LEAN IMPLEMENTATION AND THE ROLE OF LEAN ACCOUNTING IN THE TRANSPORTATION EQUIPMENT MANUFACTURING INDUSTRY

Adrienn Andersch

A DISSERTATION SUBMITTED TO

THE FACULTY OF THE VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

IN FOREST PRODUCTS

Urs Buehlmann, Chair

David E. Kline

Janice K. Wiedenbeck

Iris B. Montague

Larry N. Killough

September, 26th 2014

Blacksburg, Virginia

Keywords: Lean transformation, Lean accounting, performance, survey research, multiple imputation, regression analysis, profile deviation analysis.

LEAN IMPLEMENTATION AND THE ROLE OF LEAN ACCOUNTING IN THE TRANSPORTATION EQUIPMENT MANUFACTURING INDUSTRY

Adrienn Andersch

Abstract

Implementing Lean in the United States transportation equipment manufacturing industry holds the promise for improvements in, among other things, productivity, quality, and innovation, resulting in more competitive success and profits. Although Lean has been applied throughout the industry with noted success, there have been some difficulties in demonstrating the financial benefits derived from Lean initiatives. Most of the evidence supporting a positive relationship between Lean implementation and improved financial performance is anecdotal. As companies have become more proficient in carrying out Lean initiatives in manufacturing, they have extended Lean ideas to other parts of their organization and throughout the entire supply chain. Nowadays, it is widely recognized that a holistic, enterprise-wide view is critical to obtain the potential benefits of a Lean transformation.

However, Lean transformations are often undertaken without consideration of supporting functions such as accounting and finance. Lean transformation in accounting and finance should be run in the same way as it is in the manufacturing environment by decreasing reporting cycle time, improving transaction processing accuracy, eliminating unnecessary transaction processing, changing product costing procedures, and financial reporting among many other things, but there is limited empirical evidence of that happening.

To address these shortcomings, this research focuses on three areas. First, this study aims to evaluate transportation equipment manufacturing facilities in respect to their operational and financial performance. Second, this study aims to investigate the extent of Lean implementation of a given operation in respect to leadership, manufacturing, accounting and finance, and supplier and customer relationship and correlate these results to their performance. Finally, this study aims to further examine the contextual characteristics of companies that successfully aligned their systems with Lean.

A mixed-mode survey, addressed to a subset of the United States transportation equipment manufacturing industry, asked questions pertinent to companies' Lean transformation efforts, performance, and general characteristics. During the four months long survey period, a total of 69 valid responses were received, for a response rate of 3.78 percent. From the 69 valid responses, 8 responses were eliminated due to containing more than 20 percent missing values. Multiple imputation procedure was applied to handle remaining missing values in the dataset. Before testing study hypotheses, scale reliability and construct validity tests were run to decide whether a particular survey item should be retained in further analysis. Study hypotheses were then tested using profile deviation analysis, multiple regression analysis, and hierarchical regression analysis.

When the level of Lean implementation and performance relationship was investigated using a multiple regression analysis, results did not show any evidence that the higher level of

Lean implementation along four business dimensions (leadership, manufacturing, accounting and finance, and supplier and customer relationship) of transportation equipment manufacturing facilities positively influences their operational and financial performance. However, it was revealed that the higher level of Lean implementation in transportation equipment manufacturing facilities' manufacturing dimension resulted in better quality performance as measured by first-time through, inbound quality, and outbound quality. When the same relationship was investigated using a profile deviation analysis, results were identical.

When the level of Lean implementation in accounting and finance and its relationship with performance was investigated using a single regression analysis, results showed that the higher level of Lean implementation in transportation equipment manufacturing facilities' accounting and finance dimension has a positive effect on accounting performance and on operational performance (e.g., on time-based performance and delivery-based performance), but no effect on financial performance. When the same relationship was investigated using a profile deviation analysis, results were different by showing no relationship between the level of Lean implementation in transportation equipment manufacturing facilities' accounting and finance dimension and accounting, operational, and financial performance.

Lastly, the effect of contextual variables (e.g., industry segment, location, annual sales volume, and unionization) on performance, the level of Lean implementation, and the performance – Lean implementation relationship was investigated using hierarchical regression. Results showed that transportation equipment manufacturing facilities' performance is influenced by annual sales volume. Their level of Lean implementation in the accounting and finance dimension is influenced by location, while their performance – Lean implementation in the accounting and finance dimension relationship is influenced by industry segment.

Acknowledgement

First and foremost, I would like to express my highest gratitude to my major adviser and committee chair, Dr. Urs Buehlmann for his contributions of time, patience, immense knowledge, and funding to make my Ph.D. experience a successful and unforgettable journey. Dr. Buehlmann taught me self-confidence and scientific rigor which I plan to carry forward in my future endeavors.

I would like to express my sincere appreciation to my other committee members Dr. Larry Killough, Dr. Earl Kline, Dr. Jan Wiedenbeck, and Dr. Iris Montague, who provided me with assistance and encouragement in many ways. I am thankful for their generosity of time and effort. I am also thankful to Jeff Palmer, Matt Bumgardner, and Phil Araman for their contribution to my professional development in different ways and for providing help whenever needed.

I also would like to thank the entire faculty, staff, and students of the Department of Sustainable Biomaterials who guided and worked alongside me for my Ph.D. degree. Special thanks go to Angela Riegel, Debbie Garnand, and Linda Caudill for the precious time and effort that they spent listening to my concerns, encouraging me, and providing advice beyond their duties.

I was very fortunate to work with LISA, the statistical collaboration laboratory of Virginia Tech. Khaled Bedair, Caleb King, and Jon Atwood unselfishly shared their expertise in statistics and research with me. I am thankful for their support, enthusiasm, and spirit.

The members of Lean@VirginiaTech have contributed immensely to my personal and professional time at Virginia Tech. The team has been a great source of friendships as well as good advice and collaboration. I am especially grateful for the continuous encouragement of Rebecca Buck, Shawn Crawford, Selma Elouardighi, Omar Espinoza, Christian Fricke, Kevin Knight, Akiko Nakata, Lina Piao, Mathias Schmitt, Ana M. Serrano, Michael Sperber, Angela Zhou, Gavin Wherry, and Chao Wang.

My time at Virginia Tech was made enjoyable in large part due to the many friends that became a part of my life. I am grateful for time spent with roommates and friends and for the unforgettable memories with Amy Garrett, Angela Zhou, Mathias Schmitt, Fae Garstand and Siyang Yang, Kati and Gabi Agoston, Beth and Geza Ifju, Monica and Mark Gibson, and Anita Nagypal and Laszlo Papp.

I would like to express my heartfelt gratitude to my friends, especially to Judit Steinbach, Eszter Magyar, Melinda Kranitzne Presits, Anita Fuzi, and Dora Albecker among many others who provided me with love, inspiration, and confidence. Thank you for always being there for me!

Lastly, I would like to thank my family for all their love and encouragement! For my parents and grandparents who raised me with love and supported me in all my pursuits. For my brother who always made me smile whenever I needed it the most. And for my loving and supportive fiancé Laszlo Horvath whose love and encouragement during this Ph.D. is so appreciated. Thank you!

Table of Content

List of Tables

List of Figures

1. Introduction

1.1. Research Background

The primary purpose of this study is to investigate if different levels of Lean implementation in three sub-segments of the transportation equipment manufacturing industry (NAICS 3361 - 63) are associated with different operational and financial outcomes. Special attention is given to Lean implementation in accounting and finance and its impact on business results. In this study, Lean refers to a management concept originating from the Toyota Production System (TPS), a strategic management initiative credited with improving productivity, quality, supply chain efficiency, and speed of new product development, among other things (Byrne and Womack 2013, Shimokawa et al. 2009, Emiliani et al. 2003, Womack and Jones 1996, Womack et al. 1990).

During the 1970s and beyond, the Toyota Motor Company became "…*Japan's number one profit maker…* (Shingo and Dillon 1989, p. xix)," a feat that many credit to the development, implementation and practice, and continuous development of TPS (Liker 2003, Emiliani et al. 2003). Starting in the 1970s, Toyota began to outperform its U.S. competitors in terms of product quality, on-time delivery, and reliability, among other things (Shingo and Dillon 1989). While U.S. businesses had focused on improving profitability by cutting costs and increasing sales volume, the Japanese persistently pursued waste reduction, quality improvements, and respect for their employees as an integral part of their Lean business strategy (Shah and Ward 2007). Then, starting in the 1980s, when Toyota was making inroads against their U.S.

competitors, the U.S. Federal Government launched a research project to investigate production methods used in the motor vehicle industry worldwide. This research project revealed and acknowledged the superiority of the Japanese production systems, and especially the Toyota Production System (Womack et al. 1990). Starting from the 1990s, U.S. businesses began to learn from Japanese masters in the practice of Lean ("sensei") in an attempt to replicate the highly publicized Japanese success stories. As a result, learning from these sensei, many U.S. motor vehicle manufacturers and their suppliers started their own Lean journeys and later Lean was implemented in other industry segments as well. Success stories, some stemming from the world's leading organizations, such as Boeing, Goodyear, Watlow, and MarquipWardUnited, increased expectations of achieving impressive results through the implementation of Lean practices (Koenigsaecker 2009, Emiliani et al. 2003, Womack and Jones 1996).

However, reports about Lean implementations have not only been positive. Reasons for not achieving the expected outcomes include lack of top management commitment, lack of team autonomy, and lack of organizational communication, among others (Scherrer-Rathje et al. 2009). Also, as Emiliani et al. (2003) pointed out, companies transforming only selected parts of their business using a sequential approach over an extended period of time may not achieve the expected results. Indeed, some companies have stopped their Lean transformation due to disappointing results or transformational difficulties, causing confusion as to whether Lean is a pathway to improved performance (Scherrer-Rathje et al. 2009).

1.2. Research Problem

Today, numerous U.S. companies have made a commitment to Lean with the implied belief that their commitment will lead to improved operational and financial performance that can be objectively measured. Organizations understandably desire to have "…*Customers willing to pay; investors willing to invest; communities willing to support; and employees willing to commit their trust, confidence, and careers*… (Miller 2012, p. 18)" while assuring long-term business sustainability. All these outcomes can supposedly be achieved through successful Lean transformation efforts and the continuous practice of Lean. Becoming mature in Lean, however, requires time and commitment from every level of the company. Excluding supporting functions, such as administration or accounting, from the Lean transformation, may limit the effectiveness of improvement activities and may result in lower performance outcomes than expected (Fullerton et al. 2013, Maskell and Baggaley 2006). However, with or without the inclusion of all support functions, previous studies fall short of proving that different levels of Lean implementation correlate positively with the organization's operational and financial performance (Fullerton et al. 2013, Fullerton and Wempe 2009, Olsen 2004). Therefore, the **first objective** of this research is to investigate whether the higher level of Lean implementation along four business dimensions (leadership, manufacturing, accounting and finance, supplier and customer relationship) of transportation equipment manufacturing facilities (NAICS 3361-63) result in better operational and financial performance.

Most companies start the Lean transformation in the manufacturing area and later extend the transformation to supporting functions of the business, such as sales and marketing, new product development, or accounting, to name a few. Although, in the past decade, numerous academic and industry experts contributed to the evolution of Lean, the existing research falls short on providing evidence of the impact on a business' performance from Lean implementation in the accounting and finance area. Therefore, the **second objective** of this research is to investigate whether the higher level of Lean implementation in the accounting and finance dimension of transportation equipment manufacturing facilities (NAICS 3361-63) result in better accounting, operational, and financial performance.

Many manufacturing companies worldwide are working hard to implement Lean. Existing literature indicates that manufacturing facilities operating in different contexts, e.g., in different environmental landscape and organizational structures may pursue a different route to implement new, state of the art management practices and may present different business performance (Cua 2000, Shah 2002, Olsen 2004). Therefore, the **third objective** of this research is to investigate whether contextual factors effect transportation equipment manufacturing performance and the level of Lean implementation. Moreover, this study aims to investigate whether and how these contextual factors may strengthen or weaken the link between the level of Lean implementation and performance.

1.3. Research Methodology

This dissertation starts out with a literature review of relevant operations management concepts with a focus on Lean and then reviews the various constructs considered being essential for a successful Lean transformation. Also, the foundations of designing and collecting key performance metrics that can quantify the effect of Lean on a business are discussed.

Following this first theoretical review of the state-of-the-art, a nationwide survey is performed to test the research propositions. The survey, using an online survey instrument, is to empirically test the research propositions on a sub-segment of the transportation equipment manufacturing industry. The survey instrument comprises of three sections, including Lean transformation efforts, performance measures, and general characteristics. The collected data is transformed using multiple imputation methods and a selection of regression models and profile deviation analysis are used to test the hypotheses of the study.

1.4. Organization of the Dissertation

The dissertation is organized into nine chapters. Chapter one (1.0 Introduction) includes an introduction into the background, objectives, and methodology of this research. Chapter two (2.0 Literature Review) includes the review of literature on Lean and other relevant operations management concepts. Special focus is given to Lean implementation in accounting and finance. Also, the foundations of designing and collecting key performance metrics that can quantify the effect of Lean are discussed. Furthermore, the various statistical tools used in this research are reviewed. Chapter three (3.0 Research Hypotheses) defines the research hypotheses of this study in detail. Chapter four (4.0 Methodology) describes the research methodology used to test and analyze this study's hypotheses and discusses the limitations of this study. Chapter five (5.0 Results) discusses the results of this research including Lean implementation's impact on manufacturing performance; the performance impact of Lean implementation in accounting and finance; and the effects of contextual variables on implementing Lean and on performance. Chapter six (6.0 Discussion) synthesizes and discusses the findings presented in the results chapter. Chapter seven (7.0 Summary and Conclusions) summarizes the findings, draws conclusions, and provides directions for future research.

References

Byrne, Art, and James P. Womack. 2013. *The Lean Turnaround: How Business Leaders Use Lean Principles to Create Value and Transform Their Company*. New York, NY: McGraw-Hill Companies. pp. 200.

Cua, Kristy O. 2000. A Theory of Integrated Manufacturing Practices: Relating Total Quality Management, Just-in-Time and Total Productive Maintenance. Doctor of Philosophy, Minneapolis, MN: University of Minnesota. pp. 224.

Emiliani, Bob, David J. Stec, Lawrence Grasso, and James Stodder. 2003. *Better Thinking, Better Results : Using the Power of Lean as a Total Business Solution*. 1st edition. Kensington, CT: Center for Lean Business Management. pp. 313.

Fullerton, Rosemary R., Frances A. Kennedy, and Sally K. Widener. 2013. Management Accounting and Control Practices in a Lean Manufacturing Environment. *Accounting, Organizations and Society* 38 (1): 50–71.

Fullerton, Rosemary R., and William F. Wempe. 2009. Lean Manufacturing, Non-Financial Performance Measures, and Financial Performance. *International Journal of Operations & Production Management* 29 (3): 214–40.

Koenigsaecker, George. 2009. *Leading the Lean Enterprise Transformation.* 2nd edition. Boca Raton, FL: Productivity Press. pp. 264.

Liker, Jeffrey K. 2003. *The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer*. 1st edition. New York, NY: McGraw-Hill Companies. pp. 330.

Maskell, Brian H., and Bruce L. Baggaley. 2006. What's Lean Accounting All About? *Target Magazine*. 22 (1): 35-43.

Miller, Robert D. 2012. The Shingo Prize for Operational Excellence - Model & Application Guidelines. Logan, UT: Jon M. Huntsman School of Business, Utah State University. pp. 37.

Olsen, Eric Oscar. 2004. Lean Manufacturing Management: The Relationship between Practice and Firm Level Financial Performance. Doctor of Philosophy, Columbus, OH: The Ohio State University. pp. 220.

Scherrer-Rathje, Maike, Todd A. Boyle, and Patricia Deflorin. 2009. Lean, Take Two! Reflections from the Second Attempt at Lean Implementation. *Business Horizons* 52 (1): 79–88.

Shah, Rachna. 2002. A Configurational View of Lean Manufacturing and Its Theoretical Implications. Doctor of Philosophy, Colombus, OH: The Ohio State University. pp. 278.

Shah, Rachna, and Peter T. Ward. 2007. Defining and Developing Measures of Lean Production. *Journal of Operations Management* 25 (4): 785–805.

Shimokawa, Koichi, Takahiro Fujimoto, Brian Miller, and John Shook. 2009. *The Birth of Lean - Conversations with Taiichi Ohno, Eiji Toyoda, and Other Figures Who Shaped Toyota Management.* 1st edition. Cambridge, MA: The Lean Enterprise Institute. pp. 284.

Shingo, Shigeo, and Andrew P. Dillon. 1989. *A Study of the Toyota Production System from an Industrial Engineering Viewpoint*. Rev sub edition. Cambridge, MA: Productivity Press. pp. 296.

Womack, James P., Daniel T. Jones, Daniel Roos, and Massachusetts Institute of Technology. 1990. *The Machine That Changed the World : Based on the Massachusetts Institute of Technology 5-Million Dollar 5-Year Study on the Future of the Automobile*. 1st edition. New York, NY: Rawson Associates. pp. 352.

Womack, James P., and Daniel T. Jones. 1996. *Lean Thinking: Banish Waste and Create Wealth in Your Corporation*. 1st edition. New York, NY: Simon and Schuster. pp. 352.

2. Literature Review

By developing, implementing, practicing, and continuously improving their business principles, the Toyota Motor Company has delivered remarkably consistent success over the past 70 years (Shimokawa et al. 2009). Most new business principles behind the Toyota Production System (TPS) have been generated by overcoming crises along the company's evolution; therefore, the following sub-chapter will discuss the evolution of the TPS, and how it lead to the incubation and emergence of Lean throughout the world.

2.1. The Evolution of the Toyota Production System (TPS) and the Emergence of Lean

In the 1930s, the Toyoda family, which was originally active in the textile machinery business, was encouraged by the Japanese government to enter the motor vehicle business (Womack et al. 1990). Thus, the family founded the Toyota Motor Company in 1937 to produce primarily military trucks for the government during World War II (Womack et al. 1990). After the War, the company intended to stay in the motor vehicle business but faced challenges due to small and fluctuating domestic demand, differing customer needs, limited availability of capital and technology, and a strong presence of company unions (Womack et al. 1990). An even bigger challenge was that U.S. automakers, at that time, were ten times more productive than Japanese automakers, which created a need for the Toyota Motor Company to reconsider their entire production system (Shimokawa et al. 2009). Major milestones of TPS are summarized in Figure 1.

To improve their production, Toyota in the late **1940s** started to conduct basic **Kaizen events** (Kaizen, a Japanese word, standing for "*good change*" and used to describe an improvement event) on the shop floor (Shimokawa et al. 2009). Today, at Toyota, Kaizen events are scheduled minutes after problems are encountered rather than days or weeks later. Such immediate Kaizen events, which start as soon as a problem is detected and employees tackle problems using the Plan–Do–Check–Act (PDCA) problem solving approach, provide the basis of operation for Toyota's worldwide organization (Shimokawa et al. 2009). Early on, for Toyota to be able to take better control of events happening on the shop-floor, managers started to develop **standardized work procedures** for each job and posted them at each workstation (Shimokawa et al. 2009). These standardized work procedures served and still serve as a framework for Kaizen events allowing managers and employees to come up with new ideas for improving the standards and to evaluate them systematically using the PDCA problem solving approach (Shimokawa et al. 2009). Standardized work procedures, based on Taylor's framework, set the pace of the work based on what an average worker can handle for a full day (Shimokawa et al. 2009, Taylor 1939). By continuously eliminating waste from processes on the shop-floor and continuously improving standardized work, Toyota was able to raise production efficiency by approximately six times from 170 cars to 1,000 cars (Shimokawa et al. 2009).

Raising productivity six times, however, resulted in a large amount of unsold finished goods inventory (Shimokawa et al. 2009). Toyota not only had an issue with its finished goods inventory but also with its raw material supply. Suppliers produced vehicle parts in large batches and delivered them to Toyota whenever they happened to have them ready (Shimokawa et al. 2009). By not knowing exactly when to expect suppliers to deliver vehicle parts, Toyota was forced to hire three times more employees than should have been necessary to ensure production (Shimokawa et al. 2009). Consequently, employees often spent two-thirds of their work time waiting for parts (Shimokawa et al. 2009). To resolve the issue of unbalanced inventory and work, Toyota needed to find a way to ensure that the parts needed to arrive at the time and place they were needed (Shimokawa et al. 2009). This method, today referred to as **Just-in-Time (JIT) production**, was rolled out from department to department within the company and later it was extended throughout Toyota's supply chain. Indeed, extending JIT throughout the supply chain vastly distinguished Toyota from its competitors in terms of productivity and on-time delivery (Sugimori et al. 1977). Managers of Toyota realized that only their final assembly department knows the timing and quantity of parts required. Toyota ultimately allowed final assembly to request the parts needed from the preceding production processes, thereby creating pull, e.g., parts are pulled from one station into the next based on final demand (Shimokawa et al. 2009, Monden 1998, Sugimori et al. 1977). To communicate the need for parts between two processes, Kanban cards, e.g., cards that serve as a signal to preceding processes to produce and deliver a new shipment of parts, were introduced (Shimokawa et al. 2009, Monden 1998, Sugimori et al. 1977). By using JIT, Toyota could **split up large batches** into small lots so that only the parts that are necessary are kept in stock between two processes (Shimokawa et al. 2009). Reducing the lot size, however, required machine set-up times to be reduced dramatically. To resolve that issue, Toyota developed **quick changeover procedures** by eliminating wasteful activities and separating changeover procedures into external setups involving activities that can be performed while the machine is running and before the changeover begins and internal setups involving activities that take place when the machine is stopped (Shimokawa et al. 2009). Also, the company started reshaping its **factory layout** by reorganizing machines and processes into a sequence that allowed production to **flow** in the 1940s (Shimokawa et al. 2009, Monden 1998)**.** Once production flows, **leveling** production, e.g., taking the total number of orders and leveling them out over time in a sequence so that a consistent number of products and a similar product mix are being produced each day by both volume and product mix was necessary (Shimokawa et al. 2009, Monden 1998). Sequencing and leveling requires machines and **well-trained operators** who are able to handle multiple tasks, identify waste and problems, and who are trained in continuous improvement practices (Shimokawa et al. 2009, Monden 1998).

At Toyota, the entire production system is built around people (Shimokawa et al. 2009, Sugimori et al. 1977). All employees are treated with respect, they take responsibility, and are given authority (Shimokawa et al. 2009, Sugimori et al. 1977). For example, if an employee feels unable to keep up with the pace of production or detects a defective part, he is allowed to **stop the entire line** by pushing a button (called an "*Andon*") without any penalty (called **Jidoka;** Shimokawa et al. 2009, Sugimori et al. 1977) .

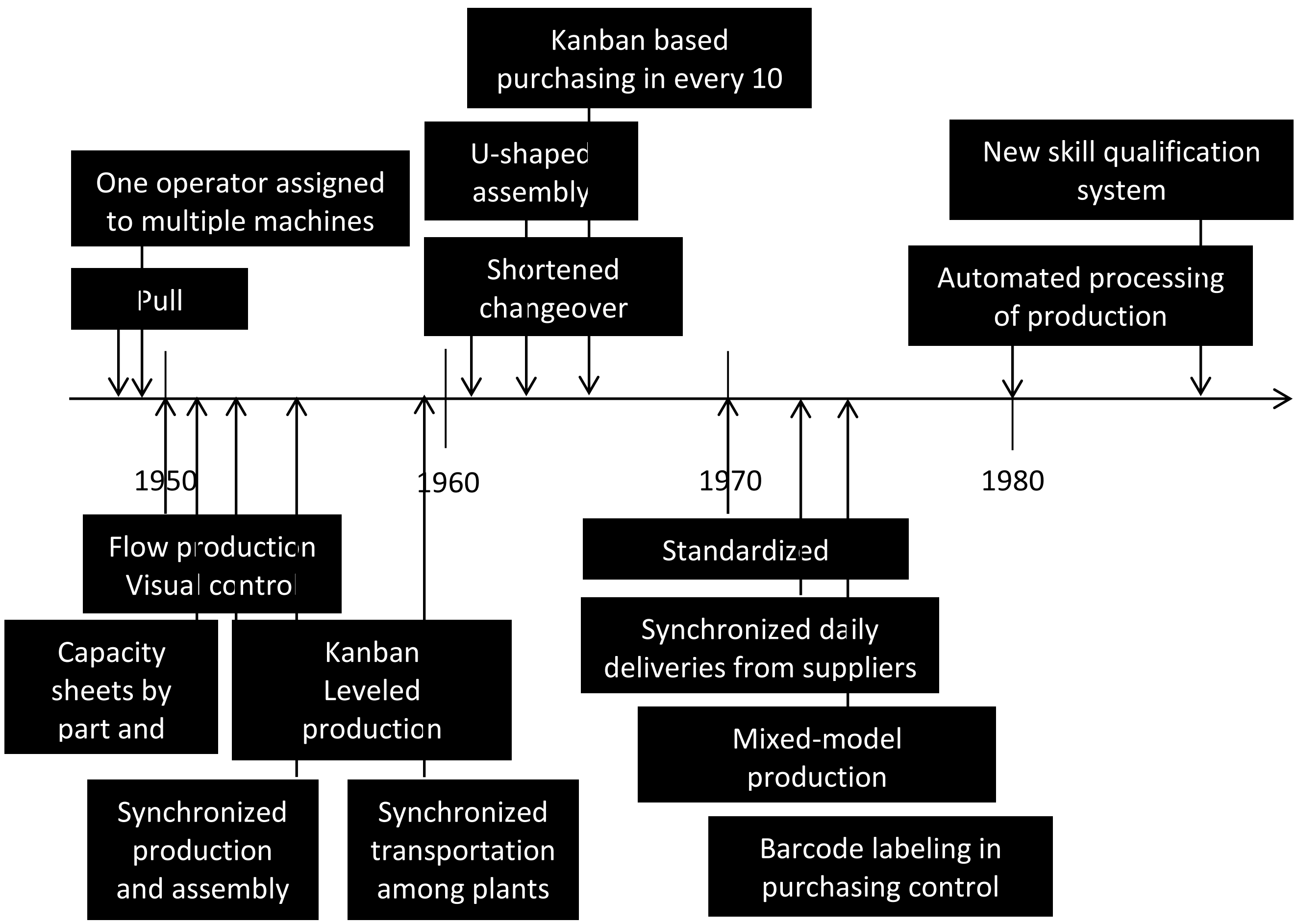


Figure 1: **Evolution of the TPS (adopted from Shimokawa et al. 2009)**

TPS being designed in an environment where resources were scarce has a unique focus on how resources are used with a particular focus on the elimination of waste. The system is so well designed from the standpoint of managing people, systems, and processes that it enabled historic gains in productivity and quality in the second half of the 20th century (Shimokawa et al. 2009). Toyota's success generated considerable interest from businesses, academics, and practitioners about its manufacturing and management practices. In the early 1990s, Womack et al. (1990) presented a comprehensive overview of the TPS to the western world. Their book, "*The Machine that Changed the World*" was the outcome of a research project funded by the

U.S. federal government. This project started in 1984 and the objective was to better understand the new Japanese management system, which enabled Toyota's superior performance (Womack et al. 1990). The term Lean was coined by John Krafcik, a team member working with Womack and Jones on the project. John indicated that the TPS is Lean because *"…It uses less of everything compared with mass productions – half the human effort in the factory, half the manufacturing space, half the investment in tools, half the engineering hours to develop a new product in half the time. Also it requires keeping far less than half the needed inventory on site, results in many fewer defects and produces a greater and ever growing variety of products…* (Womack et al. 1990, p.13)." Today, it is widely acknowledged that by applying Lean, companies can improve their performance through carefully defining value from a customer's perspective and by constantly identifying and eliminating waste, e.g., non-value-adding processes, inventories, and behavior (Shah and Ward 2007, Wood et al. 2004, Shah and Ward 2003, Pil 1996, MacDuffie 1995, Krafcik 1988).

