEW)															
CCSP	0	0	0	0.6667	0.8000	0	0	0	0	0	0	0	0	0	0
PI	0	0	0.2500	0	0.2000	0	0	0	0	0	0	0	0	0	0
ECCK	0	0	0.7500	0.3333	0	0	0	0	0	0	0	0	0	0	0
Databases and Environment (DE)															
D	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
E	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Uncertainty, Change Agent, and Management (UCAM)															
PC	0	0	0	0	0	0	0	0	0.8333	0	0.6667	0	0	0	0
ROS	0	0	0	0	0	0	0	0.8000	0	0	0.3333	0	0	0	0
MM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AI	0	0	0	0	0	0	0	0.2000	0.1667	0	0	0	0	0	0
More effective and efficient company at a minimal cost, and happy customer (MEEC)															
SDP	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2500	0.8000
MCP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GPC	0	0	0	0	0	0	0	0	0	0	0	0.6667	0	0	0.2000
FCS	0	0	0	0	0	0	0	0	0	0	0	0.3333	0	0.7500	0

D.1.1.8 Case Study 1: Supermatrix for Delivery

DELIVERY	R		KTEW			DE		UCAM				MEEC			
Relationships (R)	CEC	CB	CCSP	PI	ECCK	D	E	PC	ROS	MM	AI	SDP	MCP	GPC	FCS
CEC	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
CB	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Knowledge, training, and empowered workers (KTEW)															
CCSP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PI	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
ECCK	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Databases and Environment (DE)															
D	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
E	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Uncertainty, Change Agent, and Management (UCAM)															
PC	0	0	0	0	0	0	0	0	0.8333	0	0.6667	0	0	0	0
ROS	0	0	0	0	0	0	0	0.8000	0	0	0.3333	0	0	0	0
MM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AI	0	0	0	0	0	0	0	0.2000	0.1667	0	0	0	0	0	0
More effective and efficient company at a minimal cost, and happy customer (MEEC)															
SDP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MCP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GPC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
FCS	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0

D.1.1.9 Case Study 1: Supermatrix for Robustness

ROBUSTNESS	R		KTEW			DE		UCAM				MEEC			
Relationships (R)	CEC	CB	CCSP	PI	ECCK	D	E	PC	ROS	MM	AI	SDP	MCP	GPC	FCS
CEC	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
CB	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Knowledge, training, and empowered workers (KTEW)															
CCSP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PI	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
ECCK	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Databases and Environment (DE)															
D	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
E	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Uncertainty, Change Agent, and Management (UCAM)															
PC	0	0	0	0	0	0	0	0	0.6333	0.5679	0.5390	0	0	0	0
ROS	0	0	0	0	0	0	0	0.5571	0	0.3339	0.2973	0	0	0	0
MM	0	0	0	0	0	0	0	0.3202	0.2605	0	0.1638	0	0	0	0
AI	0	0	0	0	0	0	0	0.1226	0.1062	0.0982	0	0	0	0	0
More effective and efficient company at a minimal cost, and happy customer (MEEC)															
SDP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MCP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GPC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
FCS	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0

D.1.1.10 Case Study 1: Supermatrix for Scope

SCOPE	R		KTEW			DE		UCAM				MEEC			
Relationships (R)	CEC	CB	CCSP	PI	ECCK	D	E	PC	ROS	MM	AI	SDP	MCP	GPC	FCS
CEC	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
CB	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Knowledge, training, and empowered workers (KTEW)															
CCSP	0	0	0	0.6667	0.2000	0	0	0	0	0	0	0	0	0	0
PI	0	0	0.2500	0	0.8000	0	0	0	0	0	0	0	0	0	0
ECCK	0	0	0.7500	0.3333	0	0	0	0	0	0	0	0	0	0	0
Databases and Environment (DE)															
D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Uncertainty, Change Agent, and Management (UCAM)															
PC	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
ROS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AI	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
More effective and efficient company at a minimal cost, and happy customer (MEEC)															
SDP	0	0	0	0	0	0	0	0	0	0	0	0	0.1226	0.1062	0.0982
MCP	0	0	0	0	0	0	0	0	0	0	0	0.5390	0	0.6333	0.5679
GPC	0	0	0	0	0	0	0	0	0	0	0	0.2973	0.5571	0	0.3339
FCS	0	0	0	0	0	0	0	0	0	0	0	0.1638	0.3202	0.2605	0

D.1.1.11 Case Study 1: Supermatrix for Risk

RISK	R		KTEW			DE		UCAM				MEEC			
Relationships (R)	CEC	CB	CCSP	PI	ECCK	D	E	PC	ROS	MM	AI	SDP	MCP	GPC	FCS
CEC	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
CB	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Knowledge, training, and empowered workers (KTEW)															
CCSP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ECCK	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Databases and Environment (DE)															
D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Uncertainty, Change Agent, and Management (UCAM)															
PC	0	0	0	0	0	0	0	0	0	0.8333	0.8333	0	0	0	0
ROS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MM	0	0	0	0	0	0	0	0.7500	0	0	0.1667	0	0	0	0
AI	0	0	0	0	0	0	0	0.2500	0	0.1667	0	0	0	0	0
More effective and efficient company at a minimal cost, and happy customer (MEEC)															
SDP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MCP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GPC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
FCS	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0

D.1.1.12 Case Study 1: Converged Supermatrix for Cost

COST	R		KTEW			DE		UCAM				MEEC			
Relationships (R)	CEC	CB	CCSP	PI	ECCK	D	E	PC	ROS	MM	AI	SDP	MCP	GPC	FCS
CEC	0.500	0.500	0	0	0	0	0	0	0	0	0	0	0	0	0
CB	0.500	0.500	0	0	0	0	0	0	0	0	0	0	0	0	0
Knowledge, training, and empowered workers (KTEW)															
CCSP	0	0	0.489	0.489	0.489	0	0	0	0	0	0	0	0	0	0
PI	0	0	0.150	0.150	0.150	0	0	0	0	0	0	0	0	0	0
ECCK	0	0	0.361	0.361	0.361	0	0	0	0	0	0	0	0	0	0
Databases and Environment (DE)															
D	0	0	0	0	0	0.5	0.5	0	0	0	0	0	0	0	0
E	0	0	0	0	0	0.5	0.5	0	0	0	0	0	0	0	0
Uncertainty, Change Agent, and Management (UCAM)															
PC	0	0	0	0	0	0	0	0.375	0.375	0.375	0.375	0	0	0	0
ROS	0	0	0	0	0	0	0	0.283	0.283	0.283	0.283	0	0	0	0
MM	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000	0	0	0	0
AI	0	0	0	0	0	0	0	0.092	0.092	0.092	0.092	0	0	0	0
More effective and efficient company at a minimal cost, and happy customer (MEEC)															
SDP	0	0	0	0	0	0	0	0	0	0	0	0.263	0.263	0.263	0.263
MCP	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000
GPC	0	0	0	0	0	0	0	0	0	0	0	0.217	0.217	0.217	0.217
FCS	0	0	0	0	0	0	0	0	0	0	0	0.271	0.271	0.271	0.271

D.1.1.13 Case Study 1: Converged Supermatrix for Delivery

DELIVERY	R		KTEW			DE		UCAM				MEEC			
Relationships (R)	CEC	CB	CCSP	PI	ECCK	D	E	PC	ROS	MM	AI	SDP	MCP	GPC	FCS
CEC	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0
CB	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0
Knowledge, training, and empowered workers (KTEW)															
CCSP	0	0	0.000	0.000	0.000	0	0	0	0	0	0	0	0	0	0
PI	0	0	0.333	0.333	0.333	0	0	0	0	0	0	0	0	0	0
ECCK	0	0	0.333	0.333	0.333	0	0	0	0	0	0	0	0	0	0
Databases and Environment (DE)															
D	0	0	0	0	0	0.500	0.500	0	0	0	0	0	0	0	0
E	0	0	0	0	0	0.500	0.500	0	0	0	0	0	0	0	0
Uncertainty, Change Agent, and Management (UCAM)															
PC	0	0	0	0	0	0	0	0.375	0.375	0.375	0.375	0	0	0	0
ROS	0	0	0	0	0	0	0	0.283	0.283	0.283	0.283	0	0	0	0
MM	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000	0	0	0	0
AI	0	0	0	0	0	0	0	0.092	0.092	0.092	0.092	0	0	0	0
More effective and efficient company at a minimal cost, and happy customer (MEEC)															
SDP	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000
MCP	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000
GPC	0	0	0	0	0	0	0	0	0	0	0	0.250	0.250	0.250	0.250
FCS	0	0	0	0	0	0	0	0	0	0	0	0.250	0.250	0.250	0.250

D.1.1.14 Case Study 1: Converged Supermatrix for Robustness

ROBUSTNESS	R		KTEW			DE		UCAM				MEEC			
Relationships (R)	CEC	CB	CCSP	PI	ECCK	D	E	PC	ROS	MM	AI	SDP	MCP	GPC	FCS
CEC	0.500	0.500	0	0	0	0	0	0	0	0	0	0	0	0	0
CB	0.500	0.500	0	0	0	0	0	0	0	0	0	0	0	0	0
Knowledge, training, and empowered workers (KTEW)															
CCSP	0	0	0.000	0.000	0.000	0	0	0	0	0	0	0	0	0	0
PI	0	0	0.333	0.333	0.333	0	0	0	0	0	0	0	0	0	0
ECCK	0	0	0.333	0.333	0.333	0	0	0	0	0	0	0	0	0	0
Databases and Environment (DE)															
D	0	0	0	0	0	0.500	0.500	0	0	0	0	0	0	0	0
E	0	0	0	0	0	0.500	0.500	0	0	0	0	0	0	0	0
Uncertainty, Change Agent, and Management (UCAM)															
PC	0	0	0	0	0	0	0	0.435	0.435	0.435	0.435	0	0	0	0
ROS	0	0	0	0	0	0	0	0.297	0.297	0.297	0.297	0	0	0	0
MM	0	0	0	0	0	0	0	0.186	0.186	0.186	0.186	0	0	0	0
AI	0	0	0	0	0	0	0	0.082	0.082	0.082	0.082	0	0	0	0
More effective and efficient company at a minimal cost, and happy customer (MEEC)															
SDP	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000
MCP	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000
GPC	0	0	0	0	0	0	0	0	0	0	0	0.250	0.250	0.250	0.250
FCS	0	0	0	0	0	0	0	0	0	0	0	0.250	0.250	0.250	0.250

D.1.1.15 Case Study 1: Converged Supermatrix for Scope

SCOPE	R		KTEW			DE		UCAM				MEEC			
Relationships (R)	CEC	CB	CCSP	PI	ECCK	D	E	PC	ROS	MM	AI	SDP	MCP	GPC	FCS
CEC	0.500	0.500	0	0	0	0	0	0	0	0	0	0	0	0	0
CB	0.500	0.500	0	0	0	0	0	0	0	0	0	0	0	0	0
Knowledge, training, and empowered workers (KTEW)															
CCSP	0	0	0.289	0.289	0.289	0	0	0	0	0	0	0	0	0	0
PI	0	0	0.350	0.350	0.350	0	0	0	0	0	0	0	0	0	0
ECCK	0	0	0.361	0.361	0.361	0	0	0	0	0	0	0	0	0	0
Databases and Environment (DE)															
D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Uncertainty, Change Agent, and Management (UCAM)															
PC	0	0	0	0	0	0	0	0.250	0.250	0.250	0.250	0	0	0	0
ROS	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000	0	0	0	0
MM	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000	0	0	0	0
AI	0	0	0	0	0	0	0	0.250	0.250	0.250	0.250	0	0	0	0
More effective and efficient company at a minimal cost, and happy customer (MEEC)															
SDP	0	0	0	0	0	0	0	0	0	0	0	0.082	0.082	0.082	0.082
MCP	0	0	0	0	0	0	0	0	0	0	0	0.435	0.435	0.435	0.435
GPC	0	0	0	0	0	0	0	0	0	0	0	0.297	0.297	0.297	0.297
FCS	0	0	0	0	0	0	0	0	0	0	0	0.186	0.186	0.186	0.186

D.1.1.16 Case Study 1: Converged Supermatrix for Risk

RISK	R		KTEW			DE		UCAM				MEEC			
Relationships (R)	CEC	CB	CCSP	PI	ECCK	D	E	PC	ROS	MM	AI	SDP	MCP	GPC	FCS
CEC	0.500	0.500	0	0	0	0	0	0	0	0	0	0	0	0	0
CB	0.500	0.500	0	0	0	0	0	0	0	0	0	0	0	0	0
Knowledge, training, and empowered workers (KTEW)															
CCSP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ECCK	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Databases and Environment (DE)															
D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Uncertainty, Change Agent, and Management (UCAM)															
PC	0	0	0	0	0	0	0	0.417	0.417	0.417	0.417	0	0	0	0
ROS	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000	0	0	0	0
MM	0	0	0	0	0	0	0	0.229	0.229	0.229	0.229	0	0	0	0
AI	0	0	0	0	0	0	0	0.104	0.104	0.104	0.104	0	0	0	0
More effective and efficient company at a minimal cost, and happy customer (MEEC)															
SDP	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000
MCP	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000
GPC	0	0	0	0	0	0	0	0	0	0	0	0.250	0.250	0.250	0.250
FCS	0	0	0	0	0	0	0	0	0	0	0	0.250	0.250	0.250	0.250

