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The Application Of Lean Six Sigma To Improve A Business Process: A Study Of The Order Processing Process At An Automobile Manufacturing Facility

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THE APPLICATION OF LEAN SIX SIGMA TO IMPROVE A BUSINESS PROCESS: A STUDY OF THE ORDER PROCESSING PROCESS AT AN AUTOMOBILE MANUFACTURING FACILITY

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DEDICATION

I would like to dedicate this thesis to my parents: Rev. and Mrs. Frankie and Mary Ellis, deceased grandparents: Mr. and Mrs. Ruthel and Fredonia Fuller, Mr. and Mrs. Willie and Ruth Ellis and Mr. Rayford E. Peeler and deceased Godfathers: Mr. David Littlejohn and Mr. George Savage. I truly appreciate their encouraging me to strive for excellence and never give up in the presence of obstacles. There were times when I felt like throwing in the towel, but thinking of them and how proud they are (my parents) or would be (my grandparents and Godfathers) of me truly resulted in my continuing to press toward the mark in an effort to obtain my Master of Science Degree in Engineering Management. I could not have finished this journey without the encouragement of these people, and I am truly grateful for the role they play or have played in my life. I strive, daily, to make each of them proud!

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ABSTRACT

The objective of this study is to explore the application of Lean Six Sigma to determine root causes of process inefficiency and make recommendations for improving the order processing process at an automobile manufacturing facility. State of the art process quality improvement initiatives Lean, Six Sigma, and Lean Six Sigma are used to explore literature and provide a strong theoretical background for this study. Since the study utilizes both quantitative and qualitative data, the study's methodological approach is classified as mixed methodology. The study is empirical in nature, and single case study is strategy chosen to complete the study. The empirical case study is carried out via a DMAIC project. Portions of this Lean Six Sigma DMAIC methodology are used to collect and analyze data in regards to the current process. Additional data is provided by the automobile manufacturing facility's related stakeholders and combined with data collected throughout the DMAIC project to make recommendations for process improvement. The study reveals the root causes of process inefficiency (high cycle time) and allows recommendations to be made that will improve the current order process at the automobile manufacturing facility. The application of Lean Six Sigma to make recommendations for improving the automobile manufacturing facility's order processing process was successful.

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LIST OF SYMBOLS

σ	Greek symbol for sigma
X	Process or system inputs
Y	Process or system outputs

LIST OF ABBREVIATIONS

CI......Continuous Improvement

CTQ...... Critical to Quality

DMADVV...... Define, Measure, Analyze, Design, Verify, and Validate

DMAIC ......Define, Measure, Analyze, Improve, and Control

FMEA ......Failure Mode Effects Analysis

LCL ......Lower Control Limit

LSS......Lean Six Sigma

MSA ......Measurement System Analysis

SIPOC ...... Suppliers, Inputs, Process, Outputs, Customers

SPC ...... Statistical Process Control

TQM...... Total Quality Management

UCL...... Upper Control Limit

VOC ...... Voice of Customer

VSM...... Value Stream Mapping

CHAPTER 1

INTRODUCTION

In addition to providing a superior product, a business must strive to satisfy customers by providing each customer with an exceptional customer service experience. Since "time is money," one of the easiest ways to ensure customer satisfaction is by delivering products in a timely manner. Products and services can only be delivered in a timely manner if a company's order processing process is designed in a manner that will yield minimum order processing cycle time. If a company is experiencing a higher cycle time than desired, the company can investigate the current state of the process and use quality improvement initiatives to improve the business process. Some of the most commonly used quality improvement initiatives include Total Quality Management (TQM), Six Sigma, and Lean Six Sigma. Using those initiatives will allow one to improve the quality of a process by determining the root cause of flaws in the current process and developing as well as implementing solutions to correct those problems.

The thesis focuses on providing recommendations to improve the current order processing process at an automobile manufacturing facility. A single case study of the facility's current order processing process is conducted to provide insight in regards to flaws associated with the process. Lean Six Sigma is the quality improvement initiative that is used to develop recommendations in order to achieve order processing process improvement.

1.1 BACKGROUND OF STUDY

The automobile manufacturer is a trusted and leading manufacturer of premium chassis for walk-in van and delivery, commercial and shuttle bus, school bus, and recreational vehicle markets. The facility is located in the United States of America and has been in the same location since the 1990s. This facility prides itself on engineering excellence and leverages expertise in heavy-duty durability and precision performance in an effort to produce state of the art chassis. The automobile manufacturing facility stands firmly on delivering superior performance, safety, and reliability to each of its customers and recognizes that its customers are the driving force to company's ability to succeed in the automobile manufacturing industry.

The automobile manufacturing facility has a history of experiencing problems in relation to the order processing, and previous work has been performed to alleviate these issues. The company initially noticed issues in relation to order release errors in the last quarter of 2012. In an effort to correct this problem, a Continuous Improvement (CI) event was held in 2013. This CI event assisted with reducing order release errors as well as standardized the use for data codes and pricing for new orders. Although order release errors were reduced, the automobile manufacturing facility encountered an additional problem in regards to online processing and tracking of new orders. In 2014, a CI event was held that resulted in better visibility of orders. After overcoming troubles in relation to order visibility, the automobile manufacturing facility encountered another hurdle that related to compatibility rules differing between the databases used to place orders (Spec Pro) and store orders (IMACS). An additional CI event was held in 2014 to address this issue. This event resulted in Spec Pro being updated to eliminate any compatibility issues that existed. Shortly after correcting the compatibility issue, the facility realized order processing cycle time was higher than desired. Because high order processing cycle time taints downstream processes and can negatively impact customer experience, investigating this issue in a more thorough manner was necessary. Although previous work had been performed in relation to order processing, no work had been done to address improving the entire process that is used to process orders. The investigation in regards to how Lean Six Sigma could be used to improve the current order processing process and reduce order processing cycle time was chosen to address the issue.

1.2 Problem Statement

Although producing a superior product can help a business remain competitive, there are also other factors that contribute to the success of a business within a particular marketplace. In addition to a superior product, organizations must also be able to compete in regards to time constraints. The amount of time it takes an order to be processed can heavily delay the order's ability to reach customer in a timely manner. One of the problems, at the automobile manufacturing facility, is orders taking too long to be processed. This problem is perceived to be related to the process that is currently used by sales and marketing departments to process orders. Currently, each order is taking an average of four business days to be processed. Because the new orders are taking a while to be processed, downstream processes efficiency becomes tainted. The lag in order processing impacts all other departments (engineering, materials, and manufacturing) and their ability to complete "work" in relation to the specified order.

1.3 Purpose of Study

The purpose of this study is to explore the application of Lean Six Sigma to improve the automobile manufacturing facility's current order processing process. The process must be investigated to determine associated problems as well as the root causes of the problems. The problems and their root causes will be used to make recommendations in regards to improving the order processing process.

1.4 Research Questions

Although the order process has been identified as flawed, there is no clear indication in regards to where the flaws lie or the source of the flaws. Section 1.3 indicates that this study will determine the flaws as well as the source of these flaws. To assist with identifying the source of the flaws, factors that heavily influence the flaws will be determined. The following research questions will serve as a focus and guide for this thesis work:

1. Why is the automobile manufacturing facility's current order processing process not efficient? (What flaws are associated order processing inefficiency?)
2. How can flaws associated with the order processing process be measured?
3. How can permanent corrective action be implemented to eliminate flaws associated with the order processing process?

1.5 Significance of Study

This study is significant to the automobile manufacturing facility, the entire automobile manufacturing industry, and future researchers. The automobile manufacturing industry that was studied will benefit from this study because the study will provide recommendations to improve order processing that will later be implemented to reduce order processing cycle time and allow the company to maintain superior customer satisfaction. Since the facility is classified as an automobile manufacturing company, the entire automobile manufacturing industry will benefit from this study by utilizing the work that was done as guidance to develop and implement recommendations to improve order processes. Future researchers will benefit from this study as they will be able to use the provided information as a guide for further developing research pertaining to the utilization of Lean Six Sigma to improve business processes.

1.6 Definition of Terms

The following terms are used throughout this thesis. These terms are defined to provide clarity for any ready who is not familiar with the information covered.

Cause and Effect Diagram

A structured brainstorming tool that is designed to assist an improvement team in listing potential causes of a specific effect. This diagram is also referred to as Ishikawa Diagram, in honor of its creator or a Fishbone Diagram, for its resemblance to the bones of fish. (Lean Six Sigma Glossary, n.d.)

Continuous Improvement

A data-driven approach and process analysis used to solve problems and improve products or processes. (Lean Six Sigma Glossary, n.d.)

Control Chart

A time chart designed to display warning of changes in process performance due to sporadic or rarer events indicating that a process is not in control. This chart is used to better understand process variation and make it easier to improve the process that is out of control. (Lean Six Sigma Glossary, n.d.)

Customer

Any individual who receives the output of a process. (Lean Six Sigma Glossary, n.d.)

Downstream

Any processes or activities that occur after a given process. (Lean Six Sigma Glossary, n.d.)

I & MR Chart

Chart designed for tracking single points of continuous data. The individual (I) chart tracks individual data points while the moving range (MR) chart tracks the absolute value of the distance between each pair of consecutive data points. These charts are also known as X & MR charts and are typically used to track business performance data. (Lean Six Sigma Glossary, n.d.)

Input

A resource that is added to a process by a supplier. The resource can be a product, service, data, labor, etc. (Lean Six Sigma Glossary, n.d.)

Output

A resource that is a result of a process. The resource can be a product, service, data, labor, etc. (Lean Six Sigma Glossary, n.d.)

Pareto Chart

A quality chart of discrete data that helps identify the most significant types of defect occurrences. The chart shows the frequency of occurrences using a bar graph and cumulative total of occurrences using a line graph. Both the line graph and the bar graph are displayed on a single chart.   (Lean Six Sigma Glossary, n.d.)

Process

A combination of people, tools, materials, and methods that convert and input to an output. (Lean Six Sigma Glossary, n.d.)

Process Map

A step-by-step diagram that shows the activities needed to complete a process. This diagram is used to assist with identifying problems associated with a process. (Lean Six Sigma Glossary, n.d.)

Scatter Plot

A chart that shows the relationship between two variables. This plot is also known as a XY plot because the variables are plotted on the X and Y axis. (Lean Six Sigma Glossary, n.d.)

SIPOC

A high-level view of a process. This stands for Supplier, Input, Process, Outputs, and Customers. A SPIOC is ordered from start to finish as suppliers provide inputs to processes which results in an output that is delivered to customer. (Lean Six Sigma Glossary, n.d.)

Stakeholder

An individual who is affected by or can affect a process improvement project. (Lean Six Sigma Glossary, n.d.)

Statistical Process Control (SPC)

A quality control concept that uses statistical methods to monitor processes. SPC utilizes control charts to gather and analyze data. The gathered data determines whether or not the processes is “out of control”. (Lean Six Sigma Glossary, n.d.)

Supplier

Any person or organization that provided an input to a process. (Lean Six Sigma Glossary, n.d.)

Two-Sample T-Test

A hypothesis test that determines whether a statistically significant difference exists between the averages of two independent sets of normally distributed continuous data. This test is useful for determining if a particular strata or group could provide insight into the root cause of process issues. (Lean Six Sigma Glossary, n.d.)

Value Steam Map

A technique used for identifying and eliminating waste from a process. A Value Steam Map visually maps the flow of steps, delay, and information required to deliver a product or service. (Lean Six Sigma Glossary, n.d.)

Voice of Customer (VOC)

Data that represents the needs and wants of the customers. This data is collected through various means, including surveys and focus groups.   (Lean Six Sigma Glossary, n.d.)

1.7 Assumptions, Limitations, and Delimitations

The assumptions of the study are associated with the study are associated with the participants who were chosen to be a part of the project team as well as the participants who were chosen to be interviewed. The study’s assumptions are as follows:

- The information participants provide will be honest.

- The participants will answer questions to the best of his/her ability and will ask questions about anything that is unclear before providing a response.

The limitations of this study are associated with the chosen research strategy. The case study strategy limits the study because a case study only involves a chosen group. The results of the case study are specific to the chosen group; therefore, the results of the study cannot be generalized. Although the case study results are not able to be generalized, the results may be applied to a similar entity. Unfortunately, additional research would have to be completed to determine whether or not findings from one study would be applicable to a similar organization or not. In addition, researcher bias can be applied to the qualitative data collected during a case study. If the researcher interprets the qualitative data in a bias manner, the validity of the data decreases.

The delimitations of this study are associated with my personal choices. The primary delimitation of this study is my choosing to make the focus of the case study a single company. Choosing to focus on one company aided me in choosing to employ a single case study research strategy. As mentioned in the paragraph above, my choosing this strategy creates limitations associated with the study. In addition, my choosing to only make recommendations for process improvement was another limitation of the study. Define, measure, and analyze are the only portions of the DMAIC methodology needed to be make recommendations for improvements. Because the entire DMAIC methodology is not applied, the success of DMAIC to improve the order process and reduce cycle time is not measured.

1.8 Organization of Study

This thesis is organized into five chapters. Each chapter plays a vital role in presenting the study. The first chapter provides an introduction to the research. This chapter discusses the background, problem statement, purpose, research questions, significance, definition of terms, assumptions, limitations, and delimitations associated with the study. The second chapter provides details in regards to Lean, Six Sigma, and Lean Six Sigma process improvement as well as presents a review of the literature that was studied to provide a theoretical basis for this study. The third chapter details the methodology that was used to complete the study. The execution of the Lean Six Sigma case study is detailed in the fourth chapter. Conclusions are presented in fifth chapter.

CHAPTER 2

LITERATURE REVIEW

This chapter will provide an introduction to improvement processes that are correlated with this thesis. The chapter will begin with an overview of Lean. Next, the chapter will proceed with an overview of Six Sigma. After overviewing Lean and Six Sigma separately, an overview of Lean Six Sigma will be provided. This chapter will conclude with an overview of literature associated with the successful application and implementation of Lean, Six Sigma, and/or Lean Six Sigma within different industries that will serve as a theoretical basis for this study.

2.1 Overview of Lean

Ptack, Sperl, and Trewn (2015) define Lean as "a never-ending, systematic approach for identifying and eliminating wastes and improving flow of a process while engaging employees" (Ptacek, Sperl , & Trewn , 2015, p. xii). Lean was initially introduced by Henry Ford and Taiichi Ohno. Henry Ford introduced Lean Manufacturing through the assembly line, and Taiichi Ohno introduced Lean Management Philosophy and Practices through Toyota Production System (TPS). Although Lean was initially introduced within the manufacturing sector, Lean thinking allows Lean to be applicable to any sector. Lean is heavily focused on improving the quality of products and services delivered to customers because "it is the customer who determines the value and the amount they are willing to pay for the product or service" (Ptacek, Sperl , & Trewn , 2015, p. xii).

Mega (2016) informs us, "there are five principles to Lean thinking: defining the value, identifying the value stream, removing interruptions to the value flow, letting the customer pull the value from the manufacturer, and the pursuit of perfection" (Mega, 2016, "Win Customers with Lean Metrics" para. 2). Before any process improvement is initiated, value must be defined. Value is defined by investigating how the product or service and the cost associated with the product or service meet the customer's need. Value is dependent upon time frame; therefore, what may be considered valuable now may not be considered valuable in 10 years. After the value of a product or service is defined, the value stream associated with delivering the product or service must be defined. Value stream is defined as all the processes that are involved in producing a product or service from start to finish. Processes that create value, processes that are necessary but don't create value, and processes that are unnecessary and don't create make up the value stream (Mega, 2016). Identifying the value stream helps identify wastes and is essential to process improvement. After identifying the value stream and eliminating wastes found, the process flow can be adjusted. When the flow of a process is adjusted, the process can flow from department to department (i.e. marketing to engineering) in a smooth and painless manner. The next principle associated with Lean thinking involves the ability of the customer to pull the product from the company as opposed to the company pushing the product on the customer (Mega, 2016). Allowing the customer to "pull" the product assists with the time that may be added to production as a result of process improvement as well as ensures customer demands are met. The four principles that were previously mentioned work together to achieve the last principle, achieving process perfection.

Lean principles have been implemented into the world of manufacturing and service. These principles serve as a method to ensure that the end customer receives a quality product. Within the process of lean management, every activity that is involved in the creation of a product is examined. If a particular portion of the process does not add value to the product, that particular portion of the process is considered wasteful. The wasteful process can appear in seven categories. The categories of wastes are as follows

- Defects
- Work in Progress
- Overproduction
- Waiting
- Motion
- Transportation
- Overprocesing

Figure 2.1 provides a graphical representation as well as a brief explanation of the seven deadly wastes. Table 2.1 provides examples of how each category of waste can be within both sectors.

Figure 2.1. The Seven Deadly Wastes. Reprinted from The Definitive Guide to Waste Reduction for Manufacturers, on MFC.com by A. Carpenter, submitted by B. Defoor, March 16, 2015, Retrieved August 9, 2016 from http://www.mfg.com/blog/definitive-guide-waste-reduction-manufacturers. Copyright 2016 by MFG.com.

Table 2.1: Seven Deadly Wastes in Manufacturing and Service

Category	Manufacturing Sector	Service Sector
Inventory	• Raw material • Work in progress (WIP) • Finished goods • Consumable Supplies	• Files waiting to be worked • E-mails waiting to be read • Unused records

Table 2.1 Continued

Category	Manufacturing Sector	Service Sector
Waiting	• Parts • Print • Inspection • Information • Machine repair	• Faxes • Technology • Copy Machine • Customer Response • Files to return
Motion	• Searching for needed items (parts, tools, prints, etc.) • Sorting through materials • Reaching for tools • Lifting boxes of parts	• Searching for files • Extra clicks/key strokes • Clearing away files from work area • Looking through manuals/catalogs • Handling paperwork
Defects	• Scrap • Rework • Field Failure • Missing Parts • Variation	• Data entry or pricing error • Missed information/specification • Lost/misplaced records

Table 2.1 Continued

Category	Manufacturing Sector	Service Sector
Transportation	• Moving parts to and from storage • Moving materials from work station to work station	• Retrieving or storing files • Takings files to another person • Going from person to person to collect signatures
Overprocessing	• Cleaning parts multiple times • Paperwork • Awkward tool/part design	• Creating reports • Repeated manual data entry • Use of outdated forms/software
Overproduction	• Producing products to stock based on sales forecasts • Producing more to avoid running out of product • Batching processes resulting in additional output	• Providing more information than the customer needs • Creating unnecessary reports • Making additional copies

Lean has been utilized for several years and has been proven to assist organizations with removing wastes, which ultimately improves cost and quality. The successful implementation of Lean has created a great of confidence in the use of the process improvement tool to enhance continuous organizational growth and improvement. Ptacek, Sperl, and Trewn (2015) identify the following as reasons why Lean methodologies can be used with confidence:

1. The training requirements and implementation time for Lean are minimal.
2. The application of Lean improvement in an organization is broad.
3. Improvements made using Lean concepts, commonly referred to as Kaizen, positively impact other areas of the organization as well as the bottom-line. (Ptacek, Sperl , & Trewn , 2015, p. xii)

Lean training requirements can be taught very quickly, and Lean improvements can be successfully implemented immediately after concepts are mastered. The application of Lean improvement within an organization is referred to as broad as a result of Lean tools' ability to "get everyone engaged fairly quickly and easily with no additional resources required ((Ptacek, Sperl , & Trewn , 2015, p. xii). Improvements made using Lean concepts benefits the organization's customers and employees. Customers benefit from receiving a better quality of product and services, and employees benefit as they are "encouraged and empowered to improve their work processes" (Ptacek, Sperl , & Trewn , 2015, p. xii) to ensure customers receive great products and services.

2.2 Overview of Six Sigma

Ptacek, Sperl, & Trewn (2015) define Six Sigma in terms of statistics and process improvement. In terms of statistics, Six Sigma is a measurement that captures the variation of a process ((Ptacek, Sperl , & Trewn , 2015). In terms of process improvement, Six Sigma is “a structured, quantitative, five phase approach to continuous improvement and problem solving” (Ptacek, Sperl , & Trewn , 2015, p. xiii). Motorola originated six Sigma in the 1980s. Motorola developed and utilized the process improvement tool in terms of manufacturing. Allied Signal further developed Six Sigma as the company utilized Motorola’s developments but measured manufacturing improvements in terms of money saved. General Electric further honed Six Sigma as the company prioritized their projects by money saved as well as applied Six Sigma to the service sector. Six Sigma became exceedingly popular because of saving associated with implementation of the process improvement tool. Stern (2016) relates that General Electric “discussed the completion of more than 6000 Six Sigma projects and their probability of yielding more than $3 billion in saving” (Stern , 2016, p. 170) in the company’s 2001 annual report.

Six Sigma has a strong statistical background and heavily relies upon statistical process measurements. Six Sigma is graphically represented by the bell-shaped normal distribution curve. According to Ptacek, Sperl, & Trewn (2015), “The term Six is the number of sigmas (standard deviations) as a measure from the mean in a bell-shaped normal distribution curve” (Ptacek, Sperl , & Trewn , 2015, p. xiii). The measurement associated with 6σ is based on Defects per Million Opportunities (DPMO). A defect consists of any product or service that does not conform to quality standards. An opportunity consists of any time a product is made or service is rendered. A Six Sigma level of performance is considered to be optimal performance. “A six sigma process should operate within 6σ limits, which implies that 99.99966% of the products manufactured are statistically free of defects (3.4 defects per million)" (O'Connor & Kleyner , 2012, p. 446). If a process is operating within 6σ limits, the process aligns with the normal distribution. Figure 2.2 provides the graphical representation of Six Sigma (6σ). Table 2.2 displays Six Sigma levels in terms of DPMOs.