To get a better understanding on how the Toyota Motor Corporation can continuously provide the best quality, lowest cost, and shortest lead time through the elimination of waste, individual elements of the TPS will be discussed in the next sub-chapter.

2.2. Individual Elements of the Toyota Production System (TPS)

The Toyota Production System (TPS) has been established through decades of continuous improvement with the goal of creating and delivering quality products to customers in the most effective and efficient way possible (Liker 2003). This goal is best reached through a production system where processes do not work in isolation but work as a comprehensive system (Liker 2003). The TPS House (illustrated on Figure 2) is a reflection of a structural system that represents the interdependence of its components; meaning that if one element of the system is missing or not strong enough, the entire system will face the consequences. The TPS House was developed by Toyota's management to visualize and explain Toyota's production system (TPS) to their employees and suppliers (Liker 2003). The TPS House consists of five major sections; a foundation, two pillars, a central section, and a roof (Liker 2003).

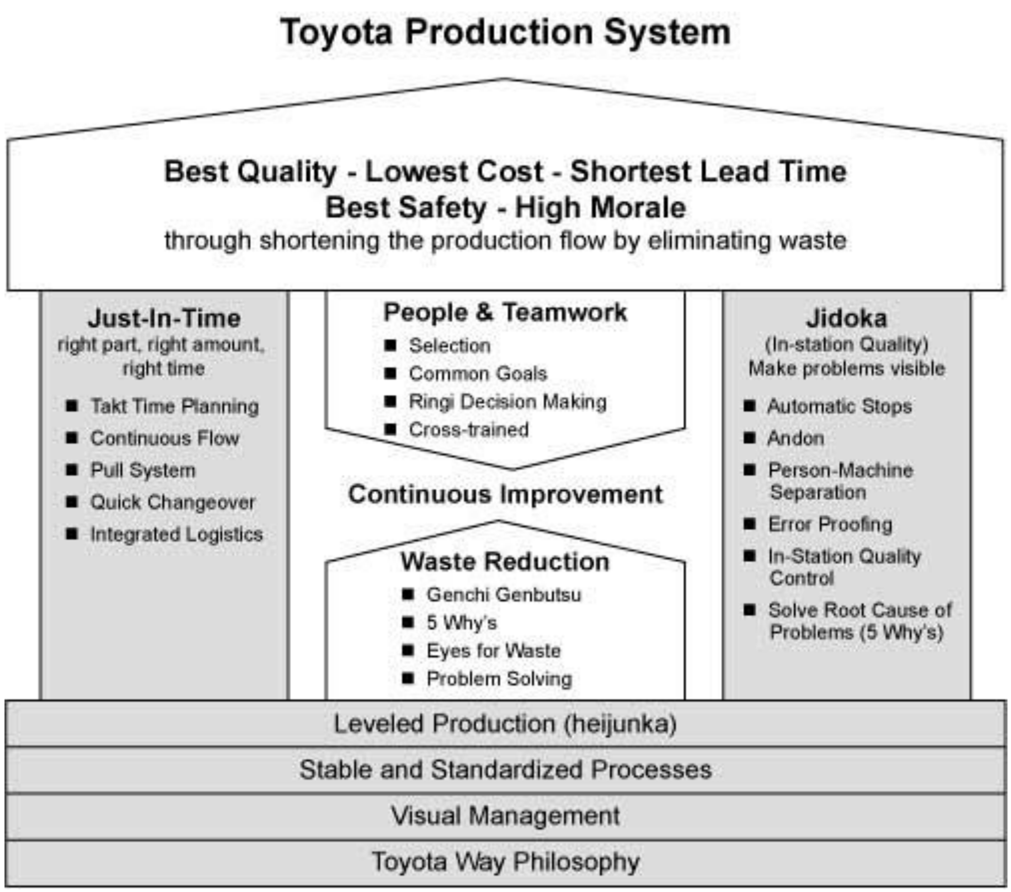


Figure 2: The Toyota Production System (TPS) House (Liker 2003, p.33)

The **foundation** of the TPS House, like the foundation of a real house, needs to be strong enough to support the walls, the center of the house, and the roof (Liker and Hoseus 2008, Liker 2003). As Liker (2003) and Liker and Hoseus (2008) explain, the effort invested into the

House's foundation will create long-term sustainability of the system. The "*Toyota Way Philosophy"* of generating value for the customer, society, and the economy represents the basis of this foundation. It is a philosophical sense of purpose, a true north that the organization is heading towards in the long-term. Everyone at Toyota must understand this philosophy to produce value and move the company forward. To help everyone understand how work is performed and whether it is deviating from the standard, "*visual management*" control is used at Toyota (Liker and Hoseus 2008, Liker 2003). Using visual performance indicators at the work place provides immediate feedback to all employees and managers on whether the actual production outcome differs from the expected outcome so as to expose abnormalities immediately that they can be eliminated permanently and consistent output can be generated (Liker 2003, Monden 1998). To generate consistent output, processes must be "*stable and standardized*" (Liker 2003, Womack and Jones 1996). At Toyota, stability and standardization adds discipline to the culture and provides a baseline for continuous improvement by allowing employees to familiarize themselves with current best practices and providing them with opportunities to creatively improve the standard (Liker 2003, Spear and Bowen 1999, Womack and Jones 1996). Once a standard is improved, it is incorporated into a new standard and becomes the new baseline for further improvement. To create stability and make standardization easier, it is necessary to prevent fluctuation that occurs in production and in supplies by using "*leveled production*" (Heijunka in Japanese, Shimokawa et al. 2009, Liker 2003, Monden 1998). Toyota mixes its products in each production batch according to customer demand but ensures that there is an inventory of parts proportional to the fluctuation in demand (Shimokawa et al. 2009, Liker 2003, Monden 1998). To level out the production, the company needs to make sure that components are sequenced and are available in the right quantity and at the right time, while changeover periods for essential processes are as short as possible (Shimokawa et al. 2009, Liker 2003, Monden 1998).

The **two pillars** of the TPS House are represented by Just-in-Time (JIT) and Jidoka (Figure 2). "*Just-in-Time*" means producing only what is needed, at the time, the place, and in the amount it is needed (Ohno 1988). In a manufacturing environment, Just-in-Time translates into supplying the production line with the required number of parts so that all orders can be assembled on schedule (Liker 2003, Monden 1998, Ohno 1988). At Toyota, Just-in-Time is based on "*pull*," meaning that the production is driven by customer demand (Liker 2003, Womack and Jones 1996, Ohno 1988). Once an order is received, production instructions are sent to the line and assembly begins. The assembly line then automatically replaces the parts that were used during the production by retrieving the same number of parts from the preceding processes (Liker 2003, Womack and Jones 1996, Ohno 1988). The preceding processes then must be fed with the same numbers of all parts and produce the parts that were retrieved by an operator from the downstream process (Liker 2003, Womack and Jones 1996, Ohno 1988). Applying pull effectively means relying on a production control system called a "*Kanban*" system (Monden 1998). In a Kanban system, Kanban cards with selected product information, e.g., product's name, code, and storage location are used, so when a process refers to a preceding process to retrieve parts, it uses Kanban cards to communicate which parts have been used and must be replenished (Monden 1998). To produce orders based on customer pull and to supply all necessary parts to each process on the assembly line on-time, the rate of customer demand must be calculated (Rother et al. 1999, Womack and Jones 1996).

The rate of customer demand is called "*takt time*" and is calculated by dividing the available work time per day in seconds with the daily customer demand in units (Rother et al. 1999, Womack and Jones 1996). Takt time is responsible for synchronizing the pace of production with customer demand (Rother et al. 1999, Womack and Jones 1996). In order to produce according to takt time, the product must "*flow*" through the entire value stream continuously and smoothly from the beginning to the end without interruptions, delays, waiting times, or rework within or between process steps (Womack et al. 2002, Rother et al. 1999, Womack and Jones 1996). At Toyota, to deal with high variability of products and still ensure Just-in-Time production, quick changeover procedures are introduced to reduce the time it takes to change a line or machine from running one product to the next (Yash and Nagendra 2012, Monden 1998). The main purpose of Just-in-Time production is to minimize all inventory levels, including raw material, work in process, and finished goods inventories while freeing up resources and capacity to improve efficiency (Liker 2003, Monden 1998, Ohno 1988).

The second pillar of the TPS House, "*Jidoka,*" translates as automation with human touch (Shimokawa et al. 2009, Sugimori et al. 1977). Jidoka is a cost-effective quality control technique that combines automation with human interaction to detect abnormalities and take immediate actions (Shimokawa et al. 2009, Sugimori et al. 1977). The automation side of Jidoka means designing equipment in a way that they "*automatically stop*" when an abnormality occurs and draw attention to the problem (Shimokawa et al. 2009, Sugimori et al. 1977). The automatic stop becomes available through "*error proofing*" (Poka-Yoke in Japanese) which means that in-built quality sensors prevent errors from happening (Monden 1998). Once an abnormality occurs, the Poka-Yoke device automatically stops the line, while the Andon device provides an illuminated signal, a sign, or alarm to the operator that highlights the area where actions need to be taken (Monden 1998, Womack and Jones 1996). The "*person-machine separation*" means that a person needs to react when a machine indicates that actions need to be taken. The human side of Jidoka means empowering employees with the ability to interrupt the production line when something suspicious occurs, correcting the problem immediately, and preventing reoccurrence (Liker 2003). To correct a problem permanently requires finding and understanding the "*root cause*" of the problem and identifying countermeasures for eliminating it to ensure that the same problem will never occur again (Liker 2003). The overall purpose of Jidoka is to ensure "*in station quality control*" meaning that the parts produced at each station must meet the company's quality standards before they get passed through to the next station (Liker 2003).

Continuous improvement is the heart, the **central section**, of the TPS House; it refers to a philosophy of "*continuously improving*" all processes and thereby continuously increasing productivity, quality, effectiveness and efficiency (Liker 2003). Knowing that all manufacturing processes are expected imperfect and problems are expected to continually surface (Liker and Hoseus 2008, Liker and Hoseus 2010, Liker 2003), one should never rest in improving what one has. Toyota has its employees mindset focused on continuously improving processes, finding problems, and resolving their root causes (Liker and Hoseus 2008, Liker and Hoseus 2010, Liker 2003). For people to find problems, however, "…*There must be a high level of trust that there will be no negative repercussions of surfacing problems and trust that if the company gets stronger all will benefit…*" (Liker and Hoseus 2010, p.27). Toyota strongly believes that being competitive fully depends on developing highly capable people with a high level of trust (Liker and Hoseus 2008, Liker and Hoseus 2010, Liker 2003). The competitiveness of Toyota as a business stems from their employees' dedication to the company's corporate philosophy and culture; therefore, the right people must be selected for the right position (Liker and Hoseus 2008, Liker and Hoseus 2010, Liker 2003). To develop an exceptional workforce, Toyota uses on-the-job training along with cross-training for all employees (Liker 2003). Toyota also sincerely believes in developing company leaders internally because this allows leaders to become the best teachers and role models of the company's philosophy (Liker 2003). The TPS is designed for employees to discover problems, identify "*waste,*" eliminate them permanently and thereby continually strengthen the system (Liker 2003). The best way of developing an eye for waste is to go to the place where the problem exists, grasp the problem in person, confirm the facts, and analyze root causes (Liker 2003, Womack and Jones 1996). Toyota uses many tools that help problem solving and waste elimination including A3 thinking, PDCA, Fishbone diagram, 5S, and 5 Why's just to mention some (Liker 2003, Womack and Jones 1996).

Finally, the **roof** of the TPS House represents what the customer wants (Liker 2003). Originally at Toyota, the roof symbolized delivering customers the best quality products and services at the lowest possible cost and in the shortest lead time through the continuous elimination of waste from the process (Liker 2003). Later high safety standards and high employee moral were added to the equation as well (Liker 2003).

2.3. Principles of Lean and the Role of Lean Accounting

Womack and Jones (1996) developed **five basic principles of Lean** (Figure 3) to help companies move towards their overall Lean goal of continuously reviewing and improving processes and to ensure that they continuously and consistently deliver value to their customers. These five principles allow companies to maintain a high level of services while being able to grow and adapt to a changing environment through implementing sustainable change (Womack and Jones 1996).

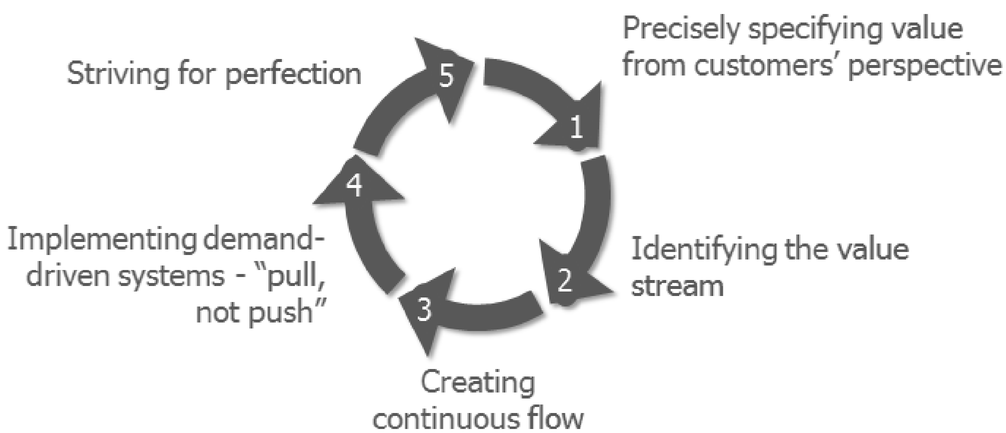


Figure 3: **Five basic principles of Lean developed by Womack and Jones (1996).**

2.3.1. Lean principles in a Manufacturing Environment

The **first principle** is to identify the company's customers and specify value from their perspective (Womack and Jones 1996). If value of a product or service is specified from the end customer's perspective. It is also easier to recognize that only a small fraction of the total time and effort in any company actually adds value for the end customer, and it is easier to target waste and non-value added activities for removal (Womack and Jones 1996).

An activity is considered value added if the customer is willing to pay for it (Womack et al. 2002, Rother et al. 1999, Womack and Jones 1996). If an activity is necessary from the production's or service's point of view, but the customer is not willing to pay for it, it is considered a non-value added activity that should be eliminated or reduced to a minimum (Womack et al. 2002, Rother et al. 1999, Womack and Jones 1996). If an activity is not necessary from the production's or service's point of view and the customer is not willing to pay for it, it is considered to be waste (**Muda** Japanese) and should be eliminated (Womack et al. 2002, Rother et al. 1999, Womack and Jones 1996).

To begin eliminating waste from any organization, one should start with identifying whether there is more variation in the organizations' activities than required by its customers (Womack 2006). Then, variations in customer demand can be smoothened internally by eliminating irregularities or unevenness (**Mura** Japanese) in the production process, such as fluctuating production volumes or unbalanced schedules, among other issues (Womack 2006). In the production process, the overburdening of equipment can result in machine down time, scrap, or defect; while the overburdening of employees can result in safety, health, and/or quality issues (Womack 2006). Therefore, overburdening (**Muri** in Japanese) of equipment and employees should be eliminated by balancing the manufacturing pace to allow employees and equipment sufficient time to achieve the correct standard of work (Womack 2006). Once unevenness (Mura) and overburden (Muri) are eliminated, waste (Muda) can be removed much faster from the organizations' activities (Womack 2006).

Within the context of manufacturing systems, waste can be divided into seven sources, including overproduction, waiting, excess transport, excess processing, excess inventory, unnecessary motion, and defects (Hicks 2007, Rother et al. 1999, Womack and Jones 1996, Ohno 1988). These seven sources of waste (referred to as "*The seven wastes*") were first identified by Ohno (1988) at Toyota and later reported by Womack and Jones (1996). Overproduction occurs when more products are being made than required at the time. Waiting occurs when an employee becomes inactive in a downstream process because an activity in the upstream process is not delivering on time. These idle employees may perform activities that either do not add value, or result in overproduction. Excess transportation occurs when work in process (WIP) materials are being moved from one operation to another. Transportation should be minimized as it adds time to the process and creates handling issues. Excess processing or incorrect processing occurs when more work is being done than necessary due to rework or reprocessing, or when tools and standards are more complex, more expensive, or less precise than expected. Excess inventory of raw materials, work in process, and finished goods occur when products are not made to order. Excess inventory requires additional handling and space, and can hide issues related to late deliveries and excess processing, among other things. Excess inventory can also be considered as a capital outlay that if not processed immediately, generates no income. Unnecessary motion occurs when employees need to carry out extra steps or movements to accommodate inefficient layouts, unorganized workspace, and broken equipment, among many other things. Defects occur when products are not produced based on customer specifications or expectations and therefore need to be reworked or reprocessed (Hicks 2007, Rother et al. 1999, Womack and Jones 1996, Ohno 1988). In addition to these seven sources of wastes, Liker (2003) named another source of waste, an eighth source of waste called underutilized people. Underutilized means that companies fail to utilize the ideas and creativity of their employees for improvement purposes (Womack and Jones 1996).

Within the context of an office environment, waste can be related to people, processes, information, and assets (Lareau 2002). According to Lareau (2002, p.22) "*people waste*" occurs when company leaders and managers fail to structure the work environment properly resulting in the underutilization or misuse of work powers (Lareau 2002). "*Process waste*" occurs when the organization's processes are not designed or executed properly (Lareau 2002, p.25). "*Information waste*" occurs when the necessary information is not available at a time when it is needed (Lareau 2002, p.32). Finally, "*asset waste*" occurs when an organization does not utilize its resources, e.g., materials, facilities, equipment, employees, etc, properly (Lareau 2002, p.35). Generally, removing waste consists of six major steps (McVay et al. 2013). At first, a list of all activities and processes need to be compiled. Second, the time and resources consumed by each activity should be identified. Third, a customer value analysis should be conducted for each activity to identify how the outcomes of those activities are used and whether or not they are relevant in a Lean environment. Fourth, the cost and impact of change for the selected activity(s) must be taken under consideration. Then, a decision can be made on which activity(s) are the best to begin the improvement with. Lastly, an action plan needs to be prepared for each continuous improvement project. The organization must remove all wastes from its processes to be able to generate value for its customers and become a time-based competitor (Liker 2003, Womack and Jones 1996).

The **second principle** is to identify and map the value stream (Womack and Jones 1996). The value stream consists of a set of activities across all parts of the organization that jointly contribute to deliver the product or service from raw materials to the hand of the customer (Womack et al. 2002, Rother et al. 1999, Womack and Jones 1996). Generally, two types of value streams can be distinguished: an order-fulfilment value stream and a new product development value stream (Baggaley and Maskell 2003a, Baggaley and Maskell 2003b). When value is created in the process for fulfilling an order involving sales, customer service, configuration, purchasing, manufacturing, shipping, cash collection, and after-sales support, is called an order-fulfillment value stream (Baggaley and Maskell 2003a, Baggaley and Maskell 2003b). When value is created in the processes for identifying, designing, and launching new products and services to market is called a new product development value stream (Baggaley and Maskell 2003a, Baggaley and Maskell 2003b). Mapping the value stream means visualizing the flows of materials and information as they are now, and envisioning a future state with better performance and a theoretical, perfect ideal state with the best performance (Womack et al. 2002, Rother et al. 1999, Womack and Jones 1996). The purpose of value stream mapping is to break down operational issues, such as hidden problems or bottlenecks to a product level, which allows managers to react more easily (Womack et al. 2002, Rother et al. 1999, Womack and Jones 1996). Mapping the value stream requires being physically present at the place where the product is produced or the service is provided (Gemba Japanese). Walking the Gemba helps management to truly understand the value stream and its problems and links the actual work in the process to the results of the process (Womack and Shook 2011). The first step of value stream mapping is to create a current-state value stream map that enables managers and employees to see the current flow of materials towards the customer and the current flow of information back from the customer while quantifying current quality rates, time, and waste through the value stream (Womack et al. 2002, Rother et al. 1999, Womack and Jones 1996). The current-state value stream map shows where obstacles are in the process and where material and information accumulates, and helps to identify and prioritize areas for improvement (Womack et al. 2002, Rother et al. 1999, Womack and Jones 1996). The current-state value stream map serves as a basis for a future-state value stream map (Womack et al. 2002, Rother et al. 1999, Womack and Jones 1996). The future-state value stream map eliminates the sources of waste identified while improving quality and customer response (Womack et al. 2002, Rother et al. 1999, Womack and Jones 1996). Once a future-state becomes a reality, managers and employees may continue drawing further future-state maps until they reach their ideal state (Womack et al. 2002, Rother et al. 1999, Womack and Jones 1996).

Once, the value stream map is done, most organizations discover that only approximately one percent of all activities add value (Womack et al. 2002, Womack and Jones 1996). Therefore, the **third principle** is to take those value-added steps and reorganize them into a tight sequence allowing the product to flow toward the customer (Womack and Jones 1996). Creating continuous flow (also referred to as single piece flow or one piece flow) requires moving items directly from one processing step to the next, one piece at a time by balancing out the production and lowering inventory levels (Rother and Harris 2001, Womack and Jones 1996). Each processing step works on one piece only, on the one that the next step needs, just before that next step needs it (Rother and Harris 2001, Womack and Jones 1996).

Processing one piece at a time instead of processing pieces in batches allows the organization to keep the amount of materials, equipment, and people to the minimum; shortens lead time; assures better communication between operations; and helps visualize and eliminate root causes of abnormalities (Rother and Harris 2001, Womack and Jones 1996).

The **fourth principle** is to respond to customer pull – meaning that as customers consume products, it signals the upstream manufacturing processes to replenish the items consumed (Womack and Jones 1996). Pull means that no one in the upstream process should produce any items until the downstream process asks (signals) for it (Smalley 2004, Womack and Jones 1996). Toyota uses a "*Kanban system*" for signaling purposes, where a production Kanban authorizes the production of a specific item, in a specific quantity, while the withdrawal Kanban authorizes movement of a container from one stock location to another (Smalley 2004, Womack and Jones 1996). Using a Kanban based pull system allows organizations to minimize overproduction, shorten lead times, lower inventory levels, and lower space requirements (Smalley 2004, Womack and Jones 1996).

The **fifth principle** is striving for perfection (Womack and Jones 1996). The implementation of the first four principles requires radical reorganization of individual processes; however, as all steps are linked together, the benefits of the transformation become truly substantial (Womack and Jones 1996). The more times the circle is completed, the more layers of waste become visible and the transformation process continues towards "*perfection,*" where every asset and every action creates value for the customer (Womack and Jones 1996).

The principles of Lean and, in particular, the removal of waste and pursuit of perfection can be applied to any business areas where "*products*" flow to meet the demand of the customer (Hicks 2007). This is certainly true for accounting and finance, where information flows and work is undertaken to add value to the information.

2.3.2. Lean Principles in an Accounting Environment

The five principles of Lean were initially developed for the primary value adding functions of the business (e.g., manufacturing); however, they can be applied for the non-value adding but necessary administrative functions (e.g., accounting and finance) as well.

Accounting and financial employees have two major responsibilities in regards to the **first principle** of identifying the company's customers and specifying value from their perspective. Since administrative functions are "non-value adding," all attempts must seek to ensure that the support necessary for primary functions is customer focused with the customer being primary value adding activities. In other words, administrative functions should never get in the way of creating value and their costs must be minimized through eliminating and simplifying administrative activities. Accounting and financial employees' primary responsibility is to contribute to the determination of target costs (Maskell and Baggaley 2003). Target costing requires connecting customer needs with product features by conducting market research, analyzing customer complaints, and gathering customer satisfaction information using a variety of marketing tools (Ansari et al. 2006, Maskell and Baggaley 2003). Once customer needs are understood, ideas can be developed as to how to incorporate those needs into the final product, thereby increasing the value of the product to the customer (Ansari et al.

2006, Maskell and Baggaley 2003, Swenson et al. 2003). This process requires a collective effort from all value stream areas. Accounting and financial employees' role in this process is to think about how the cost structure within each value stream will change with the introduction of a new product and how product features will affect the product's cost and the total value stream cost (Ansari et al. 2006, Maskell and Baggaley 2003, Swenson et al. 2003). Identification of changes required to the cost structure is crucial because customers must be willing to pay for the incremental costs (Swenson et al. 2003). To determine the new cost structure, the target cost of each component as well as the target cost of the end product has to be determined. The target cost is calculated by price minus profit (Ansari et al. 2006); thereby, the price and the profitability for each value stream have to be created (Maskell and Baggaley 2003). If there is a gap between the target cost and the actual cost, the accounting and financial employees should think about possible further Lean improvements to close the gap (Ansari et al. 2006, Maskell and Baggaley 2003, Swenson et al. 2003). It is necessary to plot costs against value to be able to bring value stream costs into line with target costs and creating an improvement plan for this reason (Maskell and Baggaley 2003). The second responsibility of accounting is to develop performance metrics to ensure that the organization's processes properly serve their customers (McVay et al. 2013). These performance metrics should support the organization's strategy, goals, and objectives and be applied at all levels of the organization including the cell level, value stream level, and enterprise level (Maskell and Baggaley 2003). Furthermore, these performance measures should be simple and easy to understand; timely and accurate; visual and disclosed to everyone; they also should motivate the right behavior (by using non-financial measures on the shop-floor and financial measures to control cash flow); measure processes and not people; and should encourage continuous improvement (Emiliani et al. 2003, Maskell and Baggaley 2003, Nightingale and Mize 2002).

In regards to the **second principle** of identifying and mapping the value stream, accounting and financial employees should assist value stream managers with their decision making by providing accounting information targets for all value streams. To provide value stream managers with the right accounting information, a value stream statement must be developed for each value stream. Developing a value stream statement starts with grouping costs into value streams rather than by departments by assigning all employees and machines to value streams with minimal overlap among value streams as it is shown on Figure 4 (McVay et al. 2013, Maskell and Baggaley 2003, Baggaley and Maskell 2003a, Baggaley and Maskell 2003b). Keeping the overlap among value streams minimal will make direct cost assignment possible and keep cost allocations to a minimal (McVay et al. 2013, Maskell and Baggaley 2003, Baggaley and Maskell 2003a, Baggaley and Maskell 2003b).