D.1.1.17 Case Study 1: Desirability for Cost

COST									
Relationships (R)	Weight (Business Plan)	eVector (Lean Six Sigma Enablers)	Converged Supermatrix	eVector (Customer Demand Implementation Alternative)	eVector (Current System Implementation Alternative)	eVector (Improvements Implementation Alternative)	Customer Demand Score	Current System Score	Improvements Score
CEC	0.067	0.750	0.500	0.080	0.195	0.475	0.00199	0.00488	0.01188
CB	0.067	0.250	0.500	0.163	0.024	0.064	0.00136	0.00020	0.00053
Knowledge, training, and empowered workers (KTEW)									
CCSP	0.267	0.557	0.489	0.158	0.345	0.054	0.01150	0.02506	0.00390
PI	0.267	0.123	0.150	0.080	0.012	0.031	0.00039	0.00006	0.00015
ECCK	0.267	0.320	0.361	0.034	0.083	0.203	0.00105	0.00257	0.00625
Databases and Environment (DE)									
D	0.333	0.750	0.500	0.488	0.071	0.191	0.06099	0.00892	0.02384
E	0.333	0.250	0.500	0.163	0.024	0.064	0.00678	0.00099	0.00265
Uncertainty, Change Agent, and Management (UCAM)									
PC	0.200	0.568	0.375	0.134	0.292	0.045	0.00570	0.01242	0.00193
ROS	0.200	0.334	0.283	0.176	0.027	0.081	0.00333	0.00052	0.00153
MM	0.200	0.000	0.000	0.017	0.106	0.049	0.00000	0.00000	0.00000
AI	0.200	0.098	0.092	0.046	0.007	0.021	0.00008	0.00001	0.00004
More effective and efficient company at a minimal cost, and happy customer (MEEC)									
SDP	0.133	0.110	0.263	0.046	0.021	0.007	0.00018	0.00008	0.00003
MCP	0.133	0.000	0.000	0.292	0.045	0.134	0.00000	0.00000	0.00000
GPC	0.133	0.544	0.217	0.176	0.027	0.081	0.00276	0.00043	0.00127
FCS	0.133	0.346	0.271	0.106	0.017	0.049	0.00133	0.00021	0.00061
						Desirability Indices	0.09743	0.05636	0.05461

D.1.1.18 Case Study 1: Desirability for Delivery

DELIVERY									
Relationships (R)	Weight (Business Plan)	eVector (Lean Six Sigma Enablers)	Converged Supermatrix	eVector (Customer Demand Implementation Alternative)	eVector (Current System Implementation Alternative)	eVector (Improvements Implementation Alternative)	Customer Demand Score	Current System Score	Improvements Score
CEC	0.067	0.750	0.500	0.080	0.195	0.475	0.00199	0.00488	0.01188
CB	0.067	0.250	0.500	0.163	0.024	0.064	0.00136	0.00020	0.00053
Knowledge, training, and empowered workers (KTEW)									
CCSP	0.267	0.000	0.000	0.158	0.345	0.054	0.00000	0.00000	0.00000
PI	0.267	0.250	0.333	0.080	0.012	0.031	0.00177	0.00026	0.00069
ECCK	0.267	0.750	0.333	0.034	0.083	0.203	0.00227	0.00556	0.01352
Databases and Environment (DE)									
D	0.333	0.750	0.500	0.488	0.071	0.191	0.06099	0.00892	0.02384
E	0.333	0.250	0.500	0.163	0.024	0.064	0.00678	0.00099	0.00265
Uncertainty, Change Agent, and Management (UCAM)									
PC	0.200	0.568	0.375	0.134	0.292	0.045	0.00570	0.01242	0.00193
ROS	0.200	0.334	0.283	0.176	0.027	0.081	0.00333	0.00052	0.00153
MM	0.200	0.000	0.000	0.017	0.106	0.049	0.00000	0.00000	0.00000
AI	0.200	0.098	0.092	0.046	0.007	0.021	0.00008	0.00001	0.00004
More effective and efficient company at a minimal cost, and happy customer (MEEC)									
SDP	0.133	0.000	0.000	0.046	0.021	0.007	0.00000	0.00000	0.00000
MCP	0.133	0.000	0.000	0.292	0.045	0.134	0.00000	0.00000	0.00000
GPC	0.133	0.667	0.250	0.176	0.027	0.081	0.00391	0.00061	0.00179
FCS	0.133	0.333	0.250	0.106	0.017	0.049	0.00118	0.00018	0.00054
						Desirability Indices	0.08935	0.03456	0.05894

D.1.1.19 Case Study 1: Desirability for Robustness

ROBUSTNESS									
Relationships (R)	Weight (Business Plan)	eVector (Lean Six Sigma Enablers)	Converged Supermatrix	eVector (Customer Demand Implementation Alternative)	eVector (Current System Implementation Alternative)	eVector (Improvements Implementation Alternative)	Customer Demand Score	Current System Score	Improvements Score
CEC	0.067	0.750	0.500	0.080	0.195	0.475	0.00199	0.00488	0.01188
CB	0.067	0.250	0.500	0.163	0.024	0.064	0.00136	0.00020	0.00053
Knowledge, training, and empowered workers (KTEW)									
CCSP	0.267	0.000	0.000	0.158	0.345	0.054	0.00000	0.00000	0.00000
PI	0.267	0.250	0.333	0.080	0.012	0.031	0.00177	0.00026	0.00069
ECCK	0.267	0.750	0.333	0.034	0.083	0.203	0.00227	0.00556	0.01352
Databases and Environment (DE)									
D	0.333	0.750	0.500	0.488	0.071	0.191	0.06099	0.00892	0.02384
E	0.333	0.250	0.500	0.163	0.024	0.064	0.00678	0.00099	0.00265
Uncertainty, Change Agent, and Management (UCAM)									
PC	0.200	0.471	0.435	0.134	0.292	0.045	0.00548	0.01195	0.00186
ROS	0.200	0.284	0.297	0.176	0.027	0.081	0.00297	0.00046	0.00136
MM	0.200	0.171	0.186	0.017	0.106	0.049	0.00011	0.00068	0.00031
AI	0.200	0.074	0.082	0.046	0.007	0.021	0.00005	0.00001	0.00003
More effective and efficient company at a minimal cost, and happy customer (MEEC)									
SDP	0.133	0.000	0.000	0.046	0.021	0.007	0.00000	0.00000	0.00000
MCP	0.133	0.000	0.000	0.292	0.045	0.134	0.00000	0.00000	0.00000
GPC	0.133	0.667	0.250	0.176	0.027	0.081	0.00391	0.00061	0.00179
FCS	0.133	0.333	0.250	0.106	0.017	0.049	0.00118	0.00018	0.00054
						Desirability Indices	**0.08885**	**0.03471**	**0.05900**

D.1.1.20 Case Study 1: Desirability for Scope

SCOPE									
Relationships (R)	Weight (Business Plan)	eVector (Lean Six Sigma Enablers)	Converged Supermatrix	eVector (Customer Demand Implementation Alternative)	eVector (Current System Implementation Alternative)	eVector (Improvements Implementation Alternative)	Customer Demand Score	Current System Score	Improvements Score
CEC	0.067	0.750	0.500	0.080	0.195	0.475	0.00199	0.00488	0.01188
CB	0.067	0.250	0.500	0.163	0.024	0.064	0.00136	0.00020	0.00053
Knowledge, training, and empowered workers (KTEW)									
CCSP	0.267	0.557	0.289	0.158	0.345	0.054	0.00680	0.01481	0.00231
PI	0.267	0.123	0.350	0.080	0.012	0.031	0.00091	0.00013	0.00036
ECCK	0.267	0.320	0.361	0.034	0.083	0.203	0.00105	0.00257	0.00625
Databases and Environment (DE)									
D	0.333	1.000	0.000	0.488	0.071	0.191	0.00000	0.00000	0.00000
E	0.333	0.000	0.000	0.163	0.024	0.064	0.00000	0.00000	0.00000
Uncertainty, Change Agent, and Management (UCAM)									
PC	0.200	0.833	0.250	0.134	0.292	0.045	0.00558	0.01215	0.00189
ROS	0.200	0.000	0.000	0.176	0.027	0.081	0.00000	0.00000	0.00000
MM	0.200	0.000	0.000	0.017	0.106	0.049	0.00000	0.00000	0.00000
AI	0.200	0.167	0.250	0.046	0.007	0.021	0.00038	0.00006	0.00017
More effective and efficient company at a minimal cost, and happy customer (MEEC)									
SDP	0.133	0.074	0.082	0.046	0.021	0.007	0.00004	0.00002	0.00001
MCP	0.133	0.471	0.435	0.292	0.045	0.134	0.00797	0.00124	0.00366
GPC	0.133	0.284	0.297	0.176	0.027	0.081	0.00198	0.00031	0.00091
FCS	0.133	0.171	0.186	0.106	0.017	0.049	0.00045	0.00007	0.00021
						Desirability Indices	**0.02849**	**0.03644**	**0.02816**

D.1.1.21 Case Study 1: Desirability for Risk

RISK									
Relationships (R)	**Weight (Business Plan)**	**eVector (Lean Six Sigma Enablers)**	**Converged Supermatrix**	**eVector (Customer Demand Implementation Alternative)**	**eVector (Current System Implementation Alternative)**	**eVector (Improvements Implementation Alternative)**	**Customer Demand Score**	**Current System Score**	**Improvements Score**
CEC	0.067	0.750	0.500	0.080	0.195	0.475	0.00199	0.00488	0.01188
CB	0.067	0.250	0.500	0.163	0.024	0.064	0.00136	0.00020	0.00053
Knowledge, training, and empowered workers (KTEW)									
CCSP	0.267	0.000	0.000	0.158	0.345	0.054	0.00000	0.00000	0.00000
PI	0.267	0.000	0.000	0.080	0.012	0.031	0.00000	0.00000	0.00000
ECCK	0.267	1.000	0.000	0.034	0.083	0.203	0.00000	0.00000	0.00000
Databases and Environment (DE)									
D	0.333	0.000	0.000	0.488	0.071	0.191	0.00000	0.00000	0.00000
E	0.333	0.000	0.000	0.163	0.024	0.064	0.00000	0.00000	0.00000
Uncertainty, Change Agent, and Management (UCAM)									
PC	0.200	0.633	0.417	0.134	0.292	0.045	0.00706	0.01539	0.00240
ROS	0.200	0.000	0.000	0.176	0.027	0.081	0.00000	0.00000	0.00000
MM	0.200	0.260	0.229	0.017	0.106	0.049	0.00020	0.00127	0.00058
AI	0.200	0.106	0.104	0.046	0.007	0.021	0.00010	0.00002	0.00005
More effective and efficient company at a minimal cost, and happy customer (MEEC)									
SDP	0.133	0.000	0.000	0.046	0.021	0.007	0.00000	0.00000	0.00000
MCP	0.133	0.000	0.000	0.292	0.045	0.134	0.00000	0.00000	0.00000
GPC	0.133	0.667	0.250	0.176	0.027	0.081	0.00391	0.00061	0.00179
FCS	0.133	0.333	0.250	0.106	0.017	0.049	0.00118	0.00018	0.00054
						Desirability Indices	**0.01580**	**0.02255**	**0.01776**

D.1.1.22 Case Study 1: Lean Six Sigma Weighted Index Business Process 1

Create Business Plan	Cost	Delivery	Robustness	Scope	Risk	LSSWI
Weight	*0.519*	*0.257*	*0.068*	*0.156*	*0.389*	
Customer Demand	0.097	0.089	0.089	0.028	0.016	0.090
Current System	0.056	0.035	0.035	0.036	0.023	0.013
Implementation of Process / Product Improvements	0.055	0.059	0.059	0.028	0.018	0.009

D.1.1.23 Case Study 1: Lean Six Sigma Weighted Index Business Process 9

Manage Product	Cost	Delivery	Robustness	Scope	Risk	LSSWI
Weight	*0.315*	*0.431*	*0.058*	*0.196*	*0.132*	
Customer Demand	0.097	0.089	0.089	0.028	0.016	0.082
Current System	0.056	0.035	0.035	0.036	0.023	0.013
Implementation of Process / Product Improvements	0.055	0.059	0.059	0.028	0.018	0.009

D.1.2 Case Study 1: Project 2

Project 2 is a large project. It creates approximately $245 million in annual sales and utilizes nine people from the manufacturing facility. This item is a smart motor controller that provides microprocessor controlled starting for standard three phase squirrel cage induction or wye delta motors. (Rockwell Automation, 2007)

The persons involved in this case study are the process improvement team, which consists of Production Control, Production, Manufacturing Engineering, and Supervision. These individuals can contribute to the process for the supply chain, order processing chain, and manufacturing processes for this product line. As with any decision, the evaluation results are very dependent on the decision makers.