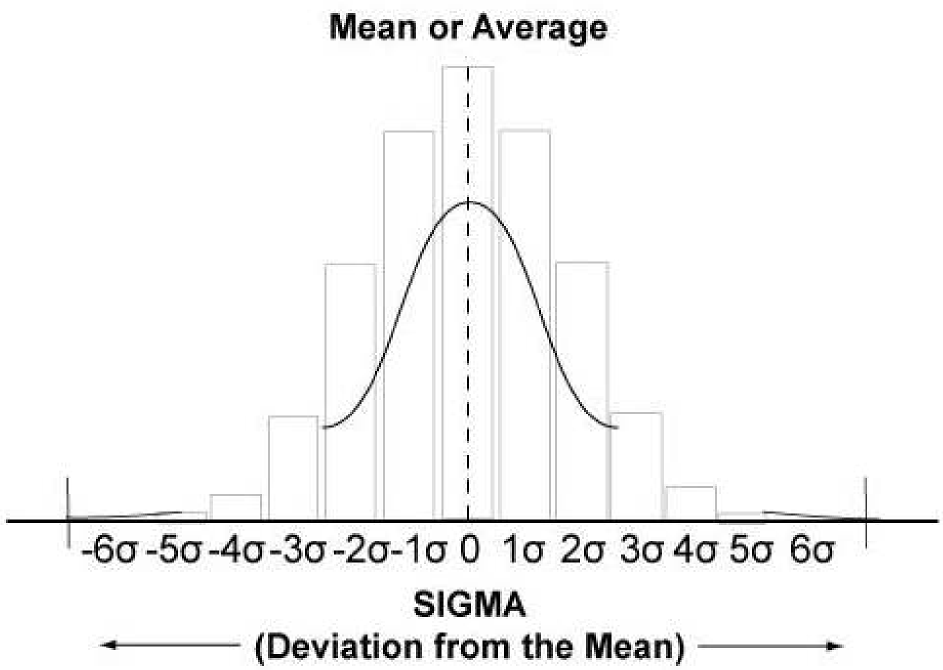

Figure 2.2. Six Sigma as a Measure of the Normal Distribution Curve. Reprinted from *The Practical Lean 6 Sigma Pocket Guide XL*: U*sing A3 and Lean Thinking to Improve Operational Performance in ANY Industry, ANY Time!* (p. xiii), by R. Ptacek, T. Sperl, & J. Trewn, 2015, Chelsea, MI: MCS Media, Inc. Copyright 2015 by MCS Media, Inc.

Table 2.2 Six Sigma Levels. Reprinted from *The Practical Lean Six Sigma Pocket Guide XL*: U*sing A3 and Lean Thinking to Improve Operational Performance in ANY Industry, ANY Time!* (p. xiii), by R. Ptacek, T. Sperl, & J. Trewn, 2015, Chelsea, MI: MCS Media, Inc. Copyright 2015 by MCS Media, Inc.

Process Capability or Sigma Level	Defects (or Errors) Per Million Opportunities (DPMO)	Percent Acceptable
6 σ	3.4	99.99966%
5 σ	233	99.9767%
4 σ	6,210	99.379%
3 σ	66,807	93.32%
2 σ	308,538	69.15%
1 σ	691,462	30.9%

There are two five phase methodologies associated with Six Sigma: Define, Measure, Analyze, Improve, and Control (DMAIC) and Define, Measure, Analyze, Design, Validate, and Verify (DMADVV). DMAIC improves processes that already exist. DMAIC is a methodology that helps identify the root cause of process variation and addresses the root cause in a manner that permanently improves the process. DMADVV helps design a new process, product, or service. DMADVV is a methodology that builds process, products, and services with minimal variation. The utilization of either methodology assists companies with meeting as well as exceeding customer expectations and remaining competitive within respective markets.

Six Sigma has been utilized for over three decades and has been proven to support process improvement and to enhance the overall performance of organizations (Stern , 2016). Improving Sigma level has several benefits, requires essential steps in order to be achieved, and is the responsibility of several people within an organization. Improving the sigma level of a process essentially results in lower costs, more efficient use of resources, generation of new and improved ideas, and increased customer loyalty, job satisfaction, and profitability. The six essential steps that are required for successful implementation of Six Sigma are as follows:

- Understanding the commitment of top leadership
- Having access to current information in regards to customer needs
- Having a process management system in place that has the capability to measure current performance and identify areas that need to be improved
- Proper resources who are sufficiently trained to assist with the design and improvement of processes
- Consistent management involvement and review to enforce process management, improvement, and design
- Communication to ensure that customers focus and Six Sigma methods and embraced throughout the entire organization

Six Sigma is the responsibility of anyone within an organization who is responsible for managing or working in a process. Every individual who is responsible for running or managing a process should be familiar with Six Sigma tools and techniques utilized to improve processes (Ptacek, Sperl , & Trewn , 2015).

2.3 Overview of Lean Six Sigma

Stern (2016) defines Lean Six Sigma as a "hybrid methodology designed to accommodate global challenges and international constraints by capitalizing on two powerful process improvement methodologies: Six Sigma and Lean Thinking" (Stern , 2016, p. xiii). Following the expansion and recognition of Lean and Six Sigma, Lean Six Sigma emerged in 1999. Allied Signal and Maytag were the first companies to start experimenting with the combination of the two process improvement methods, and Maytag was the first to realize the two methods are complimentary to one another (as the implementation of one method does not negatively impact the implementation of the other method) (Stern , 2016). Lean Six Sigma (LSS or L6σ), also commonly referred to as Lean Sigma (Lσ), improves processes by eliminating wastes (Lean) and reducing variation (Six Sigma) within processes. George (2002) provides that the combination of Lean and Six Sigma is necessary due the Lean not having the ability to bring a process under statistical control and Six Sigma not having the ability to drastically improve process speed or increase capital without being in conjunction with another process improvement method. According to Ptacek, Sperl, & Trewn (2015), "Lean Sigma tools are used to:

- Improve customer satisfaction
- Identify and eliminate wastes quickly and efficiently
- Increase communication and speed of services and information at all levels of the organization
- Reduce costs, improve quality, and meet obligations of a product or service in a safe environment
- Initiate improvement activities and empower employees to make improvement themselves
- Track and monitor or control improvements to ensure sustainability
- Implement and manage change with a systematic mindset" (Ptacek, Sperl , & Trewn , 2015, p. xv).

Lean Six Sigma became exceedingly popular because of saving associated with implementation of the process improvement tool. “In 2001, Ford Motor Company reported savings $300 million ($52 million to the bottom line) through the implementation of Lean Six Sigma” (Franchetti , 2015, p. 32).

Lean Six Sigma consists of strong philosophies and principles. The philosophies associated with LSS play an integral role in the successful implementation of the process improvement method. Ptacek, Sperl, & Trewn (2015) identify Lean Six Sigma’s Philosophies as follows:

1. Conservation of Resources
2. Relentless Pursuit of Waste Elimination.

Conservation of Resources is a principle that relates to a company striving to become “green”. Relentless Pursuit of Waste Elimination refers to a consist effort (every second, minute, and hour) to eliminate wastes from processes. Lean Six Sigma Principles also play a vital role in successful implementation of Lean Six Sigma. Ptacek, Sperl, & Trewn (2015) identify Lean Six Sigma Philosophies as follows:

1. Continuous Improvement in Processes and Results
2. Focus on Customers and Value Streams
3. Total Employee Involvement

Continuous Improvement in Processes and Results relates to an organization focusing on the continuous elimination of wastes as opposed to a continuous focus on results. Focus on Customers and Value Streams relates to focusing on the entire process in an effort to improve customer satisfaction. Total Employee Involvement relates to management and leadership making process improvement safe and easy for all employees so the employees will be more likely to willingly and actively participate in process improvement. Although Lean Six Sigma Principles are vital to successfully implementing the process improvement method, the foundation can only be created by management support. According to Ptacek, Sperl, & Trewn (2015), management support can be provided "by making employee training robust, being sincerely involved when and where practical, and letting those closest to the process be involved in any change" (Ptacek, Sperl , & Trewn , 2015, p. xviii).

Lean Six Sigma utilizes many tools to successfully improve processes. "The most popular tools used in Lean Six Sigma are the Seven Tools of Quality often referred to as the Seven Analytical Problem Solving Tools or the Seven Tools of Process Improvement" (Stern , 2016, p. 238). Stern (2016) identifies the Seven Tools of quality as follows:

- Fishbone
- Flowcharting
- Check Sheets
- Histogram/Frequency Diagram
- Pareto Chart
- Scatter Diagram
- Control Charts

In addition to the Seven Tools of Process Improvement, Lean Six Sigma also utilizes additional charts and graphs to improve processes. Stern (2016) identifies the additional charts and graphs as follows:

- Value Stream Mapping

- Gantt
- PERT
- Swim Lane Charts
- Spaghetti Diagrams
- Tim Woods or Eight Areas of Waste
- SWOT Analysis
- FMEA Thinking Process

The tools that were mentioned will be further explained in Chapter 4 as the use of the tools is incorporate in the Lean Six Sigma methodology that is used to improve processes.

Lean Six Sigma is a process improvement method that is centered around teamwork. There are several roles that must be filled in order to successfully improve a process using LSS. Lean Six Sigma key roles include White Belt (WB), Yellow Belt (YB), Green Belt (GB), Black Belt (BB), and Master Black Belt (MBB). Stern (2016) defines the roles as follows:

- White Belts – individuals who have been given basic orientation
- Yellow Belts – individuals trained in the basic application of Six Sigma management tools
- Green Belts – individuals who handle Lean Six Sigma implementation along with their other regular job responsibilities
- Black Belts – individuals who devote 100% of their time to Lean Six Sigma initiatives

- Master Black Belts – individuals who act in a teaching, mentoring, and coaching role (Stern , 2016, p. 175).

Stern (2016) also mentions and defines the following roles:

- Sponsor – individual paying for the project
- Process Owner – individual normally responsible for process success
- Cross-Functional Team – a team made up of multiple disciplines to provide expertise from other departments (Stern , 2016, pp. 175-176).

Although Stern mentions most of Lean Six Sigma's key roles, he does not mention the role of Champion. The Champion is an executive leader whose job is drive the Lean Six Sigma initiative. Each of the roles are equally important, and the person/people in each role must work together in order to successfully implement Lean Six Sigma to improve a process.

Fully implementing a Lean Six Sigma project can take variable amounts of time. Ptacek, Sperl, & Trewn (2015) inform us that the amount of time Lean Six Sigma transformations take are dependent upon the overall size of the organization, availability of tools and resources, understanding of the benefits, commitment of leadership, effective performance management, and how well the organization can manage change. If an organization is smaller in size, the amount of time required to transform a process will be significantly less than the time a larger organization will require. If tools and resources (books, outside consultants, individuals with Lean Six Sigma training, etc.) are consistently available, a process can be transformed in a shorter amount of time. When the benefits associated with implementing LSS are clearly understood, the probability of quickly transforming a process using Lean Six Sigma is higher. Leadership commitment plays a role in the time required to transform a process because employees are more likely to honor and work hard to complete tasks and initiatives that are important to upper management. In addition, leadership will be more likely to hold employees accountable to the Lean Six Sigma way if they are committed to the process improvement method. Effectively managing performance will enhance the implementation of Lean Six Sigma because measurements will increase accountability; in order for the measurements to improve, each person involved in the process transformation must be committed. The manner in which change is managed helps create a "healthy, thriving, challenging, and fun work environment" (Ptacek, Sperl , & Trewn , 2015, p. xxxi), and the creation of such an environment assists with quickly and efficiently implementing process changes.

Mega (2016) states, "For a Lean Six Sigma project to work, it needs to include three very important elements: Strong and Supportive Leadership, Capable Team Members, and a Solid and Stable Infrastructure" (Mega, 2016, "The Three Must-Haves for Implementing Lean Six Sigma", par. 2). Leadership support and commitment is essential to successfully improve a process utilizing Lean Six Sigma. Although implementing LSS will initially improve a process, leadership has to provide support and commitment in order for the implemented changes to be maintained. Leadership can show support by making budgets sufficient, constantly providing project updates, acknowledging those associated with the improvement of the process, and providing incentives as a form of motivation (Mega, 2016). The successful implementation of Lean Six Sigma is also heavily dependent upon an organization's staff: project managers and team members. Project managers must be able to effectively lead LSS initiatives by applying their LSS expertise. Team members must be highly skilled so that they can apply the knowledge that is shared by the project manager to improve the process. Having a strong and solid infrastructure also plays an integral role in the successful implementation of Lean Six Sigma. Without adequately trained staff and resources necessary to support continued learning, Lean Six Sigma implementation will fail. Figure 2.3 displays the elements that a necessary to successfully implement Lean Six Sigma.

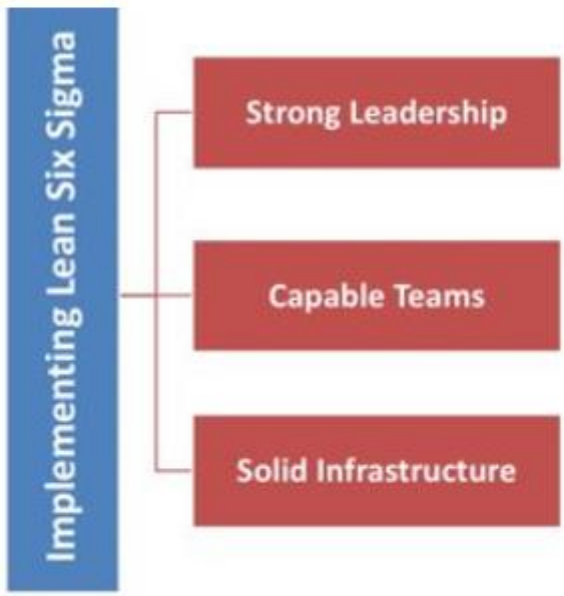

Figure 2.3 The Three Must-Haves for Implementing Lean Six Sigma. Reprinted from *The Lean Six Sigma Quickstart Guide: Lean Manufacturing Tools That Work For Any Business!* ("The Three Must-Haves for Implementing Lean Six Sigma"), by J. Mega, 2016, Copyright 2016 by JMB.

2.4 Review of Literature

In an effort to determine the relevance and trustworthiness of utilizing Lean Six Sigma to successfully improve a process, a review of related literature was completed. The literature primarily consists of journal articles, and scientific publications. The literature was retrieved from academic search engines and provides support to justify my use of Lean Six Sigma to make recommendations to improve the organization's order processing process.

2.4.1. Using a Lean Six Sigma Approach to Drive Innovation

Byrne, Lubowe, and Blitz (2007) describe the success of Lean Six Sigma application for improvement of products, services, processes, and overall business performance. The success of Six Sigma application was considered over a five-year period. Consultants from the IBM Operations Strategy Consulting Practice as well as the IBM Institute for Business Value studied the records of multiple companies who had used Lean Six Sigma to implement operations and structure management techniques. The authors indicated the use of Lean Six Sigma allowed companies to "establish disciplined working environments focused on customer needs, detailed data analysis and facts, not theories" (Byrne, Lubowe, & Blitz, 2007). Amongst companies who achieved excellent results, Caterpillar Inc. was discussed by the authors. Caterpillar launched the implementation of Lean Six Sigma (long before the methodology was well known), and the company's revenue increased by 80% from 2000 to 2005. In analyzing the characteristics of companies who successfully utilized Lean Six Sigma to drive innovation, the authors observed characteristics that were common between each company. The authors found Lean Six Sigma is truly a foundation for innovation. The authors state:

The leading companies using Lean Six Sigma that were examined were intentionally pursuing this much larger innovation agenda. They aimed beyond operational improvement to innovation throughout the enterprise. Lean Six Sigma enabled them to produce breakthrough innovations that caused profound improvements in their business performance. But perhaps more importantly, they obliterated their CEO's biggest innovation obstacle by creating an organizational climate in which innovation has become expected (Jie , Kamaruddin , & Azid , 2014).

Caterpillar's use of Lean Six Sigma eventually leads to the production of low-emissions diesel engine, the redesign of processes, and the streamlining of their supply chain.

2.4.2 Improving University Facilities Using Lean Six Sigma

Mohamed Isa and Usmen (2015) present a case study that details the utilization of Lean Six Sigma principles and tools. These principles and tools were used to study design improvement for university construction services. This project was initiated due to user complaints. In the case study, the authors found that "non-value added general improvement review form (GIRF) process steps involving revisions and rework for the design and construction result in time delays, cost increases and quality deficiencies and render cost estimates unreliable; these are unnecessary and should be minimized and eliminated" (Mohamed Isa & Usmen , 2015). In addition to this, the authors found that administrative processes also increased cycle time and cause similar problems. Because increased cycle time has a downstream impact, the authors recommended that the university's efforts be directed toward reducing cycle time as well as costs. The implementation of Lean Six Sigma proved to be successful in achieving the university's goals.

2.4.3 Critical Analysis of Six Sigma Success Factors in the IT Industry

Anand (2015) analyzes that the success factors associated with the implementation of Six Sigma (as reviewed by other researchers) can have a positive or negative impact the implementation of Six Sigma. This analysis was geared toward the IT industry, but the findings are applicable to the entire service industry. The following factors were analyzed in this study:

- Leadership
- Top management support
- Understanding Six Sigma tools and techniques
- Linking Six Sigma to business strategy, suppliers, and customers
- Projection Selection
- Cultural Change
- Management skills

The author indicates that "the success of an organization can be determined by consistent fine-tuning and advancement in their products or services which is possible predominately by strong leadership skills" (Anand , 2015). Top management support is necessary due to the role that those mangers play in the implementation of Six Sigma. Six Sigma tools and techniques have to be understood in order to be properly implemented. Linking Six Sigma to business strategy is necessary to achieve the goals of the business. Six Sigma methodologies must be linked to customers in an effort to provide greater service. Six Sigma methodologies must be linked to suppliers in an effort to deliver high quality products. The correct projects have to be selected to ensure the application of Six Sigma is successful. The organization's culture must change if the progress that is achieved from Six Sigma implementation is to be retained. Effective project management skills are a critical factor because the implementation of Six Sigma is all about managing projects and processes. If an effective manager is not in place, the implementation is bound to fail. Because correctly applying Six Sigma methodologies and utilizing Six Sigma tools and techniques is not a simplistic task, the individuals who participate in project implementation must be trained to do so. All of the reasoning for the critical success factors were based on the organization as opposed to the employee, and prior studies discussed the pros and cons of each of the critical factors but do not elaborate on the benefits gained from each success factor; therefore, the author concluded that more research needs to be done to address these two areas.

2.4.4 The Use of Lean and Six Sigma Methodologies in Surgery

Mason, Nicolay, and Darzi (2014) review literature in regards to the utilization of Lean and Six Sigma methodologies in regards to the improvement of patient care within surgery. The authors search the following bibliographies on January 1, 2014:

- Allied and Complimentary Medicine Database (1985 – present)
- British Nursing Index (1985 – present)
- Cumulative Index to Nursing and Allied Health Literature (1981 – present)
- Embase (1980 – present)
- Health Business Elite, Health Management Information Consortium, and MEDLINE from PubMed (1950 – present)
- PsycINFO (1806 – present) and
- Cochrane Database of Systematic Reviews

A literature search was performed using names and synonyms of the Lean Six Sigma methodologies. Studies were not included if they did not include patient data. Mason extracted raw data from the studies and created a spreadsheet in Excel to store the data. One hundred twenty-four studies were found to be potentially relevant. Thirty-five of those studies were duplicates; therefore, only 89 studies remained. Of the 89 remaining studies, 49 studies were excluded due to the lack of experimental design; therefore, only 43 studies were fully examined. Only 23 of the 43 studies were found to be suitable enough for inclusion; 11 used lean methodology, 6 used Six Sigma, and 6 used Lean Six Sigma. The location of the 23 studies varied widely, and the oldest study was published in 2003. The studies had significant outcomes, but the outcomes can be split into six aims: to optimize outpatient efficiency, to improve operating theater efficiency, to decrease operative complications, to reduce ward-based harms, to reduce mortality and to limit unnecessary costs and length of stay. According to authors, "the majority of studies (88%) demonstrate improvement; however, high levels of systematic bias and imprecision were evident" (Mason, Nicolay , & Darzi, 2014). Overall, the studies support that the application of lean six sigma can assist with improvements for surgical patients.

2.4.5 Multi-Faceted Views on a Lean Six Sigma Application

Assarlind, Gremyr, and Backman (2013) explored the application of Lean Six Sigma in daily operations and activities. The purpose of this study was to identify Lean Six Sigma factors of importance in an effort to improve future application of Lean Six Sigma. The case study was conducted on the production facility of a large Swedish manufacturing company. Over the course of four months, two of the authors completed the study by spending time at the facility three days per week. The time spent at the facility consisted of having a great deal of contact with shop floor operators, improvement experts, and others who were directly tied to the developing the improvement framework. The data collection consisted of informal interviews, meetings, and documentation of observations. The authors found the application of Lean Six Sigma to be intriguing but noted, “it is not feasible to adopt the same approach for incremental micro-projects performed at the lowest level by small improvement teams as you would for extensive projects performed by highly trained improvement experts.” (Assarlind , Gremyr, & Backman , 2013). The authors believe that a different level of tools and expert resources is needed for more extensive projects. The authors argue that “the benefits of Lean and Six Sigma can be achieved without a single, clear-cut, standardized approach towards an integrated Lean Six Sigma concept”, and “a critical success factor for Lean Six Sigma is having structure that guides the company towards what components of Lean Six Sigma it should apply and what competences it should involve in various projects, depending on the scope and complexity” (Assarlind , Gremyr, & Backman , 2013).

2.4.6 Implementing the Lean Six Sigma Framework In A Small Medium Enterprise (SME)

Jie, Kamaruddin, and Azid (2014) completed a case study pertaining to the implementation of the Lean Six Sigma (LSS) framework in a SME company. Lean Six Sigma (LSS) was applied due to SME facing pressure from competitors; the company was seeking to provide a product that was comparable (in regards to quality and price) to that of competitors. Another reason company management wants to implement Lean Six Sigma is because “label printing production has low productivity and produces high wastage; where it increases he lead time of the production and cost of the product” (Jie , Kamaruddin , & Azid , 2014). The Lean Six Sigma application that the authors discuss is molded for SME and applies to other companies within the label printing industry. “Due to lack of knowledge in LSS, [the authors aimed to] provide a general framework for

SME where it has high flexibility of using different lean tools within the methodology" (Jie , Kamaruddin , & Azid , 2014). Because a framework that does not provide guidance isn't useful, a simplified version of the Six Sigma DMAIC methodology was used to complete the case study. The case study's data was collected by production line observation, and discussions with the production line's supervisors and operators. Data collection indicated that the production output of machine type A was approximately 50% lower, machine type B was 40% lower, and machine type C was 45% lower than production capability. The study indicated the problem source was set up time. The root cause of high set up time was noted to be a result of test printing, ink preparation, and die-cut mold installation. Although the implementation of LSS yielded positive results, the authors inform us, "the challenges [that were faced throughout the implementation of LSS at SME] can be divided into two (2) perspectives, the management of the SME label printing section and the LSS framework" (Jie , Kamaruddin , & Azid , 2014). The authors concluded that implementation of the LSS framework provided a "systematic and guided approached to identify a problem and to provide a feasible solution and sustain the improvement made" (Jie , Kamaruddin , & Azid , 2014). Implementation of Lean Six Sigma resulted in an increase in production by 584 impressions/hour, 896, 00 impressions/year; this equates to a 21.93% increase in production output.