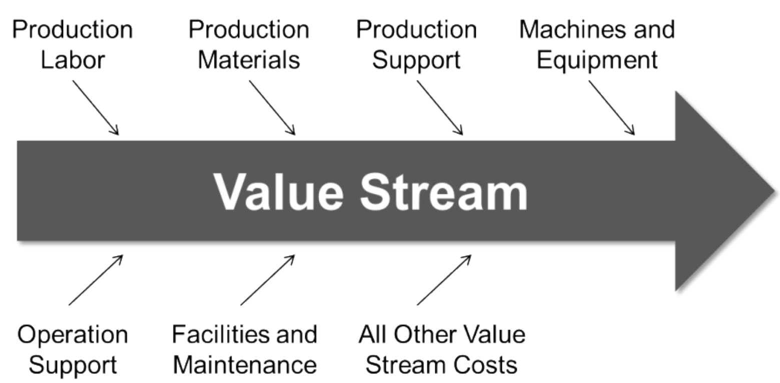


Figure 4: Value stream costing as developed by Makell and Baggaley (2003)

Employees assigned to value streams come from different functional areas with varying education and experience levels; therefore, accounting and financial employees need to develop value stream statements that can contribute to a common understanding of value stream processes, needs, and performance (McVay et al. 2013). Different value stream teams may have different information requirements, and therefore different revenue and cost categories, that support their work towards achieving their goals (McVay et al. 2013). A typical value stream statement information includes "…*Commissions, material, freight, wages and fringe benefits, supplies, tools and tooling, depreciation, travel and entertainment, outside services, promotion and advertising, warranty expense, and allocated facility expense*… (McVay et al. 2013, p.51)." Once all resources and costs are assigned to value streams, a standardized data collection procedure must be developed (McVay et al. 2013). Accountants and financial personnel need to make sure that the data is in a meaningful format by continuously seeking for feedback from the customers of their statements (McVay et al. 2013). Value steam statements should be reported on a weekly basis and should be posted on each value stream's metric board for everyone to see (McVay et al. 2013). Although, individual value stream statements may contain a deeper level of details for decision making, the same level of detail may not be necessary on the aggregated facility statement for top management (McVay et al. 2013).

The implementation of the **third principle** of continuous flow and the **fourth principle** of pull production require implementing changes in accounting and finance as well. Creating continuous flow and pull production, however, cannot be achieved from one day to another. It requires stable processes where machines are reliable and well maintained based on total-productive maintenance procedures. Also where employees are fully capable of doing their tasks and are cross-trained, and work procedures are standardized (McVay et al. 2013, Maskell and Baggaley 2003). Until processes are not stabilized and obstacles are not completely removed, inventory levels cannot be dramatically reduced as it is necessary to provide a buffer of inventory around bottleneck problems (McVay et al. 2013, Maskell and Baggaley 2003). However, as the transformation matures, inventory levels will drop substantially allowing accounting and financial personnel to transition from a standard costing system to a backflushing system (McVay et al. 2013, Maskell and Baggaley 2003). The backflushing system serves as an interim accounting system that eliminates the tracking of WIP conversion costs and records completed products as finished goods on standard costs. Then it still calculates variances between standard and actual costs and adjusts cost of goods sold accordingly (McVay et al. 2013, Maskell and Baggaley 2003). As products are produced based on customer demand, inventory comes under visual control of a Kanban system (McVay et al. 2013, Maskell and Baggaley 2003). Accounting and financial employees can support the development of the Kanban system by determining Kanban amounts and signals that trigger inventory replenishment (McVay et al. 2013, Maskell and Baggaley 2003). They also need to provide timely and visual information on inventory trends, inventory turns, throughput times, and on-time delivery (Maskell and Baggaley 2003, McVay et al. 2013). In a perfect world of one-piece flow "…*Raw material costs could be expensed as purchased, conversion costs could be expensed as incurred, and the value of finished goods would be recorded as cost of goods sold at the point of transfer of ownership to the purchaser*…" (McVay et al. 2013, p.61). To achieve continuous flow and pull production, the organization must also have the capacity to produce based on the rate of customer demand (McVay et al. 2013, Maskell and Baggaley 2003). Accounting and financial employees, therefore, have the responsibility of tracking productive, non-productive, and available capacity for each value stream (McVay et al. 2013, Maskell and Baggaley 2003). The type of capacity measured by accounting and financial employees (e.g., employee capacity, machine capacity) depends on what resources represent the biggest constraint to continuous flow and pull production (McVay et al. 2013, Maskell and Baggaley 2003). As the bottleneck determines the flow through the value stream, measuring capacity on the bottleneck process can provide information that guides the focus on Kaizen events that address issues restricting capacity (McVay et al. 2013, Maskell and Baggaley 2003). Turning non-productive capacity into available capacity allows the organization to increase revenue that can later be used to grow market share, introduce a new product, or just reassign, discard, or sell the available capacity (McVay et al. 2013, Maskell and Baggaley 2003).

To support the **fifth principle** of striving for perfection, accounting and financial employees need to become an integrated part of the Lean culture of continuous improvement (McVay et al. 2013, Maskell and Baggaley 2003). They can do this by actively participating in the organization's long-term strategic planning process by assisting top management developing capital financial policies to provide direction for the company that is in alignment with its true north (McVay et al. 2013, Maskell and Baggaley 2003). Once the company's long-term goals are defined, accounting and financial employees can help in developing quarterly strategy deployment plans (e.g., determining required production cycle times, create level schedules, plan equipment and employee capacity, etc.) to align strategies and action plans throughout the entire organization (McVay et al. 2013, Maskell and Baggaley 2003). In the short-term, accounting and financial employees are responsible for reviewing each value stream's operational and financial data, discussing issues of each value stream, and making decisions along with top managers in regards to the path forward to position the company to meet customer demand and profit targets (McVay et al. 2013, Maskell and Baggaley 2003).

An extensive literature search among scientific publications has been undertaken to understand the relevant principles and determinants of Lean that need to be implemented by companies to achieve the expected outcomes. The following sub-chapter introduces Lean principles and determinants used in survey-based research as well as assessment instruments to measure the level of Lean implementation in companies.

2.4. Determinants of Lean Used in Empirical Research

The identification of different levels of Lean implementation in a company using surveys requires careful identification and selection of key words that are frequently included and used to represent Lean in the existing literature. For the sake of this discussion, the terms "*principles*" and "*determinants*" are introduced where the term principles refers to fundamental propositions that serve as the foundation for Lean, while the term determinants refers to measurable elements of those principles that determine the nature of being Lean as presented by Ahlstrom and Karlsson (1996). Terms that are used for the same expression as principles include key drivers, lean production principles, bundles, components, and categories; while terms that are used for the same expression as determinants include practices, intermediate indicators, improvement programs, and elements. In the late 1990's, numerous articles have been published describing what Lean and its determinants are but many of these articles were only descriptive in nature or narrow in scope (Emiliani et al. 2003). Academics and practitioners interested in identifying key determinants of Lean mostly relied on comprehensive studies of various Lean experts or on anecdotal evidence presented in case studies, such as Ohno (1988), Womack et al. (1990), Womack and Jones (1996), and Monden (1998) among others. Unfortunately, numerous survey studies, such as Ahlstrom and Karlsson (1996), Sánchez and Pérez (2001), Soriano-Meier and Forrester (2002) suffer from a lack of verifiable measures for the determinants used to measure the level of Lean implementations in companies surveyed. In fact, little peer-reviewed work has been published that reflects Lean in a comprehensive way by including its most salient dimensions. Below, a discussion of the most eminent work relating to these questions can be found.

2.4.1. Survey Instruments

Ahlstrom and Karlsson (1996), using the framework of Womack et al. (1990), were the first to develop a list of principles, which, in combination, describe Lean. The authors identified nine Lean principles and generated a list of 42 measurable determinants to indicate progress made in the effort of a company to become Lean. The nine principles identified included: elimination of waste, continuous improvement, zero defects, Just-in-Time (JIT), pull system, multifunctional teams, decentralized responsibilities, integrated functions, and vertical information systems. In their study, the principles indicate the ultimate goal of a Lean company, while the determinants represent the changes made to the organization to achieve the desired performance. The focus of Ahlstrom and Karlsson (1996) was to develop an instrument that assesses whether a company's Lean implementation progresses in a beneficial direction and test it through a single, longitudinal case study (Yin 2009). By conducting a single, longitudinal case study, the authors collected information about the same single company at two or more different points of time to analyze how conditions change over time. Although, Yin (2009) emphasizes that a single, longitudinal case study cannot be considered as a complete study on its own but as a pilot case that is the first of a multiple case study, the authors did not pursue any further study using their framework.

James-Moore and Gibbons (1997) created an assessment to examine the level of Lean implementation in civil aerospace companies' different business areas, such as new product introduction, manufacturing, logistics, sales and marketing, product support, and people management in a case study format and compare the results to existing benchmarking data published by Anderson Consulting in the UK in 1992 for the automotive industry. In their manuscript, however, no information had been provided about case study participants from the civil aerospace industry and neither from the automotive industry in regards to the number of participants or any company characteristics of participants. The authors identified 38 principles of a Lean company (called key drivers in their study). They then connected them with 76 determinants (called practices in their study) and 68 performance metrics covering all six business areas mentioned above. The assessment was taken by more than 100 senior and middle-rank executives of each participating company within five days. Respondents were asked to rate 38 Lean principles in terms of relevance to their company on a scale of 1 to 3 (1 = no relevance, 3 = high relevance) and respond with yes or no (yes = 1, no = 0) to the assigned determinants and measurements related to those principles. Finally, the total scores were divided by the total number of respondents to determine the average level of alignment across the company. Based on the average scores received, the authors defined three levels of Lean implementation; high (avg. score > 0.65), medium (0.45 < avg. score < 0.65), and low (avg. score

< 0.45). Results showed that 41 percent of the key practices assigned had high, 15 percent medium, and 44 percent low level of implementation. The authors did not elaborate on the details behind the low scoring. Results also indicated that key differences between the two industry segments had been found in the areas of new product refinement, sales and marketing, the ability to predict and control costs, and operations management.

Panizzolo (1998) developed a model to conceptualize Lean determinants through the characterization of different functional areas of a company. Based on a thorough review of operations management literature, the author identified six areas of intervention and defined 48 Lean determinants (called improvement programs in the study) to measure the level of Lean implementation in the participating companies. The six areas included process and equipment, manufacturing planning and control, human resources, product design, supplier relationship, and customer relationship. All measures used in their study were tested for reliability using Cronbach's alpha and for construct validity using means of factor analysis (the constructs that did not pass the test were removed from the study). The model was empirically tested through multiple case studies. Six interview guides were developed, one for each area listed above and sent out to 27 Italian manufacturing companies whose excellence were widely recognized by "Europe's 500" rankings of Ernst and Young, Price Waterhouse, and other industry experts. Answers to perceptual questions were measured on a five point Likert-scale and the level of Lean implementation was calculated by working out the average score of answers collected (0= not used, 4= fully implemented). The outcome of the research showed that external relationship management is the most problematic area for a successful Lean implementation because investigated companies tend to struggle implementing innovative practices on the technological/strategic level between themselves and their supplier. Findings of the research show that external relationship management is affected by the size, industry structure, and product complexity of a company. Additionally, findings revealed that companies reduce supplier sources primarily for cost reduction purposes rather than for the pursuit to build reliable supplier programs. Also, numerous participating companies do not feel comfortable relying on single sourcing of parts and exclusive links with suppliers because of an increased risk of supply disruption and because they believe that the dependency reduces the efficiency of the relationship.

In 2001, **Sanchez and Perez** continued the work of Ahlstrom and Karlsson (1996) by creating a model of 36 determinants (called intermediate indicators in their study) to assess changes made to manufacturing processes following Lean principles and empirically testing a total of 41 companies in the automotive and industrial machinery industries. Their determinants were based on the following six Lean principles: 1) elimination of zero-value activities, 2) continuous improvement, 3) multifunctional teams, 4) JIT production and delivery, 5) integration of suppliers, and 6) flexible information system. In their framework, the authors measured the degree of use of each of the six principles and they found that sixty percent of the 36 principles were used by more than half of the respondents.

Also in 2001, **Cua et al.** were the first to develop a list of determinants (called components in their study) to characterize a high performing company in the 21st century and empirically test them. Although, Cua et al. (2001) have never used the term Lean throughout their study, their framework is heavily relying on Lean principles and it is, therefore, noteworthy to discuss in this place. The authors started their research by reviewing the empirical literature on Total Quality Management (TQM), Just-in-Time (JIT), and Total Productive Maintenance (TPM). From this literature review, a list of 70 organizational specifications were generated and grouped into four principles (called categories in their study) that captured essential determinants of a high performing company. The four principles included TQM, JIT, TPM, and Human and Strategic-Oriented Common Practices. The survey instrument was developed as a part of the world-class manufacturing program and was sent out to 243 plants with more than 100 employees in 5 different countries. Specific questions on the questionnaire were assigned to 26 individuals based on job title and expertise to receive more accurate information. A total of 163 plants participated in the research for a response rate of 67 percent. The outcome of the research indicated that all variables investigated had a significant correlation to operational performance except for equipment layout and proprietary equipment development.

The focus of **Soriano-Meier and Forrester (2002)'s** research was to develop and empirically test an instrument that can evaluate the level of Lean implementation among 33 companies with more than 35 employees in the UK ceramic industry. The authors relied on the instrument developed by Ahlstrom and Karlsson (1996) to measure the degree of implementation of Lean principles (called lean production principles in their study) of the participating companies. Participants were asked to rate nine Lean principles in terms of the degree of implementation in their company on a scale of 1 to 7 (1 = no implementation, 4 = partial implementation, 7= total implementation). Senior production managers were the subject of interest in the study. The outcome of the study showed that 58 percent (19 out of

33) of the companies claimed that they have implemented Lean principles in their company (score ≥ 4). Based on a cluster analysis conducted by the authors, three clusters were determined including traditional companies (12 out of 33), in-transition companies (12 out of 33), and Lean companies (8 out of 33). Results showed that the mean values of the Lean cluster are significantly higher than mean values of the in-transition and traditional clusters.

While Cua et al. (2001) identified high performing companies and analyzed manufacturing practices that make them superior, Shah and Ward (2003) identified determinants (called manufacturing practices in their study) of Lean that are related to superior performance. **Shah and Ward (2003)** were the first to identify 22 determinants related to Lean based on a scholarly review of literature, group them into four principles (called bundles in their study), and tested them for reliability and validity. The four categories included JIT, TQM, TPM, and HRM. The survey instrument was sent out to 28,000 subscribers of Penton Media, Inc. publications specifically addressed to plant managers. A total of 1,757 responses were received from a wide variety of manufacturing industries in the U.S., resulting in a 6.7 percent response rate. The results of the research indicated that all four categories had a significant correlation to operational performance and, together, they explained 23 percent of the variation in operational performance.

The focus of **Olsen's (2004)** research was to develop and empirically test an instrument designed to evaluate the level of Lean implementation in a company and relate it to the company’s operational and financial performance. The authors relied mostly on the frameworks of Cua et al. (2001) and Shah and Ward (2003) by identifying 36 determinants covering eight principles of Lean (called Lean practices in his study). The eight principles were grouped into five internally oriented Lean principles including JIT production methods, statistical process control tools to monitor quality, employee involvement, group technology to enhance the flow of products, and TPM. They were also grouped into three externally oriented Lean principles including communication with suppliers, JIT delivery by suppliers, and customer involvement. The survey instrument was distributed to 316 U.S. companies with more than 50 employees in four major industry sectors classified under SIC codes 28 and 35-38. High-level operations managers were the subjects of interest in the study. A total of 48 valid responses were received, which resulted in 15.1 percent response rate. Respondents were clustered into two groups; Lean and Non-Lean based on the result of their cluster analysis. The study revealed that the Lean cluster was highly associated with the implementation of Just-in-Time production methods, group technology, and employee involvement. It was least associated with two external components including supplier communication and customer involvement than the non-lean cluster.

The purpose of **Doolen and Hacker (2005)'s** study was to develop and test a survey instrument that identifies the type and level of implementation of Lean determinants (called Lean practices in their study) by an organization. After reviewing existing survey instruments and assessment tools related to Lean, the authors relied mainly on Panizzolo's (1998) study to identify six impact areas of Lean implementation in an organization and further specify a total of 29 Lean determinants. Three to seven follow-on items were then developed for 26 of the 29 determinants to evaluate how often a specific determinant was used within the organization. The six impact areas identified included manufacturing equipment and processes, shop-floor management, new product development, supplier relationships, customer relationships, and workforce management. The 16 pages long final instrument was addressed to 27 electronics manufacturers located in Oregon and Washington states. The instrument was addressed to manufacturing and process engineers. A total of 13 companies (48 percent) responded to the survey. The level of Lean implementation was addressed by calculating the mean and standard deviation scores for each of the impact areas; higher scores indicated higher levels of Lean implementation. No statistical tests for reliability or validity were conducted in this study. Findings of the study show that two impact areas including manufacturing equipment and processes and customer relationships received the highest implementation scores from respondents. No statistically significant differences were found among the different impact areas in regards to the type of the manufacturing organization; however, significant differences (p = 0.013) were found between responses of large versus small companies in the manufacturing equipment and processes impact area – larger companies implemented Lean determinants in a significantly greater extent than small companies.

Shah and Ward, in 2007**,** continued their work from 2003 by identifying and rigorously testing a key set of determinants (called measurement items/practice items in their study) that can empirically represent Lean principles (called Lean components in their study) by using confirmatory factor analysis. Based on a literature review, the authors created a list of 48 determinants to represent Lean. Those 48 determinants were grouped into 10 principles and included supplier feedback, JIT delivery by suppliers, supplier development, customer involvement, pull, continuous flow, set up time reduction, total productive and preventive maintenance, statistical process control, and employee involvement. A survey instrument was sent out to 750 companies for a pre-test and thereafter to an additional 2,616 companies for a large-scale study. Manufacturing executives included in the database of Productivity, Inc. were the basis for the study. The sample represented companies from a wide variety of manufacturing industries with more than 100 employees in the U.S. The response rate was nine percent for the pre-test, and 13 percent for the large-scale study. Responses were collected to investigate "how" the various Lean principles are related to each other and "why" they are related to each other. Results of this study show that the 10 Lean principles were significantly correlated to each other ($p < 0.001$), suggesting that Lean is a multidimensional and integrated system as it was proposed by the authors. More specifically, results indicate that Lean can be represented by the ten principles listed above where each principle represents an individual aspect of Lean. The correlation coefficients between Lean principles were fluctuating between 0.77 and 0.12, where the higher inter-correlation between principles represents a better configuration theory. The study revealed that total productive maintenance and customer involvement had the lowest correlation coefficient with the other Lean principles.

The purpose of **Fricke (2010)'s** study was to evaluate the level of awareness and implementation of Lean principles and its determinants within the wood products (NAICS 321) and furniture manufacturing (NAICS 337) industry in Virginia (Fricke and Buehlmann 2012a, Fricke and Buehlmann 2012b, Fricke 2010). Based on a literature review, the author identified 29 determinants (called Lean elements in his study) to represent Lean. Those 29 determinants were then structured along Liker (2003)'s four categories including philosophy, process, people, and problem solving. A mail survey was sent out to 1,193 companies and a total of 188 responses were recorded, resulting in a 16 percent response rate. Results of Fricke's research revealed that the more general determinants of Lean, such as mission statement, employee cross-training, and providing training for shop-floor employees are commonly implemented at the respondents' facilities. Although, the core Lean determinants, such as A3-report, quick changeover (SMED), one-piece-flow, supermarket system, error proofing (Poka Yoke), Kanban system, or PDCA-cycle are sparsely implemented by a minor part of the responding companies (by four to nine percent of all responding companies).

Fullerton et al. (2013) were the first to extend the identification of Lean determinants to the accounting area. The purpose of their study was to examine the role of value stream costing (VSC) in a Lean environment. The areas of investigation of their study included top management support, Lean manufacturing practices, employee empowerment, visual performance measures, traditional management accounting, simplified management accounting, and value stream costing. The survey instrument was sent out to 476 U.S. companies who participated in Lean Accounting Summits organized between 2005 and 2008. A total of 244 responses were received for a 51.2 percent response rate from controllers, CFOs, and VPs of Finance. The study revealed that top management support is positively correlated with the use of Lean manufacturing practices, simplified accounting, and value stream costing but is negatively correlated with traditional accounting.

The empirical studies discussed above use similar principles and determinants (summarized in Table 1 and Table 2) to be present in an operation to indicate the presence and the depth of a Lean system, but they largely focus on individual business areas, such as manufacturing Fullerton et al. (2013). To achieve positive results, Lean cannot be operated in the manufacturing area in isolation from other supporting functions of the business (Maskell and Baggaley 2003); it must be integrated into and throughout the entire organization (Fullerton et al. 2013, Grasso 2005). Therefore, administrative and accounting functions need to be considered in survey instruments designed to identify the principles and determinants of Lean.

Table 1: Summary of Lean "principles" in empirical research studies discussed.

Summary of Lean "Principles"											
Karlsson and Ahlstrom (1996)	**James-Moore and Gibbons (1997)**	**Panizzolo (1998)**	**Sanchez and Perez (2001)**	**Cua et al. (2001)**	**Soriano-Meier and Forrester (2002)**	**Shah and Ward (2003)**	**Olsen (2004)**	**Doolen and Hacker (2005)**	**Shah and Ward (2007)**	**Fricke (2010)**	**Fullerton et al. (2013)**
Elimination of waste	N/A	N/A	Elimination of zero-value activities	Just-in-Time	Elimination of waste	Just-in-Time	Just-in-Time	N/A	Supplier Feedback	N/A	N/A
Continuous improvement	N/A	N/A	Continuous improvement	Total quality management	Continuous improvement	Total quality management	Statistical process control	N/A	Just-in-Time delivery by suppliers	N/A	N/A
Zero defects	N/A	N/A	Multifunctional teams	Total productive maintenance	Zero defects	Total productive maintenance	Employee empowerment	N/A	Supplier development	N/A	N/A
Just-in-Time	N/A	N/A	JIT production and delivery	Human and strategic-oriented common practices	Just-in-Time	Human resources management	Group technology	N/A	Customer involvement	N/A	N/A
Pull	N/A	N/A	Integration of suppliers		Pull		Total productive maintenance	N/A	Pull	N/A	N/A
Multifunctional teams	N/A	N/A	Flexible information system		Multifunctional teams		Supplier communication	N/A	Continuous flow	N/A	N/A
Decentralized responsibilities	N/A	N/A			Decentralized responsibilities		Just-in-Time delivery by suppliers	N/A	Set-up time reduction	N/A	N/A
Integrated functions	N/A	N/A			Integrated functions		Customer involvement	N/A	Total Productive/ Preventive Maintenance	N/A	N/A
Vertical information system	N/A	N/A			Vertical information system			N/A	Statistical Process Control	N/A	N/A
	N/A	N/A						N/A	Employee Involvement	N/A	N/A

Table 2: Summary of survey characteristics in empirical research studies discussed.

Author(s)	Year	Unit of analysis	Sample size	Industry coverage	Reliability	Validity
Ahlstrom and Karlsson	1996	Firm	1	N/A	N/A	N/A
James-Moore and Gibbons	1997	Firm	N/A	Civil aerospace	N/A	N/A
Panizzolo	1998	Firm	27	All manufacturing	Cronbach's alpha	Factor analysis
Sanchez and Perez	2001	Plant	41	Automotive and industrial machinery	N/A	N/A
Cua et al.	2001	Plant	243	All manufacturing	Cronbach's alpha	Factor analysis
Soriano-Meier and Forrester	2002	Plant	33	UK ceramic industry	Cronbach's alpha	Multiple correlation
Shah and Ward	2003	Plant	1,757	SIC 20-39	Cronbach's alpha	Principal component analysis
Olsen	2004	Plant	48	SIC 28, 35-38	Cronbach's alpha	Factor analysis
Doolen and Hacker	2005	Firm	13	Electronics manufacturers	N/A	N/A
Shah and Ward	2007	Firm	67+340	SIC 20-39	Cronbach's alpha	Factor analysis
Fricke	2010	Plant	1,193	NAICS 321, 337	N/A	Fisher's exact test
Fullerton et al.	2013	Plant	244	All manufacturing	Cronbach's alpha	Principal component analysis

2.4.2. Lean Assessment Instruments

Besides the survey-based research discussed above, various other instruments exist to assess the level of Lean implementation in a company. Survey instruments allow respondents to review and question their company's Lean principles by providing aggregate data from practitioners on the current state; they are not intended to be used for self-assessment (Caffyn 1999). Other instruments can be self-assessment instruments that are "…*Initiated and driven by the individual and is used for ongoing improvement…* (Galbraith et al. 2008, p.20)". Self-assessments are widely used in the consulting industry and are also embedded in national award programs, certification programs, or qualification programs that encourage competition among companies by assessing one's company against an external framework (Nightingale and Mize 2002). Self-assessment instruments should be selected with careful consideration since poorly designed self-assessments may build on theoretical constructs instead of being explicitly linked to what respondents do in their daily practice (Galbraith et al. 2008). Also, poorly designed self-assessments may lead users to focus on knowledge and reasoning rather than actual performance in real settings (Galbraith et al. 2008). Additionally, if results are not validated independently, they may not be linked explicitly to subsequent self-improvement plans and actions (Galbraith et al. 2008). Due to their widespread use and their practical importance, the most notable Lean self-assessment instruments are described below.

The **LAI Enterprise Self-Assessment Tool (LESAT)** is a capability maturity model (CMM). CMMs describe the principles and determinants of processes to help organizations to get from a chaotic, ad hoc level of processes, to a mature, disciplined level (Paulk et al. 1993). CMMs are organized into five levels of maturity, where each level provides a layer for continuous process improvement (Paulk et al. 1993). LESAT measures a company's maturity level in the use of Lean principles and determinants. LESAT's role in the Lean transformation process is to provide direction for managers on "where are they now?" and "how far do they need to go?" (Nightingale and Mize 2002). LESAT is not only measuring the company's level of Lean implementation but also its readiness to change (Nightingale and Mize 2002). LESAT has two versions. LESAT Version 1.0 (Nightingale and Mize 2002) was developed as a joint project by the Massachusetts Institute of Technology (MIT) and the Warwick Manufacturing Group of the University of Warwick in 2002, while LESAT Version 2.0 (Nightingale et al. 2012) was developed by the Lean Advancement Initiative at MIT in 2012 to provide a structured instrument to assist in enterprise Lean transformations. LESAT Version 2.0, the latest version of the model, consists of 43 Lean determinants covering three main areas of interest including 1) enterprise transformation and leadership, 2) lifecycle processes, and 3) enabling infrastructure (Nightingale et al. 2012). The first area of interest, enterprise transformation and leadership, focuses on lean and change management principles and practices that need to be developed and maintained by the leadership of the organization (Nightingale and Mize 2002). The second area of interest, the lifecycle processes category, focuses on processes that influence the value creation for stakeholders, while the third area of interest, the infrastructure enabling category, focuses on supporting processes and internal customers (Nightingale and Mize 2002). Assessing a company against these 43 Lean determinants included in the three main areas of interest provides an overview on how well the company is doing with their Lean transformation ranked into five maturity levels (Nightingale et al. 2012). For each of the 43 Lean determinants, five maturity levels were developed, where Level 1 represents the least capable stage, while Level 5 represents the "world-class" stage (Nightingale and Mize 2002). LESAT Version 2.0 enables the company to measure the current capability of their Lean transformation and compare it to the desired capability of a "world-class" Lean transformation (Nightingale and Mize 2002). Pareto-analysis can be performed on the current capability and thus the gaps can be found between current and desired capability levels, revealing pressure points, and provide direction for further improvements (Nightingale and Mize 2002). LESAT Version 2 can be used by a representative of a business unit, major division, or an entire company (Nightingale and

Mize 2002). Results of the assessment should be reviewed primarily by individuals involved in the enterprise strategic planning process (Nightingale and Mize 2002).