D.1.2.1 Case Study 2: Worksheet 1

	Company ABC's vision is focused on being the most valued global provider of power, control and information solutions.
BP 1	*Manpower*
C1	Efficient Training Program
C2	Just in time applied training
C3	Right # of people at the right time
BP 2	*Production and Inventory Control*
C4	Customer that needs product
C5	Buildable order
BP 3	*Supply Chain*
C6	Good part quality
C7	Need parts on time and the correct quantities
BP 4	*Measurement System Analysis*
C8	Accurate measuring systems
BP 5	*Methods and Material Flow*
C9	On time delivery
C10	High labor productivity

D.1.2.2 Case Study 2: Worksheet 2

	Managerial System	Difficult to Imitate (1/0)	Provide Competitive Advantage (1/0)	Extendable to New Markets (1/0)	Customer Perceived Value (1/0)	Support (1)	Basic (2)	Critical (3)	Cutting Edge (4)	Total Score	Normalized Business Process Score
BP 1	*Manpower*									12	4
C1	Efficient Training Program	0	1	1	0		2			4	
C2	Just in time applied training	0	1	1	0		2			4	
C3	Right # of people at the right time	0	1	1	0		2			4	
BP 2	*Production and Inventory Control*									8	4
C4	Customer that needs product	0	1	1	1		2			5	
C5	Buildable order	0	1	0	0		2			3	
BP 3	*Supply Chain*									12	6
C6	Good part quality	0	1	1	1			3		6	
C7	Need parts on time and the correct quantities	0	1	1	1			3		6	
BP 4	*Measurement System Analysis*									5	5
C8	Accurate measuring systems	0	1	1	0			3		5	
BP 5	*Methods and Material Flow*									10	5
C9	On time delivery	0	1	1	1			3		6	
C10	High labor productivity	0	1	1	0		2			4	

D.1.2.3 Case Study 2: Worksheet 3

Dimension	Weight
Cost	0.2
Time	0.2
Quality	0.2
Value	0.2
Ease of Implementation	0.2

D.1.2.4 Case Study 2: Worksheet 4

	Capability	Cost	Time	Quality	Value	Ease of Implementation	Total Score	Normalized Business Process Score
	Weight	0.2	0.2	0.2	0.2	0.2	1.00	
BP 1	*Manpower*						8.2	2.7
C1	Efficient Training Program	3	3	3	3	3	3	
C2	Just in time applied training	3	3	3	3	3	3	
C3	Right # of people at the right time	1	2	3	3	2	2.2	
BP 2	*Production and Inventory Control*						7.4	3.7
C4	Customer that needs product	5	3	5	5	5	4.6	
C5	Buildable order	2	3	3	3	3	2.8	
BP 3	*Supply Chain*						6	3.0
C6	Good part quality	4	3	3	3	3	3.2	
C7	Need parts on time and the correct quantities	2	3	3	3	3	2.8	
BP 4	*Measurement System Analysis*						4.4	4.4
C8	Accurate measuring systems	5	3	5	5	4	4.4	
BP 5	*Methods and Material Flow*						4	2.0
C9	On time delivery	1	1	3	3	2	2	
C10	High labor productivity	1	1	3	3	2	2	

D.1.2.5 Case Study 2: Worksheet 5

	Business Process	Core Rating	Core Rating Converted	Performance Indicators	Performance Indicator Converted	Total Score
BP 1	Manpower	4	20	2.7	22	-2
BP 2	Production and Inventory Control	4	20	3.7	30	-10
BP 3	Supply Chain	6	30	3.0	24	6
BP 4	Measurement System Analysis	5	25	4.4	35	-10
BP 5	Methods and Material Flow	5	25	2.0	16	9

D.1.2.6 Case Study 2: Worksheet 6

Description	Market and Customer Knowledge	Leadership Commitment	Planning and Project Selection	Training and Consulting	DMAIC and Lean Processes	Resources	Voice of Customer	Quality Function	Customer and Process Measures	Process Capability and Analysis	Process Improvement	Maintaining Improvements	Financial Results Measures	Recognition and Rewards	Total LSS Score	Item	LSS Priority Rating
Supply Chain															9		4.5
Good part quality	1	5	4	5	5	5	5	5	5	5	5	5	5	3	63	1	
Need parts on time and the correct quantities	1	5	4	5	5	5	5	5	5	5	5	5	5	3	63	1	
Methods and Material Flow															9		4.7
On time delivery	1	5	5	5	5	5	5	5	5	5	5	5	5	5	66	1	
High labor productivity	1	5	5	5	5	5	5	5	5	5	5	5	5	5	66	1	

D.1.2.7 Case Study 2: Supermatrix for Cost

COST	R		KTEW			DE		UCAM				MEEC			
Relationships (R)	CEC	CB	CCSP	PI	ECCK	D	E	PC	ROS	MM	AI	SDP	MCP	GPC	FCS
CEC	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
CB	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Knowledge, training, and empowered workers (KTEW)															
CCSP	0	0	0	0.6667	0.8000	0	0	0	0	0	0	0	0	0	0
PI	0	0	0.2500	0	0.2000	0	0	0	0	0	0	0	0	0	0
ECCK	0	0	0.7500	0.3333	0	0	0	0	0	0	0	0	0	0	0
Databases and Environment (DE)															
D	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
E	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Uncertainty, Change Agent, and Management (UCAM)															
PC	0	0	0	0	0	0	0	0	0.6667	0	0.8333	0	0	0	0
ROS	0	0	0	0	0	0	0	0.2000	0	0	0.1667	0	0	0	0
MM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AI	0	0	0	0	0	0	0	0.8000	0.3333	0	0	0	0	0	0
More effective and efficient company at a minimal cost, and happy customer (MEEC)															
SDP	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2498	0.8000
MCP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GPC	0	0	0	0	0	0	0	0	0	0	0	0.6667	0	0	0.2000
FCS	0	0	0	0	0	0	0	0	0	0	0	0.3333	0	0.7502	0

D.1.2.8 Case Study 2: Supermatrix for Delivery

DELIVERY	R		KTEW			DE		UCAM				MEEC			
Relationships (R)	CEC	CB	CCSP	PI	ECCK	D	E	PC	ROS	MM	AI	SDP	MCP	GPC	FCS
CEC	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
CB	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Knowledge, training, and empowered workers (KTEW)															
CCSP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PI	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
ECCK	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Databases and Environment (DE)															
D	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
E	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Uncertainty, Change Agent, and Management (UCAM)															
PC	0	0	0	0	0	0	0	0	0.6667	0	0.8333	0	0	0	0
ROS	0	0	0	0	0	0	0	0.2000	0	0	0.1667	0	0	0	0
MM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AI	0	0	0	0	0	0	0	0.8000	0.3333	0	0	0	0	0	0
More effective and efficient company at a minimal cost, and happy customer (MEEC)															
SDP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MCP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GPC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
FCS	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0

D.1.2.9 Case Study 2: Supermatrix for Robustness

ROBUSTNESS	R		KTEW			DE		UCAM				MEEC			
Relationships (R)	CEC	CB	CCSP	PI	ECCK	D	E	PC	ROS	MM	AI	SDP	MCP	GPC	FCS
CEC	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
CB	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Knowledge, training, and empowered workers (KTEW)															
CCSP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PI	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
ECCK	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Databases and Environment (DE)															
D	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
E	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Uncertainty, Change Agent, and Management (UCAM)															
PC	0	0	0	0	0	0	0	0	0.8084	0.5813	0.6479	0	0	0	0
ROS	0	0	0	0	0	0	0	0.1226	0	0.1096	0.1222	0	0	0	0
MM	0	0	0	0	0	0	0	0.3202	0.2457	0	0.2299	0	0	0	0
AI	0	0	0	0	0	0	0	0.5571	0.4459	0.3092	0	0	0	0	0
More effective and efficient company at a minimal cost, and happy customer (MEEC)															
SDP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MCP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GPC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
FCS	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0

D.1.2.10 Case Study 2: Supermatrix for Scope

SCOPE	R		KTEW			DE		UCAM				MEEC			
Relationships (R)	CEC	CB	CCSP	PI	ECCK	D	E	PC	ROS	MM	AI	SDP	MCP	GPC	FCS
CEC	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
CB	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Knowledge, training, and empowered workers (KTEW)															
CCSP	0	0	0	0.6667	0.2000	0	0	0	0	0	0	0	0	0	0
PI	0	0	0.2500	0	0.8000	0	0	0	0	0	0	0	0	0	0
ECCK	0	0	0.7500	0.3333	0	0	0	0	0	0	0	0	0	0	0
Databases and Environment (DE)															
D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Uncertainty, Change Agent, and Management (UCAM)															
PC	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
ROS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AI	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
More effective and efficient company at a minimal cost, and happy customer (MEEC)															
SDP	0	0	0	0	0	0	0	0	0	0	0	0	0.1226	0.1062	0.0982
MCP	0	0	0	0	0	0	0	0	0	0	0	0.5390	0	0.6333	0.5679
GPC	0	0	0	0	0	0	0	0	0	0	0	0.2973	0.5571	0	0.3339
FCS	0	0	0	0	0	0	0	0	0	0	0	0.1638	0.3202	0.2605	0

D.1.2.11 Case Study 2: Supermatrix for Risk

RISK	R		KTEW			DE		UCAM				MEEC			
Relationships (R)	CEC	CB	CCSP	PI	ECCK	D	E	PC	ROS	MM	AI	SDP	MCP	GPC	FCS
CEC	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
CB	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Knowledge, training, and empowered workers (KTEW)															
CCSP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ECCK	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Databases and Environment (DE)															
D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Uncertainty, Change Agent, and Management (UCAM)															
PC	0	0	0	0	0	0	0	0	0	0.6667	0.6667	0	0	0	0
ROS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MM	0	0	0	0	0	0	0	0.3333	0	0	0.3333	0	0	0	0
AI	0	0	0	0	0	0	0	0.6667	0	0.3333	0	0	0	0	0
More effective and efficient company at a minimal cost, and happy customer (MEEC)															
SDP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MCP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GPC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
FCS	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0

D.1.2.12 Case Study 2: Converged Supermatrix for Cost

COST	R		KTEW			DE		UCAM				MEEC			
Relationships (R)	CEC	CB	CCSP	PI	ECCK	D	E	PC	ROS	MM	AI	SDP	MCP	GPC	FCS
CEC	0.500	0.500	0	0	0	0	0	0	0	0	0	0	0	0	0
CB	0.500	0.500	0	0	0	0	0	0	0	0	0	0	0	0	0
Knowledge, training, and empowered workers (KTEW)															
CCSP	0	0	0.489	0.489	0.489	0	0	0	0	0	0	0	0	0	0
PI	0	0	0.150	0.150	0.150	0	0	0	0	0	0	0	0	0	0
ECCK	0	0	0.361	0.361	0.361	0	0	0	0	0	0	0	0	0	0
Databases and Environment (DE)															
D	0	0	0	0	0	0.5	0.5	0	0	0	0	0	0	0	0
E	0	0	0	0	0	0.5	0.5	0	0	0	0	0	0	0	0
Uncertainty, Change Agent, and Management (UCAM)															
PC	0	0	0	0	0	0	0	0.375	0.375	0.375	0.375	0	0	0	0
ROS	0	0	0	0	0	0	0	0.092	0.092	0.092	0.092	0	0	0	0
MM	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000	0	0	0	0
AI	0	0	0	0	0	0	0	0.283	0.283	0.283	0.283	0	0	0	0
More effective and efficient company at a minimal cost, and happy customer (MEEC)															
SDP	0	0	0	0	0	0	0	0	0	0	0	0.262	0.262	0.262	0.262
MCP	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000
GPC	0	0	0	0	0	0	0	0	0	0	0	0.217	0.217	0.217	0.217
FCS	0	0	0	0	0	0	0	0	0	0	0	0.271	0.271	0.271	0.271

D.1.2.13 Case Study 2: Converged Supermatrix for Delivery

DELIVERY	R		KTEW			DE		UCAM				MEEC			
Relationships (R)	CEC	CB	CCSP	PI	ECCK	D	E	PC	ROS	MM	AI	SDP	MCP	GPC	FCS
CEC	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0
CB	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0
Knowledge, training, and empowered workers (KTEW)															
CCSP	0	0	0.000	0.000	0.000	0	0	0	0	0	0	0	0	0	0
PI	0	0	0.333	0.333	0.333	0	0	0	0	0	0	0	0	0	0
ECCK	0	0	0.333	0.333	0.333	0	0	0	0	0	0	0	0	0	0
Databases and Environment (DE)															
D	0	0	0	0	0	0.500	0.500	0	0	0	0	0	0	0	0
E	0	0	0	0	0	0.500	0.500	0	0	0	0	0	0	0	0
Uncertainty, Change Agent, and Management (UCAM)															
PC	0	0	0	0	0	0	0	0.375	0.375	0.375	0.375	0	0	0	0
ROS	0	0	0	0	0	0	0	0.092	0.092	0.092	0.092	0	0	0	0
MM	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000	0	0	0	0
AI	0	0	0	0	0	0	0	0.283	0.283	0.283	0.283	0	0	0	0
More effective and efficient company at a minimal cost, and happy customer (MEEC)															
SDP	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000
MCP	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000
GPC	0	0	0	0	0	0	0	0	0	0	0	0.250	0.250	0.250	0.250
FCS	0	0	0	0	0	0	0	0	0	0	0	0.250	0.250	0.250	0.250

D.1.2.14 Case Study 2: Converged Supermatrix for Robustness

ROBUSTNESS	R		KTEW			DE		UCAM				MEEC			
Relationships (R)	CEC	CB	CCSP	PI	ECCK	D	E	PC	ROS	MM	AI	SDP	MCP	GPC	FCS
CEC	0.500	0.500	0	0	0	0	0	0	0	0	0	0	0	0	0
CB	0.500	0.500	0	0	0	0	0	0	0	0	0	0	0	0	0
Knowledge, training, and empowered workers (KTEW)															
CCSP	0	0	0.000	0.000	0.000	0	0	0	0	0	0	0	0	0	0
PI	0	0	0.333	0.333	0.333	0	0	0	0	0	0	0	0	0	0
ECCK	0	0	0.333	0.333	0.333	0	0	0	0	0	0	0	0	0	0
Databases and Environment (DE)															
D	0	0	0	0	0	0.500	0.500	0	0	0	0	0	0	0	0
E	0	0	0	0	0	0.500	0.500	0	0	0	0	0	0	0	0
Uncertainty, Change Agent, and Management (UCAM)															
PC	0	0	0	0	0	0	0	0.509	0.509	0.509	0.509	0	0	0	0
ROS	0	0	0	0	0	0	0	0.089	0.089	0.089	0.089	0	0	0	0
MM	0	0	0	0	0	0	0	0.199	0.199	0.199	0.199	0	0	0	0
AI	0	0	0	0	0	0	0	0.328	0.328	0.328	0.328	0	0	0	0
More effective and efficient company at a minimal cost, and happy customer (MEEC)															
SDP	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000
MCP	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000
GPC	0	0	0	0	0	0	0	0	0	0	0	0.250	0.250	0.250	0.250
FCS	0	0	0	0	0	0	0	0	0	0	0	0.250	0.250	0.250	0.250