2.4.7 Application of lean Six Sigma Methodology To Reduce Production Costs

Cabrita, Domingues, and Requeijo (2015) completed a case study in regards to the application on Lean Six-Sigma to improve the process and reduce cycle cost. DMAIC is the methodology that was used to demonstrate that Lean Six-Sigma should be used to improve the process. As a result of using Lean Six-Sigma to improve processes, a

50% reduction in average stock level between work stations, a 10% increase in the level of availability in the stamping machine, and a 15% increase in hourly production capacity were achieved. Using the DMAIC methodology provided arguments to "demonstrate its usefulness for the implementation of improvements, both in terms of quality and in terms of the effectiveness and efficiency of processes". In addition, use of DMAIC indicated that a systematic approach must be used to successfully improve processes. The findings of this case study also indicate that DMAIC methodology can be used to improve any (whether the project is related to Six-Sigma or not project.

2.4.8 Purchasing Success Using Lean Six Sigma

Khurana (2008) discusses a workshop that was held in an effort to take participants beyond the then current realm of Lean Six Sigma and explore ways to become more creative in regards to the implantation of Lean Six Sigma. Within the workshop the follow subjects were addressed:

- Manners in which Lean and Six Sigma could be used together to enhance purchasing efficiency
- Adversities that are typically encountered during the implementation of Lean and Six Sigma
- Phases involved in implementing Lean and Six Sigma
- Successful outcome of Lean and Six Sigma Implementation
- Manners to continue to implement Lean and Six Sigma for continuous improvement

The author indicates that the term Six Sigma is usually interpreted as a model that will fix all problems and improve all processes. The author also notes that Six Sigma focuses on quality improvement and differs from TQM and other quality problems because Six Sigma "focuses on customer demands and business processes and targets better financial results. As a result, Six Sigma can be applied to any transaction in any business." In addition, the author informs us that the application and implementation of Lean Six Sigma increases speed, reduces variation, and is implemented to enhance processes as well as make business management more effective.

The successful implementation of Lean Six Sigma in purchasing is discussed by examining the process that is typically used for purchase orders and applying Six Sigma to improve upon the process, and the author drew some conclusions based on the success of the project. The implementation of Six Sigma was deemed a great application due to Match Exception that is involved in the purchase order process. The DMAIC methodology was used in this case. Using Six Sigma, the purchase order process drastically improved. In regards to why Six Sigma was used for this project, "customer satisfaction is of paramount importance in today's world and in the service sector, purchasing departments focus on fulfilling the needs of its internal customers while collaborating with its external customers or suppliers. "Because Six Sigma places an emphasis on customer satisfaction and focuses on the bottom line while providing remarkable improvement in shareholder value, the use of Six Sigma was confirmed to be correct. The author concluded that Lean Six Sigma is not a magical method and should be implemented over time by incorporating the methodology into the organization's culture. He also reiterated the fact the Lean Six Sigma can be implemented to improve any process and should be utilized more by purchasing departments.

2.4.9 Using Lean Six Sigma to Reduce Hemolysis in the Emergency Care Center

Damato and Rickard (2015) explore a project that was completed by laboratory management at Sarasota Memorial Health Care System. The main focus of the project was to improve their preanalytical work flow and blood collection processes. The problem that existed with the processes was that the identification of hemolyzed specimens causes blood to need to be re-collected, "resulting in bottleneck and rework all along the value stream." When hemolysis was analyzed, from July through December of 2009, it was found the average percentage of blood samples that contained hemolysis was 9.85 in the Emergency Care Center and 3.4% in the entire health care system. Because those percentages were large, the goal of the project was to reduce hemolysis to 2%.

The project team used Six Sigma methodology to solve the problem, and the findings of the team were valuable. As a result of hemolysis being identified as a bottle neck and having impact on the value stream, it was identified as an activity that does not add value to the process. Via several observations and interviews as well as a comparison to best practices, the team was able to verify the root cause of hemolysis. In an effort to improve upon the issue, the team implemented protocols, made the collection process more standard, and enhanced training and hiring practices. After these things were implemented, ECC hemolysis decreased from 9.8% to 0.88%, and entire system hemolysis decreased from 3.4% to 1.39%. Hemolysis continued to consistently decrease after the implementation of the project. The author concluded that Lean Six Sigma was an integral part of the project's success due to the tool's helping identify hemolysis as the root of the problem pertaining to preanalytical work flow and blood collection. The project team was able to able to improve upon the blood collection process and reduce hemolysis as a result of the implementation of Lean Six Sigma.

2.4.10 Lean Six Sigma for Quality and Business Performance

Siddh, Gadekar, Soni, and Jain (2013) elaborate on Lean Six Sigma and details advantages of the implementation of Lean Sigma to improve business performance. Lean Six Sigma is comprised of Lean Practices and Six Sigma methodology. Lean concentrates and specializes in the improvement of process flow while Six Sigma concentrates on and specializes in correcting defects. There are several similarities and differences that exist between Lean and Six Sigma. The combination of Lean and Six Sigma create Lean Six Sigma and plays an integral role in continuously improving business processes.

Lean and Six Sigma combine to produce optimal results, and these two applications have similarities and differences. One of the main similarities between Lean and Six Sigma is that teams are used to complete Lean and Six Sigma applications. Lean manufacturing utilizes Kaizen teams while Six Sigma utilizes Six Sigma Project Teams. Another similarity between the two applications is that both require specialist to spearhead getting the associated work done. In addition to this, Six Sigma and Lean both apply changes in the organization that have a major impact on the success of the business. The authors state, the “most dominating and important similarity is both tools show us possibilities to achieve our required goals”. One of the main differences between Lean and Six Sigma is that “Lean manufacturing focuses on eliminating waste and improving flow in manufacturing whereas Six Sigma focuses on eliminating defects but does not explain the improvement of the problem & how to improve process flow. Lean manufacturing do not explain statistical tool to prove results, which were achieved by Six Sigma."

The authors concluded that benefits are associated with combining Lean Manufacturing and Six Sigma. Six Sigma Projects help improve quality performance, and Lean Manufacturing helps improve business performance. The combination of Lean and Six Sigma (Lean Six Sigma) helps attain the highest level of performance by enhancing the performance of the business and delivering products that are exceptional in quality to customers. As a result of the continuous success of the Lean Six Sigma application, industry has acknowledged that those two methodologies share the objective "to create value based end customer requirement" and are a great asset to process improvement.

2.4.11 Using Study of Productivity Improvement Using Lean Six Sigma Methodology

Yadav (2014) reviewed the productivity improvement project using Lean Six Sigma tools. The Lean Six Sigma tools that were reviewed primarily focused on improving bottleneck activities in the project department as opposed to improving processes within the realm of manufacturing. The author notes that Lean focuses on eliminating wastes and adding value in an effort to make increase customer satisfaction. He also notes that Six Sigma uses two methodologies (DMAIC or DMADV) and is implemented to improve upon a specific performance measure as well as maintain the improvement that was achieved. Yadav completed a case study that pertained to a business. The goal of the business was to reduce the cycle time of engineering activities (by 25%) to enhance customer satisfaction. The DMAIC methodology was use to achieve the company's goal. Through the application of Lean Six Sigma, the company was able to improve upon engineering cycle time and attain amazing results. The author noted, "Lean Six Sigma is the logical next step for a company pursuing excellence in existing processes or products, also designing new products and services. Lean Six Sigma focuses on delivering both Lean speed and Six-Sigma defect-free quality" (Yadav , 2014).

2.4.12 Lean, Six Sigma, and the Systems Approach: Management Initiatives for Process Improvement

Pojsek (2003) examined Lean, Six Sigma, and Lean Six Sigma in an effort to convey which methodology should be applied based on the culture or organizations as well as the situations that are being addressed. He describes, Lean "focuses on shortening the time that elapses between a customer's order and the shipment of the product or the provision of the service that fills the order." The author also indicates that lean helps reduce costs and cycle time, which enhances the business overall. The author describes Six Sigma as a method to "help solve processes and business problems." To provide a better understanding of Six Sigma, the author described the DMAIC methodology as well as the implementation of Six Sigma. Posjeck indicates that many companies decide to combine Lean and Six Sigma due to the success of both methodologies, and the systems approach can be used to successfully implement Lean Six Sigma. The author concluded choosing the best method is dependent upon the culture of the organization planning to implement the method. The following methods were provided in regards to choosing the best method:

- If your organization values analytical studies, Six Sigma will be the best method to implement.

- If your organization wishes to see visible progress and implement change immediately, Lean will be the best method to implement.
- If your organization wishes to get employees involved on making a decision that will impact the business, the Systems Approach will be the best method to implement.

2.4.13 Leveraging Lean in the Office

When Lean and Six Sigma tools were initially created, those tools were created with the intent of being used to improve production processes. After the tools were proven to be exceptional, the tools started to be applied to non-production processes as well. Ruttimann, Fischer, and Stockli (2014) observed that the application of Lean and Six Sigma tools to improve office processes did not produce the same (premium) results that were produced in regards to production process improvement. As a result of their observation, the researchers explored the issue and "sketch [ed] the specific properties and show[ed] that a reinterpretation of Lean tools [was] necessary for a Lean Office approach" to be successful.

In exploring the manner in which Lean and Six Sigma could successfully be applied to the office, the authors analyzed the differences between production and office environments. The authors developed a model for the office environment jobs and compared this to traditional processes that are recognized by Lean and Six Sigma. The model for the desk job consisted of three categories: Category Operational Processes, Category Support Processes, and Category Management Processes. Although all of these processes exist in the office environment Lean Six Sigma traditionally only distinguishes between two types of processes: manufacturing and transactional processes. Office processes are relational processes; therefore, the reinterpretation of Lean and Six Sigma is necessary for the process improvement strategy to be successful in the office. Because these differences exist, the current application of Office Lean Six Sigma in is limited to using value stream mapping. The authors concluded "new and adapted Lean tools and concept for the office [can be derived] to exploit the huge improvement potential hidden in the service industry".

2.4.14 Six Sigma Applications in the Healthcare Industry

Taner, Sezen, and Antony (2007) observed the need and implementation of six sigma applications within the healthcare industry. The reduction of cycle time is useful in any industry, but is often a matter of life and death in the field of healthcare. Couple, possibly unnecessary, or preventable death, along with the rising cost of skilled labor, supplies, testing, legal fees, and payouts for incident and negligence claims healthcare organizations must look into other methods to increase efficiency and cut cost.

Five case studies are used, the DMAIC (Define- Measure- Analyst- Improve- Control) process is implemented. The study finds that there are six attributes for a quality healthcare system, which are defined as, safe, effective, patient-centered, timely, efficient, and equitable. The application of Six Sigma benefited all of these attributes to which extent was up to the healthcare systems top management. Implementation of the "six sigma culture into entire organizations, by the commitment and involvement of top management can multiply the positive effects and make a significant impact at all levels." It is up to top management to overcome the obstacles of, financial and human resources. If done, "the authors believe that six sigma as a business strategy allows health care sector to deliver a truly high-class service to patients. Think of the true impact that six sigma could have if we focus on the core issues of health care and improving the quality of lives of patients. In authors' opinion, the application of six sigma in health care industry will continue to grow".

The DMAIC process shown in the article shows resource utilization has been maximized; fewer redundancies, waste and rework have been observed. Bottle-necks related to scheduling have diminished. Working conditions have improved for healthcare personnel. Increased patient and physician satisfaction as well as cost savings have been achieved. All of these things point to the success of the six sigma process implementation into the healthcare services.

2.4.15 The Road Towards Lean Six Sigma: Sustainable Success Factors in the Service Industry

Due to questions regarding the implementation of Lean Six Sigma, Vouzas, Psychogios, and Tsironis (2014) conducted research in regards to evaluate critical factors related to the application. The study that was done consisted of qualitative case studies within the service industry. Throughout the studies, data was collected in relation to the company documents, a review of policies and procedures, and interviews with key employees. The research that was done indicated 10 key findings that have an effect on the application of Lean Six Sigma to improve processes in the service industry.

Three companies (Companies A, B, and C) were studied: Company A was in the telecommunications industry, Company B was in the airline industry, and Company C was in the insurance industry. Interviews, which consisted of open-ended questions, were used within the case studies. Interviews were conducted with mangers (from all departments). Everyone who was interviewed play a key role in implementing Lean Six

Sigma. Forty-seven interviews were conducted: 15 at Company A, 18 at company B, and 14 at Company C. The data that was found was analyzed and 10 sustainable success factors of Lean Six Sigma Application in the Service Industry. The factors are detailed in the table, below. The findings were in line with previous findings. In addition to factors that were identified in other studies, two other factors ("prior implementation of other quality management initiatives and the integration of Lean Six Sigma with the performance management system") were found to be major contributors to the successful implementation of Lean Six Sigma. The implementation of prior implementation of other quality management initiatives "This provides the necessary experience for the employees regarding quality management. Also the documentation of all the processes, required by prior systems, such as ISO, seems to facilitate L6σ. Therefore, it seems that this experience provides the appropriate knowledge and expertise for L6σ application". The integration of Lean Six Sigma performance management systems "motivates managers and employees to increase the level of commitment and involvement". Although the authors presented findings, the authors truly believe the application of Lean Six Sigma in service needs to continue to be investigated so that the application can be expanded upon.

2.4.16 Quality and Competitiveness: A Lean Six Sigma Approach

Dragulanescu and Popescu (2015) observed that the Lean Six Sigma model does not always produce impressive outcomes that have been obtained and reported by many companies. This caused the authors to study the implementation of Lean Six Sigma at a company. The methodology was applied to TNT Express Italy- the Milan branch, a global leader in the field of courier services. The DMAIC model was used to assess the activities of the courier. This model assisted with defining the field of application. Process and value stream mapping were used to streamline processes. Implementation of Lean Six Sigma to improve the project was projected to generate savings of 98,438 Euro a year: 48,438 Euro is a representation of the total hours saved, and 50,000 Euro is a representation of reducing the number of undelivered parcels. This research "emphasized organizational shortcomings within the company structure caused by repetitive processes, non-value adding activities, [and] lack of planning the activities in the various stages of the production process" (Dragulanescu & Pepescu, 2015). Lean Six Sigma helped develop solutions to improve those shortcomings and adhere to customer demands; therefore, this study validates the implantation of Lean Six Sigma for this project.

2.4.17 The Effects of Six Sigma on Corporate Performance

Shafer and Moeller (2012) completed a study to determine the impact the implementing Six Sigma has on corporate performance. The research was conducted as a result of their only being a small amount of research pertaining to this area of study. Eighty-four Six Sigma firms were utilized in conducting this research. To ensure validity of results the companies that were chosen varied in regards to industry and characteristics. The event study methodology was used for this research. The companies were evaluated over a ten-year period. "The ten year period consist[ed] of three years prior to Six Sigma implementation, the event year corresponding to the year Six Sigma was adopted, and six years post Six Sigma implementation" (Shafer & Moeller , 2012). Operating Income/Total Assets, Operating Income/Sales, Operating Income/Number of Employees, Sales/Assets, and Sales/Number of Employees were used to measure the impact of implanting Six Sigma. These measures were compared to different benchmarks, including overall industry performance as well the performance of the portfolios of selected control firms. Completion of the study indicated that the adoption of Six Sigma has a positive impact on corporate performance. Employee deployment and employee productivity were most impacted by the adoption and implementation of Six Sigma. The study indicated the implementation on Lean Six Sigma does not have any negative impacts on corporate performance.

2.4.18 Lean Six Sigma Applications in a Business Process

Ray and John (2011) conducted a case study in an effort to the reduction of cycle times in a business process outsourced (BPO) organization. Cycle time needed to be reduced because high cycle time is a major issue in service sectors. The application Lean Six-Sigma was used to reduce cycle times. This method was chosen because the Lean techniques could be applied to increase speed Six-Sigma could be used to analyze and find solutions to the problems within the current process. The application of Lean Six-Sigma was found to work very well. Cycle time was reduced, and business processes were improved. In this case, Six-Sigma's motto, "Improve results by improving the process", was proven to be true. This case study provided proof of Lean Six-Sigma success in the service sector o industry.

2.4.19 The Application of Lean Six Sigma to the Configuration Control in Intel's Manufacturing R&D Environment

Panat, Dimitrova, Selvamuniandy, Ishiko, and Sun (2014) provide an example of the application of Lean Six Sigma in the research and development sector. The purpose of implementing LSS was to eliminate waste and improve existing processes related to Intel's configuration control. The implementation of LSS was focused on the development and ramp phases of configuration control. DMAIC was used to implement Lean Six Sigma. The current state of the process was assessed to get a good understanding of the process and collect baseline data. Then, a process map was created to determine the number of wastes and inefficiencies. Next, the ideal state and realistic target were defined. After the ideal state and realistic targets were defined, the improvement actions were implemented. Improvements were document as they were recognized. Finally, a control plan was put together to maintain the improvements. As a result of LSS implementation, there was a 60% reduction in idle time and non-value-added activities. These far exceed the reduction goal of 40%. Implementing Lean Six Sigma also prompted an increase in stakeholder satisfaction. The implementation of Lean Six Sigma in R&D environment was very successful.

2.4.20 Lean Six Sigma and Organizational Culture

Kanpp (2015) examined the relationship between four organizational cultural types. The Competing Values Framework and three Lean Six implementation components (management involvement, use of Lean Six Sigma methods, and Lean Six Sigma infrastructure defined the four organizational cultural types. The methodology that was used to complete the study is surveying. A total of 446 human resource and quality managers were given surveys. The human resource and quality managers were from 223 hospitals. The location of these hospitals was Maine, New Hampshire, Vermont, Massachusetts, and Rhode Island. The surveys were administered using the Organizational Culture Assessment Instrument. Although 446 surveys were given, only 104 responses were received. These responses were analyzed, and the following was determined: “management support was significant; infrastructure was not significant; and using Lean Six Sigma methods was also not significant. Post hoc analysis identified group and development cultures having significant interactions with management support" (Knapp, 2015). The findings of this study display the manner in which cultural characteristics impact key components related to Lean Six Sigma. In order for Lean Six Sigma to be effective, certain culture values must be in place. If the culture values do not align with Lean Six Sigma, the implementation of the methodology will not be effective in improving processes.

2.4.21 Critical Failure Factors of Lean Six Sigma

Albliwi, Antony, Lim, and Wiele (2014) explored the critical failure factors for the application of Lean Six Sigma (LSS). These factors were explored in reference to several different sectors. The sectors include, but are not limited to, manufacturing, services, higher education, etc. The method that was used to complete this research was a systematic literature review. The review consisted of evaluating papers (within well-known databases) that were published using the terms Lean Six Sigma and abbreviation LSS. Fifty-six papers were reviewed, and the year of publication spanned from 1995 to 2013. The authors found 34 commons methods failure factors. The most common failure factors include "lack of top management commitment and involvement, lack of communication, lack of training and education, limited resources, and others" (Albliwi, Antony , Lim, & Wiele, 2014). Because several gaps and limited were discussed, research in regards to this service needs to be expanded upon.

2.4.22 A Lean Tool For Improving Lean Six Sigma Effectiveness

Arumugam, Antony, and Douglas (2012) conduct a case study to detail the application of a proposed "observation" procedure drawn from the social science research literature. The application of the proposed “observation” was illustrated as an application in a Lean Six Sigma project. The project took place at a European airport, and the purpose of the project was to reduce speed and improve upon processes. The case study found that utilizing “observation”, which is basically a Lean tool, not only is speed increased by eliminating waste, but also it helps to identify the root causes of variations in the output quality characteristics, whose reduction is the main objective of a Lean Six Sigma programme” (Arumugam , Antony , & Douglas , 2012). Critical observation has a great impact on an organization as well as the individuals associated with the organization. Being observant improves learning and enhances employee engagement. As a result of this study, managers may encourage more employees to partake in critical observation. “Observation” enhances the effectiveness of Lean Six Sigma. Lertwattanapongchai and Swierczek (2014) present a conceptual framework of Lean Six Sigma (LSS) as a project as well as an organizational change process. Lean Six Sigma success factors were identified to assist with assessing the process. An in-depth review of success factors was conducted, and the review resulted in delivering a set of indicators. The indicators that were revealed related to Lean Six Sigma factors as well as the change process. Three multinational companies were used to complete a comparative case analysis. All of the companies were located in Thailand, and LSS was implanted at all three of the companies. The previously mentioned indicators were utilized to identify patterns that related to effective implementation of LSS. In analyzing the case, the authors found that “an effective combination of a strong LSS project design and a comprehensive change management process achieved positive impacts in business results, employee learning and job satisfaction” (Lertwattanapongchai & Swierczek, 2014). This research supports the importance of improving processing and having appropriate project managers in place to ensure business success.

2.4.23 Accessing the Change Process Of Lean Six Sigma

Lertwattanapongchai and Swierczek (2014) present a conceptual framework of Lean Six Sigma (LSS) as a project as well as an organizational change process. Lean Six Sigma success factors were identified to assist with assessing the process. An in-depth review of success factors was conducted, and the review resulted in delivering a set of indicators. The indicators that were revealed related to Lean Six Sigma factors as well as the change process. Three multinational companies were used to complete a comparative case analysis. All of the companies were located in Thailand, and LSS was implanted at all three of the companies. The previously mentioned indicators were utilized to identify patterns that related to effective implementation of LSS. In analyzing the case, the authors found that "an effective combination of a strong LSS project design and a comprehensive change management process achieved positive impacts in business results, employee learning and job satisfaction" (Lertwattanapongchai & Swierczek, 2014). This research supports the importance of improving processing and having appropriate project managers in place to ensure business success.

2.4.24 Introduction of Lean Six Sigma Principles into Plant Maintenance Work Order Cycle Time

Dhafer (2012) studied the use of Lean Six Sigma to assist with plant maintenance work order cycle time. Although Lean and Six Sigma had been used separately and were very successful in the past, the purpose of this study was to combine Lean and Six Sigma in an effort to determine whether or not the methodologies would be equally or more successful. The DMAIC approach was used to complete the study. This study elaborated on the incorporation of Lean Six Sigma into order processing time. Throughout the study, the current process that was used by the company was evaluated. The evaluations were used and turned into an analysis that would help decrease the order cycle time. This study verified the Lean and Six Sigma are very useful when incorporated together. Through this method, the company's cycle time was reduced from an average of 214 days to 107 days. Although the compilation of the tools was deemed successful, the study revealed that the tools should be incorporated into the culture of the organization. Most importantly, this study revealed that Lean Six Sigma can be applied to any process.