The **Shingo Prize for Operational Excellence Assessment** (Miller 2012) was developed by the Jon M. Huntsman School of Business at Utah State University to help managers assess where they are in their journey to operational excellence as described by the Shingo model. The Shingo prize for operational excellence assessment consists of four areas of interest, including cultural enablers, continuous process improvement, enterprise alignment, and results (Miller 2012). The Shingo assessment, unlike the LESAT assessment, is conducted by third party representatives, who evaluate an organization's senior leadership as to how their behaviors are aligned with the principles and determinants of operational excellence. The third party representatives also investigate the organization's business processes including customer relations, product/service development, operations, supply, and management support processes, as well as how they are aligned with the four areas of interest (Miller 2012). Scoring is based on representatives' observation as they assess the facility and look for pre-determined principles and determinants of operational excellence (Miller 2012). Representatives assign a "maturity score" on a scale from one (represents a chaotic stage) to five (represents the standard for operational excellence) for each determinant in each area of interest and weight those scores based on a pre-determined weight scale to calculate final points (Miller 2012). At the end of the assessment, representatives will conduct a gap analysis to show management where improvement can be made and how to move on with the journey towards operational excellence (Miller 2012).

The **Diagnostic Questionnaire of Accounting, Control, and Measurement** was developed by Maskell (2007) at BMA, Inc. Unlike the LESAT and Shingo assessments that were designed to assess the level of Lean transformation of the entire organization, in the Diagnostic Questionnaire of Accounting, Control, and Measurement assessment the diagnostic questionnaire was designed to help companies determining how well their accounting, control, and measurement methods support their Lean transformation process. The diagnostic questionnaire uses four pre-defined “maturity path” levels including 1) traditional, 2) developing a framework, 3) managing by value stream, and 4) Lean business management levels (Maskell and Baggaley 2003, Maskell 1996). The above listed four maturity levels represent the changes that can be made in the accounting area in parallel with Lean changes that are being implemented in other areas of the organization (Maskell and Baggaley 2003, Maskell 1996). The first maturity level in the assessment represents the traditional accounting system where traditional accounting and control systems are maintained but obvious waste is eliminated from the processes by reducing detailed labor and variance reporting, reducing the number of cost centers, and simplifying accounting processes. The second maturity level represents the development of a Lean framework where detailed shop-floor tracking is eliminated as lead-time reduces and WIP becomes immaterial and unnecessary cost and financial reporting are eliminated. The third maturity level represents managing by value stream where company operations no longer need to be aligned with accounting periods; month end closings are irrelevant for sales, manufacturing, and distribution of products. The last, e.g., the fourth maturity level, represents the Lean business management level where the number of transactions is minimized and production completion or product shipment transactions are used to backflush all the relevant information through the control system. The diagnostic questionnaire covers six major areas of assessment, including 1) performance measurement, 2) value stream costing, 3) measuring financial benefits, 4) managing value stream profitability, 5) eliminating transactions, and 6) value stream management (Maskell 2007). The diagnostic questionnaire is filled out by a company representative who marks the achievement level corresponding best with the company's current state and also ranks the quality of the envisioned future state of a given company's Lean transformation (Maskell 2007). Based on the outcome of the Diagnostic Questionnaire of Accounting, Control, and Measurement assessment, gap analysis can be performed and suggestions for improvements can be made (Maskell 2007). The UK Lean Aerospace Initiative has used Maskell's Diagnostic Questionnaire of Accounting, Control, and Measurement assessment to gain insights on how far aerospace industry participants had moved toward Lean Accounting (Ward et al. 2003, Crute et al. 2003). Results indicated that the majority of the respondents had a vision on the direction their company wishes to take in regards to Lean implementation in general. Although, they had no vision on the direction their company wishes to take in regards to Lean Accounting practices to support the overall Lean transformation (Ward et al. 2003, Crute et al. 2003). Respondents to this study pointed out some drawbacks of the diagnostic questionnaire including "…*It does not either explicitly or closely relate changes in accounting practice to changes needed in Lean operations. In addition, it is assumed that there is a linear progression through the traditional and intermediate categories of accounting development to arrive at world-class status*…" (Ward et al. 2003, p.17).

The **AME Lean Assessment** (AME 2008) is a Microsoft Excel based application that helps companies assess where they are on their Lean journey based on a set of given, pre-determined 14 Lean principles. These include management support, culture, 5S, value stream mapping, setup reduction, TPM, pull systems, production flow, plant layout, standard work, Lean product and process design, accounting support for Lean, supply chain, and continuous improvement. Company representatives self-evaluate their business activities by assigning a score on a scale from one to five based on a description provided for each of the 14 principles listed above (AME 2008). Once, the 14 scores are entered, the assessment provides a scoreboard about the company's current Lean status and illustrates results on a spider graph and bar charts (AME 2008). The AME Lean assessment also provides an opportunity to assess the company's level of Lean implementation against approximately 80 other manufacturing companies depending on how many years ago the Lean implementation did start.

Jordan and Michel (2001) developed a self-assessment instrument using 36 questions to gain information about specific stakeholders groups' perceptions of their company's Lean implementation status. The authors developed an individual questionnaire for each stakeholder group, e.g., customers, executives, employees, suppliers, and investors (Jordan and Michel 2001). Each questionnaire covers the following 18 areas: 1) Respond to change, 2) Minimize waste, 3) Just-in-Time, 4) Effective relationships within the value stream, 5) Continuous improvement, 6) Optimal first-delivered unit quality, 7) Customer focus, 8) Implement integrated product and process development, 9) Identify and optimize enterprise flow, 10) Assure seamless information flow, 11) Ensure process capability, maturity, and yield, 12) Challenge existing processes to achieve continuous improvement, 13) Promote lean leadership at all levels, 14) Make decisions at the lowest level possible, 15) Optimize capabilities and utilization of human resources, 16) Develop relationships based on mutual trust and commitment, 17) Nurture a learning environment, and 18) Maximize stability in a changing environment (Jordan and Michel 2001). Respondents of each questionnaire are asked to indicate their level of agreement with the statements included in the assessment on a five-point Likert-scale (Jordan and Michel 2001). The Jordan and Michel self-assessment is not a maturity model, it rather focuses on the outcome of the Lean transformation (Jordan and Michel 2001).

This sub-chapter provided an overview about peer-reviewed publications and self-assessment instruments that described and categorized Lean determinants used to measure the level of Lean implementation in a company. Table 1 and 2 provides a summary on the peer-reviewed publications discussed, while Table 3 summarizes the characteristics of the five self-assessment tools discussed. In the following sub-chapter peer-reviewed studies and case studies focusing on the impact of Lean on company performance are introduced.

Table 3: Summary of self-assessment tools.

Assessment Tools	Assessment goal	Assessment performed by	Unit of analysis	Main categories / dimensions	Maturity level(s)	Analysis
LAI Enterprise Self-Assessment Tool	Enables the company to measure the current capability of their Lean transformation and compare it to the desired capability of their Lean transformation	Individuals involved in enterprise strategic planning process	1) Business unit 2) Major division 3) Entire company	1) Enterprise transformation and leadership 2) Lifecycle processes 3) Enabling infrastructure	5 maturity levels (level 1= least capable stage, level 5 = "world-class" stage)	Pareto analysis
Shingo Prize for Operational Excellence Assessment	Evaluates the organization's senior leadership as well as the organization's business processes as how they are aligned with the principles of operational excellence	Third party representatives	1) Business unit 2) Major division 3) Entire company	1) Cultural enablers 2) Continuous process improvement 3) Enterprise alignment 4) Results	5 maturity levels (level 1= chaotic stage, level 5 = standard for operational excellence)	Gap analysis
Diagnostic Questionnaire of Accounting, Control, and Measurement	Helps companies determining how well their accounting, control, and measurement methods support their Lean transformation process	Accounting / finance personnel involved in enterprise transformation	Accounting / Finance	1) Performance measurement 2) Value stream costing 3) Measuring financial benefits 4) Managing value stream profitability 5) Eliminating transactions 6) Value stream management	4 pre-defined maturity levels: 1) Traditional business 2) Developing a Lean framework 3) Managing by value stream 4) Lean business management	Gap analysis
AME Lean Assessment	Helps companies assessing where they are at their Lean journey	Individuals involved in enterprise strategic planning process	1) Business unit 2) Major division 3) Entire company	1) Management support 2) Culture 3) 5S 4) Value stream mapping 5) Setup reduction 6) TPM 7) Pull systems 8) Production flow	5 maturity levels (level 1= least mature, level 5 = most mature)	1) Spider graph 2) Bar chart 3) Benchmark

				9) Plant layout 10) Standard work 11) Lean product / process design 12) Accounting support for Lean 13) Supply chain 14) Continuous improvement		
Jordan and Michel (2001)	Provides information about specific stakeholders group's perception of their company's Lean implementation status	Individuals involved in enterprise strategic planning process	1) Business unit 2) Major division 3) Entire company	1) Respond to change 2) Minimize waste 3) Just-in-Time 4) Effective relationships within the value stream 5) Continuous improvement 6) Optimal first-delivered unit quality 7) Customer focus 8) Implement integrated product and process development 9) Identify and optimize enterprise flow 10) Assure seamless information flow 11) Ensure process capability, maturity, and yield 12) Challenge existing processes to achieve continuous improvement 13) Promote lean leadership at all levels 14) Make decisions at the lowest level possible 15) Optimize capabilities and utilization of human resources 16) Develop relationships based on mutual trust and commitment 17) Nurture a learning environment 18) Maximize stability	5 point Likert-scale	N/A

2.5. Lean and Performance

Numerous academics and practitioners believe that successful implementation of Lean will ultimately lead to better business (operational and financial) performance (Harris 2012, Fullerton and Wempe 2009, Olsen 2004, Shah 2002, Cua 2000). Anecdotal evidence and case studies indicate that successful Lean implementation reduces machine and equipment downtime, work in process (WIP) and finished goods inventories, and physical work space. Also, Lean increases labor and equipment utilization, and inventory turns, among other things. However, there has been little conclusive empirical evidence that Lean leads to improved performance, and, particularly, to improved financial performance. However, **success stories of individual companies** have been promoted as evidence that implementing Lean leads to operational and financial success (Minter 2010, Hostetler 2010, Vinas 2008, Brosnahan 2008, Emiliani et al. 2003, Baggaley 2003). Case studies discussing success stories of Lean implementation in both, manufacturing and support functions of businesses and their way of measuring the outcome of individual Lean transformation efforts are collected and discussed below. The discussion is primarily focusing on performance outcomes reported by the companies observed.

Watlow Electric Manufacturing Co. is the number one designer and manufacturer of thermal solutions for heaters, sensors and controls to industry around the world (Brosnahan 2008). Watlow Electrical began pursuing Lean as a growth strategy in late 2004 with a rapid rollout across seven facilities (Brosnahan 2008). In mid-2006, management decided to expand the transformation to the administrative areas, especially to their accounting system

(Brosnahan 2008). Watlow Electrical identified specific metrics for the value streams to measure, including total case incident rate (safety), defects per million (quality), on-time to promise (delivery), sales per full time equivalent (cost), days of inventory (inventory; Minter 2010, Brosnahan 2008). According to Watlow Electrical, the company's total case incident rate decreased from 2.3 to 1.7, defects per million from 14,576 to 10,803. Their on-time delivery increased from 92.6 percent to 95 percent, and their sales per full time equivalent increased from $222,000 to $248,000 from 2005 to 2007. Moreover, approximately 90 percent of the 300 employees of Watlow Electric have been involved in at least one Kaizen event, while 60 percent have participated in two or more (Minter 2010). In 2007, the company achieved a better than 15 percent increase in both sales volume and return on sales (Brosnahan 2008).

Photo Etch, an aerospace manufacturing company, got involved with Lean in 2003 primarily to improve their on-time delivery rate and the quality of their products (Minter 2010). The company has joined industry leaders like Lockheed Martin, Bombardier and The Boeing Company in a nonprofit alliance called Supplier Excellence Alliance (SEA) Lean Enterprise System (LES) to implement Lean throughout the U.S. supply chain (Ery 2006). The Lean transformation first took place on the shop-floor where manufacturing operations were redesigned into three cells producing light displays, control panels, flight simulation components, and black boxes (Minter 2010). As a result of the changes implemented on the shop-floor in the first year of the initiative, manufacturing lead time was reduced from an average of 15 weeks to seven weeks. Manufacturing square footage necessary decreased from 50,000 sq ft to 35,000 sq ft, and the defect rate decreased considerably (Minter 2010). Photo Etch increased its inventory turns from approximately two to seven and a half, while freeing up a large amount of cash (Minter 2010). Due to the high level of devotion and enthusiasm of their workforce, the company was able to reach 20 percent reduction in manufacturing costs and 30 percent increase in capacity without extra capital expenditure (Ery 2006). The Lean transformation was then expanded to the supply chain, which resulted in 74 percent decrease for part travels and 61 percent reduction in people travels, and also to the administrative area which resulted in $49,000 to $125,000 increase in sales per employee annually (Ery 2006).

The CPA firm, **Rea and Associates, Inc.** started its Lean journey at the beginning of 2008. The company published the results of their business tax return Kaizen event from 2009 (Hostetler 2010). Rea and Associates reported that with just this one single improvement event, they increased realization (the percentage of time worked that actually gets billed to a client) by 6 percent and decreased “write-offs” by 51.6 percent. They increased revenue by 1.9 percent, cash-receipts by 10 percent, and decreased chargeable hours (e.g., increasing work efficiency) by 7.5 percent (Hostetler 2010). The company also established new Lean metrics including waiting time for review, which improved from two weeks to less than one week; and waiting time to clear review, which improved from one week to less than two days (Hostetler 2010).

Buck Knives, a custom knife manufacturer, started its Lean journey in 2001 (Vinas 2008). As a first step, the company implemented Lean in the manufacturing area, which resulted in a 30 percent reduction in manufacturing costs, a 60 percent reduction in work-in-process inventory, a 33 percent reduction in facility size, and a 38 percent reduction in cycle time in the area of blade fabrication (Vinas 2008). In 2005, the company extended the implementation in the administrative area by reorganizing the entire facility by value streams. They also extended implementation by addressing cyclical sales issues, creating operational metrics that are aligned with Lean principles, and switching the traditional accounting system to lean accounting (Vinas 2008). Unfortunately, the outcome of the administrative reorganization were not discussed in Vinas' (2008) case study.

Parker Hannifin, an industry leader in motion and control technologies started their Lean journey in 2000 (Baggaley 2003). Implementing Lean on the shop-floor resulted in producing to orders instead of unreliable forecasts, reducing setup times by an average of 80 percent, and reducing lead time below an hour for each product (Baggaley 2003). Once the shop-floor had been transformed by Lean principles, management extended the implementation to the administrative area. By 2003, the following results were reportedly achieved: 78 percent improvement in return on assets (ROA), 74 percent improvements in return on sales (ROS), 95 percent improvement in on-time delivery, 100 percent reduction in freight expediting costs, 51 percent reduction in scrap rate, 41 percent improvement in average days of inventory, and 15 percent improvement in productivity (Baggaley 2003).

The **Wiremold Company**, that was a large electric wire conduit company employing 900 employees, generating $75 million sales revenue, and owning 2500 distribution centers at seven locations in North-America in 1985, started its Lean journey in 1991 (Emiliani et al. 2003). In the late 1980s, to cope with fierce time-based competition and increasing number of customer complaints, the company continuously acquired new product lines while still using batch and queue production and keeping high finished goods inventory (Emiliani et al. 2003). Between 1987 and 1990, the company started to implement Just-in-Time but they failed as no one knew exactly how to do it (Emiliani et al. 2003). In 1991, new management took place in the company that enforced a Lean transformation starting with developing a long-term strategy based upon time-based competition. In addition to changing the performance measurement system focusing on quality and other non-financial performance measures, and improving all communication channels to become both precise and consistent over many years (Emiliani et al. 2003). From the beginning, continuous improvements became the center of the transformation, e.g., the factory layout has been changed; set-up time got reduced; visual controls, production leveling, and Kanban system got introduced to support a one-piece flow system. Inventory levels were reduced that generated more cash-flow; and the supply base was taught to respond to a pull system among many other things (Emiliani et al. 2003). As a result of a nine years long transformation process, the Wiremold Company was able to increase its first shipment fill rates to its customers from 60 percent to 92 percent and decrease its individual product defect rates by 40 to 57 percent (Emiliani et al. 2003). Also, the allowable time to fill an order was reduced from 72 hours to 24 hours, while inventory turns were increased from 4 to 10 by the end of 1999 (Emiliani et al. 2003). The company's productivity, as measured by sales per full time employee, improved by 162 percent throughout the years (Emiliani et al. 2003). Although, Wiremold was not able to achieve its 20 percent goal of an annual profit sharing, it increased its rate from the 1.3 percent in 1990 to over 10 percent in 1996 (Emiliani et al. 2003).

Table 4: Summary of Lean performance measures used in case-studies.

Case-study subjects	Industry segment	Lean implemented (year)	Performance measures
Watlow Electric Manufacturing Co.	Thermal solutions	2004	1) Total case incident rate (safety) 2) Defects per million (quality) 3) On-time to promise (delivery) 4) Sales per full time equivalent (cost) 5) Days of inventory 6) Employee involvement in Kaizen events
Photo Etch	Aerospace manufacturing	2009	1) On-time delivery 2) Product quality 3) Manufacturing lead time 4) Square footage 5) Inventory turns 6) Sales per employee rate
Rea and Associates, Inc.	CPA firm	2008	1) Realization (amount billed/WIP) 2) Write-off 3) Revenue 4) Chargeable hours 5) Waiting time for review 6) Waiting time to clear review notes
Buck Knives	Custom knife manufacturer	2001	1) Manufacturing costs 2) Facility size 3) WIP inventory 4) Fabrication cycle time
Parker Hannifin	Motion and control technologies	2000	1) Set-up time 2) Manufacturing lead time 3) Return on assets 4) Return on sales 5) On-time delivery 6) Freight expediting costs 7) Scrap rate 8) Average days of inventory 9) Productivity
The Wiremold Company	Electric wire conduit	1990	1) First shipment fill rate 2) Number of defects 3) Sales per full-time equivalent employee 4) Cost of goods sold per FIFO inventory value (inventory turns) 5) Actual profit sharing dollars per actual straight time wages 6) New product development cycle 7) Pursue of selective acquisitions

Although, the success stories of case studies discussed above (Table 4) are mostly positive, they cannot be generalized to all companies that start implementing Lean. Conflicting information can be found in **peer-reviewed academic publications** in respect to operational and financial successes of a Lean transformation. A summary of scientific studies investigating the operational and financial outcomes of Lean transformations will be presented next. Some of these empirical studies may have been already introduced in the previous sub-chapter entitled "Determinants of Lean Used in Empirical Research" focusing on Lean principles and determinants while now the focus is on performance results.

One of the earliest peer-reviewed academic studies that investigated whether an integrated set of manufacturing practices (JIT, TQM, and TPM) is positively associated with the level of manufacturing performance as measured by cost efficiency, quality, delivery, and flexibility was conducted by **Cua (2000)**. More specifically, Cua defined cost efficiency as unit cost of manufacturing and inventory turnover; quality as the quality of product conformance and product capability and performance; delivery as on-time delivery rate and cycle time; and flexibility as flexibility to change volume and flexibility to change the product mix. One hundred sixty-four manufacturing facilities from 5 different countries and 3 different industry segments responded to the research questionnaire. Results showed that a combined and simultaneous implementation of different manufacturing practices such as JIT, TQM, TPM, and common practices (strategic and human resources oriented practices) is positively associated with manufacturing performance. The study, however, was not able to answer the question as to which individual manufacturing practices are more relevant for improving different performance dimension. Results show that each manufacturing practice variable have a significant effect on at least one performance dimension and therefore different configurations of manufacturing practices improve different performance dimensions. Consequently, one can assume that manufacturing practices presented in this study all support the achievement of high manufacturing performance.

The ultimate goal of **Shah (2002)'s** research was to identify Lean "determinants" (called manufacturing practices in their study) and explore different patterns for Lean implementation in a sample of the U.S. manufacturing industry (electronics, automotive, aerospace, and biotechnology industries). Lean, in Shah's (2002) study, is considered a multi-dimensional approach that encompasses seven key management "principles," including Just-in-Time production methods. In addition to statistical process control tools to monitor quality, employee involvement in problem solving, group technology to enhance the flow of products, feedback to and communication with suppliers, Just-in-Time delivery by suppliers, and customer involvement. Shah also selected 17 key operational measures including 1) unit product cost, 2) unit material cost, 3) unit direct labor cost, 4) total manufacturing overhead cost, 5) manufacturing lead times, 6) vendor lead times, 7) changeover times, 8) direct labor productivity, 9) total labor productivity, 10) percent of on time deliveries, 11) percent of new products introduced on time, 12) delivery speed, 13) delivery speed, 14) delivery reliability, 15) volume flexibility, 16) process flexibility, and 17) flexibility to adjust capacity and compared them among companies that exhibit different patterns of implementation. Operational performance measures used in Shah's research were derived from prior operations management studies, especially from Flynn et al. (1994, 1995) and Ward et al. (1994, 1995). The 17 operational performance measures were categorized around five dimensions including lower cost, time, productivity, delivery, and flexibility. Data was collected directly from managers, who were asked to indicate the change in each of the operational measures listed above. Results of the study include that “Lean companies” showed significantly higher performance in all five dimensions (cost, time, productivity, delivery, and flexibility) than “Non-Lean companies.” The greatest difference between “Lean companies” and “Non-Lean companies” were observed in respect to flexibility, time, and delivery performance, followed by productivity and cost **Shah (2002)**.

Olsen, in 2004, conducted empirical research on measuring the financial impact of Lean management. The study considers Lean as a synergistic set of eight mutually supportive and integrated management principles, including Just-in-Time production methods, statistical process control to monitor quality, employee involvement in problem solving, group technology to enhance the flow of product, total productive maintenance, communication with suppliers, Just-in-Time delivery by suppliers, and customer involvement. A total of 42 out of 316 manufacturers in four industry segments (SIC 28, 35, 36, 38) participated in the study, from which 24 companies were categorized as “Lean archetype” companies, while 18 companies were categorized as “Non-Lean archetype” ones. The author distinguished “Lean archetype” companies from a “Non-Lean archetype” companies by conducting a cluster analysis on the eight Lean principles listed above. The purpose of Olsen’s research was to determine whether “Lean archetype” companies have better operational and financial performance than “Non-Lean archetype” companies. The operational metrics used in the study included asset productivity, employee productivity, gross margin ratio, cash-to-cash cycle time, and total cycle time. The financial metrics included return on equity, sales growth, and stock return. Both operations and financial performance data were received from Compustat (2013) and CRSP (2013) databases for the years of 1998-2002. To measure asset productivity, return on book value of assets was calculated by removing cash from the asset to eliminate short-term financing decisions on the measurements. Employee productivity was measured as operating income per number of employees. Operating income, rather than sales was used to calculate employee productivity, because it emphasizes employee contribution to both, revenue and cost aspects of an operation. Gross margin ratio was calculated as the ratio of the cost of goods sold at the selling price. Lean is expected to improve product quality and on-time delivery, while reducing costs and shorten the production cycle; thus it is expected to improve sales. Cash-to-cash cycle time was selected as an operational metric because it encourages cash-flow maximization, while the total cycle time encourages the reduction of total transaction time in the company's order fulfillment process. Return on equity (ROE) was selected as a financial measure because of its high credibility (e.g., companies are unable to manipulate its value (Olsen 2004, Vick 2000) and it provides information on profits generated by companies in comparison to their historical book value of assets. Sales growth (SG) provides information on how well a company is doing in the marketplace. If a given company's growth rate is higher than the median value of its competitors, then the company is gaining market share. Stock return (SR) is a market-based measure that indicates "…*The premium that the market places on the potential earnings stream for a company*…" (Olsen 2004, p.88). In general, results of the study show that "Lean archetype" companies differ from "Non-Lean archetype" companies in respect to operational performance but do not differ in respect to financial performance. Further investigation of the difference in operational performance show that "Lean archetype" companies perform significantly better in total (p = 0.066) and cash-to-cash cycle times (p = 0.040) and significantly worse in gross margin ratio (p = 0.077) than “Non-Lean archetype” companies. None of the remaining operational metrics (e.g., asset productivity (p = 0.809) and employee productivity (p = 0.929)) indicated significant differences between Lean archetype and Non-Lean archetype companies. Also, “Lean archetype" companies did not show significantly better performance in any of the financial performance categories (e.g., ROE (p = 0.790), SG (p = 0.453), SR (p = 0.905)) than Non-lean archetype companies. Unfortunately, the sample size of the study (n=48) may be too small to discover statistical differences between archetype companies.

The purpose of **Fullerton and Wempe's (2009)** study was to examine whether non-financial performance indicators mediate the association between Lean manufacturing and financial performance or not. Hundred and seventy-seven companies from four industry segments (SIC 28, 35, 36, 38) were contacted to participate in the study and a final response rate of 68 percent was achieved. Lean is represented in this study by only four Lean principles, including shop-floor employee involvement in problem solving, set-up time reduction, the implementation of cellular manufacturing, and quality improvement. While financial performance is measured by three metrics including return on sales, return on assets, and cash-flow margin. Financial data was received from Compustat (2013) for the year of 2001. Although, the authors listed three financial metrics at the beginning of their paper, they elaborated only on results related to return on sales (ROS). The study found that, using a reduced structural equation model (non-financial performance indicators were not included), a significant relationship was found between cellular manufacturing, reduced set-up time and

ROS, while no significant relationship was found between production quality and ROS. When tested separately, the non-financial performance indicators showed moderate positive relationships with both, the lean manufacturing principles (r = 0.328) and ROS (r = 0.361). However, in a full structural equation model, when all components listed above were incorporated, none of the Lean principles showed a significant relationship with ROS.

Fricke (2010) in his study investigated the Lean implementation status of wood products (NAICS 321) and furniture manufacturing (NAICS 337) in the state of Virginia by sending out a census survey to 1,193 companies. In his study, the author used metrics developed by Emiliani et al. (2003) to measure respondents' business performance. Findings of the study show that respondents applying Lean principles and practices achieved improvements in their sales per employee ratio, followed by inventory turnover, cost per unit, lead time, and on-time delivery (40, 32, 28, 15, and 14 percent of respondents indicated an improvement, respectively).

Harris (2012) investigated whether companies who publicly announced in their annual report to start a Lean transformation by the fiscal year of 2008 achieved better financial performance than companies with similar characteristics (based on SIC code and company size) but no Lean transformation effort being announced in their annual report. A total of 19 matched pairs (Lean vs. Non-Lean) of companies were selected for comparison. In this study, financial performance was evaluated based on financial information collected from the Compustat (2013) database for the years of 2008 and 2010. These were return/profit measures (return on net operation assets, return on total assets, profit margin), cash-flow measures (operating cash flows, cash-adequacy ratio, financing-assets ratio), working-capital measures (net working capital, working capital turnover, current ratio, acid-test ratio, accounts receivable turnover, days of sales uncollected), and inventory measures (total inventory turnover, raw materials turnover, work in process turnover, finished goods turnover, days of sales in inventory). Matched-pair design and Wilcoxon rank tests were used to analyze the results. The author found that “Lean companies” outperformed their “Non-Lean” matched pairs in all return/profit measures statistically significantly (e.g., return on net operation assets – p = 0.025, return on total assets p = 0.030, profit margin p = 0.090) as well as in all cash-flow measures (e.g., operating cash flows p = 0.023, cash-adequacy ratio p = 0.028, financing-assets ratio p = 0.083); however, no differences were found between “Lean companies” and “Non-Lean companies” in any working-capital measures. Inventory measures of the study showed mixed results by reporting that “Lean companies” having significantly higher total inventory turnovers (p = 0.016), higher raw material (p = 0.002) and finished goods (p = 0.077) inventory turnovers. However, both “Lean” and “Non-Lean” companies are reported having similar work in process inventory turnovers, and “Lean companies” having significantly lower days of sales in inventory (p = 0.036) than their “Non-Lean” competitors.