D.1.2.15 Case Study 2: Converged Supermatrix for Scope

SCOPE	R		KTEW			DE		UCAM				MEEC			
Relationships (R)	CEC	CB	CCSP	PI	ECCK	D	E	PC	ROS	MM	AI	SDP	MCP	GPC	FCS
CEC	0.500	0.500	0	0	0	0	0	0	0	0	0	0	0	0	0
CB	0.500	0.500	0	0	0	0	0	0	0	0	0	0	0	0	0
Knowledge, training, and empowered workers (KTEW)															
CCSP	0	0	0.289	0.289	0.289	0	0	0	0	0	0	0	0	0	0
PI	0	0	0.350	0.350	0.350	0	0	0	0	0	0	0	0	0	0
ECCK	0	0	0.361	0.361	0.361	0	0	0	0	0	0	0	0	0	0
Databases and Environment (DE)															
D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Uncertainty, Change Agent, and Management (UCAM)															
PC	0	0	0	0	0	0	0	0.250	0.250	0.250	0.250	0	0	0	0
ROS	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000	0	0	0	0
MM	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000	0	0	0	0
AI	0	0	0	0	0	0	0	0.250	0.250	0.250	0.250	0	0	0	0
More effective and efficient company at a minimal cost, and happy customer (MEEC)															
SDP	0	0	0	0	0	0	0	0	0	0	0	0.082	0.082	0.082	0.082
MCP	0	0	0	0	0	0	0	0	0	0	0	0.435	0.435	0.435	0.435
GPC	0	0	0	0	0	0	0	0	0	0	0	0.297	0.297	0.297	0.297
FCS	0	0	0	0	0	0	0	0	0	0	0	0.186	0.186	0.186	0.186

D.1.2.16 Case Study 2: Converged Supermatrix for Risk

RISK	R		KTEW			DE		UCAM				MEEC			
Relationships (R)	CEC	CB	CCSP	PI	ECCK	D	E	PC	ROS	MM	AI	SDP	MCP	GPC	FCS
CEC	0.500	0.500	0	0	0	0	0	0	0	0	0	0	0	0	0
CB	0.500	0.500	0	0	0	0	0	0	0	0	0	0	0	0	0
Knowledge, training, and empowered workers (KTEW)															
CCSP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ECCK	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Databases and Environment (DE)															
D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Uncertainty, Change Agent, and Management (UCAM)															
PC	0	0	0	0	0	0	0	0.333	0.333	0.333	0.333	0	0	0	0
ROS	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000	0	0	0	0
MM	0	0	0	0	0	0	0	0.167	0.167	0.167	0.167	0	0	0	0
AI	0	0	0	0	0	0	0	0.250	0.250	0.250	0.250	0	0	0	0
More effective and efficient company at a minimal cost, and happy customer (MEEC)															
SDP	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000
MCP	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000
GPC	0	0	0	0	0	0	0	0	0	0	0	0.250	0.250	0.250	0.250
FCS	0	0	0	0	0	0	0	0	0	0	0	0.250	0.250	0.250	0.250

D.1.2.17 Case Study 2: Desirability for Cost

COST									
Relationships (R)	Weight (Business Plan)	eVector (Lean Six Sigma Enablers)	Converged Supermatrix	eVector (Customer Demand Implementation Alternative)	eVector (Current System Implementation Alternative)	eVector (Improvements Implementation Alternative)	Customer Demand Score	Current System Score	Improvements Score
CEC	0.067	0.750	0.500	0.080	0.195	0.475	0.00199	0.00488	0.01188
CB	0.067	0.250	0.500	0.163	0.024	0.064	0.00136	0.00020	0.00053
Knowledge, training, and empowered workers (KTEW)									
CCSP	0.267	0.557	0.489	0.158	0.345	0.054	0.01150	0.02506	0.00390
PI	0.267	0.123	0.150	0.080	0.012	0.031	0.00039	0.00006	0.00015
ECCK	0.267	0.320	0.361	0.034	0.083	0.203	0.00105	0.00257	0.00625
Databases and Environment (DE)									
D	0.333	0.750	0.500	0.488	0.071	0.191	0.06099	0.00892	0.02384
E	0.333	0.250	0.500	0.163	0.024	0.064	0.00678	0.00099	0.00265
Uncertainty, Change Agent, and Management (UCAM)									
PC	0.200	0.568	0.375	0.134	0.292	0.045	0.00570	0.01242	0.00193
ROS	0.200	0.334	0.092	0.176	0.027	0.081	0.00108	0.00017	0.00049
MM	0.200	0.000	0.000	0.017	0.106	0.049	0.00000	0.00000	0.00000
AI	0.200	0.098	0.283	0.046	0.007	0.021	0.00025	0.00004	0.00012
More effective and efficient company at a minimal cost, and happy customer (MEEC)									
SDP	0.133	0.110	0.262	0.046	0.021	0.007	0.00018	0.00008	0.00003
MCP	0.133	0.000	0.000	0.292	0.045	0.134	0.00000	0.00000	0.00000
GPC	0.133	0.544	0.217	0.176	0.027	0.081	0.00276	0.00043	0.00127
FCS	0.133	0.346	0.271	0.106	0.017	0.049	0.00133	0.00021	0.00061
						Desirability Indices	**0.09535**	**0.05604**	**0.05365**

D.1.2.18 Case Study 2: Desirability for Delivery

DELIVERY									
Relationships (R)	Weight (Business Plan)	eVector (Lean Six Sigma Enablers)	Converged Supermatrix	eVector (Customer Demand Implementation Alternative)	eVector (Current System Implementation Alternative)	eVector (Improvements Implementation Alternative)	Customer Demand Score	Current System Score	Improvements Score
CEC	0.067	0.750	0.500	0.080	0.195	0.475	0.00199	0.00488	0.01188
CB	0.067	0.250	0.500	0.163	0.024	0.064	0.00136	0.00020	0.00053
Knowledge, training, and empowered workers (KTEW)									
CCSP	0.267	0.000	0.000	0.158	0.345	0.054	0.00000	0.00000	0.00000
PI	0.267	0.250	0.333	0.080	0.012	0.031	0.00177	0.00026	0.00069
ECCK	0.267	0.750	0.333	0.034	0.083	0.203	0.00227	0.00556	0.01352
Databases and Environment (DE)									
D	0.333	0.750	0.500	0.488	0.071	0.191	0.06099	0.00892	0.02384
E	0.333	0.250	0.500	0.163	0.024	0.064	0.00678	0.00099	0.00265
Uncertainty, Change Agent, and Management (UCAM)									
PC	0.200	0.568	0.375	0.134	0.292	0.045	0.00570	0.01242	0.00193
ROS	0.200	0.334	0.092	0.176	0.027	0.081	0.00108	0.00017	0.00049
MM	0.200	0.000	0.000	0.017	0.106	0.049	0.00000	0.00000	0.00000
AI	0.200	0.098	0.283	0.046	0.007	0.021	0.00025	0.00004	0.00012
More effective and efficient company at a minimal cost, and happy customer (MEEC)									
SDP	0.133	0.000	0.000	0.046	0.021	0.007	0.00000	0.00000	0.00000
MCP	0.133	0.000	0.000	0.292	0.045	0.134	0.00000	0.00000	0.00000
GPC	0.133	0.667	0.250	0.176	0.027	0.081	0.00391	0.00061	0.00179
FCS	0.133	0.333	0.250	0.106	0.017	0.049	0.00118	0.00018	0.00054
						Desirability Indices	**0.08727**	**0.03424**	**0.05799**

D.1.2.19 Case Study 2: Desirability for Robustness

ROBUSTNESS									
Relationships (R)	Weight (Business Plan)	eVector (Lean Six Sigma Enablers)	Converged Supermatrix	eVector (Customer Demand Implementation Alternative)	eVector (Current System Implementation Alternative)	eVector (Improvements Implementation Alternative)	Customer Demand Score	Current System Score	Improvements Score
CEC	0.067	0.750	0.500	0.080	0.195	0.475	0.00199	0.00488	0.01188
CB	0.067	0.250	0.500	0.163	0.024	0.064	0.00136	0.00020	0.00053
Knowledge, training, and empowered workers (KTEW)									
CCSP	0.267	0.000	0.000	0.158	0.345	0.054	0.00000	0.00000	0.00000
PI	0.267	0.250	0.333	0.080	0.012	0.031	0.00177	0.00026	0.00069
ECCK	0.267	0.750	0.333	0.034	0.083	0.203	0.00227	0.00556	0.01352
Databases and Environment (DE)									
D	0.333	0.750	0.500	0.488	0.071	0.191	0.06099	0.00892	0.02384
E	0.333	0.250	0.500	0.163	0.024	0.064	0.00678	0.00099	0.00265
Uncertainty, Change Agent, and Management (UCAM)									
PC	0.200	0.471	0.509	0.134	0.292	0.045	0.00642	0.01399	0.00218
ROS	0.200	0.284	0.089	0.176	0.027	0.081	0.00089	0.00014	0.00041
MM	0.200	0.171	0.199	0.017	0.106	0.049	0.00011	0.00072	0.00033
AI	0.200	0.074	0.328	0.046	0.007	0.021	0.00022	0.00003	0.00010
More effective and efficient company at a minimal cost, and happy customer (MEEC)									
SDP	0.133	0.000	0.000	0.046	0.021	0.007	0.00000	0.00000	0.00000
MCP	0.133	0.000	0.000	0.292	0.045	0.134	0.00000	0.00000	0.00000
GPC	0.133	0.667	0.250	0.176	0.027	0.081	0.00391	0.00061	0.00179
FCS	0.133	0.333	0.250	0.106	0.017	0.049	0.00118	0.00018	0.00054
						Desirability Indices	**0.08787**	**0.03650**	**0.05846**

D.1.2.20 Case Study 2: Desirability for Scope

SCOPE									
Relationships (R)	Weight (Business Plan)	eVector (Lean Six Sigma Enablers)	Converged Supermatrix	eVector (Customer Demand Implementation Alternative)	eVector (Current System Implementation Alternative)	eVector (Improvements Implementation Alternative)	Customer Demand Score	Current System Score	Improvements Score
CEC	0.067	0.750	0.500	0.080	0.195	0.475	0.00199	0.00488	0.01188
CB	0.067	0.250	0.500	0.163	0.024	0.064	0.00136	0.00020	0.00053
Knowledge, training, and empowered workers (KTEW)									
CCSP	0.267	0.557	0.289	0.158	0.345	0.054	0.00680	0.01481	0.00231
PI	0.267	0.123	0.350	0.080	0.012	0.031	0.00091	0.00013	0.00036
ECCK	0.267	0.320	0.361	0.034	0.083	0.203	0.00105	0.00257	0.00625
Databases and Environment (DE)									
D	0.333	1.000	0.000	0.488	0.071	0.191	0.00000	0.00000	0.00000
E	0.333	0.000	0.000	0.163	0.024	0.064	0.00000	0.00000	0.00000
Uncertainty, Change Agent, and Management (UCAM)									
PC	0.200	0.833	0.250	0.134	0.292	0.045	0.00558	0.01215	0.00189
ROS	0.200	0.000	0.000	0.176	0.027	0.081	0.00000	0.00000	0.00000
MM	0.200	0.000	0.000	0.017	0.106	0.049	0.00000	0.00000	0.00000
AI	0.200	0.167	0.250	0.046	0.007	0.021	0.00038	0.00006	0.00017
More effective and efficient company at a minimal cost, and happy customer (MEEC)									
SDP	0.133	0.074	0.082	0.046	0.021	0.007	0.00004	0.00002	0.00001
MCP	0.133	0.471	0.435	0.292	0.045	0.134	0.00797	0.00124	0.00366
GPC	0.133	0.284	0.297	0.176	0.027	0.081	0.00198	0.00031	0.00091
FCS	0.133	0.171	0.186	0.106	0.017	0.049	0.00045	0.00007	0.00021
						Desirability Indices	**0.02849**	**0.03644**	**0.02816**

D.1.2.21 Case Study 2: Desirability for Risk

RISK									
Relationships (R)	Weight (Business Plan)	eVector (Lean Six Sigma Enablers)	Converged Supermatrix	eVector (Customer Demand Implementation Alternative)	eVector (Current System Implementation Alternative)	eVector (Improvements Implementation Alternative)	Customer Demand Score	Current System Score	Improvements Score
CEC	0.067	0.750	0.500	0.080	0.195	0.475	0.00199	0.00488	0.01188
CB	0.067	0.250	0.500	0.163	0.024	0.064	0.00136	0.00020	0.00053
Knowledge, training, and empowered workers (KTEW)									
CCSP	0.267	0.000	0.000	0.158	0.345	0.054	0.00000	0.00000	0.00000
PI	0.267	0.000	0.000	0.080	0.012	0.031	0.00000	0.00000	0.00000
ECCK	0.267	1.000	0.000	0.034	0.083	0.203	0.00000	0.00000	0.00000
Databases and Environment (DE)									
D	0.333	0.000	0.000	0.488	0.071	0.191	0.00000	0.00000	0.00000
E	0.333	0.000	0.000	0.163	0.024	0.064	0.00000	0.00000	0.00000
Uncertainty, Change Agent, and Management (UCAM)									
PC	0.200	0.633	0.333	0.134	0.292	0.045	0.00565	0.01231	0.00192
ROS	0.200	0.000	0.000	0.176	0.027	0.081	0.00000	0.00000	0.00000
MM	0.200	0.260	0.167	0.017	0.106	0.049	0.00014	0.00092	0.00042
AI	0.200	0.106	0.250	0.046	0.007	0.021	0.00024	0.00004	0.00011
More effective and efficient company at a minimal cost, and happy customer (MEEC)									
SDP	0.133	0.000	0.000	0.046	0.021	0.007	0.00000	0.00000	0.00000
MCP	0.133	0.000	0.000	0.292	0.045	0.134	0.00000	0.00000	0.00000
GPC	0.133	0.667	0.250	0.176	0.027	0.081	0.00391	0.00061	0.00179
FCS	0.133	0.333	0.250	0.106	0.017	0.049	0.00118	0.00018	0.00054
						Desirability Indices	**0.01447**	**0.01915**	**0.01719**