2.4.25 Improvement of Claim Processing Cycle Time Through Lean Six sigma Methodology

Businesses must remain competitive by not only delivering superior products as well as exceptional service. One aspect of customer satisfaction is delivering customer services and handling customer related issues in a timely manner. Services will only be delivered on time if processes are in place to monitor and control cycle time. The authors state, "In order to compete in the global business arena and explore ways to improve bottom line, manufacturing/servicing organizations are looking for strategies for process improvement" (Sarkar , Mukhopadhyay, & Ghosh, 2013). In the service sector, cycle time being too long is a known problem. Because strategies like business process reengineering (BPR) and Total Quality Management (TQM) were not producing desired results (in regards to reducing cycle time) and Lean Six Sigma (LSS) had become known for improving speed and quality, Sarkar, Mukhopadhyay, and Ghosh (2013) completed a case study in regards to reducing cycle time for the claim settlement process in insurance or financial services. As a result of the case study, the authors concluded that the application of Lean Six Sigma works very well to improve processes and reduce cycle time. This study confirms the fact the combining Lean techniques with Six Sigma methodology can enhance problem solving and improve the productivity of businesses.

2.5 Advancing Scientific Knowledge

As the implementation of Lean Six Sigma to improve business processes continues to be studied, my research will make a contribution to this field by providing additional validity in regards to the successful application of Lean Six Sigma to improve business processes. This study will advance scientific knowledge by supporting current theories related to general field of study investigating the implementation of Lean Six Sigma for business process improvement. In addition, the study will reveal that Lean Six Sigma can be used to successfully make recommendations for improving a company's order process; therefore, this research will advance scientific knowledge by providing an additional study in regards to the specific area of study investigating LSS being used to improve order processing.

CHAPTER 3

RESEARCH BACKGROUND

This chapter provides rationale for the research approach, philosophical worldview, design, and method chosen to complete this thesis. The chapter also provides an assessment of the quality of the completed research. The chapter begins with a discussion about the chosen research approach. A discussion about the chosen philosophical worldview appears next. The chapter continues with a discussion about the chosen research design. Following this discussion, the chapter provides information about the chosen research method. The chapter concludes with a discussion in regards to the quality of the thesis research.

3.1 Research Approach

Creswell (2014) informs us that “research approaches are plans and the procedures for research that span the steps from broad assumptions to detailed methods of data collection, analysis, and interpretation” (Creswell , 2014, p. 31). There are three approaches to research: quantitative, qualitative, and mixed methods. A qualitative approach uses verbiage to interpret findings, but a quantitative approach uses numerical data to interpret and report findings. A mixed method approach combines quantitative and qualitative approaches.

The research approach that was chosen to complete this thesis is the mixed methods approach. The definition of and advantages associated with using the mixed methods approach provide rationale for choosing this approach. Creswell (2014) defines mixed methods research as follows:

> *Mixed methods research* is an approach to inquiry involving collecting both quantitative and qualitative data, integrating the two form of data, and using distinct designs that may involve philosophical assumptions and theoretical frameworks. The core assumption of this form of inquiry is that the combination of qualitative and quantitative approaches provides a more complete understanding of a research problem than either approach alone (Creswell , 2014, p. 32).

Ary, Jacobs, Razavieh and Sorenson (2010) reveal the following advantages associated with the mixed methods approach:

- "Mixed methods research can take advantage of the combined strengths of strengths of qualitative and quantitative approaches and can use the strengths of one method to overcome the weaknesses of another.
- A broader range of research questions can be examined because the researcher is not confined to a single method.
- Mixed methods research can provide stronger evidence for a conclusion through corroboration of findings.
- The researcher may have insights to what could have been missed with only a single method.
- The combination may produce more complete understanding of the phenomenon or more complex knowledge to inform theory or practice" (Ary , Jacobs , Razavieh , & Sorenson, 2010, p. 567).

In an attempting to suggest recommendations for order process improvement, several aspects needed to be evaluated. Some aspects could easily be evaluated using statistical information and calculations (quantitative) while other aspects had to be evaluated by speaking with individuals directly involved with order processing or observing current processes (qualitative). Utilizing a mixed methods approach allows both types of data to be collected and enhances the reliability of the study; therefore, a mixed methods approach is the most suitable approach for this research.

Each research approach contains three essential components: philosophical worldviews (research philosophy), research design, and research methods. Figure 3.1 presents the interconnection of worldviews, designs, and research methods. The components are discussed in the next sections.

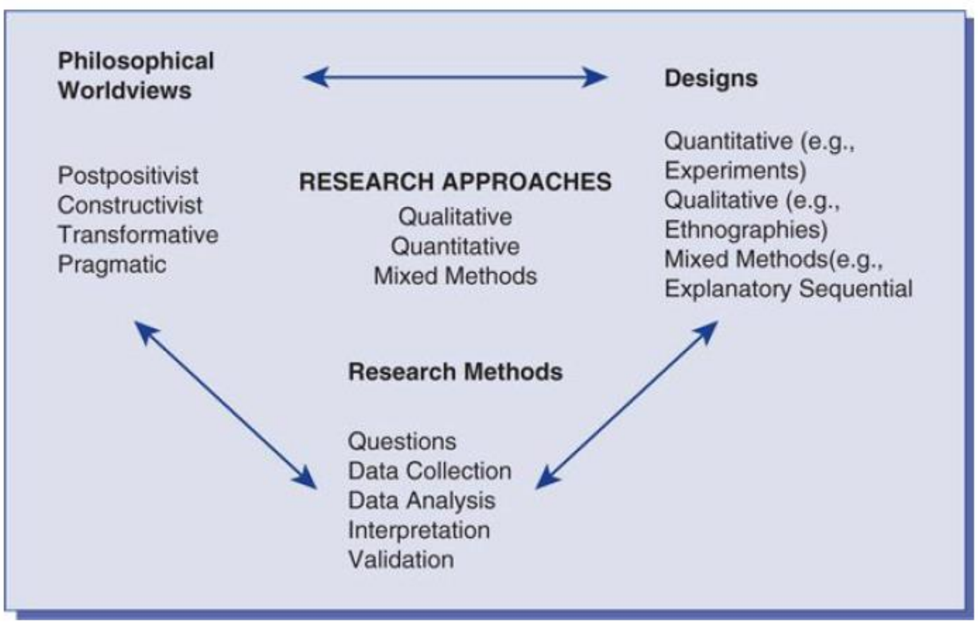

Figure 3.1. A Framework for Research – The Interconnection of Worldviews, Design, and Research Methods. Reprinted from *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches* (p. 35), by J.Creswell, 2014, Thousand Oaks, California: SAGE Publications, Inc. Copyright 2014 by SAGE Publications, Inc.

3.2 Research Philosophical Worldviews

Creswell (2014) informs us that a philosophical worldview is "a general philosophical orientation about the world and nature of research that a researcher brings to a study" (Creswell , 2014, p. 35). Worldviews are also referred to as paradigms and help researchers to embrace a research approach (Creswell , 2014). Creswell discusses four worldviews that are well known in literature: postpositivism, constructivism, transformative, and pragmatism. Table 3.1 provides a brief summarization of what each of the worldviews entail.

Table 3.1. Four Worldviews. Reprinted from *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches* (p. 36), by J. Creswell, 2014, Thousand Oaks, California: SAGE Publications, Inc. Copyright 2014 by SAGE Publications, Inc.

Postpositivism	Constructivism
• Determination • Reductionism • Empirical observation and measurement • Theory verification	• Understanding • Multiple participant meanings • Social and historical construction • Theory generation
Transformative	**Pragmatism**
• Political • Power and justice oriented • Collaborative • Change-oriented	• Consequences of actions • Problem-centered • Pluralistic • Real-world practice oriented

The postpositivist worldview is representative of the traditional form of research and holds more true for quantitative research (Creswell , 2014). This worldview is often referred to as the scientific method, empirical science, positivist/postpositivist research, and postpositivism (Creswell , 2014). "The problems studied by postpositivist reflect the need to identify and assess the causes that influence outcomes, such as found in experiments" (Creswell , 2014, p. 36). A researcher who embraces the postpositivist worldview "begins with theory, collects data that either supports or refutes the theory, and then makes necessary revisions and conducts additional tests" (Creswell , 2014, p. 36).

The constructivist worldview (constructivism) is typically used for qualitative research. The goal of a researcher who embraces the constructivist worldview "is to rely as much a possible on the participants' views of the situation being studied" (Creswell , 2014, p. 37). A constructivist researcher has intentions "to make sense of (or interpret) the meaning others have about the world" (Creswell , 2014, p. 37). Unlike the postpositivist worldview, the constructivist worldview allows the researcher to develop a theory or pattern of meaning as opposed to starting with a theory. According to Creswell, "a transformative worldview holds that research inquiry needs to be intertwined with politics and a political change agenda to confront social oppression at whatever level it occurs" (Creswell , 2014, p. 38). A transformative worldview researcher has intentions to develop suggestions for reform that will impact the lives of participants, the places the participants live or work, or his or her own life. A researcher who takes on a transformative worldview typically beings by addressing issues related day-to-day social issues and sometimes includes participants in designing the study as well as collecting and analyzing data (Creswell , 2014). Transformative worldview research "provides a voice for participants, raising their consciousness or advancing an agenda for change to improve their lives" (Creswell , 2014, p. 39).

According to Creswell (2014), "pragmatism as a worldview arises out of actions, situations, and consequences rather than antecedent conditions (as in postpositivism)" (Creswell , 2014, p. 39). Pragmatism has a focus that is centered on solving problems. Creswell states, "Instead of focusing on methods, researchers emphasize the research problem and use all approaches available to understand the problem" (Creswell , 2014, p. 39). The pragmatic worldview is considered to be most appropriate for mixed methods studies. The pragmatic worldview was chosen to complete this thesis because "pragmatism opens the door to multiple methods, different worldviews, and different assumptions, as well as different forms of data collection and analysis for the mixed methods researcher" (Creswell , 2014, p. 40).

3.3 Research Design

In addition to selecting a research approach and worldview, researchers are responsible for choosing a research design that falls within the research approach. Creswell (2014) defines research designs as "types of inquiry within qualitative, quantitative, and mixed methods approaches that provide specific direction for procedures in a research deign" (Creswell , 2014, p. 41). Another common name for research design is strategy of inquiry, and there are several strategies that can be used to complete research. Some familiar strategies of inquiry include surveys, experiments, and case studies. A case study is the strategy of inquiry that was used to evaluate the current state of the automobile manufacturing facility's order processing. Yin (2014) provides the following definition of a case study:

1. A case study is an empirical inquiry that
   - investigated a contemporary phenomenon (the "case") in depth and within real-world context, especially when
   - the boundaries between phenomenon and context many not be clearly evident. (Yin , 2014, p. 16).

2. A case study inquiry

   - copes with the technically distinctive situation in which there will be many more variables of interest that data points, as one result
   - relies on multiple sources of evidence, with data needing to converge in a triangulation fashion, and as a result
   - benefits from the prior development of theoretical propositions to guide data collection and analysis. (Yin , 2014, p. 17).

The first potion of definition provides information in regards to the scope of a case study, and the second portion of the definition provides information in regards to features of a case study. The word “case” refers to the focus of the study. Common “cases” include individuals, organizations, processes, programs, neighborhoods, institutions, and event (Yin , 2014). Case study research is the preferred strategy on inquiry when the questions associated to the research are “how” and “why” questions (Yin , 2014). “The more that your questions seek to explain some present circumstance, the more that case study research will be relevant” (Yin , 2014, p. 4). Figure 3.2 details when each strategy of inquiry should be used.

Strategy	Form of research question	Requires control over behavioural events?	Focuses on contemporary events?
Experiment	How, why	Yes	Yes
Survey	Who, what, where, how many, how much	No	Yes
Unobtrusive measures	Who, what, where, how many, how much	No	Yes/No
Case study	How, why	No	Yes

Figure 3.2. Selection Criteria for Different Research Strategies. Reprinted from *Doing Research in the Real World* (p. 267), by D. Gray, 2014, Thousand Oaks, California: SAGE Publications, Inc. Copyright 2014 by SAGE Publications, Inc.

The use of “how” and “why” research questions, need to explain a current real-world circumstance, and use of prior theoretical propositions for guidance with data collections and analysis provide rationale for using a case study as the strategy or inquiry.

3.3.1 Case Study Type

There are four major types of case studies: single holistic, single embedded, multiple holistic, and multiple embedded. A single holistic case study evaluates one case and uses one unit of analysis. A single embedded case study evaluates one case and uses more than one unit of analysis. A multiple holistic case study evaluates multiple cases and has one unit of analysis. A multiple embedded case study evaluates multiple cases and has more than one unit of analysis. Figure 3.3 provides an illustration of each of the case study types.

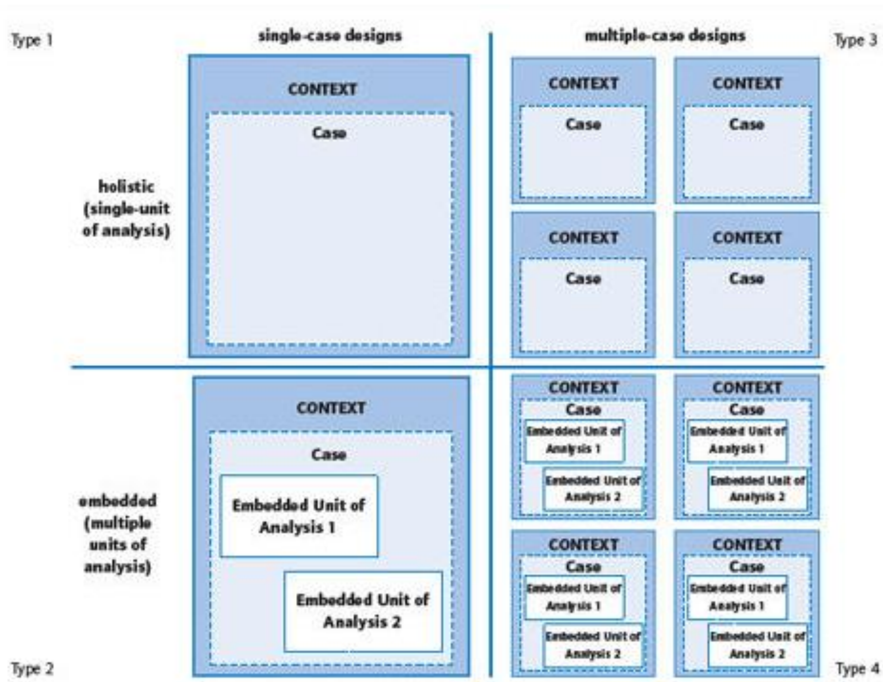

Figure 3.3. Case Study Designs. Reprinted from *Case Study Research: Designs and Methods* (p. 49), by R. Yin, 2014, Thousand Oaks, California: SAGE Publications, Inc. Copyright 2014 by SAGE Publications, Inc.

A single-case type and holistic design was selected to complete this research. The rationale for a single-case study is that a single case can be used to confirm, deny, or further extend a theoretical proposition. Yin (2014) states, “the single case can represent a significant contribution to knowledge and theory building by confirming, challenging, or extending the theory” (Yin , 2014, p. 50). This type of study can also help refocus investigations within the field of study (Yin , 2014). The utilization of the Lean Six Sigma’s DMAIC methodology to determine the root cause of process inefficiency and make recommendations for process improvement will confirm the theory that DMAIC can be utilized to remove wastes and improve processes; therefore, the single case study type was determined to be best suited for this The design of the chosen case study is holistic. The rationale for a holistic design is that only one unit of analysis (the automobile manufacturing facility’s order processing process) is used to complete this study. Since completion of this thesis only involves a study of a single company’s order processing process, the holistic designed was determined to be most suited for this research.

3.3.2 Case Study Reasoning

Before a case study design is chosen, a researcher must determine whether the study will follow an inductive or deductive reasoning approach. “Through the inductive approach, plans are made for data collection, after which the data are analyzed to see if any patterns emerge that suggest relationships between variables” (Gray , 2014, p. 17). This approach is used when cases do not start from a theoretical position, and observations from inductive approaches can be used to construct generalizations and theories (Gray , 2014). “The deductive approach moves toward hypothesis testing, after which the principle is confirmed, refuted, or modified" (Gray , 2014, p. 16). A deductive approach is used when the case study begins with a theoretical position and is confirmatory in nature. When using a deductive approach theoretical positions are tested through empirical observation and experimentations (Gray , 2014). This thesis begins based on prior use of Lean Six Sigma's DMAIC methodology to improve processes, tests the theory through an empirical study, and analyzes the study's results based on theories that already exist; therefore, this thesis employs a deductive approach to reasoning.

3.3.3 Case Study Design

Every case study has an associated research design. Yin (2014) informs us, "A research design is the logic that links the data to be collected (and the conclusions to be drawn) to the initial question of study" (Yin , 2014, p. 25). The case study's design serves a blueprint for the research and provides information in regards to what questions should be studied, what data is relevant, what data should be collected, and how results should be analyzed (Yin , 2014). Case study research design consists of five critical components:

1. the questions associated with the case study
2. the theoretical propositions associated with the case study
3. the unit(s) of analysis
4. the logic that links that data to the propositions
5. the criteria for interpreting the case study's findings

The research questions associated with this case study are defined in Section 4 of Chapter 1. The theoretical proposition associated with the case study is that the application of Lean Six Sigma DMAIC methodology can be used to make recommendations for process improvement. The unit of analysis is the automobile manufacturing facility's order processing process. Primary and secondary data were collected via interviews, direct observations, focus groups, documents, and archival records. Pattern matching was used to link the date to the theoretical proposition.   The case study's findings were interpreted based upon statistical analysis.

3.3.4 Case Study Concerns

There are five traditional concerns about using a case study as a strategy of inquiry. Yin (2014) identifies the following concerns:

- Rigorous enough?
- Confusion with teaching cases?
- Generalizing from case studies?
- Unmanageable level of effort?
- Comparative advantage?

The first concern is known as the greatest concern and was derived as a result of researchers not following systematic procedures or not having proper evidence to support findings and conclusions (Yin , 2014). The use of methodological text as a blueprint for developing the case study addresses this concern. The second concern relates to case study research being confused with the type of case study used in teaching. Unlike case studies used in teaching, the alteration of case study research is forbidden (Yin , 2014). If an individual has had prior exposure to case studies used in teaching, his or her viewpoint about using a case study as a strategy of inquiry. This concern is addressed by not altering or omitting any data. The third concern is not being able to generalize from case study findings. "In fact, generalizations in science are rarely based on single experiments; they are usually based on a multiple set of experiments that have replicated the same phenomenon under different conditions" (Yin , 2014, p. 20). This concern is addressed as the results of this case study will be used to generalize theories relate to the use of Lean Six Sigma DMAIC methodology to improve processes. The fourth concern pertains to the researcher not having enough time to dedicate to complete the study or read associated documents. This concern primarily relates to the manner in which prior case studies have been done. According to Yin (2014), this concern "incorrectly confuses case study research with a specific method of data collection such as ethnography or participant-observation" (Yin , 2014, pp. 20-21). This concern does not need to be addressed. The final concern with using a case study as a strategy of inquiry is its unclear comparative advantage. "This issue especially emerged during the first decade of the 21st century, which favored randomized controlled trials (RCTs) or "true experiments," especially in education related topics" (Yin , 2014, p. 21). This concern has since been overcome because case studies can provide insight that cannot be provided by RTCs as well as provide answers for "how" and "why" research questions.

3.4 Research Method

Creswell (2014) defines research methods as the specific forms of data collection, analysis and interpretation that are used to complete a study. This section will expand upon the data collection, analysis, and interpretation methods used to complete this study.

3.4.1 Data Collection

Data collection is an important aspect of any type of research. Data can be divided into two major categories: primary data and secondary data. Primary data is data that is observed or collected by the researcher. Sources of primary data collection include surveys, questionnaires, interviews, and observations. Secondary data is published data and data that was collected in the past by someone other than the researcher. Sources of secondary data collection include published electronic sources, books, journals, periodicals, magazines, and newspapers. This thesis utilizes primary and secondary sources of data to make recommendations for improving the automobile manufacturing facility's order processing process.

Many sources are used to collect data, and sources that are used to collect data are heavily dependent upon the strategy of inquiry chosen by the researcher. Yin (2014) states, "Case study evidence may come from six sources: documents, archival records, interviews, direct observations, participant-observations, and physical artifacts.

Documents

Documents can be in the form of letters, emails, memoranda, agendas, announcements and minutes of meetings, proposals, progress reports, formal studies or evaluations, news clippings and articles, etc. (Yin , 2014). "For case study research, the most important use of documents is to corroborate and augment evidence from other sources" (Yin , 2014, p. 107).

Archival Records

Archival records can be in the form of statistical data from the government, service records, organizational records, survey data related to the case, etc.

Yin (2014) provides the following information in regards to archival records:

> The usefulness of these archival records will vary from case study to case study. For some studies, the records can be so important that they become the object of

> extensive retrieval and quantitative analysis. In other studies, they may be of only passing relevance. (Yin , 2014, p. 109)

Interviews

Interviews are one of the most important sources of case study evidence. Yin (2014) identifies three types of case study interviews: prolonged interviews, shorter interviews, and survey interviews. Prolonged interviews take place over a period of two or more hours and can occur in either a single sitting or multiple sittings (Yin , 2014). Prolonged interviews allow the researcher to gain insight about the interviewee's "interpretations and opinions about people and events or their insights, explanations, and meanings related to certain occurrences" (Yin , 2014, p. 110). Shorter interviews don't last more than an hour and occur in one sitting (Yin , 2014). According to Yin (2014), "the interview may still remain open-ended and assume a conversational manner, but you are likely to be following your case study protocol (or a portion of it) more closely" (Yin , 2014, p. 111). Survey interviews are administered through a structured questionnaires and produce quantitative data as a part of the case study evidence (Yin , 2014).

Yin (2014) provides the following information about interviews:

> Interviews are an essential source of case study evidence because most case studies are about human affairs or interactions. Well-informed interviewees can provide insights into such affairs or actions. The interviewees can also provide shortcuts to prior history or situations, helping you identify other relevant sources of evidence. (Yin , 2014, p. 113).