The implementation of Lean principles in many U.S. companies was initially focused on the manufacturing area; however, as companies became more proficient in carrying out Lean transformations, they have extended Lean ideas to other parts of their businesses, such as to the supply chain, customer support, and administrative and accounting areas, among others. As of today, Lean is viewed as a holistic, enterprise-wide management system that can improve business results, customer satisfaction, and operational and financial performance. The individual case studies introduced above and many others have been promoting the evidence that the implementation of Lean leads to operational and financial success, yet these success stories cannot be generalized to all companies that implement Lean. The limited number of peer reviewed publications that investigated the relationship between Lean implementations and operational and financial outcomes were collected and discussed above. A summary of operational and financial performance measures used in the peer-reviewed research discussed above is summarized in Table 5 below.

Table 5: Summary of Lean performance measures used in empirical studies discussed.

Author(s)	Year	Operational measures	Financial measures
Cua	2000	1) Unit cost of manufacturing 2) Inventory turnover 3) Quality of product conformance 4) Product capability and performance 5) On-time delivery rate 6) Cycle time 7) Flexibility to change volume 8) Flexibility to change product mix	N/A
Shah	2002	1) Unit product cost 2) Unit material cost 3) Unit direct labor cost 4) Total manufacturing overhead cost 5) Manufacturing lead times 6) Vendor lead times 7) Changeover times 8) Direct labor productivity 9) Total labor productivity 10) Percent of on time deliveries 11) Percent of new products introduced on time 12) Delivery speed 13) Delivery speed 14) Delivery reliability 15) Volume flexibility 16) Process flexibility 17) Flexibility to adjust capacity	N/A
Olsen	2004	1)Asset productivity (ROCA) 2) Employee productivity (EP) 3) Gross margin ratio (GMR) 4) Cash-to-cash cycle time (CTC) 5) Total cycle time (CTT)	1) Return on equity(ROE) 2) Sales growth (SG) 3) Stock return (SR)
Fullerton and Wempe	2009	N/A	1) Return on sales (ROS) 2) Return on assets (ROA) 3) Cash-flow margin (CFM)
Fricke	2010	1) Sales per employee 2) Inventory turnover 3) Cost per unit 4) Lead time 5) On-time delivery	N/A
Harris	2012	N/A	1) Return on net operation assets 2) Return on total assets 3) Profit margin 4) Operating cash flows 5) Cash-adequacy ratio 6) Financing-assets ratio 7) Net working capital 8) Working capital turnover 9) Current ratio 10) Acid-test ratio 11) Accounts receivable turnover 12) Days of sales uncollected 13) Total inventory turnover 14) Raw materials turnover 15) Work in process turnover 16) Finished goods turnover 17) Days of sales in inventory

2.6. Transportation Equipment Manufacturing

The United States transportation equipment manufacturing industry (NAICS 336) is a fragmented industry segment comprised of companies primarily engaged in manufacturing equipment for transporting people and goods on road, rail, air, and water (Statistics Canada 2007). In 2007, the United States transportation equipment manufacturing industry consisted of 13,071 establishments, employed 1,579,550 employees, and had a total value of shipments of $746 billion (U.S. Census Bureau 2007a). The North American Industry Classification System (NAICS) classifies the United States transportation equipment manufacturing industry into seven major categories: motor vehicle manufacturing (NAICS 3361), motor vehicle body and trailer manufacturing (NAICS 3362), motor vehicle parts manufacturing (NAICS 3363), aerospace product and parts manufacturing (NAICS 3364), railroad rolling stock manufacturing (NAICS 3365), ship and boat building (NAICS 3366), and other transportation equipment manufacturing (NAICS 3369), as shown in Table 6.

Table 6: Structure of the Transportation Equipment Manufacturing Industry (Statistics Canada 2007).

Transportation Equipment Manufacturing (NAICS 336)						
Motor Vehicle Mfg. (NAICS 3361)	**Motor Vehicle Body and Trailer Mfg. (NAICS 3362)**	**Motor Vehicle Parts Mfg. (NAICS 3363)**	**Aerospace Product and Parts Mfg. (NAICS 3364)**	**Railroad Rolling Stock Mfg. (NAICS 3365)**	**Ship and Boat Building (NAICS 3366)**	**Other Transportation Equipment Mfg. (NAICS 3369)**
Automobile mfg.	Motor vehicle body mfg.	Motor vehicle gasoline engine and engine parts mfg.	Aircraft mfg.	Railroad rolling stock mfg.	Ship building and repairing	Motorcycle, bicycle, and parts mfg.
Light truck and utility vehicle mfg.	Truck trailer mfg.	Motor vehicle electrical and electronic equipment mfg.	Aircraft engine and engine parts mfg.		Boat building	Military armored vehicle, tank, and tank component mfg.
Heavy duty truck mfg.	Motor home mfg.	Motor vehicle steering and suspension components mfg.	Other aircraft parts and auxiliary equipment mfg.			All other transportation equipment mfg.
	Travel trailer	Motor vehicle	Guided missile			

	and camper mfg.	brake system mfg.	and space vehicle mfg.			
		Motor vehicle transmission and power train parts mfg.	Guided missile and space vehicle propulsion unit and propulsion unit parts mfg.			
		Motor vehicle seating and interior trim mfg.	Other guided missile and space vehicle parts and auxiliary equipment mfg.			
		Motor vehicle metal stamping				
		Other motor vehicle parts mfg.				

From the seven industry categories listed above (Table 6), only three of them – motor vehicle manufacturing (NAICS 3361), motor vehicle body and trailer manufacturing (NAICS 3362), and motor vehicle parts manufacturing (NAICS 3363) – are considered in this study.

2.6.1. Motor Vehicle Manufacturing (NAICS 3361)

The motor vehicle manufacturing industry (NAICS 3361) comprises of companies primarily engaged in producing automobiles, light duty motor vehicles, and/or heavy duty motor vehicles (Statistics Canada 2007). In 2007, the United States motor vehicle manufacturing industry classified under NAICS 3361 consisted of 379 establishments, employed 179,362 employees and had a total value of shipments of $258 billion (U.S. Census Bureau 2007b). The industry consists of three major geographical hubs. The first hub is located in the Great Lakes area and is often referred to as the "Big Three" area as it includes the U.S. headquarters of the three largest U.S. motor vehicle manufacturers of General Motors (GM), Ford, and Chrysler. The Great Lakes area also provides homes to numerous other motor vehicle production plants such as Oshkosh, Navistar, Freightliner and many other companies. The second hub is located in the Southeast region and provides homes for the U.S.

headquarters of Volkswagen and Nissan and is home to numerous other motor vehicle production plants – mainly Japanese and Korean manufacturers such as Hyundai, Kia, Toyota, and Honda and German manufacturers such as BMW and Mercedes-Benz. A third hub is located on the West Coast, mainly in California, where companies such as Mazda, Isuzu, Mitsubishi, Suzuki, Kia, Honda, Toyota, Hyundai have their U.S. headquarters (IBISWorld 2013a).

2.6.1.1. Automobile Manufacturing (NAICS 336111)

The automobile manufacturing sub-segment (NAICS 336111) consists of companies involved with producing complete automobiles, or automobile chassis only (Statistics Canada 2007). In 2007, the United States automobile manufacturing sub-segment consisted of 188 establishments, employed 65,436 employees and had a total value of shipments of $84.7 billion (U.S. Census Bureau 2007c). The automobile manufacturing sub-segment has a moderate level of market share concentration, the top four players accounting for 54.3 percent of total industry revenue in 2012 (IBISWorld 2013a). The 2012 IBISWorld industry report ranks Toyota Motor Corporation as the market leader in the U.S. with its market share of 15.6 percent, followed by General Motors Corporation with 15.3 percent, Ford Motor Company with 12 percent, and Hyundai-Kia Automotive Group with 11.4 percent (IBISWorld 2013a). The remaining market players share 45.7 percent of the total industry revenue (IBISWorld 2013a). During the past five years to 2013, the economic downturn hit the already struggling automotive manufacturing sub-segment hard because the financial crisis made it difficult for consumers to finance a new car (IBISWorld 2013a, Ward's Automotive Group 2010). Customer demand for new motor vehicles hit historic lows in 2009 with annual sales of new vehicles in that year being below 10 million, as opposed to the all-time high of 17 and 16 million in 2000 and 2007, respectively (Canis and Yacobucci 2010). The decline resulted in plant closures, suspension of research and development activities, and drastic reductions of workforce, among other things (IBISWorld 2013a, Ward's Automotive Group 2010). Consequently, two companies of the Big Three (Chrysler and GM) sought bankruptcy protection in 2009 (IBISWorld 2013a). To help automobile manufacturers to reduce inventory levels, the U.S. government introduced a car buying incentive program called "Car Allowance Rebate System" to provide cash rebates to consumers who traded their used, old vehicle for a new, fuel-efficient one (IBISWorld 2013a). In 2010, consumer demand restored somewhat when financing became more accessible again and the recent positive development in the economy and in car demand over the next two years helped the industry cover some of the losses it encountered during the recession (IBISWorld 2013a, Ward's Automotive Group 2010). Industry sales are expected to grow by approximately 3.5 percent annually to $103.4 billion by 2018 (IBISWorld 2013a). Also, experts expect that automotive manufacturers are starting to focus on producing smaller, lighter, and more fuel-efficient vehicles to become more competitive in the wake of rising gas prices and to comply with increasing mileage per gallon of fuel mandates by the U.S. Federal government (IBISWorld 2013a).

2.6.1.2. Light truck and utility vehicle manufacturing (NAICS 336112)

The light truck and utility vehicle manufacturing sub-segment (NAICS 336112) comprises of companies primarily engaged in "…*Manufacturing complete light trucks and utility vehicles, or manufacturing light truck and utility vehicle chassis only. Vehicles made include light duty vans, pick-up trucks, minivans, and sport utility vehicles…*" (U.S. Census Bureau 2014a). In 2007, the United States light truck and utility vehicle manufacturing sub-segment consisted of 90 establishments, employing 84,806 employees and generating a total value of shipments of $154.0 billion (U.S. Census Bureau 2007d). The light truck and utility vehicle manufacturing sub-segment is concentrated with the top four companies accounting for 69.7 percent of the total industry revenue in 2012 (IBISWorld 2012a).

The IBISWorld industry report ranks General Motors Corporation as the largest producer of light truck and utility vehicle with its market share of 22.3 percent, followed by Ford Motor Company with 21.0 percent, Toyota Motor Corporation with 13.3 percent, and Chrysler Group LLC with 13.1 percent (IBISWorld 2012a). The remaining market participants share the remaining 30.3 percent of the total industry revenue (IBISWorld 2012a). The light truck and utility vehicle manufacturing sub-sector operates in similar circumstances as does the automobile manufacturing sub-segment (IBISWorld 2012a). Rising oil prices, consumers' rising environmental concerns, and the difficulties to obtain credit undermined the profitability of sport utility vehicle (SUV) and light duty truck manufacturers causing industry revenue to fall at an annualized rate of 4.2 percent to $134.4 billion over the five years up to 2012 (IBISWorld 2012a). Governmental programs such as the "Car Allowance Rebate System" and the "Corporate Average Fuel Economy" regulation offered help for industry participants to sell out piled up inventories and to revolutionize engine technologies (IBISWorld 2012a). Industry participants are continuously adapting to changing consumer perceptions and changing governmental regulations (e.g., Corporate Average Fuel Economy, CAFE) by introducing new products, such as hybrids and crossover-utility vehicles with improved fuel efficiency (IBISWorld 2012a). Despite the popularity of these new products, demand still remains low but industry revenue is expected to grow at an average annual rate of 3.0 percent and reach $156.1 billion over the next five years to 2017 (IBISWorld 2012a).

2.6.1.3. Heavy duty truck manufacturing (NAICS 336120)

The heavy duty truck manufacturing sub-segment (NAICS 336120) comprises of companies primarily engaged in "…*Manufacturing heavy duty truck chassis and assembling complete heavy duty trucks, buses, heavy duty motor homes, and other special purpose heavy duty motor vehicles for highway use or manufacturing heavy duty truck chassis only…*" (U.S. Census Bureau 2014b). In 2007, the United States heavy duty truck manufacturing sub-segment consisted of 101 establishments, employed 29,120 employees and generated a total value of shipments of $19.4 billion (U.S. Census Bureau 2007e). The heavy duty truck manufacturing sub-segment is highly concentrated, the top four companies account for 76.7 percent of the total industry revenue in 2012 (IBISWorld 2013b). The IBISWorld industry report ranks Volvo AB as the market leader with a market share of 23.6 percent, followed by PACCAR, Inc. with 21 percent, Daimler AG with 19.8 percent, and Navistar International Corporation with 12.3 percent (IBISWorld 2013b). The remaining market players share the remaining 23.3 percent of total industry revenue (IBISWorld 2013b). The economic downturn that started in 2007 had a negative influence on the performance of the heavy duty truck manufacturing sub-segment by slowing down trade-flows and therefore postponing truck purchasing activities (IBISWorld 2013b). As a result, industry revenue fell by 2.6 percent in 2009 (IBISWorld 2013b). In response to the declining trends of the U.S. markets, the major players expanded their businesses internationally, especially in Asia and South America (IBISWorld 2013b). Emerging countries, such as Brazil, Russia, India, and China (e.g., the BRIC countries), where demand for transport rises substantially compared with developed countries, encouraged the U.S. heavy duty truck manufacturers to outsource their production (IBISWorld 2013b). Consequently, the number of establishments in the U.S. has decreased over the past five years to 91 in 2012 (IBISWorld 2013b). Also impacting the heavy duty truck manufacturing industry sub-segment is the 2004 Environmental Protection Agency (EPA) announcement of new emission regulations; the first phase of those regulations has been implemented in 2007 and the second phase in 2010 (IBISWorld 2013b). Due to these regulations, the heavy duty truck manufacturers were required to invest heavily in research and development (R&D) to fulfill the new emission requirements. The EPA anticipated a 1 percent increase in truck prices as a result of the R&D efforts of the industry participants; however, industry participants anticipated truck price increases of approximately 5 percent (IBISWorld 2013b). The U.S. Bureau of Labor Statistics reported a 6.5 percent increase in heavy duty manufacturer's price index from 2006 to 2007 as opposed to the 3.5 percent increase from 2005 to 2006 (U.S. Bureau of Labor Statistics 2014). When the economy started to improve in 2010 and freight movements in the U.S. increased, the industry's revenue grew 31.1 percent in 2012 (IBISWorld 2013b). For the five years from 2012 to 2017, IBISWorld forecasts that trade activity will heighten and freight movement will further increase, which will result in an average annual 1.4 percent growth rate for the industry to $25.7 billion in 2017 (IBISWorld 2013b). The recovery process is expected to be slow because there is still a large stock of second hand vehicles on the market. Although, industry profitability will rise over the next five years, both industry revenue and export activities will stay below 2006 levels and the number of establishments is expected to fall to 88 by 2017 (IBISWorld 2013b). Also, the Federal Government's 2011 legislation, which introduced a new fuel economy standard that would require heavy duty truck manufacturers to produce more fuel efficient, hybrid engines, will result in higher truck prices in the future (IBISWorld 2013b).

2.6.2. Motor vehicle trailer and body manufacturing industry (NAICS 3362)

The motor vehicle trailer and body manufacturing industry (NAICS 3362) comprises of companies primarily engaged in producing motor vehicle bodies and cabs for trucks, automobiles, utility trailers, truck trailer chassis, detachable trailer bodies, and/or detachable trailer chassis (Statistics Canada 2007). In 2007, the United States motor vehicle trailer and body manufacturing industry consisted of 2,215 establishments, employed 145,863 employees and had a total value of shipments of $36 billion (U.S. Census Bureau 2007f). Most motor vehicle trailer and body manufacturers are located in the Great Lakes region, primarily in Indiana, Chicago, and Detroit (IBISWorld 2012b). California, Iowa, Oregon, and Texas are the next largest trailer and body manufacturing states in terms of revenue (IBISWorld 2012b). The United States motor vehicle trailer and body manufacturing industry has a low market share concentration; the top three companies (Thor Industries Inc. 10.9 percent, Berkshire Hathaway Inc. 5.1 percent, Wabash National Corporation 4.0 percent) are estimated to account for approximately 20 percent of total revenue, while small manufacturers account for the rest of the industry revenue (IBISWorld 2012b). In 2007, the retirement of a part of the baby boomer generation provided increased demand for the motor vehicle trailer and body manufacturing industry, mainly for recreational vehicles (RV's), while freight companies provided high demand in truck trailers before the new environmental regulations introduced by the U.S. government affected truck prices (IBISWorld 2012b). However, in the following years up to 2012, the industry experienced an average 7.2 percent annual decline due to reduced credit access and decreased spending of RV and semi-truck trailer consumers (IBISWorld 2012b). Consequently, over the past five years, many industry participants underwent mergers, acquisitions, or filed for bankruptcy (IBISWorld 2012b). However, over the five years to 2017, demand is expected to stabilize and reach its pre-recession level (IBISWorld 2012b). Yet, new governmental regulations in regards to fuel-efficiency, as well as the change in consumer behavior towards more economic, environmentally friendly vehicles, may set demand back. However, the introduction of new, hybrid-electric vehicles may soften this threat (IBISWorld 2012b).

2.6.3. Motor vehicle parts manufacturing industry (NAICS 3363)

The motor vehicle parts manufacturing industry (NAICS 3363) is primarily engaged in producing motor vehicle gasoline engines and engine parts, motor vehicle electrical and electronic equipment, motor vehicle steering and suspension components, motor vehicle brake systems, motor vehicle transmission and power train parts, motor vehicle seating and interior trimmings, motor vehicle metal stampings, and/or other motor vehicle parts (Statistics Canada 2007). In 2007, the United States motor vehicle manufacturing industry consisted of 5,742 establishments, employed 584,440 employees and had a total value of shipments of $206 billion (U.S. Census Bureau 2007g). Motor vehicle parts manufacturers, similarly to motor vehicle manufacturers, are clustered in the Great Lakes, Southeast, and West regions.

The performance of motor vehicle parts manufacturers highly correlates with the performance of motor vehicle manufacturers (IBISWorld 2012c). The economic slowdown forced motor vehicle part manufacturers to downsize their businesses and find ways to improve productivity (IBISWorld 2012c). Although, the economy started to improve in 2010, industry participants are careful with re-hiring, open idle facilities, or extending the scope of their businesses (IBISWorld 2012c). However, increasing demand from both national and foreign-owned automakers is expected to create new opportunities for parts suppliers in the long-term (IBISWorld 2012c). In the next five years, full recovery of motor vehicle manufacturers and recent consumer trends toward smaller, fuel efficient cars, such as hybrid and electric cars is expected to drive industry growth (IBISWorld 2012c).

2.6.3.1. The motor vehicle gasoline engines and engine parts manufacturing (NAICS 33631)

The motor vehicle gasoline engines and engine parts manufacturing sub-segment (NAICS 33631) is primarily engaged in manufacturing and/or rebuilding motor vehicle gasoline engines (Statistics Canada 2007). In 2007, the United States motor vehicle gasoline engines and engine parts sub-segment consisted of 994 establishments, employed 61,886 employees and had a total value of shipments of $27.7 billion (U.S. Census Bureau 2007h). The motor vehicle gasoline engines and engine parts manufacturing sub-segment is moderately concentrated, the top four companies account for 58.1 percent of the total industry revenue in 2012 (IBISWorld 2012c). The IBISWorld industry report ranks General Motors as the market leader with its market share of 18.6 percent, followed by Ford Motor Company with 15.8 percent, Toyota Motor Corporation with 12.9 percent, and Chrysler Group LLC with 10.8 percent (IBISWorld 2012c). The remaining market players share 41.9 percent of the total industry revenue (IBISWorld 2012c). Continuously increasing gasoline prices, the economic recession that started in 2007, changes in consumer perspectives towards more compact, fuel-efficient cars, and looming legislative standards caused a strong decline in consumer demand and resulted in an approximately 2.3 percent annual decline in industry revenue to $28.7 billion by 2012 (IBISWorld 2012c). The industry is expected to invest heavily in developing new, fuel-efficient gasoline engines; however, the introduction and expansion of electric vehicles, such as the Chevrolet Volt and Nissan Leaf, which run on an electric motor and high-powered lithium-ion batteries threatens the industry segment's future performance (IBISWorld 2012c).

2.6.3.2. The motor vehicle electrical and electronic equipment manufacturing (NAICS 33632)

The motor vehicle electrical and electronic equipment manufacturing sub-segment (NAICS 33632) is primarily engaged in manufacturing/rebuilding vehicular lighting and/or motor vehicle electrical and electronic equipment (Statistics Canada 2007). In 2007, the United States motor vehicle electrical and electronic equipment manufacturing sub-segment consisted of 816 establishments, employed 72,698 employees and had a total value of shipments of $20.5 billion (U.S. Census Bureau 2007i). The motor vehicle electrical and electronic equipment manufacturing sub-segment is moderately concentrated, with the top four companies accounting for 57.6 percent of total industry revenue in 2012 (IBISWorld 2013c). The IBISWorld industry report ranks Johnson Controls, Inc. as the market leader with its market share of 20.9 percent, followed by Delphi Corporation with 16.6 percent, Lear Corporation with 14.7 percent, and Denso Corporation with 5.4 percent (IBISWorld 2013c). The remaining market players share 42.4 percent of the total industry revenue (IBISWorld 2013c). As with all participants of the United States transportation equipment manufacturing industry (NAICS 336), the recession caused declines in the motor vehicle electrical and electronic equipment manufacturing sub-segment, but the industry started to rebound in 2010 as the economy started to recover (IBISWorld 2013c). Looming legislative standards regarding fuel-efficiency encourages industry participants to invest in new materials and technologies (IBISWorld 2013c). For example, Delphi Corporation introduced aluminum alternatives to copper wiring, which reduces motor vehicle weight (IBISWorld 2013c). Unlike motor vehicle gasoline engines and engine parts manufacturers, motor vehicle electrical and electronic equipment manufacturers may also benefit from the production of electric vehicles because electric vehicles require large amounts of electrical components (IBISWorld 2013c).

Therefore, the industry revenue is expected to grow by 2.7 percent annually to $20.4 billion by 2018 (IBISWorld 2013c).

2.6.3.3. The motor vehicle steering and suspension component manufacturing (NAICS 33633)

The motor vehicle steering and suspension component manufacturing sub-segment (NAICS 33633) is primarily engaged in manufacturing/rebuilding motor vehicle steering mechanisms and suspension components (Statistics Canada 2007). In 2007, the United States motor vehicle steering and suspension component manufacturing sub-segment consisted of 259 establishments, employed 35,856 employees and had a total value of shipments of $10.6 billion (U.S. Census Bureau 2007j). The motor vehicle steering and suspension component manufacturing sub-segment is highly fragmented, the top two companies (TRW Automotives Inc. and Tenneco Inc.) accounted for 17.4 percent of the total industry revenue in 2012 (IBISWorld 2012d). The industry's major consumers are domestic automobile and light duty truck manufacturers; therefore, when those industry segments started to collapse due to the recession in 2007, high gasoline prices, and environmental concerns of consumers, the motor vehicle steering and suspension component manufacturing sub-segment suffered losses (IBISWorld 2012d). To thrive and survive, the industry provided repair and replacement services for steering and suspension parts for the motor vehicle parts aftermarkets but industry revenue still declined an annualized 2.1 percent (accounts for $10.3 billion in dollar value) over the five years to 2012 (IBISWorld 2012d). In the next five years up to 2017, demand from major customers is expected to stabilize; however, due to high steel prices and continuously growing international competition, the growth in industry revenue is expected to be only around one percent annually (to $10.8 billion, IBISWorld 2012d).

2.6.3.4. Motor vehicle brake system manufacturing (NAICS 33634)

The motor vehicle brake system manufacturing sub-segment (NAICS 33634) is primarily engaged in manufacturing/rebuilding motor vehicle brake systems and related components (Statistics Canada 2007). In 2007, the United States motor vehicle brake system manufacturing sub-segment consisted of 241 establishments, employed 30,434 employees and had a total value of shipments of $11.2 billion (U.S. Census Bureau 2007k). The motor vehicle brake system manufacturing sub-segment is highly fragmented, with the top three companies (TRW Automotive Inc., Akebono Brake Corporation, Continental AG) controlling 24.9 percent of total industry revenue in 2012 (IBISWorld 2012e). The industry, having motor vehicle manufacturers as their primary markets, experienced major losses during the recession with an average annualized decline of 1.1 percent (IBISWorld 2012e). In the near future, demand is expected to stabilize and fall in line with the production of major automobile manufacturers (IBISWorld 2012e). New trends toward hybrid and electric vehicles encouraged the industry to develop more fuel efficient technologies, such as regenerative brakes (IBISWorld 2012e). The industry revenue is expected to improve by an annualized 2.7 percent ($12 billion) over the next five years to 2017 (IBISWorld 2012e).

2.6.3.5. Motor vehicle transmission and power train parts manufacturing (NAICS 33635)

The motor vehicle transmission and power train parts manufacturing sub-segment (NAICS 33635) is primarily engaged in manufacturing/rebuilding motor vehicle transmissions and power train parts (Statistics Canada 2007). In 2007, the United States motor vehicle transmission and power train parts manufacturing sub-segment consisted of 537 establishments, employed 75,485 employees and had a total value of shipments of $35.9 billion (U.S. Census Bureau 2007l). The motor vehicle transmission and power train parts manufacturing sub-segment is highly fragmented, too, with the top two companies (Dana Holding Corporation and American Axle & Manufacturing Holdings Inc.) accounting for 12.6 percent of the total industry revenue in 2012 (IBISWorld 2012f). The industry produces exclusively for original equipment manufacturers (OEMs); therefore, the collapse of the motor vehicle markets in 2007 decreased demand for motor vehicle transmissions, axles, and other components and decreased the industry revenue by 0.5 percent to $36.4 billion in 2012 (IBISWorld 2012f). To accommodate the motor vehicle industry's new diesel and hybrid vehicles, transmission and power train parts manufacturers are developing automated transmission gearboxes that work efficiently with high-efficiency engines (IBISWorld 2012f). Starting in 2010, demand from upstream manufacturers toward transmission and power train parts showed continuous increases, a trend that is expected to continue. Therefore, industry revenue is expected to increase by 3.2 percent annually to $42.6 billion by 2017 (IBISWorld 2012f).

2.6.3.6. Motor vehicle seating and interior trim manufacturing (NAICS 33636)

The motor vehicle seating and interior trim manufacturing sub-segment (NAICS 33636) is primarily engaged in manufacturing motor vehicle seating, seats, seat frames, seat belts, and interior trimmings (Statistics Canada 2007). In 2007, the United States motor vehicle seating and interior trim manufacturing sub-segment consisted of 434 establishments, employed 54,376 employees and had a total value of shipments of $21.3 billion (U.S. Census Bureau 2007m). The market power of motor vehicle seating and interior trim manufacturers is somewhat concentrated, with the top four players controlling 61.4 percent of total industry revenue in 2012 (IBISWorld 2013d). Major competitors of this industry segment include Johnson Controls Inc. with 21.2 percent market share, followed by Lear Corporation with 18.6 percent, International Automotive Components Group North America 16.9

percent, and Visteon Corporation with 4.7 percent market share (IBISWorld 2013d). Remaining players shared 38.6 percent of the total industry revenue in 2012 (IBISWorld 2013d). Motor vehicle seating and interior trim manufacturers needed to accommodate falling demand and financial pressure during the recession by applying serious cost-cutting strategies (IBISWorld 2013d). By 2018, as the economy recovers, national and international demand is expected to increase and industry revenue is expected to reach an annualized 2.3 percent growth leading to total revenues of $21.8 billion by 2018 (IBISWorld 2013d).