D.1.2.22 Case Study 2: Lean Six Sigma Weighted Index Business Process 3

Supply Chain	Cost	Delivery	Robustness	Scope	Risk	LSSWI
Weight	*0.459*	*0.339*	*0.061*	*0.141*	*0.228*	
Customer Demand	0.095	0.087	0.088	0.028	0.014	0.086
Current System	0.056	0.034	0.036	0.036	0.019	0.013
Implementation of Process / Product Improvements	0.054	0.058	0.058	0.028	0.017	0.008

D.1.2.23 Case Study 2: Lean Six Sigma Weighted Index Business Process 5

Methods and Material Flow	Cost	Delivery	Robustness	Scope	Risk	LSSWI
Weight	*0.429*	*0.313*	*0.057*	*0.201*	*0.130*	
Customer Demand	0.095	0.087	0.088	0.028	0.014	0.081
Current System	0.056	0.034	0.036	0.036	0.019	0.013
Implementation of Process / Product Improvements	0.054	0.058	0.058	0.028	0.017	0.008

D.1.3 Case Study 3: Project 3

Project 3 is a medium project. It will create approximately $8 million in annual sales and utilizes six people from the manufacturing facility. This item is a smart motor controller with fusible disconnect or circuit breaker configured into an enclosure. (Rockwell Automation, 2007)

The persons involved in this case study are the process improvement team, which consists of Production Control, Production, Manufacturing Engineering, and Supervision. These individuals can contribute to the process for the supply chain, order processing chain, and manufacturing processes for this product line. As with any decision, the evaluation results are very dependent on the decision makers.

D.1.3.1 Case Study 3: Worksheet 1

	Rockwell Automation's vision is focused on being the most valued global provider of power, control and information solutions.
BP 1	*Buyer / Planner*
C1	Efficient way to get order
C2	Process to check for parts
C3	Effective way to get order to line
BP 2	*Engineering*
C4	Gather information to update and print schematic
C5	Effective way to get schematic to line
BP 3	*Flush Parts*
C6	Get parts
C7	Front flush parts
BP 4	*Layout and mount components on plate and in enclosure*
C8	Mark unit and mount components

Section D.1.3.1 Table - continued

BP 5	*Heavy and Control Wiring*
C9	Identify and get proper gage
C10	Prepare and connect wire
BP 6	*Test*
C12	Verify components and their locations
C13	Perform pull test and program HIM
C14	Enter results into system data collector
BP 7	*Pack and RECO*
C15	Prepare packaging material
C16	Get carton label and place on box / Write on box
C17	Place unit in box
C18	Scan product and take to shipping

D.1.3.2 Case Study 3: Worksheet 2

	Managerial System	Difficult to Imitate (1/0)	Provide Competitive Advantage (1/0)	Extendable to New Markets (1/0)	Customer Perceived Value (1/0)	Support (1)	Basic (2)	Critical (3)	Cutting Edge (4)	Total Score	Normalized Business Process Score
BP 1	*Buyer / Planner*									9	3
C1	Efficient way to get order	0	0	1	0		2			3	
C2	Process to check for parts	0	0	1	0		2			3	
C3	Effective way to get order to line	0	0	1	0		2			3	
BP 2	*Engineering*									6	3
C4	Gather information to update and print schematic	0	0	1	0		2			3	
C5	Effective way to get schematic to line	0	0	1	0		2			3	
BP 3	*Flush Parts*									6	3
C6	Get parts	0	0	1	0		2			3	
C7	Front flush parts	0	0	1	0		2			3	
BP 4	*Layout and mount components on plate and in enclosure*									5	5
C8	Mark unit and mount components	1	0	1	1		2			5	
BP 5	*Heavy and Control Wiring*									7	4
C9	Identify and get proper gage	0	0	1	0		2			3	
C10	Prepare and connect wire	0	0	1	1		2			4	
BP 6	*Test*									9	3
C12	Verify components and their locations	0	0	1	0		2			3	
C13	Perform pull test and program HIM	0	0	1	0		2			3	
C14	Enter results into system data collector	0	0	1	0		2			3	
BP 7	*Pack and RECO*									13	3
C15	Prepare packaging material	0	0	1	0		2			3	
C16	Get carton label and place on box / Write on box	0	0	1	0		2			3	
C17	Place unit in box	0	0	1	1		2			4	
C18	Scan product and take to shipping	0	0	1	0		2			3	

D.1.3.3 Case Study 3: Worksheet 3

Dimension	Weight
Cost	0.2
Time	0.2
Quality	0.2
Value	0.2
Ease of Implementation	0.2

D.1.3.4 Case Study 3: Worksheet 4

	Capability	Cost	Time	Quality	Value	Ease of Implementation	Total Score	Normalized Business Process Score
	Weight	0.2	0.2	0.2	0.2	0.2	1.00	
BP 1	*Buyer / Planner*						11.6	3.9
C1	Efficient way to get order	3	3	4	4	5	3.8	
C2	Process to check for parts	4	3	4	5	3	3.8	
C3	Effective way to get order to line	3	4	4	4	5	4	
BP 2	*Engineering*						7.6	3.8
C4	Gather information to update and print schematic	3	3	4	5	3	3.6	
C5	Effective way to get schematic to line	3	4	4	4	5	4	
BP 3	*Flush Parts*						8.2	4.1
C6	Get parts	3	3	3	5	4	3.6	
C7	Front flush parts	4	5	4	5	5	4.6	
BP 4	*Layout and mount components on plate and in enclosure*						3.8	3.8
C8	Mark unit and mount components	4	3	4	5	3	3.8	
BP 5	*Heavy and Control Wiring*						8.2	4.1
C9	Identify and get proper gage	3	4	4	5	5	4.2	
C10	Prepare and connect wire	3	3	4	5	5	4	
BP 6	*Test*						13.8	4.6
C12	Verify components and their locations	4	4	5	5	5	4.6	
C13	Perform pull test and program HIM	4	4	5	5	5	4.6	
C14	Enter results into system data collector	4	4	5	5	5	4.6	
BP 7	*Pack and RECO*						17.6	4.4
C15	Prepare packaging material	4	4	4	5	5	4.4	
C16	Get carton label and place on box / Write on box	4	4	4	5	5	4.4	
C17	Place unit in box	4	4	4	5	5	4.4	
C18	Scan product and take to shipping	4	4	4	5	5	4.4	

D.1.3.5 Case Study 3: Worksheet 5

	Business Process	Core Rating	Core Rating Converted	Performance Indicators	Performance Indicator Converted	Total Score
BP 1	Buyer / Planner	3	15	3.9	31	-16
BP 2	Engineering	3	15	3.8	30	-15
BP 3	Flush Parts	3	15	4.1	33	-18
BP 4	Layout and mount components on plate and in enclosure	5	25	3.8	30	-5
BP 5	Heavy and Control Wiring	4	18	4.1	33	-15
BP 6	Test	3	15	4.6	37	-22
BP 7	Pack and RECO	3	16	4.4	35	-19

D.1.3.6 Case Study 3: Worksheet 6

Description	Market and Customer Knowledge	Leadership Commitment	Planning and Project Selection	Training and Consulting	DMAIC and Lean Processes	Resources	Voice of Customer	Quality Function	Customer and Process Measures	Process Capability and Analysis	Process Improvement	Maintaining Improvements	Financial Results Measures	Recognition and Rewards	Total LSS Score	Item	LSS Priority Rating
Layout and mount components on plate and in enclosure															4		4.3
Mark unit and mount components	4	1	4	5	5	5	5	5	5	5	5	5	5	1	60	1	
Engineering															7		3.3
Gather information to update and print schematic	1	4	4	5	5	5	3	5	3	3	4	4	3	1	50	1	
Effective way to get schematic to line	1	1	1	5	4	5	3	3	3	3	4	4	3	1	41	1	
Heavy and Control Wiring															8		4.1
Identify and get proper gage	4	1	1	5	5	5	5	5	3	5	5	5	5	1	55	1	
Prepare and connect wire	4	1	4	5	5	5	5	5	5	5	5	5	5	1	60	1	

D.1.3.7 Case Study 3: Supermatrix for Cost

COST	R		KTEW			DE		UCAM				MEEC			
Relationships (R)	CEC	CB	CCSP	PI	ECCK	D	E	PC	ROS	MM	AI	SDP	MCP	GPC	FCS
CEC	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
CB	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Knowledge, training, and empowered workers (KTEW)															
CCSP	0	0	0	0.6667	0.8000	0	0	0	0	0	0	0	0	0	0
PI	0	0	0.2500	0	0.2000	0	0	0	0	0	0	0	0	0	0
ECCK	0	0	0.7500	0.3333	0	0	0	0	0	0	0	0	0	0	0
Databases and Environment (DE)															
D	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
E	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Uncertainty, Change Agent, and Management (UCAM)															
PC	0	0	0	0	0	0	0	0	0.1667	0	0.8000	0	0	0	0
ROS	0	0	0	0	0	0	0	0.1667	0	0	0.2000	0	0	0	0
MM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AI	0	0	0	0	0	0	0	0.8333	0.8333	0	0	0	0	0	0
More effective and efficient company at a minimal cost, and happy customer (MEEC)															
SDP	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7500	0.1667
MCP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GPC	0	0	0	0	0	0	0	0	0	0	0	0.3333	0	0	0.8333
FCS	0	0	0	0	0	0	0	0	0	0	0	0.6667	0	0.2500	0

D.1.3.8 Case Study 3: Supermatrix for Delivery

DELIVERY	R		KTEW			DE		UCAM				MEEC			
Relationships (R)	CEC	CB	CCSP	PI	ECCK	D	E	PC	ROS	MM	AI	SDP	MCP	GPC	FCS
CEC	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
CB	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Knowledge, training, and empowered workers (KTEW)															
CCSP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PI	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
ECCK	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Databases and Environment (DE)															
D	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
E	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Uncertainty, Change Agent, and Management (UCAM)															
PC	0	0	0	0	0	0	0	0	0.3333	0	0.8000	0	0	0	0
ROS	0	0	0	0	0	0	0	0.1667	0	0	0.2000	0	0	0	0
MM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AI	0	0	0	0	0	0	0	0.8333	0.6667	0	0	0	0	0	0
More effective and efficient company at a minimal cost, and happy customer (MEEC)															
SDP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MCP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GPC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
FCS	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0

D.1.3.9Case Study 3: Supermatrix for Robustness

ROBUSTNESS	R		KTEW			DE		UCAM				MEEC			
Relationships (R)	CEC	CB	CCSP	PI	ECCK	D	E	PC	ROS	MM	AI	SDP	MCP	GPC	FCS
CEC	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
CB	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Knowledge, training, and empowered workers (KTEW)															
CCSP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PI	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
ECCK	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Databases and Environment (DE)															
D	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
E	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Uncertainty, Change Agent, and Management (UCAM)															
PC	0	0	0	0	0	0	0	0	0.4459	0.3339	0.5571	0	0	0	0
ROS	0	0	0	0	0	0	0	0.1062	0	0.0982	0.1226	0	0	0	0
MM	0	0	0	0	0	0	0	0.2605	0.2457	0	0.3202	0	0	0	0
AI	0	0	0	0	0	0	0	0.6334	0.8085	0.5679	0	0	0	0	0
More effective and efficient company at a minimal cost, and happy customer (MEEC)															
SDP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MCP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GPC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
FCS	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0

D.1.3.10 Case Study 3: Supermatrix for Scope

SCOPE	R		KTEW			DE		UCAM				MEEC			
Relationships (R)	CEC	CB	CCSP	PI	ECCK	D	E	PC	ROS	MM	AI	SDP	MCP	GPC	FCS
CEC	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
CB	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Knowledge, training, and empowered workers (KTEW)															
CCSP	0	0	0	0.6667	0.2000	0	0	0	0	0	0	0	0	0	0
PI	0	0	0.2500	0	0.8000	0	0	0	0	0	0	0	0	0	0
ECCK	0	0	0.7500	0.3333	0	0	0	0	0	0	0	0	0	0	0
Databases and Environment (DE)															
D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Uncertainty, Change Agent, and Management (UCAM)															
PC	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
ROS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AI	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
More effective and efficient company at a minimal cost, and happy customer (MEEC)															
SDP	0	0	0	0	0	0	0	0	0	0	0	0	0.6334	0.5390	0.5679
MCP	0	0	0	0	0	0	0	0	0	0	0	0.5571	0	0.2973	0.3339
GPC	0	0	0	0	0	0	0	0	0	0	0	0.1226	0.1062	0	0.0982
FCS	0	0	0	0	0	0	0	0	0	0	0	0.3202	0.2605	0.1638	0