Direct Observations

Direct observations serve as a source of case study evidence because case studies evaluate situations within real-world settings. Direction observations can include anything from casual to formal data collection. Observations of meetings, factory work, and classrooms are examples of direct observations used for formal data collection (Yin , 2014). Observations that take place during fieldwork, such as collection of other sources of evidence (i.e. interviews) is an example of direct observation used for casual data collection (Yin , 2014). Direct observations play a vital role in understanding an area of study. Yin (2014) states, “Observational evidence is often useful in providing additional information about the topic being studies.

Participant-Observation

Participant-observation refers to a form of observation that allows the observer to play an active role in the situation or actions being studied. This source of evidence can be used in small groups as well as large organizations. Participant-observation is useful because of its ability to provide unusual opportunities for data collection (Yin , 2014). Yin (2014) identifies the unusual opportunities for data collection as follows:

- Ability to gain access to events or groups that would not normally be accessible
- Ability to perceive reality from the viewpoint of someone inside the case
- Ability to manipulate minor events (Yin , 2014, p. 116)

Physical Artifacts

Physical artifacts, also known as cultural artifacts, are not typically relevant in most case studies but can be an asset to the entire case when they are deemed relevant (Yin , 2014). Physical or cultural artifacts provide valuable information about the culture of the individual who created the artifact as well as the individuals who used the artifact. Examples of physical artifacts include technological devices, tools and instruments, and

According to Yin (2014), “Such artifacts may be collected or observed as part of a case study and have been used extensively in in anthropological research” (Yin , 2014, p. 117).

Although six sources of data collection are typically used to complete case study research, other sources can also be used to collect data. Gray (2014) informs us that case study research is quite flexible, and “adjustments might be made during the data collection process by decided to make use of additional data collection sources” (Gray , 2014, pp. 276-277). An additional source of evidence or method of data collection is a focus group.

Focus Group

A focus group is a group of individuals who were selected and brought together for the purpose of discussing a particular topic or issue.

> Gray (2014) provides the following description about a focus group:
>
> A focus group is essentially an organized discussion among a selected group of individuals with the aim of eliciting information about their views. The purpose is to gain a range of perspectives about subjects and situations. While similar to group interviewing, they are not the same. In some group interviews, a number of people are interviewed at the same time. In focus groups, however, the purpose is to generate interactions and discussions with a group. (Gray , 2014, p. 468)

A focus group allows researchers to explore feelings, attitudes, beliefs, and prejudices about a subject matter that is not possible through other sources of evidence. The ideal size of a focus group is 6-8 people, and focus group sessions should last between one to two hours (Gray , 2014).

Each of the sources mentioned has its own set of strengths and weaknesses. Table 4.1 provides an overview of the six sources of evidence typically used by case studies as well as the strengths and weakness associated with each source. Figure 3.4 provides an overview of the strengths and weaknesses associated with focus groups.

This thesis utilized many sources of evidence to collect primary and secondary data. The sources of evidence used to collect the case study data include documents, interviews, observations, and a focus group. Primary data were collected through interviews, observations and focus groups. Secondary data were collected through documents and archival records. The use of each source of evidence is as follows:

- Primary Data
    - Interviews
        - Conducted to corroborate findings
        - Shorter interview is type used
        - Member from each all impacted departments chosen as interviewees
        - Held face-to-face
        - Notes used to collect information
    - Direct Observations
        - Conducted to become more familiar with the order processing
        - Completed by shadowing individuals from departments within the automobile manufacturing facility

    - Focus Groups
        - Formed to discuss perspectives about problems associated with order processing and develop potential solutions to the problem
        - Worked together to complete Define, Measure, and Analyze phases of DMAIC project
        - Consisted of 8 members
        - Met 14 times throughout case study
- Secondary Data
    - Documents
        - Used to complete a Literature Review (Chapter 2) that serves as the theoretical basis for this thesis
        - Consist of journal articles and scientific publications
        - Found via academic search engines
    - Archival Records
        - Used to provide history about the automobile manufacturing facility's prior work done to improve order processing
        - Found within manufacturing facility's Continuous Improvement (CI) database

Table 3.2. Six Sources of Case Study Evidence Reprinted from *Case Study Research: Designs and Methods* (p. 105), by R. Yin, 2014, Thousand Oaks, California: SAGE Publications, Inc. Copyright 2014 by SAGE Publications, Inc.

SOURCE OF EVIDENCE	Strengths	Weaknesses
Documentation	• Stable—can be reviewed repeatedly • Unobtrusive—not created as a result of the case study • Specific—can contain the exact names, references, and details of an event • Broad—can cover a long span of time, many events, and many settings	• Retrievability—can be difficult to find • Biased selectivity, if collection is incomplete • Reporting bias—reflects (unknown) bias of any given document's author • Access—may be deliberately withheld
Archival records	• *[Same as those for documentation]* • Precise and usually quantitative	• *[Same as those for documentation]* • Accessibility due to privacy reasons
Interviews	• Targeted—focuses directly on case study topics • Insightful—provides explanations as well as personal views (e.g., perceptions, attitudes, and meanings)	• Bias due to poorly articulated questions • Response bias • Inaccuracies due to poor recall • Reflexivity—interviewee gives what interviewer wants to hear
Direct observations	• Immediacy—covers actions in real time • Contextual—can cover the case's context	• Time-consuming • Selectivity—broad coverage difficult without a team of observers • Reflexivity—actions may proceed differently because they are being observed • Cost—hours needed by human observers
Participant-observation	• *[Same as above for direct observations]* • Insightful into interpersonal behavior and motives	• *[Same as above for direct observations]* • Bias due to participant-observer's manipulation of events
Physical artifacts	• Insightful into cultural features • Insightful into technical operations	• Selectivity • Availability

Strengths	Weaknesses
Affords the opportunity to identify collective perspectives	Potential for breach of confidentiality
Discussion in the group allows for validation of ideas and concepts	Conflicts may arise in the group that are difficult to manage
Allows access to culturally and linguistically diverse groups	Success is dependent on the skills and experience of the moderator
Allows access to a wide range of participants	Complexity of monitoring verbal and nonverbal responses of participants
Can become a catalyst for change both during and after the focus group	

Figure 3.4. Focus Group Strengths and Weaknesses. Reprinted from *Doing Research in the Real World* (p. 471), by D. Gray, 2014, Thousand Oaks, California: SAGE Publications, Inc. Copyright 2014 by SAGE Publications, Inc.

3.4.2 Data Analysis

According to Yin (2014), "Data analysis consists of examining, categorizing, tabulating, testing, or otherwise recombining evidence to produce empirically based findings" (Yin , 2014, p. 132). Analyzing case study data is difficult. In an effort to avoid difficulties associated with case study data analysis, case study researchers must follow an analytic strategy and use analytic techniques. "The purpose of the analytical strategy is to link your case study data to some concepts of interest, then to have the concepts give you a sense of direction in analyzing the data" (Yin , 2014, p. 141). Researchers have an opportunity to develop their own analytic strategy, or researchers can use one the four general analytic strategies used for case study analysis. Within any analytic strategy, researchers should choose one of five analytic techniques, and the purpose of the techniques is to assist with establishing case study validity (Yin , 2014). Gray (2014) informs us that analytic strategies and techniques assist with discovering relationships and contrasts between variable.

3.4.2.1 Analytic Strategy

According to Yin (2014), "The best preparation for conducting case study analysis is to have a general analytic strategy" (Yin, 2014, p. 141). Four general strategies used to analyze case studies include relying on theoretical propositions, working data from the "ground up", developing a case description, and examining plausible rival explanations. Relying on theoretical proposition consists of following the theoretical propositions that lead to the case study. This strategy utilizes the propositions to shape the data collection plan (Yin , 2014). Working data from the ground up consists of evaluating data and organizing data in an effort to determine relationships or patterns that exist amongst the data. With the strategy, the researcher plays with the data until correlations are found (Yin , 2014). Developing a case description consists of organizing a case study according to descriptive framework. “This strategy is workable in its own right but also serves as an alternative if you are having difficulty using either of the first two strategies” (Yin , 2014, p. 138).

Yin (2014) provides the following information in regards to the final strategy:

> A fourth general analytic strategy, trying to define and test plausible rival explanations, generally works with all of the previous three: Initial theoretical propositions (the first strategy) above might have included rival hypotheses; working from the ground up (the second strategy) may produce rival inductive frameworks; and case descriptions (the third strategy) may involve alternative descriptions of the case. (p. 140)

The analytic strategy used to complete this research is relying on theoretical proposition. This strategy utilizes the same theoretical proposition that was used to trigger the study, help develop research questions, influence the review of literature, and shape the collection of data. The case study’s theoretical proposition is that Lean Six Sigma DMAIC methodology can be used to determine the root cause of order processing inefficiency and make recommendations that can be implemented for long-term process improvement. As a result of the theoretical proposition, DMAIC methodology must be used to guide the analysis; therefore, relying on theoretical proposition was deemed the most suitable analytic strategy.

3.4.2.2 Analytic Technique

Analytic techniques are used to assist with developing the internal and external validity of a case study (Yin , 2014). Five analytic techniques typically used to analyze case studies include pattern matching, explanation building, time-series analysis, logical models, and cross-case synthesis. Gray (2014) states, "The logic behind pattern matching is that the patterns to emerge from that data, match (or perhaps fail to match) those that were expected" (Gray , 2014, p. 282). Explanation building is considered a special type of pattern matching and is most applicable to explanatory case studies. "Here, the goal is to analyze the case study data building an explanation about the case" (Yin , 2014, p. 147). Time-series analysis is used to trace variables over time in an effort to create patterns. According to Yin (2014), "Whatever the stipulated nature of the time series, the important case study objective is to examine some relevant "how" and "why" questions about the relationship of the events over time, not merely to observe the time trends alone" (Yin , 2014, p. 154). Logic models are a combination of pattern matching and time series analysis techniques (Gray , 2014). "As an analytic technique, the use of logic models consists of matching Cross-case synthesis is an analytic technique that is only applicable to multiple-case studies. Cross-case synthesis treats every individual case study as a separate study and aggregates findings across the studies (Yin , 2014).

The analytic technique that was chosen to complete this case is pattern matching. There are two types of pattern matching: non-equivalent dependent variables as a pattern and rival independent variables as a pattern. "With non-equivalent dependent variables as a pattern, a research study may have a number of dependent variables or outcomes that emerge from it" (Gray , 2014, p. 283). When rival explanations are used, "several cases may be known to have a certain outcome, but there may be uncertainty as to the case, that is, which independent variable is the determining one" (Gray , 2014, p. 283). The type of pattern matching that was chosen is non-equivalent dependent variables as a pattern. This type of pattern matching was chosen in an effort to provide validity to the assertion that Lean Six Sigma DMAIC methodology can be used to determine the root cause of process inefficiency and provide recommendations to permanently improve the manufacturing facility's order processing process. Improving the order processing process will result in other outcomes such as reduced order processing cycle time and enhanced customer satisfaction. Figure 3.5 details pattern matching of case study data.

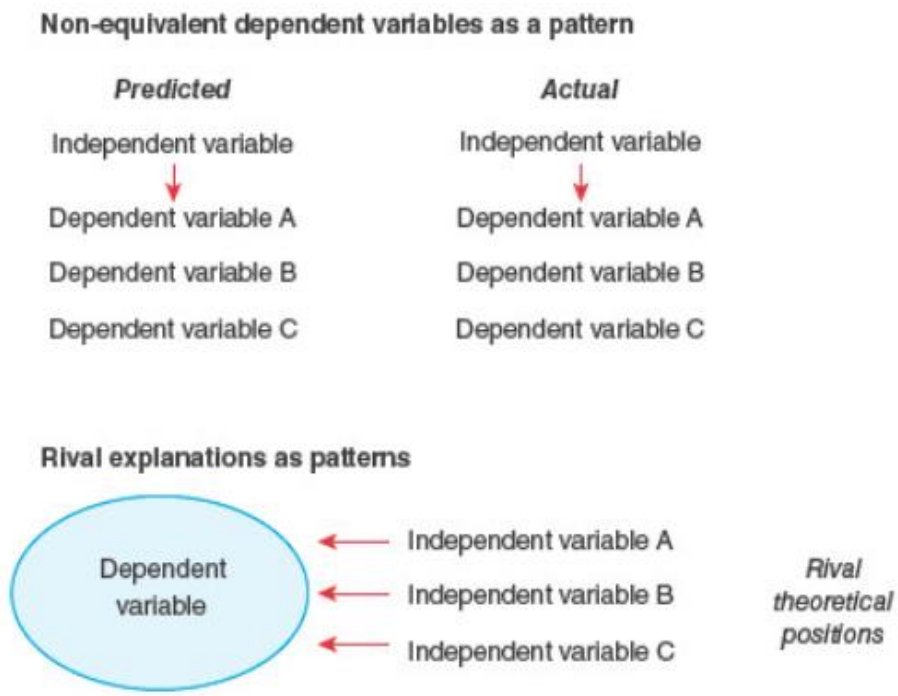

Figure 3.5. Case Study Pattern Matching. Reprinted from *Doing Research in the Real World* (p. 283), by D. Gray, 2014, Thousand Oaks, California: SAGE Publications, Inc. Copyright 2014 by SAGE Publications, Inc.

3.5 Research Quality

The relevance of research is highly dependent upon the quality of the research design. "Because a research design is supposed to represent a logical set of statements, you also can judge the quality of any given design according to certain logical tests" (Yin

, 2014, p. 45). The four tests commonly used to judge the quality of case studies include construct validity, internal validity, external validity, and reliability. Certain tactics are used to conquer each test, and each tactic occurs within a specific phase of research (Yin , 2014). Table 3.3 details each of the tests, the tactics used to conquer each test, and the phase of research in which the tactic occurs.

Table 3.3. Case Study Quality Tests. Reprinted from *Case Study Research: Designs and Methods* (p. 45), by R. Yin, 2014, Thousand Oaks, California: SAGE Publications, Inc. Copyright 2014 by SAGE Publications, Inc.

TESTS	Case Study Tactic	Phase of Research in which Tactic Occurs
Construct validity	• use multiple sources of evidence • establish chain of evidence • have key informants review draft case study report	data collection (see Chap. 4) data collection (see Chap. 4) composition (see Chap. 6)
Internal validity	• do pattern matching • do explanation building • address rival explanations • use logic models	data analysis (see Chap. 5) data analysis (see Chap. 5) data analysis (see Chap. 5) data analysis (see Chap. 5)
External validity	• use theory in single-case studies • use replication logic in multiple-case studies	research design (see Chap. 2) research design (see Chap. 2)
Reliability	• use case study protocol • develop case study database	data collection (see Chap. 3) data collection (see Chap. 4)

3.5.1 Construct Validity

Yin (2014) defines construct validity as "identifying correct operational measures for the concepts being studied" (Yin , 2014, p. 45). The three tactics used to increase construct validity are using multiple sources of evidence, establishing a chain of evidence, and having key informants review a draft of the case study report. Using multiple sources of evidence occurs during data collection. According to Yin (2014), the most important advantage presented by using multiple sources of evidence is the development of converging lines on inquiry" (Yin , 2014, p. 120). Basing a case study on multiple sources of evidence is likely to be perceived as more accurate having more relevance. Establishing a chain of evidence also occurs during data collection. Establishing a chain of evidence allows an external observer to trace the case study's steps from conclusions back to initial research questions or from research questions to conclusions (Yin , 2014). A chain of evidence can be created by properly citing relevant sources used to arrive at specific findings, having a case study database that contains relevant sources of data, ensuring the circumstances under which data is collected is consistent with procedures and questions within the case study protocol, and ensuring there is a link between protocol questions and original study questions. Having key informants review the case study report consists of allowing individuals who actually participated in the case study to review the report. Allowing others involved in the case study review the report will help ensure researchers reported events and perspectives accurately. "From a methodological standpoint, the corrections made through this process will enhance the accuracy of the case study, hence increasing the construct validity of the study" (Yin , 2014, p. 199).

The tactics that were used to increase the construct validity of this case study include using multiple sources of evidence and establishing a chain of evidence. Interviews, direct observation, focus group sessions, documents, and archival record are all the sources of evidence used to complete this case study. A chain of evidence was created through the development of a case study protocol, the creation of a case study database, and clear documentation about the steps that were used within in each phase of the DMAIC methodology. The use of multiple sources of evidence and the creation of a chain of evidence enhances the construct validity of the case study used to complete this thesis.

3.5.2 Internal Validity

Yin (2014) defines internal validity as "seeking to establish a causal relationship whereby certain conditions are believed to lead to other conditions, as distinguished from spurious relationships" (Yin , 2014, p. 45). Internal validity is a concern for explanatory case studies as well as the inferences that are made throughout case studies.

Yin (2014) provides the following explanation for the concern associated with explanatory case studies:

> If the investigator incorrectly concludes that there is a causal relationship between x and y without knowing that some third factor – z – may actually have caused y, the research design has failed to deal with some threat to internal validity. (p.47)

During the completion of case study research, only certain events are able to be directly observed by the researcher. "Basically, a case study involves an inference every time an event cannot be directly observed" (Yin , 2014, p. 47). Addressing questions related to whether or not the inference is correct, whether or not all rival explanations and possibilities have been considered, and the convergence of the data will address the concern associated with inferences made throughout case studies and increase internal validity (Yin , 2014). The analytical techniques that were mentioned in sections 3.4.2.2 (pattern matching, explanation building, addressing rival explanations, and using logic models) are the tactics used to increase internal validity, and these tactics occur during data analysis.

The tactic used to increase internal validity is pattern matching. The theoretical proposition associated with the case study indicates that the application of Lean Six Sigma DMAIC methodology will determine the root cause of the manufacturing facility's order processing process and assist with making recommendations that will permanently improve the process. According to Yin (2014), "If the empirical and predicted patterns appear to be similar, the results can help a case study to strengthen its internal validity" (Yin , 2014, p. 142). The successful application of Lean Six Sigma DMAIC methodology to determine the root cause and make recommendations and to improve the automobile manufacturing facility's order processing process was successful; therefore, the predicted (theoretical) and case study (empirical) patterns were proven to be similar and provide increased internal validity for the case study. Also, utilizing the DMAIC methodology eliminates the internal validity concern associated with explanatory case studies because this methodology allows the order process to be investigated in such a way that causal relationships are proven to be between x and y. In addition, internal validity is increased by exploring the questions Yin (2014) suggested for events or processes that were not able to be directly observed.

3.5.3 External Validity

Yin (2014) defines external validity as "defining the domain to which a study's findings can be generalized" (Yin , 2014, p. 45). The tactic used to increase external validity depends on the type of case study that is chosen, and the tactic occurs during the research design phase. Theory is used to increase the external validity of single-case studies, and replication logic is used to increase the external validity of multiple-case studies. Since a single-case study is used complete this research, the tactic that is used to increase external validity is using theory. The theory used is that the application of Lean Six Sigma DMAIC methodology will determine the root cause of a problem as well as assist with the developing long-term solutions to permanently alleviate the problem. Prior studies, within several different industries, have been done to increase the relevance of this theory. According to Gray (2014), "Dooley (2002) advises that external validity can be strengthened by relating the findings from one or multiple cases back to literature, showing that the results are theoretically feasible or are supported by similar empirical studies" (Gray , 2014, p. 280). The case study's external validity was increased by using similar cases as a form of support for this case's findings.

3.5.3 Reliability

Yin (2014) defines reliability as "demonstrating that the operations of a study – suchas the data collection procedures – can be repeated with the same results" (Yin , 2014, p. 45). Two tactics used to increase reliability are using a case study protocol and developing a case study database. These tactics occur during the data collection phase. A case study protocol is prepared in an effort to keep the researched targeted on the research topic and force the researchers to anticipate adversities. A case study protocol consists of four sections: Section A provides an overview of the case study; Section B provides the procedure used to collect data; Section C provides data collection questions; and Section D provides a guide for the case study report (Yin 2014). According to Yin (2014), "The protocol is a major war of increasing the reliability of case study research and is intended to guide the researcher in carrying out the data collection from a single case" (Yin , 2014, p. 84). A case study database consists of the organization and documentation of data collected for a case study. This database includes documents as well as other materials collected from the field. Yin (2014) states, “The database’s main function is to preserve your collected data in a retrievable form” (Yin , 2014, p. 124). The development of case study database increases the reliability of this thesis.

CHAPTER 4

METHODOLOGY

The methodology used to study and analyze the automobile manufacturing facility's current order processing process is DMAIC. DMAIC is an acronym for the five phases associated with the problem-solving methodology: Define, Measure, Analyze, Improve, and Control. Each phase utilizes specific tools to help determine the root cause of process inefficiency as well as derive solutions that will enhance the process.

Stern (2016) describes each phase of the DMAIC process as follows:

Define

- Identifying, prioritizing, and selecting the opportunities
- Defining the processes to be improved and preparing process maps
- Developing project team charters
- Building effective teams
- Identifying the customer segment and requirements

Measure

- Determining the parameters to be measured
- Managing the measure process
- Understanding variation
- Evaluating the measure system and selecting the measuring devices

- Determining the process performance

Analyze

- Identifying potential root causes
- Implementing alternative methods
- Conducting sources of variation studies
- Conducting correlation analysis

Improve

- Generating solutions
- Identifying alternatives
- Ranking alternatives
- Selecting the best solution
- Discussing the implementation aspects
- Implementing the final solution as per plan

Control

- Developing a control plan (specify the check points and control points)
- Implementing a suitable monitoring system for control
- Reviewing and evaluating the impact of changes
- Updating the documents, incorporating process changes
- Closing the project, rewarding the team members, and disbanding the team (Stern , 2016, pp. 64-65).

The phases occur in sequential order, and a tollgate review occurs at the end of each phase. The tollgate review ensures one phase is complete before moving on to another phase. These interconnected phases allow a team to adequately identify a problem(s) associated with a process, measure the performance of the current process, analyze process inefficiencies and determine the root cause of the inefficiencies, make recommendations to improve the current process, and verify that the recommended improvements will positively impact the process in the long run. This chapter will provide a brief summary of each phase as well as the tools that utilized within each phase.