2.6.3.7. Motor vehicle metal stamping (NAICS 33637)

The motor vehicle metal stamping sub-segment (NAICS 33637) is primarily engaged in manufacturing motor vehicle stampings, such as fenders, tops, body parts, trim, and molding (Statistics Canada 2007). In 2007, the United States motor vehicle metal stamping sub-segment consisted of 825 establishments, employed 99,703 employees and had a total value of shipments of $29.5 billion (U.S. Census Bureau 2007n). The motor vehicle metal stamping sub-segment is moderately concentrated; the top four players accounted for 34.6 percent of total industry revenue in 2012 (IBISWorld 2012g). Major competitors in this industry sub-segment include General Motors Corporation (12 percent market share), followed by Ford Motor Company (10.4 percent), Toyota Motor Corporation (7 percent), and Flex-N-Gate Corporation (6.9 percent, IBISWorld 2012g). Remaining players shared 63.7 percent of total industry revenue in 2012 (IBISWorld 2012g). The industry's primary market consists of motor vehicle manufacturers; therefore, industry revenue showed an average of 2.7 percent annualized decline between 2007 and 2012 (IBISWorld 2012g). Although, demand is expected to pick up in the near future, new trends toward producing fuel-efficient vehicles, which require less steel per vehicle, subdue the potential for increasing profit margins and growth (IBISWorld 2012g). IBISWorld forecasts annualized 2.4 percent revenue growth to $30.9 billion by 2017 (IBISWorld 2012g).

This sub-chapter introduced three major sub-segments (motor vehicle manufacturing (NAICS 3361), motor vehicle body and trailer manufacturing (NAICS 3362), motor vehicle parts manufacturing (NAICS 3363)) of the U.S. transportation equipment manufacturing industry, which is one of the largest industries in the U.S. and is a vital engine of the U.S. economy, contributing greatly to the nation's employment and productivity. In the following sub-chapter, an overview of existing survey research methodologies will be introduced.

2.7. Primary Data Collection

Primary data collection mechanisms from individuals or organizations, which allow researchers to collect reliable estimates of the characteristics of a population by sampling and obtaining results from a subset of the population in question, have been transformed over the past decades from being a comfortable face-to-face conversation (up to the 1970s) to a highly impersonal experience often facilitated by an electronic device (Dillman et al. 2009a). Rapid changes in survey practices not only affect the mode of conducting surveys but the methods used for designing questions and questionnaires and obtaining answers from respondents to receive results and satisfactory response rates from participants (Dillman et al. 2009a, Connelly et al. 2003). Despite all the changes, the major steps involved in designing, implementing, and analyzing a quality survey remain the same today as in the past: 1) a clear definition of the research objectives, 2) a clear definition of the population to be sampled, 3) the development of a sampling plan, 4) a questionnaire design, 5) a pre-test and a revision of the questionnaire, if necessary, 6) data collection, 7) data analysis, and 8) a final report (Ott and Longnecker 2010).

2.7.1. Survey Design

When designing a survey, the overall research objectives as well as specific research questions must be clearly and concisely defined to ensure that the survey provides the data researchers need to answer their questions (Scheaffer et al. 2011). Once the research objectives are defined, the population, e.g., the overall group of interest to this study, must be identified and a sampling plan must be devised (Scheaffer et al. 2011). The goal of a sampling plan is to randomly select a small percentage of the total population of interest that will in turn represent the behaviors and attitudes of the population as a whole (Scheaffer et al. 2011). Developing a sampling plan involves two major tasks, e.g., selecting the appropriate sampling technique and determining the sample size (Scheaffer et al. 2011). The four sampling techniques that can be differentiated include (a) simple random sampling, (b) stratified random sampling, (c) cluster sampling, and (d) systematic sampling (Scheaffer et al. 2011, Ott and Longnecker 2010). In simple random sampling (a), participants are chosen from the population by a random mechanism, where each participant has an equal chance of being selected (Scheaffer et al. 2011, Ott and Longnecker 2010). Stratified random sampling (b) divides the population into strata based on a similarity and then randomly selects participants from each stratum (Scheaffer et al. 2011, Ott and Longnecker 2010). In cluster sampling (c) the population consists of many different clusters from which a number of clusters are selected randomly and then participants are selected from each pre-selected cluster randomly (Scheaffer et al. 2011, Ott and Longnecker 2010). In systematic sampling (d) , every k^{th} participant from a list of all possible participants is selected (Scheaffer et al. 2011, Ott and Longnecker 2010). Once the population and sampling technique are defined, the sample size (number of completed responses) can be determined based on time, money, and precision required. The completed sample size is calculated based on Equation 1 (Dillman et al. 2009a, p.56):

$$N_s = [(N_p)*(p)*(1-p)] / [(N_p-1)*(B/C)^2 + (p)*(1-p)] \quad (1)$$

where N_s represents the size of the completed sample, N_p represents the population size, p represents the expected variation in responses to the questions of interest, B represents the margin of error, and C represents the Z-score associated with the amount of statistical confidence (Dillman et al. 2009a, p.56).

Receiving high quality responses in sufficient quantities requires developing a questionnaire design that minimizes survey errors (Groves 1989). Four types of survey errors can be differentiated: (a) coverage error, (b) sampling error, (c) non-response error, and (d) measurement error (Groves 1989). Coverage error (a) occurs if the selected survey mode does not properly represent the population being investigated (Groves 1989). In the survey process, all members of the population must have a known, nonzero chance of being represented in the sample; otherwise those excluded may differ from those included (Dillman et al. 2009a). Today, computer technologies and the Internet enable researchers to compile and maintain enormous and up-to-date databases for all kind of population (Dillman et al. 2009a). Sampling error (b) is the degree to which a survey statistic differs from its “true” value due to the fact that the survey is conducted among only some rather than all members of the population (Groves 1989). Sampling error is the imprecision of the survey estimates that researchers are willing to live with (Groves 1989). Nonresponse error (c) occurs when not all people selected in the sample respond to the survey and those who do not respond are different from those who respond in a way that is important to the study (Groves 1989). The biasing effects of the nonresponse error are the function of the missing data rate and the difference between respondents and non-respondents (Biemer and Lyberg 2003). Measurement error (d) occurs from inaccurate or imprecise answers provided by respondents due to poor question wording, poor questionnaire construction, incorrect survey mode, and/or aspects of the respondents' behavior (Groves 1989). To minimize the survey errors listed above (coverage error (a), sampling error (b), non-response error (c), and measurement error (d)), it is necessary to select a survey mode that provides adequate coverage of the population from which a large enough sample can be drawn; to design the survey implementation in a way that it motivates various types of people to respond; and to design the questionnaire in a way that it encourages respondents to provide thoughtful and honest answers (Dillman et al. 2009a).

2.7.1.1. Survey Mode Selection

Four commonly used survey modes can be differentiated, including (a) in-person interviews, (b) telephone surveys, (c) mail surveys, and (d) internet based surveys (Dillman et al. 2009a). Before the 1970s, **in-person interviews** (a) were the only generally accepted mode of conducting surveys (Dillman et al. 2009a). At that time, well-trained interviewers visited selected participants in their homes or workplace and tried to build good personal relationships with them to receive high quality answers (Dillman et al. 2009a). Although, these well-trained interviewers were able to achieve great response rates of 70 to 90 percent on average by conducting in-person interviews, such surveys required complex sampling methods, high labor costs, and long data collection periods due to large distances between selected participants (Dillman et al. 2009a). In the 1970s, **telephone and mail surveys** (b and c) started to emerge primarily to overcome distance, reduce the need for developing multistage sampling methods, and reduce costs (Dillman et al. 2009a). Since the 1970s, in-person interviews were applied mostly when strict coverage criteria exist, telephone surveys were applied when national household samples were needed, and mail surveys were applied when cost was a concern and postal addresses were available (Dillman et al. 2009a). From the 1990s on, however, in-person interviews started to lose access to respondents' newly secured homes and workplaces and telephone surveys started to have issues with unlisted phone numbers, answering machines, caller identification, call blocking, and people's tolerance (Dillman et al. 2009a). Cultural changes accompanied by the rise of electronic technology, especially by the spread of the Internet, created the potential for **internet-based-surveys** (d, Dillman et al. 2009a). As internet-based communication tools such as e-mail and social media became the standard way of communication, the survey process can now be executed faster, more cost efficient, and more convenient for researchers (Dillman et al. 2009a). However, the large number of surveys directed at individuals made possible by the internet nowadays requires researchers to differentiate their survey from the many others to achieve satisfactory response rates (Dillman et al. 2009a).

Unfortunately, research by Connelly et al. (2003) shows, that regardless of the survey mode selected, response rates dropped an average of 0.77 percent every year between 1971 and 2000; however, there is also evidence that response rate can be improved by applying a **mixed-mode survey design** (Dillman et al. 2009a, Biemer and Lyberg 2003). The mixed-mode survey design means applying a primary survey mode (personal, telephone, mail, or internet-based) and keeping in mind all design requirements and assumptions and then, if necessary, combining it with a second or third mode to increase response rate (Biemer and Lyberg 2003). As of today, it is unknown why different modes produce different response rates (Biemer and Lyberg 2003). There are numerous advantages of using a mixed-mode survey design other than improving response rate and thereby reducing non-response error (Dillman et al. 2009a, Biemer and Lyberg 2003). First, survey costs can be significantly reduced by collecting responses with the least expensive mode (e.g., internet-based survey) and then switching to another mode (e.g., mail survey or telephone survey) for targeted respondents who did not respond. Second, the length of data collection can be reduced if businesses/respondents are matched with the mode that is most convenient for them to respond. Third, incentives, especially financial incentives, can be delivered more easily and effectively with one mode e.g., mail survey then with other modes, such as internet-based survey or telephone survey where respondents may become suspicious about electronic financial transactions. Fourth, when a single survey mode cannot adequately cover the entire population of interest, the application of mixed-mode surveys can help to reduce coverage error. Also, for surveys containing sensitive questions, e.g., health, alcohol, drug, financing, etc. related questions in a survey can cause measurement errors, which can be greatly reduced by applying less personal modes, such as internet-based survey or mail survey as opposed to telephone or in-person interviews.

Four types of mixed-mode survey designs can be differentiated (Dillman et al. 2009a). The first design is using one mode to contact and encourage respondents to fill out the survey, which is presented in another mode (Dillman et al. 2009a). For example, one can send a letter by mail to potential respondents and encourage them to fill out internet-based survey (Dillman et al. 2009a). This first design has the advantage of improving response rate and reducing coverage and non-response errors, but it may increase implementation costs (Dillman et al. 2009a). The second design is using one mode throughout the questionnaire, but another mode is used to collect sensitivity information from the same respondents often at a later time (Dillman et al. 2009a). The advantage of this second design is that it reduces measurement error and possible bias caused by social desirability, but it may increase survey cost and non-response bias (Dillman et al. 2009a). The third design is using different modes for different respondents in the same survey period (Dillman et al. 2009a, Dillman et al. 2009b). Dillman et al. (2009b) demonstrated two examples of the possibility of using different modes for different respondents in the same survey period (e.g., the third design method). In the first example, all survey participants (U.S. household) received a standard pre-notice letter with a request to respond to a 12 pages long questionnaire including 51 questions requiring 81 answers. Three days later, an invitation letter with a $5 incentive, a mail questionnaire and return envelope were sent to all participants. Two weeks after the pre-notice letter, thank you/reminder cards were sent to respondents and non-respondents. Four weeks after the initial letter, a replacement questionnaire was sent to non-respondents with a return envelope and a cover letter that also included a URL and access code for the internet-based version of the survey. Using this mixed-mode survey design, researchers were able to receive a 70 percent response rate via mail and an additional one percent response rate via the Internet (Dillman et al. 2009b). In a second example, the same pre-notification letter was sent out to all survey participants (U.S. household) and the invitation letter sent three days later included a URL and access code for an Internet survey and included the same $5 incentive. Two weeks after the pre-notice letter, thank you/reminder cards were sent to respondents/non-respondents. Four weeks after the initial letter, a remainder letter with the URL and access code was sent to non-respondents accompanied with a mail questionnaire and return envelope for the mail option. Following the mixed-mode survey design described in this second example, researchers were able to receive a 41 percent response rate via internet and an additional 14 percent response rate via mail. The advantage of this third design is the improved response rate and reduced cost, coverage error, and non-response error, but measurement error may apply since respondents with different characteristics may respond to different modes (Dillman et al. 2009a, Dillman et al. 2009b). The fourth design is applied primarily in longitudinal survey studies, e.g., medical studies and retirement studies where collecting responses from sampled individuals may take 20 to 30 years or sometimes longer. In longitudinal studies, the mode of collecting responses from the same individuals may change between survey periods to reduce costs or to apply more up-to-date modes (Dillman et al. 2009a). Applying the fourth design may reduce survey cost but increases design cost and measurement error by threatening the ability of researchers to accurately measure change in attitudes, opinions, or behavior (Dillman et al. 2009a).

A mixed-mode survey design must be carefully implemented because different survey modes may require different survey constructions (Dillman et al. 2009a). For example, if survey questions are written and presented in the same way in all of the individual designs, it can ensure that respondents receive a common mental stimulus (Dillman et al. 2009a). However, in some cases different modes require different wording and different display of questions depending on the capabilities of each mode, or in other cases some features are not equally available for all modes (Dillman et al. 2009a). Thus, to design a high quality survey, researchers must match the survey mode or the combination of modes to the target population, research questions, technological capabilities of different modes, budget, and timeframe of the study (Dillman et al. 2009a).

2.7.1.2. Survey Question and Questionnaire Design

Different survey modes require different communication channels. For example, telephone surveys are affected by the voice and spoken words of an interviewer and participants' memory may become an issue, while mail and internet-based surveys are affected by written words and visual design (Dillman et al. 2009a). Designing good survey questions requires an understanding on how each component of the questions forms cohesive meaning to respondents (Dillman et al. 2009a).

Before the 1990s, a large amount of research had been conducted on how **written words** in mail and internet surveys influence the overall response rate, the quality, and the accuracy of such studies (Dillman et al. 2009a, Brace 2004, Smith 2003, De Leeuw and De Heer 2002, Foddy 1993, Brislin 1986). Every question to form a survey question must require an answer from each survey participant; otherwise non-response bias can occur (Dillman et al. 2009a). Every question must be written in sentence form with simple sentence structure (Dillman et al. 2009a). "Double-barreled" questions that contain two different verbs or state two different concepts must be avoided (Brace 2004, Fink 2002, Fowler 1992, Brislin 1986). Survey questions must be technically accurate (Dillman et al. 2009a) and grammatically correct (Dörnyei 2003, Dillman 2000, Brislin 1986). Complex words and phrases as well as technical vocabulary that not all respondents will understand should be avoided. Instead, simple and familiar words should be used (Dillman et al. 2009a). Survey questions should use specific and concrete words to specify the response task. Words that indicate vagueness should be avoided (Dillman et al. 2009a, Dillman 2000, Brislin 1986). Specific quantifiers in the response options of frequency questions must be applied to avoid misinterpretation of survey questions (Dillman et al. 2009a, Fink 2002, Schwarz et al. 1985). Survey questions should use as few words as possible, e.g., Brislin (1986) suggests using a maximum number of 16 words, while Oppenheim (1992) recommends using a maximum number of 20 words to form a question. Double negative wording in survey questions should also be avoided (Dillman et al. 2009a).

Since the 1990s, the focus of research started to shift from the science of written words to the science of **visual perception** (Dillman et al. 2009, Christian and Dillman 2004, Hoffman 2004, Palmer 1999). Dillman et al. (2009a) differentiate four design elements including words, numbers, symbols, and graphics that communicate information to respondents. Each of these design elements can be presented in a different way based on their size, font type, color, and location (Dillman et al. 2009, Ware 2004, Schwarz et al. 1998). Standardization of all design properties and response options are crucial to send consistent messages to respondents (Dillman et al. 2009a). For example, creating a separation between question and answer by using large/dark prints for questions and smaller/lighter prints for answers can help more respondents to provide an answer (Dillman et al. 2009a). Selecting proper line spacing, font and text sizes can ensure the legibility of questions and minimize the need to re-read portions of questions (Dillman et al. 2009a). Using visual design properties to emphasize important elements can help more respondents to provide an answer (Dillman et al. 2009a). Integrating special instructions into questions and emphasizing them with font or symbol variation can assure that they are applied properly by respondents at the time when they matter (Christian and Dillman 2004).

Both, wording and visual perception can be applied for all survey question types; they just require a slightly different configuration (Dillman et al. 2009a). Three types of **question format** can be differentiated, e.g., open-ended questions, closed-ended questions, and partially closed ended questions (Dillman et al. 2009a). An open-ended question format is used when the goal is to collect detailed information on a topic without limiting or influencing respondent answers (Dillman et al. 2009a). In open-ended questions, respondents are asked to write their answers using their own words in a blank space or box (Dillman et al. 2009a). The drawback of using an open-ended question format is that respondents often tend to skip such questions or provide only short answers (Dillman et al. 2009a). Also, the analysis of open-ended questions is complex, because answers can be highly variable, in fact, they can be much higher than when using any other question formats (Dillman et al. 2009a). A closed-ended question format is used when researchers provide respondents with a list of answer choices from which they must choose to answer (Dillman et al. 2009a). Four types of closed-ended questions exist: (a) nominal, (b) ordinal, (c) ratio, and (d) interval questions (Dillman et al. 2009a). Nominal questions (a) include categorically discrete answer options, such as name of the respondent's school, type of the car the respondent drive (Dillman et al. 2009a). Ordinal questions (b) include an ordered set of answer categories, such as the level of satisfaction on a rating scale from 1 to 5 (Dillman et al. 2009a). Ratio questions (c) include interval answers with a natural zero point, e.g., time. Interval questions (d) include answers where intervals between each value are equally split, e.g., degrees Fahrenheit (Dillman et al. 2009a). Partially closed ended questions are used when listing too many answer choices would overwhelm respondents (Dillman et al. 2009a). Adding an "Other" category to the answer choices allows respondents to provide a response that does not fit in the list, but hopefully most respondents will be able to select a response from the list (Dillman et al. 2009a).

When designing a survey, transforming a list of well-designed questions into a well-designed questionnaire can maximize response rate and minimize measurement bias and non-response bias (Dillman et al. 2009a). Questions that cover similar topics should be grouped together and be separated into different survey sections. The first question of the survey should be relevant to nearly all respondents (Dillman et al. 2009a, Groves 2006, Heberlein and Baumgartner 1978), while sensitive questions should be placed at the end of the questionnaire (Dillman et al. 2009a). All questions should be numbered or identified with a letter (Dillman et al. 2009a). Survey questions should be listed in a chronological order within each survey section to help respondents access their memories (Dillman et al. 2009a, Belli 1998). Visual presentation of questions (e.g., color and contrast), as well as the alignment of questions, should be consistent throughout the entire questionnaire to help respondents organize and visually emphasize the information on the page (Dillman et al. 2009a, Lidwell et al. 2003).

2.7.1.3. Survey Implementation Planning

To receive a large number of high quality responses, survey implementation procedures must be planned with careful consideration (Dillman et al. 2009a). A significant body of research has been conducted on identifying factors that have a positive impact on survey response rate in both mail and internet-based surveys. In mail surveys, research shows that **personalizing** all contacts to survey participants by using high quality papers, real names, blue-ink signatures, and recognizable graphics, among other things, may increase response rates between three to twelve percent (Dillman et al. 2009a). Since internet-based surveys and emails are less personal forms of communication than mail surveys and letters, personalizing an email invitation with a “Dear [First Name]” style and sending it to individual recipients rather than multiple recipients at once can increase response-rates by up to four percent (Joinson and Reips 2007, Heerwegh 2005, Barron and Yechiam 2002). Additionally, sending out the email to multiple recipients also raises serious ethical considerations, since it violates confidentiality (Dillman et al. 2009a). In mail surveys, using a **token of appreciation** is a novel and unexpected gesture that encourages participants to respond by completing questionnaires (Dillman et al. 2009a). Research shows that using a token of appreciation reduces non-response bias because it encourages participants who were relatively uninterested in completing the questionnaire to respond (Groves 2006, Church 1993, James and Bolstein 1992). Sending a small amount of money, between $1 and $5, for survey participation is an encouraging gesture that puts the questionnaire in a positive light

(Dillman et al. 2009a). In certain cases, small things like a piece of chocolate or a postage stamp can also have a positive effect on response rates and response quality (Gendall and Healey 2008). In internet-based surveys, sending a token of appreciation is a more complicated task because physical objects cannot be delivered over the Internet. Instead, electronic gift certificates, gift cards, magazine subscriptions, among other things can be offered to participants (Birnholtz et al. 2004). Göritz (2006) found that financial incentives provided electronically can increase response rate by an average of four percent. In mail surveys, **approaching survey participants multiple times** by sending them a pre-notification letter, a questionnaire with a cover letter, a reminder postcard, a replacement questionnaire, a final contact with possibly a different mode of delivery, and a thank you note for each participant can improve the overall response rate (Dillman et al. 2009a, Heberlein and Baumgartner 1978). In internet-based surveys, the same approach can be used, although if the first email gets flagged as spam, it is very likely that none of the follow-up emails will be delivered and read (Dillman et al. 2009a, Cook et al. 2000). Therefore Dillman et al. (2009a) recommends using another mode, e.g., mail-surveys parallel with internet-based surveys, whenever it is possible.

Scheduling mailings and follow-ups are important. In mail surveys, the pre-notification letter should arrive three days to one week prior to the initial questionnaire mailing so that it can be processed and not forgotten by participants (Dillman et al. 2009a). With follow-ups, an average of two to four weeks waiting is suggested before sending the next postcard or questionnaire (Dillman et al. 2009a). In mail surveys, all documents should be professional-appearing and the information should be placed exactly where it should be (Dillman et al. 2009a). The document should enclose a return envelope with pre-paid postage that is recognizable for respondents (Dillman et al. 2009a). Also, an identification number should be included that ensures that follow-up mails are only sent to non-respondents (Dillman et al. 2009a). If the mail is returned as undeliverable due to change of residence, incorrect address, or closed business, a new schedule for a new mail-out with updated addresses should be created (Dillman et al. 2009a). Refused or unclaimed questionnaires should be removed from the mailing list (Dillman et al. 2009a). In internet-based surveys, scheduling and timing is a more sensitive issue since the internet-based survey process is generally faster but also more easily dismissible (Dillman et al. 2009a). Email reminders can be sent out more frequently than mail reminders; however, too frequent emails may irritate respondents (Dillman et al. 2009a). The best time to send out an internet-based survey is before work hours, because it allows participants to read and fill out the survey before they get busy (Dillman et al. 2009a, Trouteaud 2004). Regardless of the survey mode, federal holidays should be avoided while scheduling a survey (Dillman et al. 2009a). In internet-based surveys, the sender name, address, and subject line should be carefully selected and the body of the email should be short and straight to the point (Dillman et al. 2009a). To avoid spam filters, researchers should make sure that their computer's IP address is not flagged by major email providers and their message is sent as a text message rather than an HTML message to individual recipients (Dillman et al. 2009a). In internet-based surveys, clear instructions, possibly even step-by-step instructions, must be provided to all participants on how to access the survey, e.g., which website to go to, how to enter the personal access code, how to go forward and backward, how to track progress, and how to submit responses once the survey is completed (Dillman et al. 2009a). The notification email and the survey website should have an obvious connection that ensures respondents that they are at the right location (Dillman et al. 2009a). A study conducted by Heerwegh and Loosveldt (2002) found that if an access code is provided to enter an internet-based survey, respondents tend to provide higher quality responses than without an access code, most likely because they feel that their information is secure. In internet-based surveys, if survey software such as Survey Monkey (SurveyMonkey 1999) or Qualtrics (Qualtrics 2002) are used to contact participants, these software have inbuilt functions to handle incoming responses and outgoing reminders/thank you notes that ensure that no reminder is sent out to people who already responded or unsubscribed. If an email is returned undelivered due to incorrect email address, a new schedule for the new email with a corrected address should be created (Dillman et al. 2009a).

Once the survey is designed and implementation procedures are planned, the survey must be pre-tested to collect feedback from numerous people whose areas of expertise are different in regards to their knowledge about the survey subject, wording, question order, visual design, and navigation problems (Ott and Longnecker 2010, Dillman et al. 2009a). Then the survey should be sent out for a pilot test to a subsample of the population to evaluate interconnections among questions, the questionnaire, and implementation procedures (Ott and Longnecker 2010, Dillman et al. 2009a).

2.8. Survey Analysis

The analysis of survey results starts with the review of the data set collected. Researchers in social and behavioral sciences frequently face the problem of incomplete data sets due to survey design, refused response, insufficient knowledge, and loss of contacts, especially when information about a large number of characteristics for each respondent is collected (Berglund 2010, Raghunathan et al. 2001). Sometimes missing data occurs because the survey is designed in a way that it intentionally produces missing values, e.g., measurements may be taken on only a subset of the sample (Berglund 2010, Raghunathan et al. 2001). More often, missing values occur because respondents refuse to answer certain questions, e.g., sensitive questions or respondents have insufficient knowledge about the question asked (Berglund 2010, Raghunathan et al. 2001). Also, missing values are common in longitudinal studies, when respondents drop out due to lost contact or death (Berglund 2010, Raghunathan et al. 2001). Missing data are potential sources of bias when analyzing survey data. The interpretation of survey results is problematic when a large number of returned survey instruments miss values. Unfortunately, there is no methodological approach for handling missing values that is universally accepted for all situations; therefore, a thorough understanding of the advantages and disadvantages of the existing methods dealing with missing data is essential.

2.8.1. Missing Survey Data Handling Methods

A theoretical framework on how to handle missing data was developed by Rubin (1976) who described three mechanisms on how the probability of a missing value can relate to the data set. The first missing data mechanism – missing at random (MAR) – describes a situation when the missing data is related to other measured variables in the analysis model, but not to the underlying values of the incomplete variable (Rubin 1976, Enders 2010, Baraldi and Enders 2010). For example, in the subject of this document, the "Lean implementation in transportation equipment manufacturing" survey, sampled individuals are asked whether their facility was involved in a Lean transformation. From individuals responding "no" to this question, responses are not collected on what year their facility started the Lean transformation and whether the transformation is still ongoing due to a skip question mechanism incorporated in the survey design. Therefore, responses for the second and third questions of this example will be missing for individuals responding "no" to the first question. Consequently, the probability of a missing value in question two and three of this example is simply a function of a “no” response to question one and is unrelated to the facility’s performance. The practical problem with the MAR mechanism is that it is impossible to confirm that the probability of missing data (e.g., the year when the Lean implementation started in the facility) on the outcome variable (e.g., business performance) is only a function of other measured variables (e.g., no Lean implementation in the facility). Therefore, it is impossible to statistically test that the mechanism is MAR, it’s assumed. The second missing data mechanism – missing completely at random (MCAR) – describes a situation where the probability of missing data is unrelated to other measured variables in the analysis model and to the underlying values of the incomplete variable (Rubin 1976, Enders 2010, Baraldi and Enders 2010). It means that missing values in a facility performance variable are unrelated to other measured variables, such as the involvement in Lean transformation variable and unrelated to the values of facility performance as well. Although, it is impossible to statistically verify that values are MAR, it is possible to test whether values are MCAR with Little’s MCAR test (Little 1988, Enders 2010). The last missing data mechanism – missing not at random (MNAR) – describes a situation when the probability of missing values on a given variable is related to the given variable itself, even after controlling for other variables (Rubin 1976, Enders 2010). For example, in the subject of this document, MNAR data would occur in the “Lean implementation in transportation equipment manufacturing” survey if companies with no Lean transformation efforts are more likely to skip questions out of fear of performing worse than others. Similarly to MAR, it is impossible to statistically verify that values are MNAR without knowing the values of the missing variables (Enders 2010). Several existing methods on analyzing missing data are discussed below.