D.1.3.11 Case Study 3: Supermatrix for Risk

RISK	R		KTEW			DE		UCAM				MEEC			
Relationships (R)	CEC	CB	CCSP	PI	ECCK	D	E	PC	ROS	MM	AI	SDP	MCP	GPC	FCS
CEC	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
CB	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Knowledge, training, and empowered workers (KTEW)															
CCSP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ECCK	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Databases and Environment (DE)															
D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Uncertainty, Change Agent, and Management (UCAM)															
PC	0	0	0	0	0	0	0	0	0	0.3333	0.3333	0	0	0	0
ROS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MM	0	0	0	0	0	0	0	0.3333	0	0	0.6667	0	0	0	0
AI	0	0	0	0	0	0	0	0.6667	0	0.6667	0	0	0	0	0
More effective and efficient company at a minimal cost, and happy customer (MEEC)															
SDP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MCP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GPC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
FCS	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0

D.1.3.12 Case Study 3: Converged Supermatrix for Cost

COST	R		KTEW			DE		UCAM				MEEC			
Relationships (R)	CEC	CB	CCSP	PI	ECCK	D	E	PC	ROS	MM	AI	SDP	MCP	GPC	FCS
CEC	0.500	0.500	0	0	0	0	0	0	0	0	0	0	0	0	0
CB	0.500	0.500	0	0	0	0	0	0	0	0	0	0	0	0	0
Knowledge, training, and empowered workers (KTEW)															
CCSP	0	0	0.489	0.489	0.489	0	0	0	0	0	0	0	0	0	0
PI	0	0	0.150	0.150	0.150	0	0	0	0	0	0	0	0	0	0
ECCK	0	0	0.361	0.361	0.361	0	0	0	0	0	0	0	0	0	0
Databases and Environment (DE)															
D	0	0	0	0	0	0.5	0.5	0	0	0	0	0	0	0	0
E	0	0	0	0	0	0.5	0.5	0	0	0	0	0	0	0	0
Uncertainty, Change Agent, and Management (UCAM)															
PC	0	0	0	0	0	0	0	0.242	0.242	0.242	0.242	0	0	0	0
ROS	0	0	0	0	0	0	0	0.092	0.092	0.092	0.092	0	0	0	0
MM	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000	0	0	0	0
AI	0	0	0	0	0	0	0	0.417	0.417	0.417	0.417	0	0	0	0
More effective and efficient company at a minimal cost, and happy customer (MEEC)															
SDP	0	0	0	0	0	0	0	0	0	0	0	0.229	0.229	0.229	0.229
MCP	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000
GPC	0	0	0	0	0	0	0	0	0	0	0	0.292	0.292	0.292	0.292
FCS	0	0	0	0	0	0	0	0	0	0	0	0.229	0.229	0.229	0.229

D.1.3.13 Case Study 3: Converged Supermatrix for Delivery

DELIVERY	R		KTEW			DE		UCAM				MEEC			
Relationships (R)	CEC	CB	CCSP	PI	ECCK	D	E	PC	ROS	MM	AI	SDP	MCP	GPC	FCS
CEC	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0
CB	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0
Knowledge, training, and empowered workers (KTEW)															
CCSP	0	0	0.000	0.000	0.000	0	0	0	0	0	0	0	0	0	0
PI	0	0	0.333	0.333	0.333	0	0	0	0	0	0	0	0	0	0
ECCK	0	0	0.333	0.333	0.333	0	0	0	0	0	0	0	0	0	0
Databases and Environment (DE)															
D	0	0	0	0	0	0.500	0.500	0	0	0	0	0	0	0	0
E	0	0	0	0	0	0.500	0.500	0	0	0	0	0	0	0	0
Uncertainty, Change Agent, and Management (UCAM)															
PC	0	0	0	0	0	0	0	0.283	0.283	0.283	0.283	0	0	0	0
ROS	0	0	0	0	0	0	0	0.092	0.092	0.092	0.092	0	0	0	0
MM	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000	0	0	0	0
AI	0	0	0	0	0	0	0	0.375	0.375	0.375	0.375	0	0	0	0
More effective and efficient company at a minimal cost, and happy customer (MEEC)															
SDP	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000
MCP	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000
GPC	0	0	0	0	0	0	0	0	0	0	0	0.250	0.250	0.250	0.250
FCS	0	0	0	0	0	0	0	0	0	0	0	0.250	0.250	0.250	0.250

D.1.3.14 Case Study 3: Converged Supermatrix for Robustness

ROBUSTNESS	R		KTEW			DE		UCAM				MEEC			
Relationships (R)	CEC	CB	CCSP	PI	ECCK	D	E	PC	ROS	MM	AI	SDP	MCP	GPC	FCS
CEC	0.500	0.500	0	0	0	0	0	0	0	0	0	0	0	0	0
CB	0.500	0.500	0	0	0	0	0	0	0	0	0	0	0	0	0
Knowledge, training, and empowered workers (KTEW)															
CCSP	0	0	0.000	0.000	0.000	0	0	0	0	0	0	0	0	0	0
PI	0	0	0.333	0.333	0.333	0	0	0	0	0	0	0	0	0	0
ECCK	0	0	0.333	0.333	0.333	0	0	0	0	0	0	0	0	0	0
Databases and Environment (DE)															
D	0	0	0	0	0	0.500	0.500	0	0	0	0	0	0	0	0
E	0	0	0	0	0	0.500	0.500	0	0	0	0	0	0	0	0
Uncertainty, Change Agent, and Management (UCAM)															
PC	0	0	0	0	0	0	0	0.334	0.334	0.334	0.334	0	0	0	0
ROS	0	0	0	0	0	0	0	0.082	0.082	0.082	0.082	0	0	0	0
MM	0	0	0	0	0	0	0	0.207	0.207	0.207	0.207	0	0	0	0
AI	0	0	0	0	0	0	0	0.502	0.502	0.502	0.502	0	0	0	0
More effective and efficient company at a minimal cost, and happy customer (MEEC)															
SDP	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000
MCP	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000
GPC	0	0	0	0	0	0	0	0	0	0	0	0.250	0.250	0.250	0.250
FCS	0	0	0	0	0	0	0	0	0	0	0	0.250	0.250	0.250	0.250

D.1.3.15 Case Study 3: Converged Supermatrix for Scope

SCOPE	R		KTEW			DE		UCAM				MEEC			
Relationships (R)	CEC	CB	CCSP	PI	ECCK	D	E	PC	ROS	MM	AI	SDP	MCP	GPC	FCS
CEC	0.500	0.500	0	0	0	0	0	0	0	0	0	0	0	0	0
CB	0.500	0.500	0	0	0	0	0	0	0	0	0	0	0	0	0
Knowledge, training, and empowered workers (KTEW)															
CCSP	0	0	0.289	0.289	0.289	0	0	0	0	0	0	0	0	0	0
PI	0	0	0.350	0.350	0.350	0	0	0	0	0	0	0	0	0	0
ECCK	0	0	0.361	0.361	0.361	0	0	0	0	0	0	0	0	0	0
Databases and Environment (DE)															
D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Uncertainty, Change Agent, and Management (UCAM)															
PC	0	0	0	0	0	0	0	0.250	0.250	0.250	0.250	0	0	0	0
ROS	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000	0	0	0	0
MM	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000	0	0	0	0
AI	0	0	0	0	0	0	0	0.250	0.250	0.250	0.250	0	0	0	0
More effective and efficient company at a minimal cost, and happy customer (MEEC)															
SDP	0	0	0	0	0	0	0	0	0	0	0	0.082	0.082	0.082	0.082
MCP	0	0	0	0	0	0	0	0	0	0	0	0.435	0.435	0.435	0.435
GPC	0	0	0	0	0	0	0	0	0	0	0	0.297	0.297	0.297	0.297
FCS	0	0	0	0	0	0	0	0	0	0	0	0.186	0.186	0.186	0.186

D.1.3.16 Case Study 3: Converged Supermatrix for Risk

RISK	R		KTEW			DE		UCAM				MEEC			
Relationships (R)	CEC	CB	CCSP	PI	ECCK	D	E	PC	ROS	MM	AI	SDP	MCP	GPC	FCS
CEC	0.500	0.500	0	0	0	0	0	0	0	0	0	0	0	0	0
CB	0.500	0.500	0	0	0	0	0	0	0	0	0	0	0	0	0
Knowledge, training, and empowered workers (KTEW)															
CCSP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ECCK	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Databases and Environment (DE)															
D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Uncertainty, Change Agent, and Management (UCAM)															
PC	0	0	0	0	0	0	0	0.167	0.167	0.167	0.167	0	0	0	0
ROS	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000	0	0	0	0
MM	0	0	0	0	0	0	0	0.250	0.250	0.250	0.250	0	0	0	0
AI	0	0	0	0	0	0	0	0.333	0.333	0.333	0.333	0	0	0	0
More effective and efficient company at a minimal cost, and happy customer (MEEC)															
SDP	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000
MCP	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000
GPC	0	0	0	0	0	0	0	0	0	0	0	0.250	0.250	0.250	0.250
FCS	0	0	0	0	0	0	0	0	0	0	0	0.250	0.250	0.250	0.250

D.1.3.17 Case Study 3: Desirability for Cost

COST									
Relationships (R)	Weight (Business Plan)	eVector (Lean Six Sigma Enablers)	Converged Supermatrix	eVector (Customer Demand Implementation Alternative)	eVector (Current System Implementation Alternative)	eVector (Improvements Implementation Alternative)	Customer Demand Score	Current System Score	Improvements Score
CEC	0.067	0.750	0.500	0.080	0.195	0.475	0.00199	0.00488	0.01188
CB	0.067	0.250	0.500	0.163	0.024	0.064	0.00136	0.00020	0.00053
Knowledge, training, and empowered workers (KTEW)									
CCSP	0.267	0.557	0.489	0.158	0.345	0.054	0.01150	0.02506	0.00390
PI	0.267	0.123	0.150	0.080	0.012	0.031	0.00039	0.00006	0.00015
ECCK	0.267	0.320	0.361	0.034	0.083	0.203	0.00105	0.00257	0.00625
Databases and Environment (DE)									
D	0.333	0.750	0.500	0.488	0.071	0.191	0.06099	0.00892	0.02384
E	0.333	0.250	0.500	0.163	0.024	0.064	0.00678	0.00099	0.00265
Uncertainty, Change Agent, and Management (UCAM)									
PC	0.200	0.334	0.242	0.134	0.292	0.045	0.00216	0.00471	0.00073
ROS	0.200	0.098	0.092	0.176	0.027	0.081	0.00032	0.00005	0.00015
MM	0.200	0.000	0.000	0.017	0.106	0.049	0.00000	0.00000	0.00000
AI	0.200	0.568	0.417	0.046	0.007	0.021	0.00216	0.00034	0.00099
More effective and efficient company at a minimal cost, and happy customer (MEEC)									
SDP	0.133	0.633	0.229	0.046	0.021	0.007	0.00088	0.00041	0.00014
MCP	0.133	0.000	0.000	0.292	0.045	0.134	0.00000	0.00000	0.00000
GPC	0.133	0.106	0.292	0.176	0.027	0.081	0.00073	0.00011	0.00033
FCS	0.133	0.260	0.229	0.106	0.017	0.049	0.00085	0.00013	0.00039
						Desirability Indices	**0.09114**	**0.04843**	**0.05193**

D.1.3.18 Case Study 3: Desirability for Delivery

DELIVERY									
Relationships (R)	Weight (Business Plan)	eVector (Lean Six Sigma Enablers)	Converged Supermatrix	eVector (Customer Demand Implementation Alternative)	eVector (Current System Implementation Alternative)	eVector (Improvements Implementation Alternative)	Customer Demand Score	Current System Score	Improvements Score
CEC	0.067	0.750	0.500	0.080	0.195	0.475	0.00199	0.00488	0.01188
CB	0.067	0.250	0.500	0.163	0.024	0.064	0.00136	0.00020	0.00053
Knowledge, training, and empowered workers (KTEW)									
CCSP	0.267	0.000	0.000	0.158	0.345	0.054	0.00000	0.00000	0.00000
PI	0.267	0.250	0.333	0.080	0.012	0.031	0.00177	0.00026	0.00069
ECCK	0.267	0.750	0.333	0.034	0.083	0.203	0.00227	0.00556	0.01352
Databases and Environment (DE)									
D	0.333	0.750	0.500	0.488	0.071	0.191	0.06099	0.00892	0.02384
E	0.333	0.250	0.500	0.163	0.024	0.064	0.00678	0.00099	0.00265
Uncertainty, Change Agent, and Management (UCAM)									
PC	0.200	0.334	0.283	0.134	0.292	0.045	0.00253	0.00552	0.00086
ROS	0.200	0.098	0.092	0.176	0.027	0.081	0.00032	0.00005	0.00015
MM	0.200	0.000	0.000	0.017	0.106	0.049	0.00000	0.00000	0.00000
AI	0.200	0.568	0.375	0.046	0.007	0.021	0.00194	0.00030	0.00089
More effective and efficient company at a minimal cost, and happy customer (MEEC)									
SDP	0.133	0.000	0.000	0.046	0.021	0.007	0.00000	0.00000	0.00000
MCP	0.133	0.000	0.000	0.292	0.045	0.134	0.00000	0.00000	0.00000
GPC	0.133	0.250	0.250	0.176	0.027	0.081	0.00147	0.00023	0.00067
FCS	0.133	0.750	0.250	0.106	0.017	0.049	0.00266	0.00041	0.00122
						Desirability Indices	**0.08406**	**0.02733**	**0.05690**