4.1 Define

According to Stern (2016), the main objective in the Define Phase is to clarify and document the process improvement goal" (Stern , 2016, p. 69). A great deal of activities take place during this phase in an effort to accomplish this objective. A discussion in regards to the costs and timeline associated with the process improvement takes place during this phase. A discussion in regards to team member roles and resource allocation also occurs in an effort to avoid confusion amongst the project team. Another discussion that takes place during this phase is what constitutes successful process improvement. According to Wiesenfelder, "All of these things will ensure that the stakeholders are all on the same page regarding what is going on and how to evaluate the project's progress and ultimate success" (Wiesenfelder , DMAIC Phase 1: Define, 2011). A clarification about the project's purpose and scope, a basic understanding of the process to be improved, and an understanding of customer expectations and quality are outcomes of the Define Phase.

Tools commonly used during the Define Phase include process map, Project Charter, Stakeholder Analysis, SIPOC Diagram, Voice of the Customer, and Affinity Diagram. In an effort to accurately illustrate the current state of process, the project team works together to develop a process map. The Project Charter serves as documentation that justifies the need for process improvement and ensures that all parties involved in the process improvement project understand the process that is to be improved. A Stakeholder Analysis identifies key persons are able to impact or will be impacted by the process improvement initiative. Completing a stakeholder analysis helps gain support that is critical to successful project completion. A Supplier Input Process Output Customer (SIPOC) diagram determines the project's Critical to Quality (CTQ) factors; CTQ factors are simply factors that are critical to the success of the project. The Voice of the Customer (VOC) captures the preferences, expectations, and aversions of the customer and is used develop specifications for process improvement. An affinity diagram is used by the project team to create relationships between a host of ideas that are presented by team members. Grouping the ideas into categories develops the relationships between the different ideas.

Although each of the tools used and documents created during the Define Phase are valuable, a few of those documents must be complete before moving to the next phase. According to Wiesenfelder (2011), "At the end of the Define phase, the team should have completed a project charter, a high-level process map, and one or more CTQs that will allow data to be gathered in the Measure phase" (Wiesenfelder , DMAIC Phase 1: Define, 2011). The project charter serves a reference document throughout the entire project, and the process map as well as the CTQ assists with determining key measurable aspects of the process (Stern , 2016).

4.2 Measure

According to Stern (2016), "The main purpose of the Measure Phase is to establish a clear as-is picture of where the existing process is today and to make sure the tools used to measure the activity are reliable and valid" (Stern , 2016, p. 81). The activities that take place during this phase help identify process that must be improved to enhance the product or service. The Measure Phase begins with an evaluation of how as well as how well the current process works. The project team evaluates each activity associated with the process and notes pertinent information (what each activity entails, the amount of time completing each activity takes, the impact the activity has on the process' other activities, etc.) about the process. In addition, the project team works together to ensure all the process information is factual and free of any biased or judgmental information that may not accurately reflect the existing process. During the Measure Phase the entire project team works together to determine which tools will be used to measure defects, mistakes, and variations within in the current process. After measure tools are chosen, a data collection is typically developed. Finally, baseline data is collected. A good understanding about the current state of the process in relation to the desired future state of the process and a collection of data that accurately describes the current state of the existing process are results of the Measure Phase.

Tools typically used during the Measure Phase include a detailed process map, process capability analysis, Statistical Process Control (SPC) Measurement System Analysis (MSA), Pareto Chart, and data collection plan. The detailed process map is a more in-depth version of the process map developed during the Define Phase. The detailed process map pinpoints the source of process inefficiencies as well as outlines a functional relationship between the process and data to be collected. The process capability analysis is conducted in an effort to determine whether or not the current process is capable of meeting customer requirement. Statistical Process Control (SPC) is used to build an interpret control charts that will display the variation in and stability of the current process A Measurement System Analysis (MSA) identifies variation within the measurement system and plays an integral role in the Measure Phase. Stern (2016) states, "It is a component of analysis as to how the data were gathered, and the reliability of the data; as the data may be questioned should the team present results that are unpopular" (Stern , 2016, p. 90). The data collection plan serves as a communication tool and details how to collect and use data.

Before the project team can transition from the Measure Phase to the Analyze Phase, the team must produce a specific set of information. "In order to move to the next phase, measurements of the key aspects of the current process must be completed along with the collection of all relevant data" (Stern , 2016, p. 91). Measurements of the key aspects of the current process helps provide an accurate description of the process' current state. The collection of all relevant data helps to identify the root cause of process inefficiencies during the next phase.

4.3 Analyze

According to Stern (2016), "The objective of the Analyze Phase is to leave the phase with three to five solid process improvement solutions" (Stern , 2016, p. 93). The activities that place during this phase help identify and analyze the gaps between current and desired performance. The team initiates this phase by identifying potential root causes. After the team has compiled a list of potential root causes, the potential root causes are organized in manner that allows the team to easily prioritize and access each of them (Wiesenfelder , DMAIC Phase 3: Analyze, 2011). Following the prioritization and organization of potential root causes, the team works together to determine whether or not the potential root causes actually contribute to process inefficiency. Data that was collected during the Measure Phase is used to confirm the root cause(s) of process inefficiency. A confirmation of root cause(s) associated with process inefficiencies and three to five suggestions for process improvements are results of the Analyze Phase.

Tools commonly used during the Analyze Phase include brainstorming, 5 Whys Analysis, process map, Cause-and-Effect Diagram, correlation analysis, Statistical Process Control, ANOVA, and statistical hypothesis testing. The project team uses brainstorming to generate a list of factors that impact the performance of the existing process. A 5 Whys Analysis assists with identifying the root cause(s) of process inefficiency. During this analysis "a question is asked five times on the basis of the information received in the previous answer until the conclusion is reached" (Stern , 2016, p. 96). The detailed process map created during the Measure Phase is used to rearrange or eliminate process activities during the Analyze Phase. Rearranging or eliminating process activities reveals the impact the location or inclusion or the activity has on improving the process. A Cause-and-Effect Diagram, also referred to as a Fishbone Diagram, graphically displays all potential causes of process inefficiency and helps the project team identify the root cause(s). A Pareto Chart displays the contribution of each cause associated with process inefficiency. This chart is used to prioritize the causes associated with process efficiency and is used to further analyze the root cause of the problem during the Analyze Phase. The project team determines relationships between variables by conducting a correlation analysis. Statistical Process Control (SPC) allows the project team to interpret the control charts created through the Measure

Phase's process capability analysis. Interpretation of the control chart allows the project team to identify process variation ad determine process capability. Statistical hypothesis testing allows the project team to confirm or deny theories they believe to be rue about the root cause(s) of process inefficiencies. An Analysis of Variance (ANOVA) is used to indicate he differences between two or more independent groups and allows the project team to determine if the process inefficiencies are common amongst all the different groups.

The activities that must be complete before moving to the Improve Phase include a thorough analysis of the data, root causes associated with process inefficiencies, and suggestions for process improvement. A thorough analysis of the data helps identify potential root causes associated with the current process. Confirming the root cause leads to process improvement suggestions that can be implemented during the Improve Phase.

4.4 IMPROVE

According to Stern (2016), "The main purpose of the Improve Phase is to demonstrate, with facts and data, that the solutions solve the problem" (Stern , 2016, p. 124). Several activities take place during this phase, and the project team must complete these activities in a specified order. The project team must list three to five solutions, provide all necessary documentation, agree upon which solution (s) will be tested, perform a pilot design and project plan, and roll out the solutions (Stern , 2016). This phase begins by listed the solutions that were derived during the Analyze Phase. Information collected during the Measure and Analyze Phases necessary documentation to support the suggested solutions. After presented the suggested solutions and supporting evidence, the project team works together to determine come to an agreement about which solution(s) should be tested. The solution(s) the project team decides upon is then tested to determine if implementing the solution(s) will actually improve the process. If the pilot proves the suggested improvement is successful, the project team works together to develop a plan for permanently implementing the solution(s). The solution(s) is finally implemented according to the project plan. A demonstration that the suggested solution(s) provided expected improvement as well as implantation of the solution(s) are results of the Improve Phase.

Tools commonly used during the Improve Phase include brainstorming, decision matrix, pilot, project plan, and Failure Mode Effects Analysis. Brainstorming and decision matrix allows the team to reach an agreement about which solution(s) should be tested. The pilot allows the chosen solution to be tested and reveals the impact implementing the solution will have on the existing process. Completing a Failure Mode Effects Analysis (FMEA) allows the project team to access failure modes associated with implementing a solution. Creation of a project plan allows the team to document the details that will ensure successful implementation of solutions. Tools that were used during the Measure Phase (See Section 4.2) are also used to display improvements by comparing data collected before and after process improvements are implemented.

The Improve Phase is not considered complete until the project tram is able demonstrate that implementing the suggested solutions has a positive impact on the existing process. Actions that were taken to improve the process must also be well documented before the Improve Phase is considered complete. Stern (2016) states, "To enter the Control Phase, an improvement has to be shown and documented" (Stern , 2016, p. 115). Showing and documenting improvements assists with maintaining those improvements.

4.5 Control

According to Stern (2016), "The Control Phase is designed to ensure that the problem does not recur and that the new process can be further improved over time" (Stern , 2016, p. 125). The activities that take place during this phase help communicate the manner in which process improvements will be sustained over time. When applicable, the Control Phase begins with an articulation of the improvement in terms of dollars. The project team also develops a plan for monitoring and sustain the improved process during this phase. The last activity involved in the Control Phase is closing out the project. Standardizing and documenting the new process, communicating details of the new process to others, and closing out the project are results of the Control Phase.

Tools commonly used during the Control Phase include Return on Investment Formula, control charts, control plan, and transition plan. The Return on Investment (ROI) Formula displays the process improvement in terms of dollars. Control charts display process improvement by detailing variation reduction in process performance. A control plan details how processes are standardized as well as how procedures are documented. The purpose of the control plan is to outline steps that need to be taken ensure the process improvements remain in place. A transition plan is prepared to ensure the process owner is able to successfully monitor and control the new process upon project completion. The transition plan contains information about how to utilize the control plan and explains how daily operations should be handled.

The Control Phase is not considered complete until close-out activities have taken place. Stern (2016) identifies close-out activities as informing all parties the project has been completed, recording best practices, and updating documentation. Completing these activities ensures the process improvements made throughout the project are maintained.

CHAPTER 5

ANALYSIS AND RESULTS

This chapter provides details about the execution of the Lean Six Sigma DMAIC project. Define, Measure, and Analyze are the Phases used for the case study. The chapter begins by presenting results from conducting the Define Phase. The chapter proceeds by presenting results from conducting the Measure Phase. A presentation of results from conducting the Analyze Phase occurs next. The chapter concludes with a presentation of recommendations for permanently improving and controlling the order processing process.

5.1 DEFINE

This section will provide insight in regards to the activities that took place during the Define Phase. Section 4.1 explains the importance of each of the tools used to complete the Define Phase, and utilizing those tools resulted in clarification about the project's purpose and scope, a basic understanding of the process to be improved, and an understanding of customer expectations and quality. The typical tools used include a project charter, process map, stakeholder analysis, SIPOC Diagram, and VOC. In addition to tools typically, we also used a communication plan. This section will provide details about the application of each of the tools.

5.1.1 PROJECT CHARTER

The development of a project charter began upon the decision to complete the project. The project charter details the problem statement, project metric and goal, business benefit, project resources, project constraints, current status/progress, next steps, and project tracking. The project statement, project metric and goal, business benefit, project resources, and project constraints remain the same throughout the entire project. Updating the current status/progress, next steps, and project tracking sections occurs at the end of each phase. The constant details of the project charter are below.

- Problem Statement
  - New orders are taking too long to release. The average time taken to release new orders is four business days.
- Project Metric and Goal
  - The goal of the project is to improve the process used to release new orders. The project metric is to reduce order processing cycle time by 50% (from four days to two days).
    - Choosing a goal of two is based on the automobile manufacturing facility's annual customer service rating, and revenue when order processing cycle time averaged two days. Please see the section below, Business Benefit, for more details.
- Business Benefit
  - New orders released into engineering status increase downstream process efficiency in engineering, materials, and manufacturing in order to meet customer expectations and delivery date. This results in an 8.25% (4.125% per day reduced) increase in the automobile manufacturing facility's annual customer service rating.

    - The increase in customer satisfaction has an impact on annual revenue. When the customers are more satisfied with the automobile manufacturing facility's service, the customer typically orders more automobiles or recommends the automobile manufacturing facility's services to others. This results in a 6.48% (3.24% per day reduced) increase in the automobile manufacturing facility's annual revenue.

- Project Resources
  - 1 Lean Six Sigma Black Belt
  - 1 Lean Six Sigma Green Belt
  - 1 Lean Six Sigma Project Champion
  - 2 Marketing/Sales Department Personnel
  - 3 Engineering Department Personnel
  - 2 Product Data Management Personnel
  - 2 Materials Department Personnel
- Project Constraints
  - Do not decrease the quality of the process while working to improve the process.

5.1.2 Process Map

The process map provided a visual display of the current state of the automobile manufacturing company's order processing process. The process map created during this phase is high level and only contains information that is essential to presenting a visual representation of how the activities that are a part of the current order processing process.

In an effort to create an accurate visual representation, the entire project team worked together to develop the process map. The process map created during this phase assisted with the creation of a more detailed process map during the Measure Phase. The process map cannot be shared due to confidentiality.

5.1.3 Stakeholder Analysis

Conducting a stakeholder analysis allowed us to gauge each of the key stakeholders' level of commitment to successful project completion. Members of the automobile manufacturing facility's Engineering, Sales/Marketing, Product Data Management (PDM), and Materials Departments are key stakeholders for the process improvement. An assessment of each of the key stakeholder's level of commitment was determined and documented. The scaled used for the assessment was -2 to +2. The meaning of each of the numerical ratings is as follows:

- -2 = Strong Against
- -1 = Moderately Against
- 0 = Neutral
- +1 = Moderately Supportive
- +2 = Strongly Supportive

The stakeholder analysis indicates members of the Engineering and Product Data Management Departments are strongly supportive of the project, but members of the Sales, Marketing, and Materials Departments are moderately supportive of the project. Table 5.1 displays the stakeholder analysis.

Table 5.1: Stakeholder Analysis

Key Stakeholders	Level of Commitment				
	Strongly Against -2	**Moderately Against -1**	**Neutral 0**	**Moderately Supportive +1**	**Strongly Supportive +2**
Engineering					X
Sales/Marketing				X	
PDM					X
Materials				X	

5.1.4 SIPOC DIAGRAM

Creating a SIPOC allowed us to identify the project's CTQ factors. The identified suppliers include PDM, Sales, and Scheduling. The identified inputs include internal order processing databases and time. The identified processes include process order, review order, update and translate order, schedule order, and release order. The identified outputs include processed order, reviewed order, translated order, scheduled order, and released order. The customers are Sales, PDM, and Scheduling. The Critical to Quality factors are an order in order processing database, clean order, build dates listed in order processing database, and clean and scheduled order. Table 5.2 displays the correlation between supplier, input, process, output, customer, and CTQ (Requirements).

Table 5.2: SIPOC Diagram

Supplier	Input	Process	Output	Customer	Requirements
PDM	Database, Time	Process Order	Processed Order	Sales	Order in Database
Sales	Database, Time	Review Order	Reviewed Order	PDM	Order in Database
PDM	Database, Time	Update and Translate Order	Translated Order	Scheduling	Clean Order
Scheduling	Database, Time	Schedule Order	Scheduled Order	PDM	Build Dates in Database
PDM	Database, Time	Release Order	Released Order	PDM	Clean and Scheduled Order

5.1.5 Voice of the Customer (VOC)

Conducting interviews allowed The Voice of the Customer to be collected. Interviewees were either members of the project team or members of departments associated with the process to be improved. The interviews were semi-structured in nature. Each interviewee answered questions about the inefficiency of the current process as well as how to alleviate those inefficiencies. The VOC is as follows:

- "I do not understand why we allow errors to go to the next step of the process. We are sending incorrect information; orders should be clean when entered into the system. The cycles that occur when orders have to go back and forth between marketing and engineering is something that we need to look into more to see if we can do something better to the process." – *Project Champion*

- “The biggest issue really does concern altered codes. When orders come in with data codes that are not in spec pro due to proto/pre-series units, or when quotes have not been updated with spec pro, the whole process is slowed and errors occur.” – *PDM Department Team Member*
- “I think the biggest issue is a people problem; in terms of why is uncertain. It could be training, lack of action, and/or not utilizing the system to its fullest potential. If there was more preemptive action, we might see an increase in process efficiency.” – *PDM Department Non Team Member*
- “Biggest issue is proto/pre-series rules and the way we do business. Everything takes longer (due to material sourcing not being local and design work being more complex), but scheduling remains the same. No rules in the GOP to move a proto/pre-series through the process fit how we do things today. The rules hard block things that is not available like certain data codes; the answers that I need to have for spec pro and all the conditions that need to be met I simply cannot always get because they do not exist yet. In addition, modules that generate automatically in IMS should not be optional in spec pro. For example, I have no idea what electrical modules to pick, they should just generate by themselves. This would really help the process because it does not matter what rules have or have not be written yet, the customer has already been told that they will receive those options. Spec pro should just generate these type of modules and if something changes, we can fix in the GOP. Overall, the process today just does not fit how we take and schedule orders.” – *Sales/Marketing Team Member*

- "The only real issue I have the inability to reference old serials with same CWO issues. It would be great to have a list or a way to look up serials with CWOs that I answered in the past that apply to new serials. It would save a lot of time devoted to researching the problem all over again. Referencing past serial numbers quickly would make things go faster." – *Engineering Non Team Member*
- "I think copying old orders and hard coding creates a lot of problems. Many changes can occur within a year and an order from a year ago that is copied into a new order creates problems and slows the process. There should be a way to block the use of data codes that are not in the data book, especially since proto/pre-series data codes are in the data book. This type of block would really enable production orders to only have stuff that are already designed in releases." – *Engineering Team Member*
- "I would like to be able to view CWOs when I first get the order so I can make sure that everything on my end is correct. This would help the overall process of the orders." – *Sales/Marketing Team Member*

5.1.5 Communication Plan

In an effort to ensure every team member receives consistent updates throughout the project, we created a communication plan. The communication plan details stakeholder information, reasons for contacting stakeholders, and the stakeholders' preferred method of contact for each reason contacted. The methods of contact include email, phone, and meeting. An E indicates email; a P indicates phone; and an M indicates meeting. Table 5.3 details the communication plan.

Table 5.3 Communication Plan

Stakeholders	Reasons for Contact				
	Tollgates	**Tollgate Materials**	**Process Decisions**	**Experiments**	**Meeting Minutes**
Engineering	M	M	M	E	E
Sales/Marketing	E	E	M	E	E
PDM	E	E	M	E	E
Materials	E	E	E	E	E

5.2 Measure

This section will provide insight in regards to the activities that took place during the Measure Phase. Section 4.2 explains the importance of each of the tools used to complete the Measure Phase, and utilizing those tools resulted in a good understanding about the current state of the process in relation to the desired future state of the process and a collection of data that accurately describes the current state of the existing process. The tools used include a detailed process map, data collection plan, MSA, process capability analysis, and statistical process control This section will provide details about the application of each of the tools.

5.2.1 Detailed Process Map

Further development of the process map created during the Define Phase, resulted in a more detailed process map. The detailed process map reveals how the current process works as well as the inputs and resources that are required to deliver a specific output. Brainstorming sessions allowed project team members to contribute input in regards to activities associated with the process to develop this detailed process map. Utilizing the detailed process map helped the team identify measurable aspects of the process. The process map cannot be displayed due to the confidentiality.

5.2.2 Data Collection Plan

Before collecting any baseline data, a data collection plan was developed. To ensure the proper data collection, development of an operational definition was necessary. The operational definition consisted of defining the project (Y), defining how to measure Y, and defining the data collection method. The operational definition is as follows:

- What is the project Y?
  - Order processing cycle time in regards to the length of time (in business days) that transpires from when an order is received into the company's database (from the Sales department) until date the order is released
- Measuring Y
  - Order Received Date
  - Order Release Date
  - 1 Business Day = Days (s) present in database from initial entry until release
    - Example: An order received on 12/02/2012 and released on 12/02/2012 has a cycle time of 1 day.
    - Examples: An order received on 12/04/2012 and released on 12/05/2016, the order processing cycle time equals 2 days.

- Baseline Data Collection
    - Visit the automobile manufacturing facility's order processing website
    - Click on 'Reports'
        - Click on 'Data Management Tools'
    - Go to 'Order Information' Box
        - Click on 'Order Tracker'
    - Enter Desired Start and End Date
        - Click 'Search'
    - Check 'Excel' to export the generated list

In addition to the providing an operational definition, information in regards to the start and end dates used for baseline data collection are included the data collection plan. We decided upon a start date of 10/01/2014 and an end date of 01/30/2015. This data range produced a sample size of 1065. Thanksgiving and Christmas Holidays were accounted for when the net working days were calculated. Creation of the data collection plan helped to ensure valid data collection.

5.2.3 Measurement System Analysis (MSA)

Conducting a MSA helped identify variation in the measurement system. Multiple team members using the same search criteria and comparing results to ensure that each team member achieved the same results tested repeatability. One team member conducting the same search multiple times to ensure generation of the same results each time tested repeatability. To increase validity of the collected data, multiple team members randomly selected 30 random data points from the automated report and compared the received and released dates from the automated report to the received and released dates listed in a separate database. Of the 30 randomly chosen samples, all the appraisers achieved a 100% match rate between the received and released dates generated from the automated report and stored in the other database. As a result of completing the MSA, we confirmed there is not variation in the measurement system. Figure 5.1 displays MSA results.