2.8.1.1. Listwise deletion or complete-case analysis

Listwise deletion or complete-case analysis is one of the most common used missing data handling method (Enders 2010). Listwise deletion removes all responses with one or more missing values from analysis (Enders 2010). The advantage of listwise deletion is that it restricts the analysis to complete cases and therefore provides a strong basis for analysis and also eliminates the need for using complex statistics and statistical software packages (Enders 2010). The disadvantage of this method is that it always assumes that the missing data is missing completely at random (MCAR). If that assumption does not hold, it may provide skewed estimates for analysis. For example, if two variables in a survey are positively correlated to each other and some data are missing in regards to one of those two variables, listwise deletion would exclude cases from the lower or upper tail of the other variable cases as well causing skewed results in the other variable's mean estimates (Enders 2010). Also, deleting all incomplete responses would result in a dramatic reduction of the response rate and thus of the statistical power of the survey (Enders 2010). Despite its disadvantages, listwise deletion can provide accurate data for regression analysis under any missing data mechanisms as long as the missing data is a function of a dependent variable but not an independent variable (Little 1992, Enders 2010).

2.8.1.2. Pairwise deletion or available-case analysis

Pairwise deletion or available-case analysis is another commonly used missing data handling method that uses complete cases for analysis by disregarding data for any case that has one or more missing values (Enders 2010). Unlike listwise deletion, pairwise deletion uses complete case analysis on a question by question basis which may result in different response rates for each question (Enders

2010). The advantage of pairwise deletion is its simplicity and its tendency to be more powerful than listwise deletion if there is a large sample size with only a few missing values and the variables of the data set are not highly correlated (Glasser 1964, Enders 2010). The disadvantage of the method, similarly to listwise deletion, is that it only provides accurate estimates for MCAR data (Enders 2010).

2.8.1.3. Arithmetic mean imputation

Arithmetic mean imputation, also called mean substitution or unconditional mean imputation, is a single imputation method that generates a single replacement value for each missing data point based on the arithmetic mean of the available cases (Wilks 1932, Enders 2010). Although, arithmetic mean imputation is an easy to perform analysis, it imputes a constant for each missing value and thereby restricts the variability of the data, infuses the data with uncorrelated observations and weakens measures of observations provided by respondents (Enders 2010, Enders and Bandalos 2001, Gleason and Staelin 1975). For example, if two variables are positively correlated and in regards to the first variable the lowest data values are missing because they were not collected. The arithmetic mean imputation would replace the missing values of the first variable with the average of the remaining values of the same variable (Enders 2010). By doing so, the variability of those data values will become higher indicating misleadingly that no correlations between the original two variables exist (Enders 2010). Enders (2010) therefore claims that arithmetic mean imputation is the worst available missing data handling method.

2.8.1.4. Regression imputation or conditional mean imputation

Regression imputation or conditional mean imputation is a single imputation method that uses observed values to complete missing values based on a regression equation (Buck 1960, Enders 2010).

The imputation requires two steps. At first, a set of regression equations need to be created to estimate missing values from the observed ones based on a complete-case analysis and then predicted values need to be generated for missing values (Enders 2010). Although, regression imputation is superior to the arithmetic mean imputation method (Enders 2010), it often imputes the data with perfectly correlated values and thereby creates overestimated correlations and r-square statistics (Beale and Little 1975, Gleason and Staelin 1975).

2.8.1.5. Stochastic regression imputation

The stochastic regression imputation method is another single imputation method that uses a set of regression equations to predict missing values based on the observed ones by applying complete-case analysis (Enders 2010). Stochastic regression imputation outperforms the regression imputation by adding residuals – the distance between the actual value of the dependent variable and the predicted value of the regression model – to the imputed values (Enders 2010). Stochastic regression imputation is performed in three steps. First, the entire case analysis is used to establish a set of regression equations to predict missing values based on the observed ones (Enders 2010). Then, the observed values are inserted into the established regression equations to create predictions for missing values (Enders 2010). Finally, each predicted value is augmented with a normally distributed residual value that is added to compensate for lost variability (Enders 2010). Although, stochastic regression imputation outperforms regression imputation, it has the disadvantage of producing inappropriately small standard errors (Enders 2010, Little 1992).

2.8.1.6. Hot-deck imputation

Hot-deck imputation was originally developed by Census Bureau statisticians to deal with missing data in public-use data sets by imputing missing values with values from other, similar respondents (Scheuren 2005). Although, the Census Bureau often uses hot-deck imputation, it is not commonly used in social sciences because it is not designed to estimate measures of associations and it produces biased estimates for correlations and regression coefficients (Enders 2010, Schafer and Graham 2002).

2.8.1.7. Similar response pattern imputation

Similar response pattern imputation replaces each missing value with a value from a “donor case” that has matching values (Jöreskog and Sörbom 1993, Enders 2010). Finding a donor case as well as a matching value is a challenge and greatly influences the success of the imputation (Enders 2010). Similar response pattern imputation is not widely used by social scientists because it doesn’t have a strong theoretical foundation and it produces biased estimates for MAR data (Enders 2010, Enders and Bandalos 2001).

2.8.1.8. Averaging the available items method

Computing scale scores by averaging the available items is a common method for dealing with incomplete questionnaires in psychological studies (Enders 2010). If a respondent answers eight out of the 10 questions of a survey, the average score of the eight answers for that person is calculated and then multiplied by the total number of questions, which are 10 in this example (Enders 2010). The resulting scale scores then reflect each respondent’s view on the subject of interest; therefore, this method is also called as a “person mean imputation” in the literature (Bono et al. 2007, Sijtsma and

Van der Ark 2003, Bernaards and Sijtsma 2000). The few empirical studies that tested this method (Schafer and Graham 2002, Graham 2009) concluded that the meaning of scale scores may vary among respondents and that averaging the available items may be problematic when missing items have different means than complete items; therefore, Schafer and Graham (2002) suggest using this imputation method with caution.

2.8.1.9. Last observation carried out method

The last observation carried out method is used in longitudinal studies, mostly in clinical studies (Enders 2010, Wood et al. 2004). If responses are collected from sampled individuals once a week for 10 weeks, but a respondent drops out at week eight, values of the respondent's last observation is used for the last two weeks (Enders 2010). The last observation carried out method often produces biased estimated when data is MCAR (Enders 2010, Molenberghs and Kenward 2007) and is claimed to be a poor strategy for handling missing data in longitudinal studies (Enders 2010, Molenberghs and Kenward 2007, Cook et al. 2004).

2.8.2. State of the art missing data handling methods

2.8.2.1. Maximum likelihood method

Maximum likelihood is one of the two state of the art missing data handling methods (Schafer and Graham 2002). The maximum likelihood method generates several different combinations of population parameter values and selects the combination that produces the highest log-likelihood value (logarithm of the individual likelihood values) and the best fit for the data (Enders 2010). The maximum likelihood method estimates the parameters directly from complete data without imputation from the researchers (Enders 2010). The advantage of the maximum likelihood method over all other methods described above is that it generates accurate estimates when data is MAR and MCAR (Enders 2010), allowing it to produce accurate parameter estimates that have the highest probability of reproducing the sample data. If the data is MNAR, the maximum likelihood method may produce biased parameter estimates, but unlike the methods described previously that create bias throughout the entire analysis, the maximum likelihood method isolates the bias to the subset of the analysis (Enders 2010).

2.8.2.2. Multiple imputation

Multiple imputation is the second state of the art missing data handling method (Schafer and Graham 2002). Multiple imputation replaces each set of missing values with more than one plausible set of values and creates several "complete" data set. Then, each "complete" data set, with its combination of imputed values and observed values, is analyzed *m* times creating *m* sets of parameter estimates and *m* sets of standard errors. As a last step, the arithmetic average of the *m* sets of parameter estimates and *m* sets of standard errors provides the pooled parameter estimate (Enders 2010, Raghunathan and Grizzle 1995, Rubin 1976). Multiple imputation also provides accurate estimates when the data is MCAR and MAR, but similarly to maximum likelihood estimation it may provide biased estimation with MNAR data (Enders 2010). Therefore, multiple imputation is an alternative method to maximum likelihood estimation; both produce very similar parameter estimates and standard errors (Enders 2010). The maximum likelihood estimation method is preferred over the multiple imputation method if the goal of the study is to estimate interaction effects or to build a structural equation model (Enders 2010). Maximum likelihood estimation is also built into more software packages then multiple imputation; therefore, it may be easier to use (Enders 2010). However, multiple imputation is the preferred method over maximum likelihood estimation if there are missing outcome variables in the data set, or missing data needs to be analyzed on an item-level, or if auxiliary variables (variables that potentially correlate to missing data) are in use. In any other case, selection of one method over the other is based on the researchers' preference. For this study about Lean implementation and the role of Lean accounting in the transportation equipment manufacturing industry where the multiple imputation method was chosen as the preferred method. A more detailed discussion of the method follows below.

2.8.3. Multiple Imputation

The **first step** of handling missing data using the multiple imputation method is to identify the observed and missing variables of a dataset (Reiter et al. 2006, Raghunathan et al. 2001, Van Buuren et al. 1999). For example, let X be an $n \times p$ covariate matrix containing all the variables with no missing values in a sample size of n. X consists of different types of variables including continuous, binary, count, mixed, and categorical variables. Let Y be an $n \times q$ matrix of partially observed outcome variables, where Y_{mis} and Y_{obs} represent the missing and observed parts of Y. Let R be an $n \times q$ binary matrix indicating the elements of Y that are observed (R_{ij} =1 if Y_{ij} is observed; Raghunathan et al. 2001, Van Buuren et al. 1999).

The **second step** of handling missing data with the multiple imputation method is to identify missing data mechanisms of the dataset (Berglund 2010, Van Buuren et al. 1999). The response mechanism models the probability that Y is observed as a function of observed and missing data, and is written as a conditional density $p(R = 1 \mid Y_{obs}, Y_{mis}, X)$. Different assumptions concerning the relation between R, Y_{obs} and Y_{mis}, and X define the different types of response mechanisms (e.g., MAR, MCAR, MNAR). As described previously, missing at random (MAR) means that there is a systematic relationship between one or more variables and the probability of missing data, missing completely at random (MCAR) means that the missing variables are completely unrelated to the dataset, and missing not at random (MNAR) means that the probability of missing values on a given variable is related to the given variable itself, even after controlling for other variables (Enders 2010).

The **third step** of handling missing data with multiple imputation method is to characterize the "missingness" by examining missing data patterns (Berglund 2010, Van Buuren et al. 1999). Six types of missing data patterns can be differentiated including univariate missing data pattern (missing values are isolated to a single variable), unit nonresponse missing data pattern (some variables are refused to be answered by some respondents), monotone missing data pattern (in longitudinal studies, study participants drop out and never return), general missing data pattern (missing values disperse throughout the entire dataset), planned missing data pattern (missing values are intentional by splitting surveys among sampled individuals), and latent variable missing data patterns (variables are missing for the entire sample; Enders 2010, Berglund 2010).

The **fourth step** of handling missing data with the multiple imputation method is to select the appropriate covariates for the imputation (Van Buuren et al. 1999). To minimize bias and maximize certainty, all covariates should be included in the imputation model; however, large surveys may consist of hundreds of variables and using all of them may lead to multicolinearity and computational problems (Van Buuren et al. 1999). Van Buuren et al. (1999) suggests the use of 15 to 25 covariates for the imputation by including all variables that appear in the complete-data model and adding to those the variables that appear in the response model and the variables that explain a considerable amount of variance of the "target variable," and subtracting the variances that have too many missing values within the subgroup of missing cases.

The **fifth step** of handling missing data using the multiple imputation method is to select the appropriate form of the model to impute missing values (Raghunathan et al. 2001, Van Buuren et al. 1999). If the data set has a monotone pattern, either a parametric method that assumes multivariate normality or a nonparametric method is appropriate to impute missing values (Berglund 2010). Parametric methods include the regression method, which is the most commonly used method (Rubin 1978) and the predictive mean matching method (Schenker and Taylor 1996, Heitjan and Little 1991), while the nonparametric method includes the propensity score method (Rubin 1987). The selection of the appropriate regression model is based on the following conditions (Raghunathan et al. 2001):

1) Normal linear regression is used if Y_j is a continuous variable
2) Logistic regression is used Y_j is a binary variable
3) Polytomous or generalized logit regression is used if Y_j is a categorical variable
4) Poisson loglinear regression is used if Y_j is a count variable
5) Logistic and normal linear regressions are used parallel if Y_j represents a mixed variable.

If the data set has an arbitrary pattern, a Markov chain Monte Carlo (MCMC) method (Metropolis and Ulam 1949) that assumes multivariate normality is used to impute all or enough missing values to make the imputed data sets have monotone missing patterns (Berglund 2010). Once the imputed data set has a monotone missing pattern, methods for data sets with monotone missing patterns can be used to impute remaining missing values (Berglund 2010). Raghunathan et al. (2001) however argue that the missing data pattern does not need to be monotone to apply the regression method for the imputation.

Once the set of covariates are entered into the imputation model and the form of the model has been selected, the posterior predictive density *p* $(Y_{mis} \mid X, R)$ can be determined (Van Buuren et al. 1999). The **sixth step** of handling missing data using the multiple imputation method is to draw imputations from the determined posterior predictive density to produce complete data sets (Berglund 2010, Raghunathan et al. 2001, Van Buuren et al. 1999). At first, the variable with the fewest number of missing values should be imputed under the appropriate form of the regression model, followed by the variable with the next fewest missing values (Berglund 2010, Raghunathan et al. 2001, Van Buuren et al. 1999). The imputation should be repeated until all variables have been imputed. Repeating these steps *m* times produces *m* completed data sets (Berglund 2010, Raghunathan et al. 2001, Van Buuren et al. 1999). If the proportion of missing values is approximately 20 percent, three to five imputations are adequate to achieve a 0.90 or higher relative efficiency (Rubin 1996).

Once the imputation step is complete, *m* joint imputed data sets are created that can be analyzed using standard statistical testing procedures to generate valid statistical inferences about these parameters by combining results from the *m* analyses (Berglund 2010). The following sub-chapter, therefore, aims to provide an overview of feasible statistical testing procedures for the integration or "*fit*" of Lean principles and determinants and the effect of a "*good fit*" on business performance.

2.8.4. Perspectives of Fit and their Subsequent Statistical Testing Procedures

As this study seeks to investigate the interrelationship of Lean principles and determinants throughout numerous functional areas, determine how they all "*fit*" together, and analyze the effect of a "*good fit*" on business performance, this sub-chapter will discuss the different statistical approaches to examine "fit."

Venkatraman (1989) identified and classified six types of "fit" including 1) fit as moderation, 2) fit as mediation, 3) fit as profile deviation, 4) fit as matching, 5) fit as covariation, and 6) fit as gestalts. The author expressed that the selection of the appropriate concept of fit depends on 1) the degree of specificity of the fit relationship, e.g., how well the theoretical relationship of Lean principles and determinants through different functional areas are predicted to fit together and 2) whether the fit relationship is connected to a particular criteria, e.g., business performance (Table 7, Venkatraman 1989). According to Venkatraman (1989) the degree of specificity is reciprocally proportional to the number of variables in the equation, meaning that the more specific the test is, the lower number of variables it contains, which also comes with the danger of oversimplification and reduced explanatory power (Venkatraman 1989, Blarr 2012). On the contrary, the less specific the test is the higher number of variables are included in the model, which results in higher explanatory power.

Table 7: **Venkatraman's concept of fit framework (Venkatraman 1989, p.425)**

Degree of specificity		Choice of anchoring the specification: Criterion-specific	Choice of anchoring the specification: Criterion-free	Number of variables in the fit equation
	High	1) Fit as moderation	4) Fit as matching	**Few**
		2) Fit as mediation	5) Fit as covariation	
	Low	3) Fit as profile deviation	6) Fit as gestalts	**Many**

2.8.4.1. Fit as Moderation

Fit as moderation is applied when the effect of an independent variable (X) on a dependent variable (Y) also depends on the level of a third variable (Z), called the moderator (Venkatraman 1989, p. 425):

$$Y = f(X, Z, X*Z)$$

In the above equation, let Y represent the business performance, let X represent the organizational strategy, let Z represent the investigated context, while let X*Z represent the interaction effect of the organizational strategy and the investigated context (Venkatraman 1989). In this model, fit is best understood when only two variables (X and Z) are involved and when the model is anchored with a particular criterion (Y, Venkatraman 1989). By using fit as moderation, researchers can either hypothesize that the predictive ability of certain organizational strategies differs across different contexts thereby investigating the strength of the moderation, or they can hypothesize that the organizational strategy and the investigated context jointly determine the business performance thereby investigating the form of the moderation (Venkatraman 1989). The strength of the moderation can be analyzed using subgroup analysis, where fit is supported when statistically significant differences exist in the value of correlation coefficients between organizational strategy and business performance across the investigated context groups (Arnold 1982, Venkatraman 1989). The form of the moderation can be analyzed using moderated regression analysis, where fit is supported when the unstandardized coefficient of the interaction effect significantly differs from zero (Arnold 1982, Venkatraman 1989).

The application of fit as moderation; however, has some limitations. First, multicollinearity arises when "…*Correlation between independent variables are extremely high, producing large standard errors of regression coefficients and unstable coefficients*" (Venkatraman 1989. p. 426). Second, joint assessment of main (e.g., organizational strategy's effect on performance) and interaction effects (e.g., fit between organizational strategy and the investigated context) cannot be accomplished using fit as moderation because the standardized coefficients would be meaningless (Venkatraman 1989). Lastly, it may be difficult to attach theoretical meanings to the interaction terms, especially if multiple sets of interactions or higher order interactions imply errors in logical explanations (Venkatraman 1989).

2.8.4.2. Fit as Mediation

Fit as mediation is applied when an intervening mechanism (Z), called a mediator, exists between the independent variable (X) and the dependent variable (Y, Rozeboom 1956, Venkatraman 1989, p. 429):

$$Y = f(X), \text{ if } Z = f(X) \text{ and } Y = f(Z)$$

In the above equation, let Y represent the business performance, let X represent the organizational structure, while Z (the mediator) represents the organizational strategy (Venkatraman 1989). The equation implies that a variable acts like a mediator only if "…*Variations in the independent variable affect the presumed mediator significantly; variations in the mediator affect the dependent variable significantly; and if the first and second effects are controlled, a previously significant relationship between the independent variable and the dependent variable is no longer significant…*" (Blarr 2012, p. 33). Similarly to the fit as moderation model, the fit as mediation model is anchored with a particular criterion, but here fit is best understood as an indirect effect, which suggests that the model is less precise than the fit as moderation model (Venkatraman 1989). By using fit as mediation in this example, researchers hypothesize that at least part of the organizational structure related increase in business performance is mediated by organizational structure related organizational strategy (Venkatraman 1989). To analyze fit as mediation, a path-analytic framework can be used, where fit as mediation is fully supported (complete mediation model) when the unstandardized coefficient of the mediator does not significantly differ from zero. However, if the unstandardized coefficient differs from zero, fit as mediation is only partially supported (partial mediation model, Venkatraman 1989). Venkatraman (1989) emphasizes that if researchers would like to specify the effects of performance that are attributable to fit, estimation and interpretation problems due to the complexity of the model may arise.

Blarr (2012) claims that researchers tend to apply the fit as moderation more often than fit as mediation. Regardless, the author argues that neither model performs better than the other; therefore, theoretical considerations should determine the choice (Blarr 2012). Fullerton and Wempe (2009) used a multi-perspective approach of fit as moderation and fit as mediation to investigate whether non-financial manufacturing performance moderates or mediates the relationship between Lean initiatives and financial performance (Fullerton and Wempe 2009). The authors failed to show any moderating effects but the results supported the concept of fit as mediation (Fullerton and Wempe 2009).

2.8.4.3. Fit as Profile Deviation

Fit as profile deviation relies on a principle that an ideal profile on implementing an organizational strategy for an investigated context (e.g., business environment) can be determined and associated with business performance (Xu et al. 2006, Venkatraman 1989). Adherence to this ideal profile will positively affect business performance if the context-strategy co-alignment is high, while deviations from this ideal profile will negatively affect business performance if the context-strategy co-alignment is weak (Xu et al. 2006, Venkatraman 1989). Therefore, fit as a profile deviation is anchored with a particular criterion (e.g., business performance), and ideal profiles are specified along a set of closely related variables (Xu et al. 2006, Venkatraman 1989).

The analysis of fit as a profile deviation is carried out in three steps (Blarr 2012, Venkatraman 1989). As a first step, an ideal profile must be determined (Blarr 2012, Venkatraman 1989). An ideal profile can be determined theoretically or empirically (Xu et al. 2006, Vorhies and Morgan 2003, Venkatraman 1989, Drazin and Van de Ven 1985). Theoretical determination of an ideal profile requires the relevant literature to be sufficiently detailed allowing researchers to estimate precise numerical scores for the appropriate set of dimensions in the ideal profile (Vorhies and Morgan 2003, Venkatraman 1989, Drazin and Van de Ven 1985). Researchers however often experience that the relevant literature is not detailed enough to objectively translate theoretical statements from the literature into precise numerical estimates across multiple dimensions (Vorhies and Morgan 2003, Venkatraman 1989, Drazin and Van de Ven 1985). If an ideal profile cannot be determined theoretically, it can be determined empirically with the identification of high-performing organizations implementing a given organizational strategy and a standardization of their investigated context as an ideal profile for implementing that organizational strategy (Vorhies and Morgan 2003, Venkatraman 1989, Drazin and Van de Ven 1985). In this case, the ideal profile is represented by a company that has configured its investigated context in a way that enables superior implementation of its organizational strategy that results in superior business performance (Vorhies and Morgan 2003, Venkatraman 1989, Drazin and Van de Ven 1985). As a second step, the set of dimensions included in the model must be weighted based on their relative importance to the context (Blarr 2012, Venkatraman 1989). In a third step, the predictive power of the test must be determined through a baseline model using weighted Euclidian distance calculations (Blarr 2012, Venkatraman 1989).

2.8.4.4. Fit as Matching

Fit as matching relies on a principle that "…*Fit is a theoretically defined match between two related variables*… (Venkatraman 1989, p.431)." In this model, fit is best understood when only two related variables, such as organizational strategy and an investigated context are involved and the model is not anchored with a particular criterion of Y (e.g., business performance, Venkatraman 1989). By using fit as matching, researchers can hypothesize that fit between organizational strategy (X) and an investigated context (Z) will be a significant predictor of business performance (Y, Alexander and Randolph 1985).

The analysis of fit as matching can be carried out through three different analytical schemes, including the deviation score analysis, residual analysis, and analysis of variance (ANOVA, Venkatraman 1989). The deviation score analysis, which was first applied by Alexander and Randolph (1985) as an operationalization of fit in strategic research, calculates the absolute difference between the standardized scores of the two variables of X and Z (Venkatraman 1989). In this model, "…*The performance implications of fit are tested by examining the impact that this variable* [absolute difference between the standardized scores of the two variables] *has on performance*…" (Venkatraman 1989, p.431). Venkatraman (1989) pointed out three potential limitations of the deviation score analysis, including the potential unreliability of the fit measure, the possibility of false association with an external variable, and the possibility of generally weak discriminant validity. The second analytical scheme is called residual analysis and was first applied by Dewar and Werbel (1979) as an operationalization of fit in strategic research (Venkatraman 1989). In this analysis, residuals from the regression of the two variables of X and Z are used to reflect fit, which can subsequently be related to Y (Venkatraman 1989). Using residual analysis is appropriate if the fit-based relationship is conceptualized as deviation and if the limitations of the deviation scores are not serious, but it is not appropriate if the fit-based relationship is conceptualized as moderation (Venkatraman 1989). Venkatraman (1989) pointed out four potential problem areas of the residual analysis, including the difficulty of selecting an appropriate baseline model to calculate the residuals, the possible misinterpretation of error variance of the residuals, the possible misinterpretation of the arithmetic sign of the residuals, and the possibility of interchanging the residual of X on Z with the residuals of Z on X. The third analytical scheme is called analysis of variance (ANOVA) and was first applied by Joyce et al. (1982) as an operationalization of fit in strategic research (Venkatraman 1989). The advantage of this scheme over the previous two is that it can test "…*Competing perspectives of fit within a common analytical framework*…" (Venkatraman 1989, p.432).

2.8.4.5. Fit as Covariation

Fit as covariation relies on a principle that there is a pattern of internal consistency, e.g., a pattern of covariation among a set of underlying, theoretically related variables (Venkatraman 1989, p.435). In this model, fit is best understood as a set of variables that require a precise explanation of the logical link among them; however, the model is not anchored with a particular criterion of Y e.g., business performance, (Venkatraman 1989). By using fit as covariation, researchers can hypothesize that an organizational strategy that is best represented as covariation among the constituent dimensions of manufacturing, accounting, sales, and logistics among others have a positive effect on business performance (Venkatraman 1989).

The analysis of fit as covariance can be carried out via structural equation modelling rather than via traditional regression analysis. Regression analysis is not highly recommended for this model, because regression coefficients may show statistical significance but they fail to show any logical linkage among the dimensions. Structural equation modelling on the other hand is capable of "…*Explaining covariation among a set of indicators in terms of a smaller set of factors and explaining the covariation among the first-order factors in terms of second-order factors*…" (Venkatraman 1989, p.436). To develop performance implications of fit, Venkatraman (1989) suggests comparing the coefficients of determinants, calculating the target coefficient, and calculating the statistical significance of the second-order factor loadings.

2.8.4.6. Fit as Gestalts

Fit as gestalts relies on a principle that internal coherence exists among a set of theoretical attributes and these attributes tend to form some kind of clusters or gestalts (Miller 1981, Venkatraman 1989). In this model, fit is best understood as a configuration of different contingencies that are each having distinctive implications for organizational strategy; however, the model is not anchored with a particular criterion of Y (e.g., business performance, Venkatraman 1989). By using fit as gestalts, researchers can hypothesize organizational strategy gestalts as a positive effect on business performance (Venkatraman 1989).

The analysis of fit as gestalts can be carried out through cluster analysis and q-factor analysis (Cua 2000, Venkatraman 1989, Miller 1981). Gestalts are few in number and may be very different from one another in terms of attributes; therefore, a systematic scheme must be developed to calibrate the differences in the degree of fit and to judge the descriptive validity of gestalts (Cua 2000, Venkatraman 1989, Miller 1981). According to Venkatraman (1989) descriptive validity requires formal statistical testing, such as C-H index, the cross-validation of results, and the description of theory the input variable selection was based upon. To develop performance implications of fit, Miller (1981) and Venkatraman (1989) suggests isolating generic successful and unsuccessful gestalts in an exploratory fashion.

Cua (2000) applied fit as gestalts in her dissertation to investigate whether fit of gestalts (involving common practices and basic techniques of TQM, JIT, and TPM) is positively associated with manufacturing performance. Olsen (2004) also used fit as gestalts analysis in his dissertation to investigate whether Lean gestalts (called Lean archetypes in his study) have better operational and financial performance than non-Lean gestalts.