D.1.3.19 Case Study 3: Desirability for Robustness

ROBUSTNESS									
Relationships (R)	Weight (Business Plan)	eVector (Lean Six Sigma Enablers)	Converged Supermatrix	eVector (Customer Demand Implementation Alternative)	eVector (Current System Implementation Alternative)	eVector (Improvements Implementation Alternative)	Customer Demand Score	Current System Score	Improvements Score
CEC	0.067	0.750	0.500	0.080	0.195	0.475	0.00199	0.00488	0.01188
CB	0.067	0.250	0.500	0.163	0.024	0.064	0.00136	0.00020	0.00053
Knowledge, training, and empowered workers (KTEW)									
CCSP	0.267	0.000	0.000	0.158	0.345	0.054	0.00000	0.00000	0.00000
PI	0.267	0.250	0.333	0.080	0.012	0.031	0.00177	0.00026	0.00069
ECCK	0.267	0.750	0.333	0.034	0.083	0.203	0.00227	0.00556	0.01352
Databases and Environment (DE)									
D	0.333	0.750	0.500	0.488	0.071	0.191	0.06099	0.00892	0.02384
E	0.333	0.250	0.500	0.163	0.024	0.064	0.00678	0.00099	0.00265
Uncertainty, Change Agent, and Management (UCAM)									
PC	0.200	0.307	0.334	0.134	0.292	0.045	0.00274	0.00598	0.00093
ROS	0.200	0.069	0.082	0.176	0.027	0.081	0.00020	0.00003	0.00009
MM	0.200	0.319	0.207	0.017	0.106	0.049	0.00022	0.00140	0.00064
AI	0.200	0.305	0.502	0.046	0.007	0.021	0.00140	0.00022	0.00064
More effective and efficient company at a minimal cost, and happy customer (MEEC)									
SDP	0.133	0.000	0.000	0.046	0.021	0.007	0.00000	0.00000	0.00000
MCP	0.133	0.000	0.000	0.292	0.045	0.134	0.00000	0.00000	0.00000
GPC	0.133	0.333	0.250	0.176	0.027	0.081	0.00195	0.00030	0.00090
FCS	0.133	0.667	0.250	0.106	0.017	0.049	0.00236	0.00037	0.00108
						Desirability Indices	**0.08402**	**0.02911**	**0.05739**

D.1.3.20 Case Study 3: Desirability for Scope

SCOPE									
Relationships (R)	Weight (Business Plan)	eVector (Lean Six Sigma Enablers)	Converged Supermatrix	eVector (Customer Demand Implementation Alternative)	eVector (Current System Implementation Alternative)	eVector (Improvements Implementation Alternative)	Customer Demand Score	Current System Score	Improvements Score
CEC	0.067	0.750	0.500	0.080	0.195	0.475	0.00199	0.00488	0.01188
CB	0.067	0.250	0.500	0.163	0.024	0.064	0.00136	0.00020	0.00053
Knowledge, training, and empowered workers (KTEW)									
CCSP	0.267	0.557	0.289	0.158	0.345	0.054	0.00680	0.01481	0.00231
PI	0.267	0.123	0.350	0.080	0.012	0.031	0.00091	0.00013	0.00036
ECCK	0.267	0.320	0.361	0.034	0.083	0.203	0.00105	0.00257	0.00625
Databases and Environment (DE)									
D	0.333	1.000	0.000	0.488	0.071	0.191	0.00000	0.00000	0.00000
E	0.333	0.000	0.000	0.163	0.024	0.064	0.00000	0.00000	0.00000
Uncertainty, Change Agent, and Management (UCAM)									
PC	0.200	0.333	0.250	0.134	0.292	0.045	0.00223	0.00486	0.00076
ROS	0.200	0.000	0.000	0.176	0.027	0.081	0.00000	0.00000	0.00000
MM	0.200	0.000	0.000	0.017	0.106	0.049	0.00000	0.00000	0.00000
AI	0.200	0.667	0.250	0.046	0.007	0.021	0.00152	0.00024	0.00070
More effective and efficient company at a minimal cost, and happy customer (MEEC)									
SDP	0.133	0.471	0.435	0.046	0.021	0.007	0.00125	0.00057	0.00019
MCP	0.133	0.284	0.297	0.292	0.045	0.134	0.00328	0.00051	0.00151
GPC	0.133	0.074	0.082	0.176	0.027	0.081	0.00014	0.00002	0.00006
FCS	0.133	0.171	0.186	0.106	0.017	0.049	0.00045	0.00007	0.00021
						Desirability Indices	**0.02097**	**0.02887**	**0.02475**

D.1.3.21 Case Study 3: Desirability for Risk

RISK									
Relationships (R)	**Weight (Business Plan)**	**eVector (Lean Six Sigma Enablers)**	**Converged Supermatrix**	**eVector (Customer Demand Implementation Alternative)**	**eVector (Current System Implementation Alternative)**	**eVector (Improvements Implementation Alternative)**	**Customer Demand Score**	**Current System Score**	**Improvements Score**
CEC	0.067	0.750	0.500	0.080	0.195	0.475	0.00199	0.00488	0.01188
CB	0.067	0.250	0.500	0.163	0.024	0.064	0.00136	0.00020	0.00053
Knowledge, training, and empowered workers (KTEW)									
CCSP	0.267	0.000	0.000	0.158	0.345	0.054	0.00000	0.00000	0.00000
PI	0.267	0.000	0.000	0.080	0.012	0.031	0.00000	0.00000	0.00000
ECCK	0.267	1.000	0.000	0.034	0.083	0.203	0.00000	0.00000	0.00000
Databases and Environment (DE)									
D	0.333	0.000	0.000	0.488	0.071	0.191	0.00000	0.00000	0.00000
E	0.333	0.000	0.000	0.163	0.024	0.064	0.00000	0.00000	0.00000
Uncertainty, Change Agent, and Management (UCAM)									
PC	0.200	0.297	0.167	0.134	0.292	0.045	0.00133	0.00289	0.00045
ROS	0.200	0.000	0.000	0.176	0.027	0.081	0.00000	0.00000	0.00000
MM	0.200	0.164	0.250	0.017	0.106	0.049	0.00014	0.00087	0.00040
AI	0.200	0.539	0.333	0.046	0.007	0.021	0.00164	0.00026	0.00075
More effective and efficient company at a minimal cost, and happy customer (MEEC)									
SDP	0.133	0.000	0.000	0.046	0.021	0.007	0.00000	0.00000	0.00000
MCP	0.133	0.000	0.000	0.292	0.045	0.134	0.00000	0.00000	0.00000
GPC	0.133	0.333	0.250	0.176	0.027	0.081	0.00195	0.00030	0.00090
FCS	0.133	0.667	0.250	0.106	0.017	0.049	0.00236	0.00037	0.00108
						Desirability Indices	**0.01076**	**0.00977**	**0.01599**

D.1.3.22 Case Study 3: Lean Six Sigma Weighted Index Business Process 2

Engineering	Cost	Delivery	Robustness	Scope	Risk	LSSWI
Weight	*0.424*	*0.311*	*0.056*	*0.209*	*0.129*	
Customer Demand	0.091	0.084	0.084	0.021	0.011	0.075
Current System	0.048	0.027	0.029	0.029	0.010	0.010
Implementation of Process / Product Improvements	0.052	0.057	0.057	0.025	0.016	0.007

D.1.3.23 Case Study 3: Lean Six Sigma Weighted Index Business Process 4

Layout and mount components on plate and in enclosure	Cost	Delivery	Robustness	Scope	Risk	LSSWI
Weight	*0.296*	*0.409*	*0.124*	*0.171*	*0.054*	
Customer Demand	0.091	0.084	0.084	0.021	0.011	0.076
Current System	0.048	0.027	0.029	0.029	0.010	0.010
Implementation of Process / Product Improvements	0.052	0.057	0.057	0.025	0.016	0.007

D.1.3.24 Case Study 3: Lean Six Sigma Weighted Index Business Process 5

Heavy and Control Wiring	Cost	Delivery	Robustness	Scope	Risk	LSSWI
Weight	*0.293*	*0.388*	*0.122*	*0.197*	*0.056*	
Customer Demand	0.091	0.084	0.084	0.021	0.011	0.074
Current System	0.048	0.027	0.029	0.029	0.010	0.010
Implementation of Process / Product Improvements	0.052	0.057	0.057	0.025	0.016	0.007

BIBLIOGRAPHY

1. Allen, T. (2006). *Introduction to Engineering Statistics and Six Sigma*. Germany: Springer-Verlag.

2. Andel, Tom (2007, March). Lean and Six Sigma Traps to Avoid. *Material Handling Management*, 23-28.

3. Andersen, E. (2006). *Growing Great Employees: Turning Ordinary People into Extraordinary Performers*. New York: Penguin Group.

4. Arnheiter, E., Maleyeff, J. (2005). The Integration of Lean Management and Six Sigma. The *TQM Magazine*, *17*(1), 5-18.

5. Atkinson, K. (1993). *Elementary Numerical Analysis*. New York: John Wiley & Sons, Inc.

6. Basu, R., Wright, J. (2003). *Quality Beyond Six Sigma*. New York: Butterworth-Heineman.

7. Bather, J. (2000). *Decision Theory: An Introduction to Dynamic Programming and Sequential Decisions.* New York: John Wiley & Sons, LTD.

8. Bell, D., Raiffa, H., Tversky, A. (1988). *Decision Making: Descriptive, Normative, and Prescriptive Interactions*. New York: Cambridge University Press.

9. Bendell, T. (2006). A Review and Comparison of Six Sigma and the Lean Organisations. *TQM Magazine, 18* (3). Emerald Group Publishing Limited.

10. Bernstein, D. (2005). *Matrix Mathematics: Theory, Facts, and Formulas with Application to Linear Systems Theory.* New Jersey: Princeton University Press.

11. Besterfield, D., Besterfield-Michna, C., Besterfield, G., Besterfield-Sacre, M. (1995). *Total Quality Management*. New Jersey: Prentice- Hall, Inc.

12. Bicheno, J. (2000). *The Lean Toolbox Second Edition*. Buckingham: PICSIE Books.

13. Bicheno, J. (2000), *Cause and Effect Lean: Lean Operations, Six Sigma, and Supply Chain Essentials*. Buckingham: PICSIE Books.

14. Bonabeau, E. (2003, May). Don't' Trust Your Gut. *Harvard Business Review,* 116-123.

15. Bowles, J., Hammond, J. (1991). *Beyond Quality: How 50 Winning Companies Use Continuous Improvement*. New York: G. P. Putnam's Sons.

16. Breyfogle III, Forrest (2007, May). The Three Rs of Business. *Quality*, p. 42-48.

17. Brown, M. (2000). *Winning Score: How to Design and Implement Winning Scorecards*. Portland: Productivity, Inc.

18. Buyukyazici, M., Sucu, M. (2003). The Analytical Hierarchy and Analytical Network Processes. *Hacettepe Journal of Mathematics and Statistics, 32,* 65-73.

19. Campbell, K. (2007, February). Automation, Lean Join Forces to Keep Products Moving. *Plant Engineering Magazine,* 36-38.

20. Carlivati, Peter (2007, April). Six Sigma. *ABA Bank Marketing*, 24-29.

21. Carreira, B., Trudell, B. (2006). *Lean Six Sigma that Works*. New York: AMACOM American Management Association.

22. Chicken, J., Hayns, M. (1999). *Strategy and Priority*. Australia: Business Press.

23. Chung, S., Lee, A., Pearn, W. L. (2005). Product Mix Optimization for Semiconductor Manufacturing Based on AHP and ANP Analysis. *International Journal of Advanced Manufacturing Technology, 25*, 1144-1156.

24. Cveykus, R., Carter CPA, E. (2006 July). Fix the Process, Not the People. *Strategic Finance*, 27-33.

25. Deif, A. (1982). *Advanced Matrix Theory For Scientists and Engineers*. New York: Halsted Press Division.

26. Deliman, Dr. Maria (1993). *Optimization of Process Improvement and Inspection Location for Serial Manufacturing* (Doctoral Dissertation, Mississippi State University, 1993). Michigan: UMI Microform 9328709.

27. Devane, T. (2004, May). Integrating Lean Six Sigma and High Performance Organizations. *Mechanical Engineering*, 59.

28. Donaldson, L. (2001). *The Contingency Theory of Organizations.* London: Sage Publications.

29. Dunphy, M., Lewis, R. (2006 August). Answering the Call: BellSouth Tailors Lean and Six Sigma to Fit the Service Industry. *Industrial Engineer Magazine,* 24-29.

30. Dweiri, Dr. F. (1995). *Application of Fuzzy Decision Making in the Facilities Layout Process* (Doctoral Dissertation, University of Texas at Arlington). Michigan: UMI Microform 9603998.

31. Edres, Al (2000, April). Assessing the Quality Status of Research Organizations. *Quality Progress, 51-56.*

32. Faro, Dr. Valerie. (2005). *Super Lean: A Streamlined Transactional Process Improvement Paradigm* (Doctoral Dissertation, University of Texas at Arlington, 2005). Michigan: UMI Microform 3181006.

33. Fiore, C. (2005). *Accelerated Product Development: Combining Lean and Six Sigma for Peak Performance*. New York: Productivity Press.

34. Fosdick, Glen, Uphoff, Mary Ellen (2007, May / June). Adopting Cross-Industry Best Practices for Measurable Results. *Healthcare Executives*, p. 14-20.

35. Furterer, Sandra (2004). *A Framework Roadmap for Implementing Lean Six Sigma in Local Governmental Entities* (Doctorate Dissertation, University of Central Florida, 2004). Michigan: UMI Microform 3162092.

36. George, M. (2002). *Lean Six Sigma: Combining Six Sigma Quality with Lean Speed.* New York: McGraw-Hill.

37. Golden, B., Wasil, E., Harker, P. (1989). *The Analytical Hierarchy Process.* New York: Springer-Verlag.

38. Goldsby, Dr. T., Martichenko, R. (2005). *Lean Six Sigma Logistics: Strategic Development to Operational Success.* Florida: J. Ross Publishing.