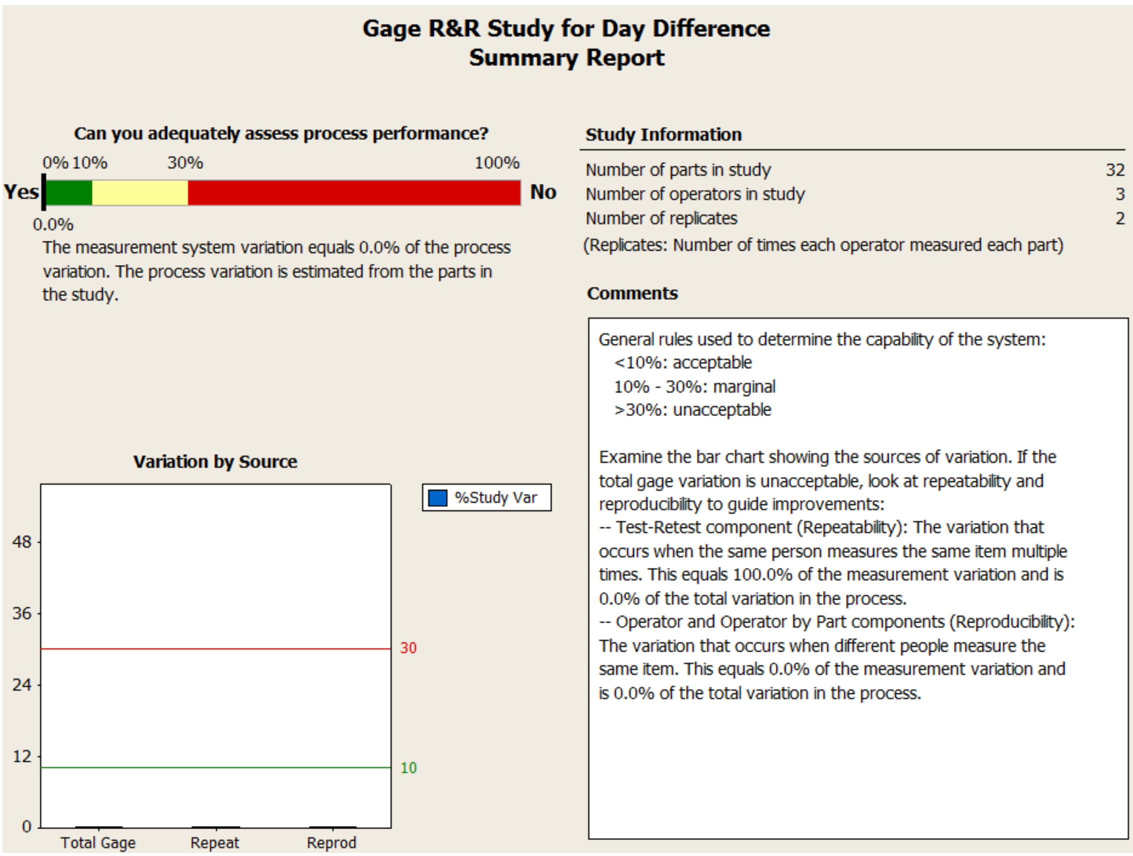

Figure 5.1 Measurement System Analysis

5.2.4 Process Capability Analysis

Conducting an initial process capability analysis determined if the current process is able to support the project's goal of reducing order processing cycle time from four to two days. The customer requirements consisted of an upper control limit of 2.0. Lower control limit and target values were not chosen. Process characterization resulted in a mean of 4.3287, which is higher than the desired mean of two. The capability analysis indicates that 84.32% of the data points have a process cycle time of greater than 2 days. The process capability analysis indicates that the current process is not capable of meeting customer requirements. Figure 5.2 displays the results of the process capability analysis.

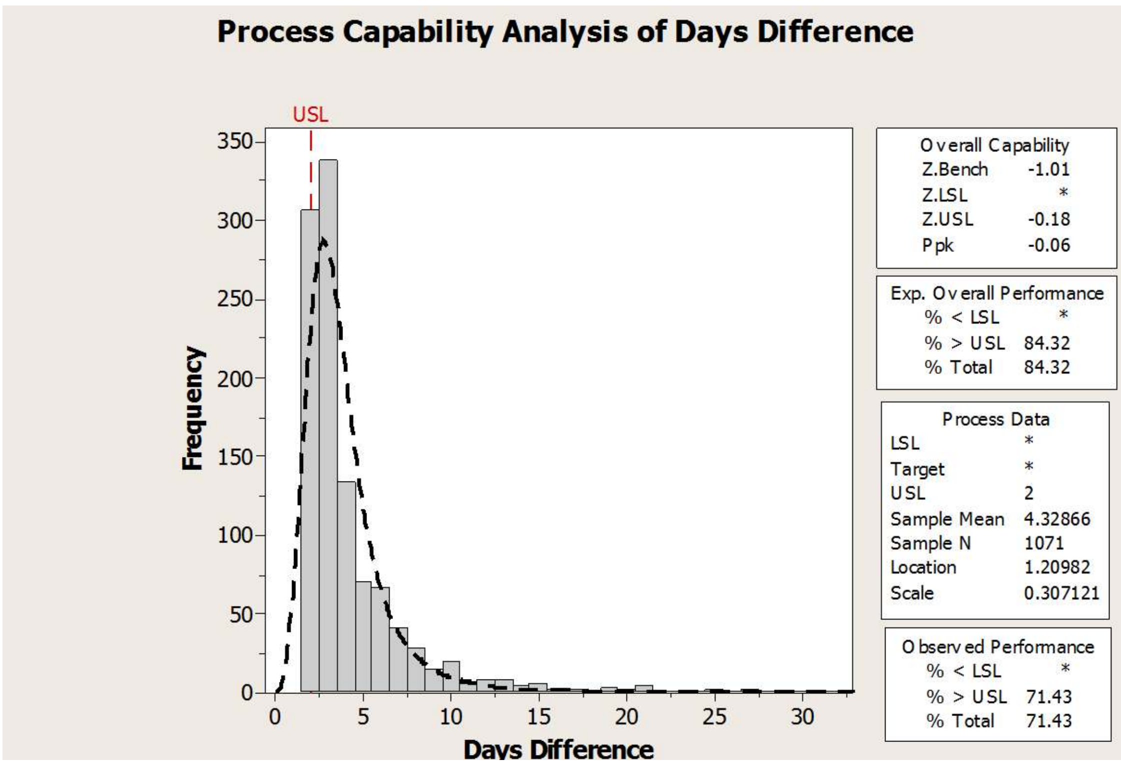

Figure 5.2 Initial Process Capability Analysis

5.2.5 Statistical Process Control

Statistical process control (SPC) resulted in the creation of control charts. The control charts determine the stability of the current process. The type of control chart used is the individuals and moving range (I-MR) chart. The individual (I) chart measured the trends and shifts in the data. The moving range (MR) chart details the variability in the process. An upper control limit (UCL), lower control limit (LCL) and mean were generated during the creation of both charts. Evaluation of the MR chart identifies whether the current process is in control or not. If the MR chart deems process variation as in control, the I chart is then evaluated. If the MR chart does not deem process variation as in control, the I chart's control limits are considered inaccurate; therefore, the I chart is not reviewed.

This phase of the project resulted in the creation of one I-MR control chart. The chart utilized all of the data that had been collected. The MR chart's UCL was 6.74, LCL was zero, and average was 2.06. The I chart's UCL was 9.81, LCL was 1.16, and average was 4.33. As a result of several data points lying outside of the control limits, process variation is considered to be out of control; therefore, the I chart was not evaluated. This chart indicates that the process is simply unstable. Section 5.3 provides a more in-depth analysis of the control chart. Figure 5.3 displays the I-MR control chart.

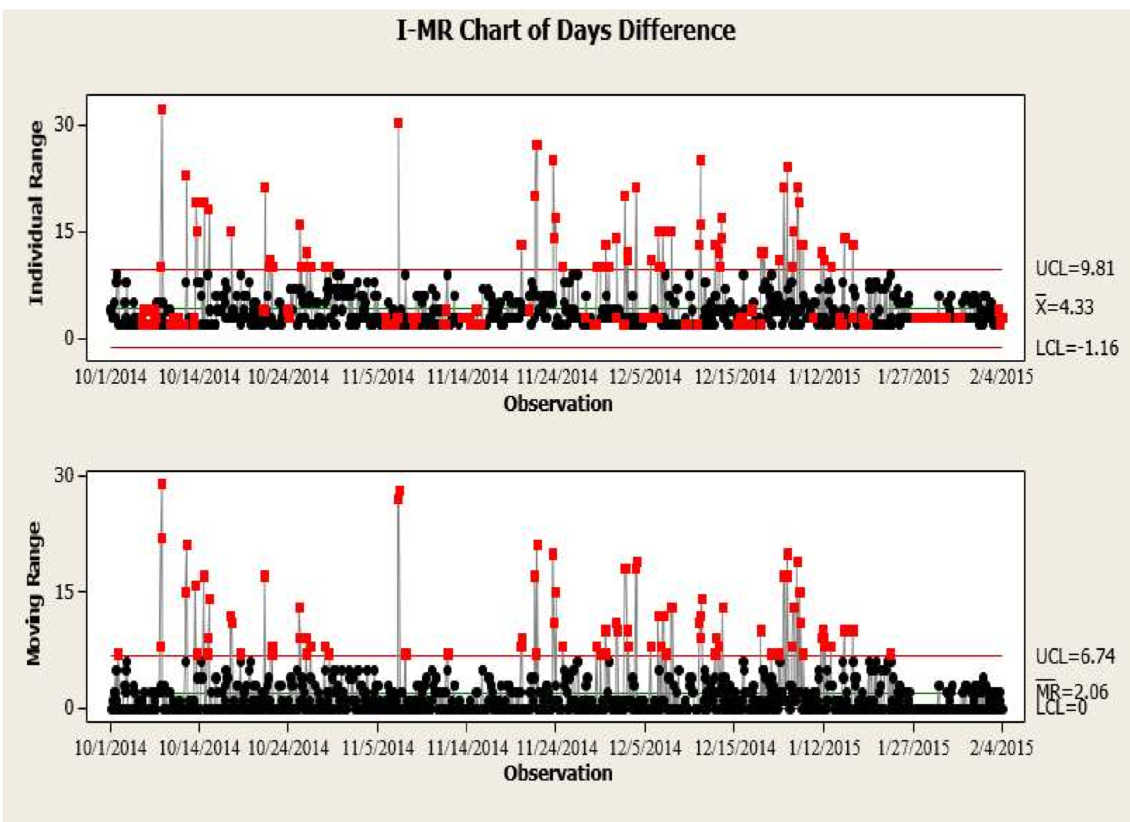

Figure 5.3 Initial I-MR Chart

5.3 ANALYZE

This section will provide insight in regards to the activities that took place during the Analyze Phase. Section 4.3 explains the importance of each of the tools used to complete the Analyze Phase, and utilizing those tools resulted a confirmation of root cause(s) associated with process inefficiencies and three to five suggestions for process improvements. The tools used include statistical process control, process capability analysis, Pareto Chart, and statistical hypothesis testing. This section will provide details about the application of each of the tools.

5.3.1 STATISTICAL PROCESS CONTROL

Statistical Process Control (SPC) helped to further analyze and interpret the control chart created during the Measure Phase and identify potential root causes of process inefficiency. An analysis of the out of control data points took place. This analysis identified “quick wins”. A “quick win” is simply a process improvement that has low risk, can be implemented shortly after the project begins, and is agreed upon by project team members. Identified quick wins included a process change for altered data codes, a process change for order scheduling, and process change that implements pre-order translation. Implementation of these quick wins required a plan. The implementation plan includes the name of the quick win, how the quick win was implemented, what data was to be collected and used as a comparison to determine the impact of implementing the quick win, and the deadline for implementing the quick win. The plan used to implement quick wins is as follows:

- Process Change for Altered Codes – 03/11/2015
    - New orders with altered codes directly to SpecPro/PDM before marketing
    - Cycle time on units during the month of March with altered codes were collected and compared to units processed in February
- Process Change Model A Scheduling – 03/11/2015
    - If Model A is void of hits and CWOs, unit is sent straight to scheduling
- Cycle time on units during the month of March with altered codes were collected and compared to units processed in February
- Pre-Order Translation for Model C – 03/11/2015
    - Desired build dates on Model C units will be sent out prior to order entering GOP to improve order translation accuracy prior to marketing review
    - Cycle time on units during the month of March with altered codes were collected and compared to units processed in February

After the implementation of quick wins, the creation and interpretation of an additional control chart provided us with process stability. Data collection ranged from 03/11/2015 until 03/312015. The MR chart's UCL was 3.81, LCL was 0, and average was 1.16. The I chart's UCL was 6.31, LCL was 0.12, and average was 3.21. As a result of several data points lying outside of the control limits, process variation was considered to be out of control; therefore, the I chart was not evaluated. The UCL, LCL, and average for MR and I charts decreased after implementing quick wins. This indicated that there was a decrease in average variance and cycle time. Although implementing the quick wins appeared to have a positive impact on stability (variance and cycle time), the control chart still revealed that the current process is unstable. Figure 5.4 displays the I-MR Chart after the implementation of quick wins.

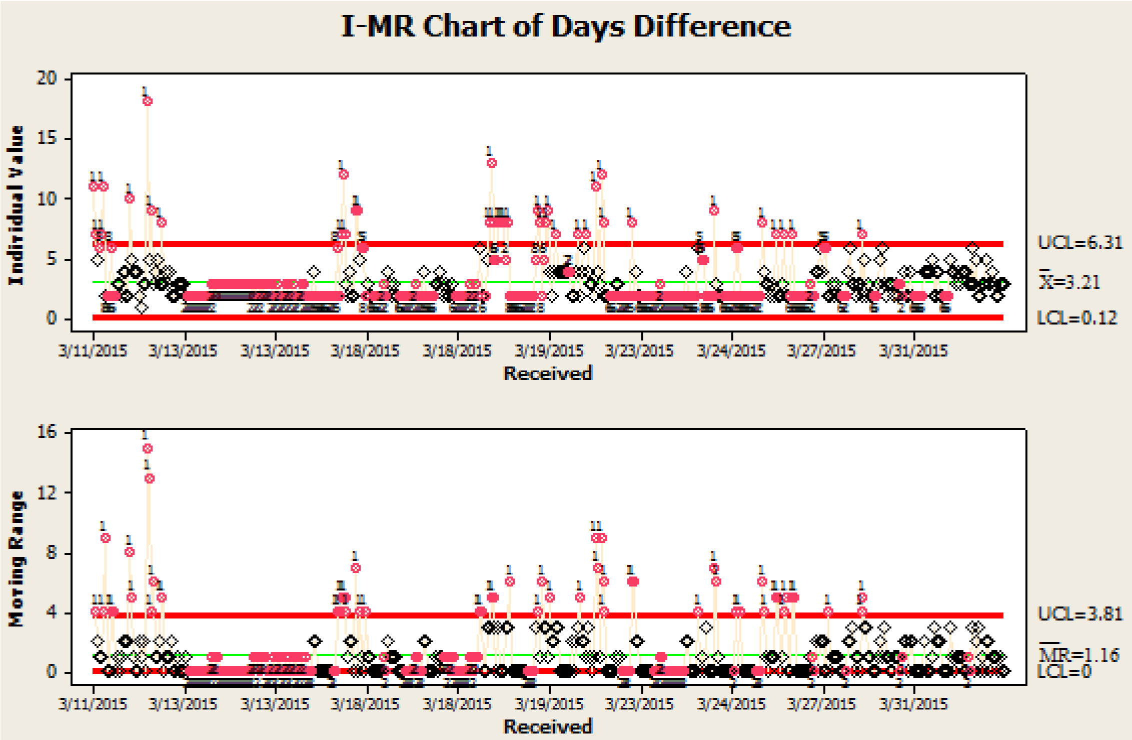

Figure 5.4 I-MR Chart After the Implementation of Quick Wins

5.3.2 Process Capability Analysis

After the implementation of quick wins, an additional process capability analysis took place to determine whether implementing the quick wins positively influenced the capability of the current process. The customer requirements consisted of an upper control limit of 2.0. Lower control limit and target values were not chosen. Process characterization resulted in a mean of 3.2146, which is higher than the desired mean of two but lower than the mean (4.3287) that resulted from the initial process capability analysis. The capability analysis indicates that 72.54% of the data points have a process cycle time of greater than 2 days, which is also lower than the percentage (84.22%) that resulted from the initial capability analysis. Although the mean and percentage of data points that have a process cycle time greater than two days are lower than initial process capability analysis results, the current process is still not capable of meeting customer requirements. Figure 5.5 displays the results of the process capability analysis.

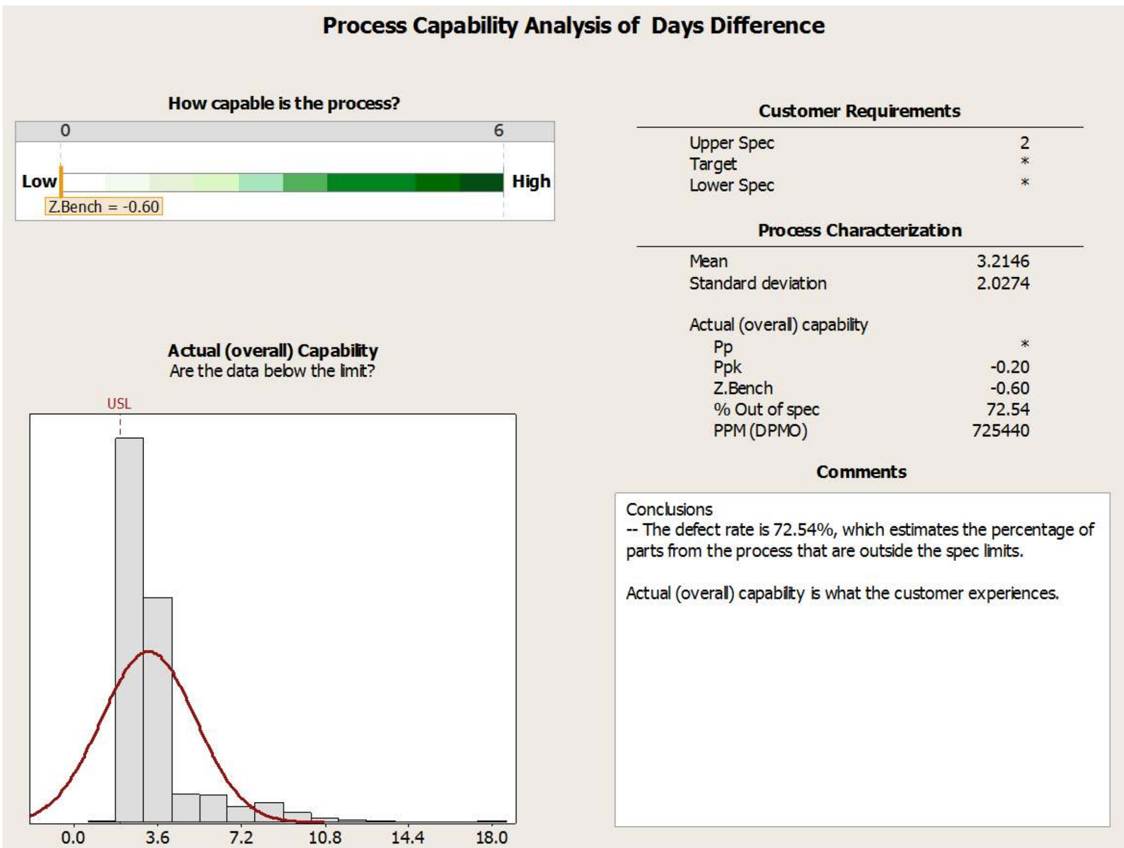

Figure 5.5 Process Capability Analysis After the Implementation of Quick Wins

5.3.3 Pareto Chart

Tracking of all March 2015 orders with an order processing cycle time greater than two days helped identify potential root causes of process inefficiency. We worked together to developed potential reasons why the orders were outside of the upper control limit. The team identified the following reasons: CWO/Compatibility, Altered Code, Personnel, SpecPro, Communication, Pre-series/Prototype, CodeGen, and Credit Hold. Creating the initial Pareto Chart allowed us to display the contribution of each of the reasons makes to process inefficiencies. Three hundred thirty-six March 2015 orders have an order processing cycle time greater than two days. The Pareto Chart indicates the number and percentage of orders associated with each of the reasons we developed. The contribution of each of the reasons is as follows:

- CWO/Compatibility
    - 116 orders
    - 34.52%
- Altered Code
    - 70 orders
    - 20.83%
- Personnel
    - 43 orders
    - 12.80%
- SpecPro
    - 41 orders
    - 12.20%
- Communication
    - 22 orders
    - 6.55%
- Pre-series/Prototype
    - 21 orders

- 6.25%

- CodeGen
  - 17 orders
  - 5.06%
- Credit Hold
  - 6 orders
  - 1.79%

The Pareto Chart reveals CWO/Compatibility and Altered Codes as the top two factors that influence order processing cycle times greater than two days. Figure 5.6 displays the Pareto Chart for flaws associated with orders with an order processing cycle time greater than two days.

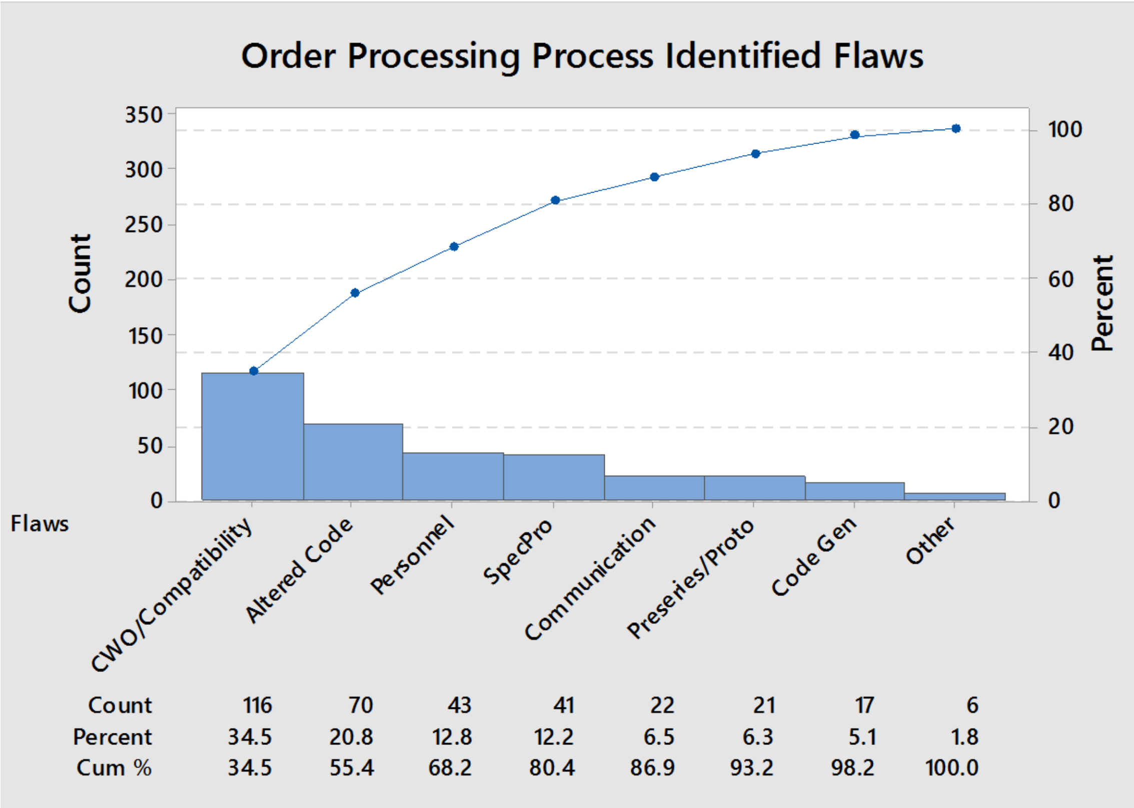

Figure 5.6 Order Processing Process Identified Flaws

5.3.4 Statistical Hypothesis Testing

Conducting two-sample T-tests for CWO/Compatibility and Altered Codes allowed us to determine the average amount of days difference for orders with those issues present and orders without those issues present. The two-sample T-test conducted for CWO/Compatibility reveals a mean of 4.52 for orders without CWO/Compatibility issues and a mean of 6.92 for orders with CWO/Compatibility issues; therefore, the presence of CWO/Compatibility further taints process inefficiency and increases order processing cycle time by 2.4 days. The two-sample T-test conducted for Altered Codes reveals a mean 5.01 for orders without Altered Codes and a mean of 7.56 for orders with Altered Codes; therefore, the presence of Altered Codes further taints process inefficiency and increases order processing cycle time by 2.55 days. The results of the two-sample T-tests indicates altered codes have more of an impact on order processing cycle time than CWO/Compatibility issues.

5.3.5 Pareto Chart

We worked together to developed potential reasons for altered codes. The team identified the following reasons: SPD File Not Updated, Spec Pro Not Updated, New Data Codes, and Unpublished Data Codes. Creating the Pareto Chart allowed us to display the contribution of each of the reasons makes to altering data codes on orders. Seventy of the 336 March 2015 tracked orders have altered codes. The Pareto Chart indicates the number and percentage of orders associated with each of the reasons we developed for codes being altering. The contribution of each of the reasons is as follows:

- Spec Pro Not Updated
  - 37 orders

- 52.86%

- SPD File Not Updated
    - 22 orders
    - 31.43%
- New Data Codes
    - 6 orders
    - 8.57%
- Unpublished Data Codes
    - 5 orders
    - 7.14%

The Pareto Chart reveals SPD File Not Updated and Spec Pro Not Updated as the top two factors that influence altering codes on orders. Figure 5.7 displays the Pareto Chart for flaws associated with orders with altered codes.

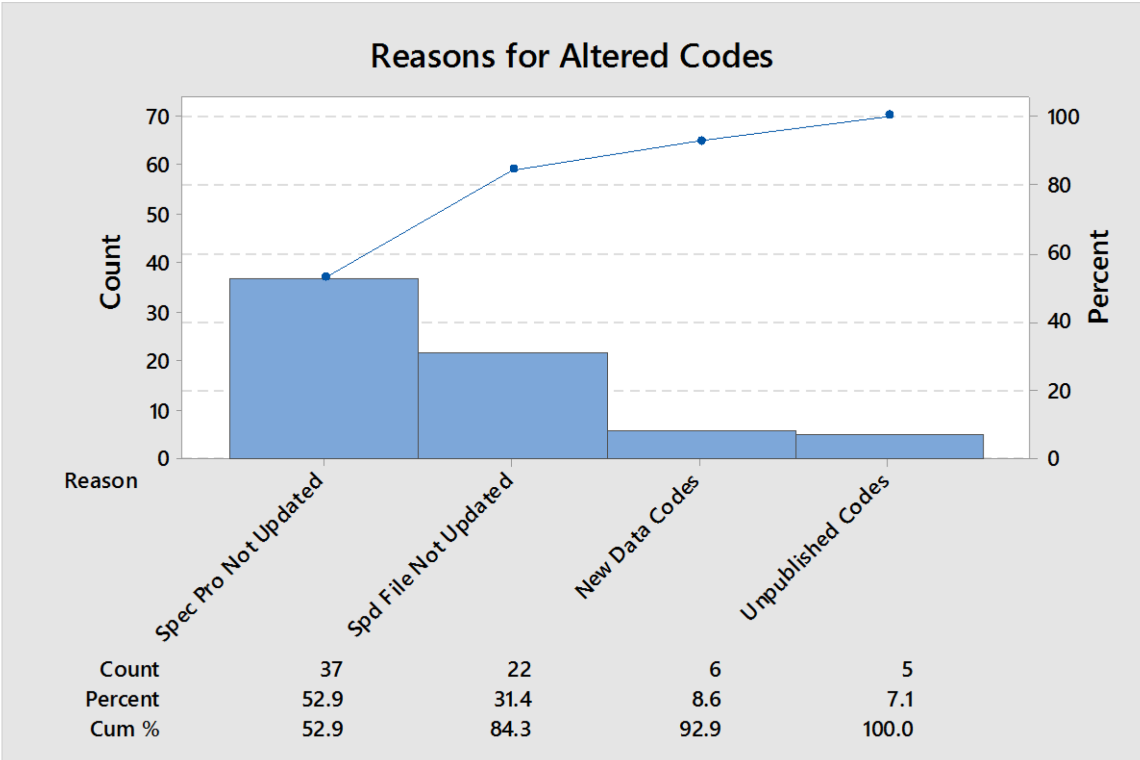

Figure 5.7 Reasons for Altered Codes

5.3.6 Statistical Hypothesis Testing

In an effort to determine if there is a difference in average cycle time on orders with altered codes related to Spec Pro not updated versus a SPD not being updated, a two-sample T-test was conducted. The two-sample T-test reveals a mean of 7.93 for Spec Pro not updated and a mean of 7.45 for SPD file not updated; therefore, the average cycle time on altered code orders is not affected by driver of altered code.

In an effort to determine the difference in average cycle time of orders without issues present and orders with altered codes due to the identified reasons associated with altered codes, four more two-sample T-tests were conducted. For all four of the two-sample T-tests, the orders without issues present have a mean of 3.15 days. The two-sample T-test conducted for Spec Pro not updated reveals a mean of 8.18; therefore, orders for which Spec Pro has not been updated increases order processing cycle time by

5.03 days. The two-sample T-test conducted for SPD file not updated reveals a mean of 7.61; therefore, orders for which SPD file not has not been updated increases order processing cycle time by 4.46 days. The two-sample T-test conducted for New Data Codes reveals a mean 6.62; therefore, the use of new data codes increases order processing cycle time by 3.47 days. The two-sample T-test conducted for Unpublished Data Codes reveals a mean 7.09; therefore, the use of unpublished data codes increases order processing cycle time by 3.94 days. The results of the two-sample T-tests indicates Spec Pro not updated is the key reason for altered codes. Altered order codes due to Spec Pro not updated occurs due to the submission of orders before Spec Pro is updated; therefore, orders being submitted before Spec Pro updates are made was identified as the root cause of process inefficiency.

5.3.6 Process Improvement Recommendations

After we identified the root cause as orders submitted before data code are updated in Spec Pro, we worked together to develop recommendations for improving the current process. In working together to develop a solution, we began with the following question: How do we ensure Spec Pro readiness before order submission? After several brainstorming sessions, we determined the automobile manufacturing facility can ensure Spec Pro readiness before order submission by doing the following:

- Delay orders
- Update Spec Pro sooner

Since order processing cycle time begins the day the order is entered into the system and does not end until the order is released from the system, delaying order entry until Spec Pro has been updated will ensure that the order does not encounter errors and prolonged cycle time. Choosing this option will result in the automobile manufacturing facility altering current state business practices in regards to when an order entry is permitted. Updating Spec Pro sooner will also ensure that orders do not get hung up in the order processing process due to errors encountered as a result of applicable data codes being present. Choosing this option will allow the automobile manufacturing facility to maintain current state business practices in regards to when an order entry is permitted.

5.4 Improve

As stated in Section 5.4, the purpose of the Improve Phase is testing and permanently implementing the solutions developed during the Analyze Phase. Because the objective of this thesis is to make suggestions for improving the automobile manufacturing facility's current order processing process, carrying out the Improve Phase was not necessary for thesis completion. Section 5.4 describes the steps necessary to complete this phase of the project.

5.5 Control

As stated in Section 5.5, the purpose of the Control Phase is setting up measures to ensure the problem does not occur again. Carrying out this phase was not necessary for meeting the objective of this thesis. Although carrying out this phase did not occur, this section provides recommendations for controlling the order processing process after the implementation of improvements.

5.5.1 Recommendations

Analyzing the current process revealed a great deal of variation within the current order processing process. In an effort to monitor the variation of the future process, the automobile manufacturing facility can use Statistical Process Control (SPC) charts. The use of control charts will allow the automobile manufacturing facility to monitor the variation within the process over time as well uncover any abnormal happening or inconsistencies associated with the process. Using SPC on a regular basis will keep the automobile manufacturing facility informed about whether the process is operating within specified limits and continuing to meet customer requirements. If SPC is used on a regular basis (perhaps monthly), the process will remain in control. In addition to the process remaining in control, the quality of services rendered by the automobile manufacturing facility will also remain satisfactory.

CHAPTER 6

CONCLUSION

As a result of completing this case study, answers were provided to the research questions in Section 1.4. The questions and answers to the questions are as follows:

1. Why is the automobile manufacturing facility's current order processing process not efficient? (What flaws are associated order processing inefficiency?)
    a. CWO/Compatibility, Altered Codes, Personnel, Spec Pro Issues, Communication, Pre-series/Prototype, Code Gen, and Credit Hold are the flaws associated with order processing inefficiency. The most influential flaw is Altered Codes. Reasons for Altered Codes include Spec Pro not Updated, SPD file not Updated, Data Code not Published, and New Data Code. The most influential reason is Spec Pro Not Updated. Orders being submission before Spec Pro Updates is the root cause or biggest flaw associated with process inefficiency.
2. How can flaws associated with the order processing process be measured?
    a. Order processing cycle time measures flaws associated with the order processing process.
3. How can permanent corrective action be implemented to eliminate flaws associated with the order processing process?

a. Delaying orders or updating Spec Pro sooner will eliminate the most influential flaw associated with order processing process.

The application of Lean Six Sigma did determine the root cause of process inefficiency and make recommendations for improving the order processing process at an automobile manufacturing facility.

REFERENCES

Abliwi, S., Antony , J., Lim, S. A., & Wiele, T. v. (2014). Critical failure factors of Lean Six Sigma: a systematic literature review. *International Journal of Quality & Reliability Management, 31*(9), 1012-1030. doi:http://dx.doi.org/10.1108/IJQRM-09-2013-0147

Anand , K. (2015). Critical Analysis Of The Success Factors For Implemeniting Six Sigma In IT Industry. *IOSR Journal of Business and Managemetn, 17*(2), 18-24. doi:10.9790/487X-17221824

Arumugam , V., Antony , J., & Douglas , A. (2012). Observation: a Lean tool for improving the effectiveness of Lean Six Sigma. *The TQM Journal, 24*(3), 275-287. doi:http://dx.doi.org/10.1108/17542731211226781

Ary , D., Jacobs , L. C., Razavieh , A., & Sorenson, C. K. (2010). *Introduction to Research in Education* (8th ed.). Belmont, California , USA: Wadsworth.

Assarlind , M., Gremyr, I., & Backman , K. (2013). Multi-faceted view on a Lean Six Sigma application. *International Journal of Quality & Reliability Management, 30*(4), 387-402. doi:http://dx.doi.org/10.1108/02656711311308385

Byrne, G., Lubowe, D., & Blitz, A. (2007). Using a Lean Six Sigma approach to drive innovation. *Strategy & Leadership, 35*(2), 5-10. doi:http://dx.doi.org/10.1108/10878570710734480

Cabrita , M. R., Domingues , J. P., & Requeijo, J. (2015). Application of Lean Six-Sigma methodology to reducing production cost: case study of a Portuguese bolt manufacturer. *International Journal of Managment Science and Engineering Management*. doi:10.1080/17509653.2015.1094755

Creswell , J. W. (2014). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches* (4th ed.). Thousand Oaks , California : SAGE Publications, Inc. .

Dal Forno , A. J., Pereira, F. A., Forcellini, F. A., & Kipper, L. M. (2014). Value Stream Mapping: a study about the problems and challenges found in the literature from the past 15 years about application of Lean tools. *The International Journal of Advanced Manufacturing Technology, 72*(5), 779-790. doi:10.1007/s00170-014-5712-z

Damato, C., & Rickard , D. (2015, March 1). Using Lean-Six Sigma to Reduce Hemolysis in the Emergency Care Center in a Collaborative Quality Improvement Project with theHospital Laboratory. *The Joint Commission Journal on Quality and Patient Safety,, 41*(3), 99-99.

Dhafer, A. Y., & Aramco, S. (2012). Introduction of Lean Six Sigma principles into Plant Maintenance Work Order Cycle Time. *Proceedings of the 2012 International Conference on Industrial Engineering and Operations Management.* Istanbul, Turkey. Retrieved from http://iieom.org/ieom2012/pdfs/510.pdf

Dragulanescu, I.-V., & Pepescu, D. (2015). Quality and Competitiveness: A Lean Six Sigma Approach. *Amfiteatru Economic, 17*(9), 1167-1182.

Duranik , T., Stopper, M., & Ruzbarsky, J. (2011). APPLYING VALUE STREAM MAPPING TO IDENTIFY HIDDEN RESERVES AND AVOID BOTTLENECKS. In B. Katalinic (Ed.), *Annals of DAAAM for 2011 & Proceedings of the 22nd International DAAAM Symposium. 22.* Vienna, Austria: DAAAM International. Retrieved from www.daaam.info/Downloads/Pdfs/proceedings/.../0969_Duranik.pdf

Franchetti , M. J. (2015). *Lean Six Sigma for Engineers and Managers Wih Applied Case Studies.* Boca Raton, FL: Taylor & Francis Group, LLC.

Gracanin, D., Buchmeister, B., & Lalic, B. (2014). Using Cost-Time Profile for Value Stream Optimization. *Procedia Engineering. 69*, pp. 112-1231. Elsevier Ltd. . Retrieved from http://ac.els-cdn.com/S1877705814003592/1-s2.0-S1877705814003592-main.pdf?_tid=ec8036e2-9a4d-11e5-8c5f-00000aab0f26&acdnat=1449209697_9c5223d9c77fb3b10011a0e713c1a78c

Gray , D. E. (2014). *Doing Research in the Real World* (3rd ed.). Thousand Oaks , California: SAGE Publications, Inc.

Heidi , W. (2011, June 29). *DMAIC Phase 2: Measure*. (J. Scheid , Editor) Retrieved September 19, 2016, from Bright Hub Project Management: http://www.brighthubpm.com/six-sigma/25326-dmaic-phase-two-measuring/

Heifi , W. (2011, May 23). *DMAIC Phase 3: Analyze*. (M. McDonough , Editor) Retrieved Septemeber 19, 2016, from Bright Hub Project Management: http://www.brighthubpm.com/six-sigma/24789-dmaic-phase-three-the-analyze-phase/

Jie , J. C., Kamaruddin , S., & Azid , I. A. (2014). Implementing the Lean Six Sigma Framework in a Small Medium Enterprise (SME) - A Case Study in a Printing Company. *Peoceedings of the 2014 International Conference on Industrial Engineering and Operations Management.*

Khurana, G. S. (2008). Purchasing Success for the Service Sector: Using Lean & Six Sigma. *93rd Annual International Conference Proceedings* . Retrieved from https://www.instituteforsupplymanagement.org/files/Pubs/Proceedings/ALTKhurana

Knapp, S. (2015). Lean Six Sigma implementation and organization culture. *International Journal of Health Care Quality Assurance, 28*(8), 855-863. doi:http://dx.doi.org/10.1108/IJHCQA-06-2015-0079

Lean Six Sigma Glossary. (n.d.). Retrieved April 18, 2016, from GoLeanSixSigma.com: https://goleansixsigma.com/glossary/

Lertwattanapongchai, S., & Swierczek, F. W. (2014). Assess the change process of Lean Six Sigma: a case analysis. *International Journal of Lean Six Sigma, 5*(4), 423-443. doi:http://dx.doi.org/10.1108/IJLSS-07-2013-0040

Mason, S. E., Nicolay , C. R., & Darzi, A. (2014). The use of Lean and Six Sigma methodologies in surgery: A systematic review. *The Surgeon, 13*, 91-100.

Mega, J. E. (2016). *Lean Management Using Six Sigma: Proven Strategies That Work!* JMB. Retrieved August 10, 2016, from https://read.amazon.com/

Mohamed Isa , M. F., & Usmen , M. (2015). Improving univeristy facilities services using Lean Six Sigma: a case study. *Journal of Facilities Management, 13*(1), 70-84. doi:http://dx.doi.org/10.1108/JFM-09-2013-0048

O'Connor , P. D., & Kleyner , A. (2012). *Practical Reliability Engineering* (5th ed.). Chichester , West Sussex, United Kingdom : John Wiley & Sons, Ltd.

Panat, R., Dimitrova, V., Selvamuniandy , T. S., Ishiko , K., & Sun , D. (2014). The application of Lean Si Sigma to the configuration control in manufacturing R&D environment. *International Journal of Lean Six Sigma, 5*(4), 444-459. doi:http://dx.doi.org/10.1108/IJLSS-02-2014-0004

Patel , M., Sisodiya, P. S., Qureshi, S., & Bansod, D. V. (2014). Reduction in Process Cycle Time in Mechanical Production Industries by Using Eight Core Approaches. *International Journal of Engineering Development and Research (IJDES), 2*(1), 772-778. Retrieved from http://www.ijedr.org/papers/IJEDR1401140.pdf

Pojasek , R. B. (2003). Lean, Six Sigma, and the Systems Approach: Management Initiatives for Process Improvement. *Environmental Quality Management, 13*(2), 85-92. doi:10.1002/tqem.10113

Ptacek, R., Sperl , T., & Trewn , J. (2015). *The Practical Lean Six Sigma Pocket Guide XL: Using the A3 and Lean Thinking to Improve Operational Performance in ANY Industry, ANY Time.* Chelsea, Michigan: MCS Media, Inc.

Ray , S., & John , B. (2011). Lean Six-Sigma application in business process outsourced organiation. *International Journal of Lean Six Sigma, 2*(4), 371-380. doi:http://dx.doi.org/10.1108/20401461111189443

Razavieh , A., Sorenson, C. K., Jacobs , L. C., & Ary , D. (2010). *Introduction to Research in Education* (8th ed.). Belmont, California, USA: Wadsworth.

Ruttimam, B. G., Fischer, U. P., & Stockli, M. T. (2014). Leveraging Lean in the Office: Lean Office Needs a Novel and Differentiated Approach. *Journal of Service and Management, 7*(5), 352-360. doi:10.4236/jssm.2014.75032

Sarkar , S. A., Mukhopadhyay, A. R., & Ghosh, S. K. (2013). Improvement of claim processing cycle time through Lean Six Sigma methodology. *International Journal of Lean Six Sigma, 4*(2), 171-183. doi:http://dx.doi.org/10.1108/20401461311319347

Shafer, S. M., & Moeller , S. B. (2012). The effects of Six Sigma on corporate performance: An emperical investigation. *Journal of Operations Management, 30*, 521-532.

Shaw , E. (2015). *Lean Six Sigma Simplified: A Beginner's Guide.*

Siddh, M. M., Gadekar, G., Soni, G., & Jain, R. (2013). Lean Six Sigma Approach for Quality and Business Performance. *Global Journal of Management and Business Studies, 3*(6), 589-594. Retrieved from http://www.ripublication.com/gjmbs_spl/gjmbsv3n6_04.pdf

Singh, B., Garg, S. K., & Sharma, S. K. (2011). Value stream mapping: literature review and implications for Indian industry. *The International Journal of Advanced Manufacturing Technology, 53*(5), 799-809. doi:10.1007/s00170-010-2860-7

Stern , T. V. (2016). *Lean Six Sigma International Standards and Global Guidelines* (2nd ed.). Boca Raton, Florida : CRC Press .

Tanner, M. T., Sezen, B., & Antony , J. (2007). An overview of six sigma applications in healthcare industry. *International Journal of Health Care Quality Assurance, 20*(4), 329-340. doi:http://dx.doi.org/10.1108/09526860710754398

Terry , K. (n.d.). *What is DMAIC?* Retrieved April 5, 2016, from iSixSigma: http://www.isixsigma.com/methodology/dmaic-methodology/what-dmaic/

Vouzas, F., Psychogios , A., & Tsironis , L. (2014). The Road towards Lean Six Sigma: Sustainable Success Factors in Service Industry. *Nan Yan Business Journal, 2*(1), 31-38. doi:10.2478/nybj-2014-0023

Wiesenfelder , H. (2011, May 22). *DMAIC Phase 1: Define*. (G. Marlene , Editor) Retrieved September 19, 2016, from Bright Hub Project Management: http://www.brighthubpm.com/six-sigma/23947-dmaic-phase-one-define/

Wiesenfelder , H. (2011, June 29). *DMAIC Phase 2: Measusre*. (J. Scheid , Editor) Retrieved September 19, 2016, from Bright Hub Project Management: http://www.brighthubpm.com/six-sigma/25326-dmaic-phase-two-measuring/

Wiesenfelder , H. (2011, May 23). *DMAIC Phase 3: Analyze*. (M. McDonough , Editor) Retrieved September 19, 2016, from Bright Hub Project Management: http://www.brighthubpm.com/six-sigma/24789-dmaic-phase-three-the-analyze-phase/

Wiesenfelder , H. (2011, May 25). *DMAIC Phase 4: Improve*. (J. Scheid , Editor) Retrieved September 19, 2016, from Bright Hub Project Management: http://www.brighthubpm.com/six-sigma/25328-dmaic-phase-four-the-improve-phase/

Wiesenfelder , H. (2013, October 17). *DMAIC Phase 5: Control*. (J. Scheid , Editor) Retrieved Septemeber 19, 2016, from Bright Hub Project Management: http://www.brighthubpm.com/six-sigma/27134-dmaic-phase-five-the-control-phase/

Yadav , D. (2014). Study of Productivity Improvement Using Lean Six Sigma Methodology. *International Review of Applied Engineering Research, 4*(1), 33-38. Retrieved from http://www.ripublication.com/iraer.htm

Yin , R. K. (2014). *Case Study Reserch: Design and Methods* (5th ed.). Thousand Oaks, California : SAGE Publications, Inc.