39. Gore, David. (2003). Lean Versus Six Sigma – Friends or Foes? *Proceedings of the 2003 American Society for Engineering Education Annual Conference and Exposition. Session 2163*.

40. Graham, Dr. A. (1979). *Matrix Theory and Applications for Engineers and Mathematicians.* New York: John Wiley & Sons.

41. Gupta, B., Walker, H. (2005). *Applies Statistics for the Six Sigma Green Belt*. Milwaukee: Quality Press.

42. Hacker, D. (2002). *The Bedford Handbook.* New York: Bedford / St. Martin's.

43. Hanacek, Andy (2007, June). *The National Provisioner*, 33-44.

44. Hansmann, U., Merk, L., Nicklous, M., Stober, T. (2001). *Pervasive Computing Handbook.* New York: Springer-Verlag.

45. Henderson, B., Larco, J. (1999). *Lean Transformation: How to Change Your Business into a Lean Enterprise*. Richmond: The Oaklea Press.

46. High Achievers (2006, October). *Industry Week*, p. 26-27.

47. Hoeft, Steve, Davey, Melinda, Newsome, Dean (2007, May – June). Proactively Managing Risk. *Defense AT&L*, 38-40.

48. Hoerl, Roger (2001, October). Six Sigma Black Belts: What Do They Need to Know. *Journal of Quality Technology*, *33* (4), 391-406.

49. Ivancevick, J., Lorenzi, P., Skinner, S., Crosby, P. (1997), *Management Quality and Competitiveness*. Chicago: Irwin.

50. Keeney, R., Raiffa, H. (1976). *Decisions with Multiple Objectives: Preferences and Value Tradeoffs.* New York: John Wiley & Sons.

51. Klausse, S., Lytle, J. (2006, July 10). Lean Six Sigma Working in the Latex Industry. *Rubber and Plastics News, 35* (25), 17-20.

52. Krar, S., Gill, A. (2007, February). Lean – Early Problems. *Shop Talk Magazine*, 20-23.

53. Ladhar, Dr. H. (2007, March). Effective Lean Six Sigma Deployment in a Global EMS Environment. *Circuits Assembly,* 40-45.

54. Langer, F. (2007, February 22). Lean Manufacturing Challenges Outsourcing. *Machine Design Magazine*, 71.

55. Lawson, Raef (2007, June). Combining Lean and Six Sigma. *Strategic Finance*, 21 & 69.

56. Lean Sis Sigma (2007, January). *Naval Forces*, 56-60.

57. Lean Six Sigma Glossary (2006, November – December). *Army Logistician*, 10-11.

58. Lean Six Sigma Helps NAVSUP Transform (2006, January – February). *Navy Supply Corps Newsletter*, 30-31.

59. Liu, Dr. E. (2004). *A Methodology for Implementing Total Productive Maintenance in Small Manufacturing Enterprises: Using the Transform Enterprise Methodology* (Doctoral Dissertation, University of Texas at Arlington, 2004). Michigan: UMI Microform 3138785.

60. Lynch, R., Werner, T. (1992). *Continuous Improvement: Teams and Tools*. Atlanta: QualTeam, Inc.

61. Maddox, M. (2006, December). When Lean is Mean. *Industrial Engineer Magazine*, 22.

62. The Manager (2007, May). *Latin Trade*, 40-42.

63. Manufacturing Output Grows (2007, March). *Quality*, 10.

64. Martin, MPH, PsyD, William (2007, May – June). Quality Models: Selecting the Best Model to Drive Results. *The Physician Executive*, 24-29.

65. McCarty, T., Daniels, L. Bremer, M., Gupta, P. (2005). *The Six Sigma Black Belt Handbook.* New York: McGraw-Hill.

66. McCormick-Jennings, R. (2007, April 20). State pushing more firms to "go lean". *The Business Journal*, pp. A24-A25.

67. Meade, Dr. L. (1997). *A Methodology for the Formulation of Agile Critical Business Processes* (Doctoral Dissertation, University of Texas at Arlington, 1997). Michigan: UMI Microform 9804676.

68. Meade, L. M., Liles, D. H. (1997). Justifying Strategic Alliances and Partnering: A Prerequisite for Virtual Enterprising. *International Journal of Management Science, 25* (1), 29-42.

69. Meade, L. M., Sarkis, J. (1998). Strategic Analysis of Logistics and Supply Chain Management Systems using the Analytical Network Process. *Logistics and Transportation Review, 34* (3), 201-215.

70. Meade, L. M., Sarkis, J. (1999). Analyzing Organizational Project Alternatives for Agile Manufacturing Processes; An Analytical Network Approach. *International Journal of Production Research, 37* (2), 241-261.

71. Meade, Laura. Presley, Adrien. (2002, February). R&D Project Selection Using the Analytical Network Process. *IEEE Transaction on Engineering Management*, *49* (1), 59-66.

72. Mehta, Merwan. (2006, July). Design Competitively. *Industrial Engineer Magazine: Lean Division eNewsletter*.

73. Merriam-Webster Dictionary. (1997). Massachusetts: Merriam-Webster, Incorporated.

74. Montgomery, Douglas. (1991). *Introduction to Statistical Quality Control*. New York: Hamilton Printing Company.

75. Morgan, J. (2005). *Creating Lean Corporations: Reengineering from the Bottom Up to Eliminate Waste.* New York: Productivity Press.

76. Muir, Dr. A. (2006). *Lean Six Sigma Statistics: Calculating Process Efficiencies in Transactional Projects.* New York: McGraw-Hill.

77. Nash, M., Poling, S., Ward, S. (2006, November). Six Sigma Speed: Faster Results Come from a Lean Culture. *Industrial Engineer Magazine*, 40-44.

78. Nash, M., Poling, S., Ward, S. (2006). *Using Lean for Faster Six Sigma Results*. New York: Productivity Press.

79. Olcer, A.I., Odabasi, A.Y. (2005). A New Fuzzy Multiple Attributive Group Decision Making Methodology and Its Application to Propulsion: Manoeuvring System Selection Problem. *European Journal of Operational Research, 116,* 93-114.

80. Ostwald, P. (1992). *Engineering Cost Estimating.* New Jersey: Prentice Hall.

81. Page, Stephan (2000, January). Research: The Key to Quality Policies and Procedures. *Quality Progress*, 58-62.

82. Palanna, Namita (2004). *Lean Manufacturing and Six Sigma* (Master of Science Thesis, California University Dominguez Hills, 2004). Michigan: UMI Microform 1417803.

83. Palmer, K. (2005, November 1). Deep Thinkers. *Government Executive*, *37* (19), 23-24.

84. Pannell, A. (2006, March). Happy Together. *Industrial Engineer Magazine*, 46-49.

85. Pojasek, B. (2003, Winter). Lean, Six Sigma, and the Systems Approach: Management Initiatives for Process Improvement. *Environmental Quality Management*, 85-92.

86. Prahalad, C. K., Hamel, G. (1990, May - June). The Core Competence of the Corporation. *Harvard Business Review*, 79-91.

87. QuickMBA (2007). *Strategic Management: Core Competencies*. Retrieved May 11, 2007, from <http://www.quickmba.com/strategy/core-competencies/>.

88. Rath and Strong Management Consultants. (2003). *Six Sigma Pocket Guide*. Massachusetts: Rath and Strong.

89. Raulerson, Colonel A., Sparks, P. (2006, November - December). Lean Six Sigma at Anniston Army Depot. *Army Logistician*, 6-9.

90. Reece, B. (2006, December). Lean Six Sigma Eases Fiscal Constraint Challenges. *Defense AT&L*, 54-56.

91. Reinke, Jeff (2007, June). Propelling Efficiency. *Industrial Maintenance and Plant Operation*, 40-42.

92. Rockwell Automation. Rockwell Automation Network Systems. Milwaukee Mainframe.

93. Rockwell Automation (2006, December). Selection Guide.

94. Rockwell Automation (2007). *Signaling Products*. <http://www.ab.com/industrialcontrols/products/signaling/index.html>.

95. Rockwell Automation (2007). Our Vision and Values. <http://rain.ra.rockwell.com>

96. Saaty, Thomas (1982). *Decision Making for Leaders: The Analytical Hierarchy Process for Decisions in a Complex World.* California: Lifetime Learning Publications.

97. Saaty, Thomas. L. (1994). *Fundamentals of Decision Making and Priority Theory with the Analytic Hierarchy Process.* Pennsylvania: RWS Publications.

98. Saaty, T., Ozdemir, M. (2003). Priority as Dominance in Derived Measurement: Invariance if the Principal Eigenvector. *International Journal of Information Technology & Decision Making, 2* (2), 185-195.

99. Saaty, Thomas. (2005). *Theory and Applications of the Analytical Network Process: Decision Making with Benefits, Opportunities, Costs, and Risks*. Pennsylvania: RWS Publications.

100. Sachkov, V. N., Tarakanov, V. E. (2002). *Combinatorics of Nonnegative Matrices.* Rhode Island: American Mathematical Society.

101. Salvendy, G. (2001). *Handbook of Industrial Engineering: Technology and Operations Management.* New York: John Wiley & Sons, Inc.

102. Savage, L. (1972). *The Foundation of Statistics.* New York: Dover Publications, Inc.

103. Schutta, J. (2006). *Business Performance through Lean Six Sigma.* Wisconsin: ASQ Quality Press.

104. Shannon MD, MPH, Diane (2007, May – June). Challenges in Patient Safety and Quality: Replacing Discouragement with Hope. *The Physician Executive*, 16-21.

105. Sharma, U. (2003, Summer). Implementing Lean Principles with the Six Sigma Advantage: How a Battery Company Realized Significant Improvements. *Journal of Organizational Excellence,* 43-52.

106. Smith, D., Blakeslee, J., Koonce, R., (2002). *Strategic Six Sigma*. New Jersey: John Wiley & Sons.

107. Stigum, B., Wenstop, F. (1983). *Foundations of Utility and Risk Theory with Applications.* Holland: D. Reidel Publishing Company.

108. Stoner, J., Freeman, R. (1992). *Management*. New Jersey: Prentice Hall.

109. Vavra, B. (2007, March*).* Tie Lean, Six Sigma Strategies to Plant Worker's Knowledge. *Plant Engineering Magazine*, 18.

110. Villacreses, Dr. Kleber Barcia (2003). *A Methodology for Identifying and Eliminating Waste in Office Environments* (Doctoral Dissertation, University of Texas at Arlington, 2003). Michigan: UMI Microform 3092472.

111. Vinhais, J. (2004, November). Leaning into Six Sigma. *Medical Design Technology*, 32-34.

112. Welty, R. (2004, October 15). Using Lean Six Sigma Principles to Create Increased Profitability. *Central New York Business Journal*, 14-15.

113. Wikipedia (2007, April 16). *Business Process*. Retrieved May 11, 2007, from <http://en.wikipedia.org/wiki/Business_process>.

114. Wikipedia (2007, January 6). *Core Business*. Retrieved May 11, 2007, from <http://en.wikipedia.org/wiki/Core_business>.

115. Wikipedia (2007, May 4). *Core Competency*. Retrieved May 11, 2007, from <http://en.wikipedia.org/wiki/Core_competence>.

116. Wikipedia. (2007, June 29). *Factors of* Production. Retrieved July 5, 2007, from <http://en.wikipedia.org/wiki/Factors_of_production>.

117. Wikipedia (2007, January 14). *Thomas Saaty*. Retrieved January 30, 2007, from <http://en.wikipedia.org/wiki/Thomas_Saaty>.

118. Williams, Dr. D. (1997). *Manufacturing System Testing Measurement and Management Process* (Doctoral Dissertation, University of Texas at Austin, 2005). Michigan: UMI Microform 3184807.

119. Wilson, G. (2005). *Six Sigma and the Product Development Cycle*. Massachusetts: Elsevier Butterworth-Heinemann.

120. Winkler, R. (1990, March). Decision Modeling and Rational Choice: AHP and Utility Theory. *Management Science*, *36* (3), 247-275.

121. Womack, J., Jones, D. (1996). *Lean Thinking: Banish Waste and Create Wealth in Your Corporation*. New York: Simon & Schuster Inc.

122. Yang, Dr. Z. (2004). *A Decision Making Framework for Ozone Pollution Control* (Doctoral Dissertation, University of Texas at Arlington, 2004). Michigan: UMI Microform 3145840.

123. Yurdakul, M. (2003). *Measuring Long-term Performance of a Manufacturing Firm using the Analytical Network Process (ANP) Approach*. International Journal of Production Research. Vol 41. Number 11. Taylor and Francis Group.

124. Zinkgraf, S. (2006). *Six Sigma: The First 90 Days*. New Jersey: Prentice Hall.

BIOGRAPHICAL INFORMATION

The author received her doctorate in Industrial and Manufacturing Systems Engineering from the University of Texas at Arlington in December 2007. The author became a certified Professional Engineer in January 2006. She led the research for the Zero Force Push Button Efficiency Improvement Project. Through this project, she became a certified Six Sigma Greenbelt in July 2005. The author received her masters in Engineering Management with an emphasis on Manufacturing from the University of Missouri at Rolla in December 1996. She received her bachelors in Industrial Engineering with a Business Administration minor from Bradley University in December 1994. The author is always seeking opportunities to participate in Lean and Six Sigma projects, due to her passion for process improvements. She is presently working on two Lean Six Sigma projects, Smart Motor Controller Quality and Delivery Improvement Project and Configured Area Enhanced Delivery Project.