Primary data collection and survey research mechanisms have been greatly transformed over the past decades with the presence of the Internet and electronic devices (Dillman et al. 2009a). New and innovative ways of conducting survey research to improve survey response rates have been developed (Dillman et al. 2009a, Connelly et al. 2003). The above sub-chapter introduced survey research mechanisms with special attention on the mode of conducting surveys as well as the methods used for designing questions and questionnaires from the past and present in the sequence of major steps involved in designing, implementing, and analyzing a quality survey. In addition, a detailed description of the available methods on handling missing data and the perspectives of fit with their subsequent statistical testing procedures were introduced.

References

Ahlstrom, Par, and Christer Karlsson. 1996. Change Processes towards Lean Production - The Role of the Management Accounting System. *International Journal of Operations & Production Management* 16 (11): 42–56.

Alexander, Judith W., and Alan W. Randolph. 1985. The Fit between Technology and Structure as a Predictor of Performance in Nursing Subunits. *Academy of Management Journal* 28 (4): 844–59.

AME. 2008. *Lean Assessment Tool*. Rolling Meadows, IL: Association for Manufacturing Excellence.

Ansari, Shahid, Janice Bell, and Dan Swenson. 2006. A Template for Implementing Target Costing. *Journal of Cost Management* 20 (5): 20–27.

Arnold, Hugh J. 1982. Moderator Variables: A Clarification of Conceptual, Analytic, and Psychometric Issues. *Organizational Behavior and Human Performance* 29 (2): 143–74.

Baggaley, Bruce L. 2003. Costing by Value-Stream. *Journal of Cost Management* 17 (3): 24–30.

Baggaley, Bruce L., and Brian H. Maskell. 2003a. Value Stream Management for Lean Companies – Part I. *Journal of Cost Management* 17 (2): 23–27.

———. 2003b. Value Stream Management for Lean Companies - Part II. *Journal of Cost Management* 17 (3): 24–30.

Baraldi, Amanda N., and Craig K. Enders. 2010. An Introduction to Modern Missing Data Analysis. *Journal of School Psychology* 48 (1): 5–37.

Barron, Greg, and Eldad Yechiam. 2002. Private E-Mail Requests and the Diffusion of Responsibility. *Computers in Human Behavior* 18 (5): 507–20.

Beale, Evelyn M., and Roderick J. Little. 1975. Missing Values in Multivariate Analysis. *Journal of the Royal Statistical Society Series B (Methodological)* 37 (1): 129–45.

Belli, Robert F. 1998. The Structure of Autobiographical Memory and the Event History Calendar: Potential Improvements in the Quality of Retrospective Reports in Surveys. *Memory* 6 (4): 383–406.

Berglund, Patricia A. 2010. An Introduction to Multiple Imputation of Complex Sample Data Using SAS 9.2. In *Statistics and Data Analysis*, pp. 265–77. Ann Arbor, MI: Institute for Social Research, University of Michigan.

Bernaards, Coen A., and Klaas Sijtsma. 2000. Influence of Imputation and EM Methods on Factor Analysis When Item Nonresponse in Questionnaire Data Is Nonignorable. *Multivariate Behavioral Research* 35 (3): 321–64.

Biemer, Paul P., and Lars E. Lyberg. 2003. *Introduction to Survey Quality*. 1st edition. Hoboken, NJ: John Wiley and Sons, Inc. pp. 377.

Birnholtz, Jeremy P., Daniel B. Horn, Thomas A. Finholt, and Sung Joo Bae. 2004. The Effects of Cash, Electronic, and Paper Gift Certificates as Respondent Incentives for a Web-Based Survey of Technologically Sophisticated Respondents. *Social Science Computer Review* 22 (3): 355–62.

Blarr, Henning W. 2012. *Organizational Ambidexterity: Implications for the Strategy-Performance Linkage*. Leipzig, Germany: Gabler Verlag. pp. 223.

Bono, Christine, L. Douglas Ried, Carole Kimberlin, and Bruce Vogel. 2007. Missing Data on the Center for Epidemiologic Studies Depression Scale: A Comparison of 4 Imputation Techniques. *Research in Social and Administrative Pharmacy* 3 (1): 1–27.

Brace, Ian. 2004. *Questionnaire Design. How to Plan, Structure and Write Survey Material for Effective Market Research*. 1st edition. London: Kogan Page Ltd. pp. 303.

Brislin, Richard W. 1986. The Wording and Translation of Research Instruments. In *Field Methods in Cross-Cultural Research*, pp. 137–164. In Walter J. Lonner & John W. Berry (eds.). Thousand Oaks, CA: Sage Publications, Inc.

Brosnahan, Jan P. 2008. Unleash the Power of Lean Accounting. *Journal of Accountancy* 206 (1): 60–66.

Buck, Samuel F. 1960. A Method of Estimation of Missing Values in Multivariate Data Suitable for Use with an Electronic Computer. *Journal of the Royal Statistical Society Series B (Methodological)* 22 (2): 302–6.

Caffyn, Sarah. 1999. Development of a Continuous Improvement Self-Assessment Tool. *International Journal of Operations & Production Management* 19 (11): 1138–53.

Canis, Bill, and Brent D. Yacobucci. 2010. The U.S. Motor Vehicle Industry: Confronting a New Dynamic in the Global Economy. CRS Report for Congress R41154. Washington D.C.: Congressional Research Service. pp. 68.

Christian, Leah M., and Don A. Dillman. 2004. The Influence of Graphical and Symbolic Language Manipulations on Responses to Self-Administered Questions. *Public Opinion Quarterly* 68 (1): 57–80.

Church, Allan H. 1993. Estimating the Effect of Incentives on Mail Survey Response Rates: A Meta-Analysis. *Public Opinion Quarterly* 57 (1): 62–79.

Compustat. 2013. *S&P Capital IQ - Compustat*. New York, NY: McGraw Hill Financial.

Connelly, Nancy A., Tommy L. Brown, and Daniel J. Decker. 2003. Factors Affecting Response Rates to Natural Resource-Focused Mail Surveys: Empirical Evidence of Declining Rates over Time. *Society & Natural Resources* 16 (6): 541–49.

Cook, Colleen, Fred Heath, and Russel L. Thompson. 2000. A Meta-Analysis of Response Rates in Web- or Internet-Based Surveys. *Educational and Psychological Measurement* 60 (6): 821–36.

Cook, Richard J., Leilei Zeng, and Grace Y. Yi. 2004. Marginal Analysis of Incomplete Longitudinal Binary Data: A Cautionary Note on LOCF Imputation. *Biometrics* 60 (3): 820–28.

CRSP. 2013. *Center for Research in Security Prices*. Chicago, IL: Univeristy of Chicago, Booth School of Business.

Crute, Valerie, Yvonne Ward, Steve Brown, and Andrew Graves. 2003. Implementing Lean in Aerospace — Challenging the Assumptions and Understanding the Challenges. *Technovation* 23 (12): 917–28.

Cua, Kristy O. 2000. A Theory of Integrated Manufacturing Practices: Relating Total Quality Management, Just-in-Time and Total Productive Maintenance. Doctor of Philosophy, Minneapolis, MN: University of Minnesota. pp. 224.

Cua, Kristy O., Kathleen E. McKone, and Roger G. Schroeder. 2001. Relationships between Implementation of TQM, JIT, and TPM and Manufacturing Performance. *Journal of Operations Management* 19 (6): 675–94.

De Leeuw, Edith D. and Walter De Heer. 2002. Trends in Household Survey Nonresponse: A Longitudinal and International Comparison. In *Survey Non-Response*, Chapter 3, pp. 41–54. In Robert M. Groves, Don A. Dillman, John L. Eltinge, and Roderick J. Little (eds.). New York, NY: Wiley and Sons, Inc.

Dewar, Robert, and James Werbel. 1979. Universalistic and Contingency Predictions of Employee Satisfaction and Conflict. *Administrative Science Quarterly* 24: 426–48.

Dillman, Don A. 2000. The Role of Behavioral Survey Methodologist in National Statistical Agencies. *International Statistical Review* 68 (2): 199–220.

Dillman, Don A., Glenn Phelps, Robert Tortora, Karen Swift, Julie Kohrell, Jodi Berck, and Benjamin L. Messer. 2009a. Response Rate and Measurement Differences in Mixed Mode Surveys Using Mail, Telephone, Interactive Voice Response and the Internet. *Social Science Research* 38 (1): 1–18.

Dillman, Don A., Jolene D. Smyth, and Leah M. Christian. 2009b. *Internet, Mail, and Mixed-Mode Surveys: The Tailored Design Method*. 3rd edition. Hoboken, NJ: Wiley and Sons, Inc. pp. 500.

Doolen, Toni L., and Marla E. Hacker. 2005. A Review of Lean Assessment in Organizations: An Exploratory Study of Lean Practices by Electronics Manufacturers. *Journal of Manufacturing Systems* 24 (1): 55–67.

Dörnyei, Zoltán. 2003. *Questionnaires in Second Language Research: Construction, Administration and Processing*. Second Language Acquisition Research Series. Mahwah, NJ: Lawrence Erlbaum Associates, Inc. Publishers. pp. 168.

Drazin, Robert, and Andrew H. Van de Ven. 1985. Alternative Forms of Fit in Contingency Theory. *Administrative Science Quarterly* 30 (4): 514–39.

Emiliani, Bob, David J. Stec, Lawrence Grasso, and James Stodder. 2003. *Better Thinking, Better Results: Using the Power of Lean as a Total Business Solution*. 1st edition. Kensington, CT: Center for Lean Business Management. pp. 313.

Enders, Craig K. 2010. *Applied Missing Data Analysis*. 1st edition. Methodology in the Social Sciences. New York, NY: The Guilford Press. pp. 377.

Enders, Craig K., and Deborah L. Bandalos. 2001. The Relative Performance of Full Information Maximum Likelihood Estimation for Missing Data in Structural Equation Models. *Structural Equation Modeling* 8 (3): 430–57.

Ery, Randy. 2006. Photo Etch Newsletter. http://www.photo-etch.com/PEnewsletterwinter06.pdf. Accessed: February 15, 2013.

Fink, Arlene G. 2002. *How to Ask Survey Questions*. 2nd edition. The Survey Kit 2. Thousand Oaks, CA: Sage Publications. pp. 160.

Flynn, Barbara B., Roger G. Schroeder, and Sadao Sakakibara. 1994. A Framework for Quality Management Research and an Associated Measurement Instrument. *Journal of Operations Management* 11 (4): 339–66.

———. 1995. The Impact of Quality Management Practices on Performance and Competitive Advantage. *Decision Sciences* 26 (5): 659–91.

Foddy, William. 1993. *Constructing Questions for Interviews and Questionnaires: Theory and Practice in Social Research*. Cambridge, United Kingdom: Cambridge University Press. pp. 244.

Fowler, Floyd J. 1992. How Unclear Terms Affect Survey Data. *Public Opinion Quarterly* 56 (2): 218–31.

Fricke, Christian. 2010. Lean Management: Awareness, Implementation Status, and Need for Implementation Support in Virginia's Wood Industry. Master Theses, Blacksburg, VA: Virginia Tech. pp. 183.

Fricke, Christian, and Urs Buehlmann. 2012a. Lean and Virginia's Wood Industry - Part I: Awareness and Implementation. *BioResources* 7 (4): 5074-93.

———. 2012b. Lean and Virginia's Wood Industry - Part II: Results and Need for Support. *BioResources* 7 (4): 5094-5108.

Fullerton, Rosemary R., Frances A. Kennedy, and Sally K. Widener. 2013. Management Accounting and Control Practices in a Lean Manufacturing Environment. *Accounting, Organizations and Society* 38 (1): 50–71.

Fullerton, Rosemary R., and William F. Wempe. 2009. Lean Manufacturing, Non-Financial Performance Measures, and Financial Performance. *International Journal of Operations & Production Management* 29 (3): 214–40.

Galbraith, Robert M., Richard E. Hawkins, and Eric S. Holmboe. 2008. Making Self-Assessment More Effective. *Journal of Continuing Education in the Health Professions* 28 (1): 20–24.

Gendall, Philip, and Benjamin Healey. 2008. Alternatives to Prepaid Monetary Incentives in Mail Surveys. *International Journal of Public Opinion Research* 20 (4): 517–27.

Glasser, Marvin 1964. Linear Regression Analysis with Missing Observations among the Independent Variables. *Journal of the American Statistical Association* 59 (307): 834–44.

Gleason, Terry C., and Richard Staelin. 1975. A Proposal for Handling Missing Data. *Psychometrika* 40 (2): 229–52.

Göritz, Anja S. 2006. Incentives in Web Studies: Methodological Issues and a Review. *International Journal of Internet Science* 1 (1): 58–70.

Graham, John W. 2009. Missing Data Analysis: Making It Work in the Real World. *Annual Review of Psychology* 60 (1): 549–76.

Grasso, Lawrence P. 2005. Are ABC and RCA Accounting Systems Compatible with Lean Management? *Management Accounting Quarterly* 7 (1): 12–27.

Groves, Robert M. 1989. *Survey Errors and Survey Costs*. 1st edition. Hoboken, N.J: Wiley and Sons, Inc. pp. 590.

———. 2006. Nonresponse Rates and Nonresponse Bias in Household. *Public Opinion Quarterly* 70 (5): 646–75.

Harris, Daniel C. 2012. The Adoption of Lean Operations and Lean Accounting on the Financial-Performance Measures of Publicly Traded Companies. Doctor of Philosophy, Oxford, MS: The University of Mississippi. pp. 162.

Heberlein, Thomas A., and Robert Baumgartner. 1978. Factors Affecting Response Rates to Mailed Questionnaires: A Quantitative Analysis of the Published Literature. *American Sociological Review* 43 (4): 447–62.

Heerwegh, Dirk. 2005. Effects of Personal Salutations in E-Mail Invitations to Participate in a Web Survey. *Public Opinion Quarterly* 69 (4): 588–98.

Heerwegh, Dirk, and Geert Loosveldt. 2002. An Evaluation of the Effect of Response Formats on Data Quality in Web Surveys. *Social Science Computer Review* 20 (4): 471–84.

Heitjan, Daniel F., and Roderick J. A. Little. 1991. Multiple Imputation for the Fatal Accident Reporting System. *Applied Statistics* 40 (1): 13–29.

Hicks, Ben J. 2007. Lean Information Management: Understanding and Eliminating Waste. *International Journal of Information Management* 24 (7): 233–49.

Hoffman, Donald D. 2004. *Visual Intelligence: How We Create What We See*. New York, NY: W. W. Norton & Company. pp. 320.

Hostetler, Dustin. 2010. Get Results: Improve Your Accounting Firm Processes Using Lean Six. *Journal of Accountancy* 209 (1): 38–42.

IBISWorld. 2012a. SUV & Light Truck Manufacturing in the US. IBISWorld. https://www.ibisworld.com/industry/default.aspx?indid=817 Accessed: March 02, 2014.

———. 2012b. Truck, Trailer, and Motor Home Manufacturing in the U.S. IBISWorld. http://www.ibisworld.com/industry/default.aspx?indid=820. Accessed: March 02, 2014.

———. 2012c. Automobile Engine and Parts Manufacturing in the U.S. IBISWorld. http://www.ibisworld.com/industry/default.aspx?indid=826. Accessed: March 02, 2014.

———. 2012d. Automobile Steering and Suspension Manufacturing in the U.S. IBISWorld. http://www.ibisworld.com/industry/default.aspx?indid=832. Accessed: March 02, 2014.

———. 2012e. Automobile Brakes Manufacturing in the U.S. IBISWorld. http://www.ibisworld.com/industry/default.aspx?indid=833. Accessed: March 02, 2014.

———. 2012f. Automobile Transmission Manufacturing in the U.S. IBISWorld. http://www.ibisworld.com/industry/default.aspx?indid=834. Accessed: March 02, 2014.

———. 2012g. Automobile Metal Stamping in the U.S. IBISWorld. http://www.ibisworld.com/industry/default.aspx?indid=836. Accessed: March 02, 2014.

———. 2013a. Car & Automobile Manufacturing in the US. IBISWorld. http://clients1.ibisworld.com.ezproxy.lib.vt.edu:8080/reports/us/industry/default.aspx?entid=816. Accessed: February 15, 2014.

———. 2013b. Truck and Bus Manufacturing in the U.S. IBISWorld. http://www.ibisworld.com/industry/default.aspx?indid=818. Accessed: March 02, 2014.

———. 2013c. Automobile Electronics Manufacturing in the U.S. IBISWorld. http://www.ibisworld.com/industry/default.aspx?indid=829. Accessed: March 02, 2014.

———. 2013d. Automobile Interior Manufacturing in the U.S. IBISWorld. http://www.ibisworld.com/industry/default.aspx?indid=835. Accessed: March 02, 2014.

James, Jeannine M., and Richard Bolstein. 1992. Large Monetary Incentives and Their Effect on Mail Survey Response Rates. *Public Opinion Quarterly* 56 (4): 442–53.

James-Moore, S., and A. Gibbons. 1997. Is Lean Manufacture Universally Relevant? An Investigative Methodology. *International Journal of Operations & Production Management* 17 (9): 899–911.

Joinson, Adam N., and Ulf-Dietrich Reips. 2007. Personalized Salutation, Power of Sender and Response Rates to Web-Based Surveys. *Computers in Human Behavior* 23 (3): 1372–83.

Jordan, James A., and Frederick J. Michel. 2001. *The Lean Company: Making the Right Choices*. Dearborn, MI: Society of Manufacturing. pp. 344.

Jöreskog, Karl G., and Dag Sörbom. 1993. *LISREL 8: Structural Equation Modeling with the SIMPLIS Command Language*. Chicago, IL: Scientific Software International. pp. 262.

Joyce, William, John W. Slocum, and Mary Ann Von Glinow. 1982. Person-Situation Interaction: Competing Models of Fit. *Journal of Organizational Behavior* 3 (4): 265–80.

Krafcik, John F. 1988. Triumph of the Lean Production System. *Sloan Management Review* 30 (1): 41–52.

Lareau, William. 2002. *Office Kaizen: Transforming Office Operations into a Strategic Competitive Advantage*. Milwaukee, WI: American Society for Quality. pp. 174.

Lidwell, William, Kristina Holden, and Jill Butler. 2003. *Universal Principles of Design*. Glouchester, MA: Rockport Publishers. pp. 216.

Liker, Jeffrey K. 2003. *The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer*. 1st edition. New York, NY: McGraw-Hill Companies. pp. 330.

Liker, Jeffrey K., and Michael Hoseus. 2008. *Toyota Culture: The Heart and Soul of the Toyota Way*. 1st edition. New York, NY: McGraw-Hill Companies. pp. 562.

———. 2010. Human Resource Development in the Toyota Culture. *International Journal of Human Resources Development and Management* 10 (1): 34-50.

Little, Roderick J. 1988. A Test of Missing Completely at Random for Multivariate Data with Missing Values. *Journal of the American Statistical Association* 83 (404): 1198–1202.

———. 1992. Regression with Missing X's: A Review. *Journal of the American Statistical Association* 87 (420): 1227–37.

MacDuffie, John P. 1995. Human Resource Bundles and Manufacturing Performance: Organizational Logic and Flexible Production Systems in the World Auto Industry. *Industrial & Labor Relations Review* 48 (2): 197–221.

Maskell, Brian H. 1996. *Making the Numbers Count: The Management Accountant as Change Agent on the World Class Team*. 1st edition. New York, NY: Productivity Press. pp. 243.

———. 2007. *The Diagnostic Questionnaire of Accounting, Control, and Measurement*. Cherry Hill, NJ: BMA, Inc.

Maskell, Brian H., and Bruce L. Baggaley. 2003. *Practical Lean Accounting: A Proven System for Measuring and Managing the Lean Enterprise*. New York, NY: Productivity Press. pp. 359.

McVay, Gloria, Frances A. Kennedy, and Rosemary R. Fullerton. 2013. *Accounting in the Lean Enterprise*. Boca Raton, FL: CRC Press, Taylor and Francis Group. pp. 184.

Metropolis, Nicholas, and Stanislaw Ulam. 1949. The Monte Carlo Method. *Journal of the American Statistical Association* 44 (247): 335–41.

Miller, Danny. 1981. Toward a New Contingency Approach: The Search for Organizational Gestalts. *Journal of Management Studies* 18 (1): 1–26.

Miller, Robert D. 2012. The Shingo Prize for Operational Excellence - Model & Application Guidelines. Jon M. Huntsman School of Business, Utah State University. http://www.shingoprize.org/files/ModelsGuidelines_v5.pdf. Accessed: March 12, 2012.

Minter, Steve. 2010. Measuring the Success of Lean. *Industry Week* 259 (2): 32-35.

Molenberghs, Geert, and Michael Kenward. 2007. *Missing Data in Clinical Studies*. 1st edition. New York, NY: Wiley and Sons, Inc. pp. 526.

Monden, Yasuhiro. 1998. *Toyota Production System: An Integrated Approach to Just-in-Time*. 1st edition. New York, NY: Productivity Press. pp. 480.

Nightingale, Deborah J., Leyla Abdimomunova, Thomas Shields, Nathan L. Perkins, Jayakanth Srinivasan, and Ricardo Valerdi. 2012. *LAI Enterprise Self-Assessment Tool (LESAT) Version 2.0*. Massachusetts, MA: Massachusetts Institute of Technology, Lean Advancement Initiative.

Nightingale, Deborah J., and Joe H. Mize. 2002. Development of a Lean Enterprise Transformation Maturity Model. *Information Knowledge Systems Management* 3 (1): 15-30.

Ohno, Taiichi. 1988. *Toyota Production System: Beyond Large-Scale Production*. 1st edition. Cambrige, MA: Productivity Press. pp. 152.

Olsen, Eric Oscar. 2004. Lean Manufacturing Management: The Relationship between Practice and Firm Level Financial Performance. Doctor of Philosophy, Columbus, OH: The Ohio State University. pp. 220.

Oppenheim, Abraham N. 1992. *Questionnaire Design, Interviewing and Attitude Measurement*. 1st edition. London: Pinter Publishers, Ltd. pp. 312.

Ott, Lyman R., and Michael T. Longnecker. 2010. *An Introduction to Statistical Methods and Data Analysis*. 6th edition. Belmont, CA: Brooks/Cole Cengage Learning. pp. 1254.

Palmer, Stephen E. 1999. *Vision Science: Photons to Phenomenology*. 1st edition. Massachusetts, MA: The MIT Press. pp. 832.

Panizzolo, Roberto. 1998. Applying the Lessons Learned from 27 Lean Manufacturers: The Relevance of Relationships Management. *International Journal of Production Economics* 55 (3): 223–40.

Paulk, Mark C., Bill Curtis, Mary Beth Chrissis, and Charles V. Weber. 1993. Capability Maturity Model, Version 1.1. *Software, IEEE* 10 (4): 18–27.

Pil, Frits K. 1996. The International and Temporal Diffusion of High-Involvement Work Practices. Doctor of Philosophy, Philadelphia, PA: University of Pennsylvania. pp. 211.

Qualtrics. 2002. Qualtrics Online Survey Software and Insight Platform. http://www.qualtrics.com/. Accessed: March 2, 2014.

Raghunathan, Trivellore E., and James E. Grizzle. 1995. A Split Questionnaire Survey Design. *Journal of the American Statistical Association* 90 (429): 54–63.

Raghunathan, Trivellore E., James M. Lepkowski, John Van Hoewyk, and Peter Solenberger. 2001. A Multivariate Technique for Multiply Imputing Missing Values Using a Sequence of Regression Models. *Survey Methodology* 27 (1): 85–96.

Reiter, Jerome P., Trivellore E. Raghunathan, and Satkartar K. Kinney. 2006. The Importance of Modeling the Survey Design in Multiple Imputation for Missing Data. *Survey Methodology* 32 (2): 143–50.

Rozeboom, William W. 1956. Mediation Variables in Scientific Theory. *Psychological Review* 63 (4): 249–64.

Rother, Mike, and Rick Harris. 2001. *Creating Continuous Flow: An Action Guide for Managers, Engineers & Production Associates*. 1st edition. Cambridge, MA: Lean Enterprise Institute. pp. 105.

Rother, Mike, John Shook, Daniel T. Jones, and James P. Womack. 1999. *Learning to See: Value Stream Mapping to Add Value and Eliminate MUDA*. Cambridge, MA: Lean Enterprise Institute. pp. 102.

Rubin, Donald B. 1976. Inference and Missing Data. *Biometrika* 63 (3): 581–92.

———. 1978. Multiple Imputations in Sample Surveys — a Phenomenological Bayesian Approach to Nonresponse. In *Proceedings of the Section on Survey Research Methods*, pp. 20–29. The American Statistical Association.

———. 1996. Multiple Imputation after 18+ Years. *Journal of the American Statistical Association* 91 (434): 473–89.

Sánchez, Angel M., and Manuela P. Pérez. 2001. Lean Indicators and Manufacturing Strategies. *International Journal of Operations & Production Management* 21 (11): 1433–52.

Schafer, Joseph L., and John W. Graham. 2002. Missing Data: Our View of the State of the Art. *Psychological Methods* 7 (2): 147-177.

Scheaffer, Richard L., William III. Mendenhall, Lyman R. Ott, and Kenneth G. Gerow. 2011. *Elementary Survey Sampling*. 7th edition. Boston, MA: Cengage Learning. pp. 448.

Schenker, Nathaniel, and Jeremy MG Taylor. 1996. Partially Parametric Techniques for Multiple Imputation. *Computational Statistics & Data Analysis* 22 (4): 425–46.

Scheuren, Fritz. 2005. Multiple Imputation: How It Began and Continues. *The American Statistician* 59 (4): 315–19.

Schwarz, Norbert, Carla E. Grayson, and Bärbel Knäuper. 1998. Formal Features of Rating Scales and the Interpretation of Question Meaning. *International Journal of Public Opinion Research* 10 (2): 177–83.

Schwarz, Norbert, Nans J. Hippler, Brigitte Deutsch, and Fritz Strack. 1985. Response Scales: Effects of Category Range on Reported Behavior and Comparative Judgments. *Public Opinion Quarterly* 49 (3): 388–95.

Shah, Rachna. 2002. A Configurational View of Lean Manufacturing and Its Theoretical Implications. Doctor of Philosophy, Columbus, OH: The Ohio State University. pp. 278.

Shah, Rachna, and Peter T. Ward. 2003. Lean Manufacturing: Context, Practice Bundles, and Performance. *Journal of Operations Management* 21 (2): 129–49.

———. 2007. Defining and Developing Measures of Lean Production. *Journal of Operations Management* 25 (4): 785–805.

Shimokawa, Koichi, Takahiro Fujimoto, Brian Miller, and John Shook. 2009. *The Birth of Lean - Conversations with Taiichi Ohno, Eiji Toyoda, and Other Figures Who Shaped Toyota Management.* Cambridge, MA: The Lean Enterprise Institute. pp. 284.

Sijtsma, Klaas, and L. Andries van der Ark. 2003. Investigation and Treatment of Missing Item Scores in Test and Questionnaire Data. *Multivariate Behavioral Research* 38 (4): 505–28.

Smalley, Art. 2004. *Creating Level Pull: A Lean Production-System Improvement Guide for Production-Control, Operations, and Engineering Professionals*. Cambridge, MA: Lean Enterprise Institute. pp. 114.

Smith, Tom W. 2003. Developing Comparable Questions in Cross-National Surveys. In *Cross-Cultural Survey Methods*, 325:69–91. In Janet A. Harkenss, Fons J. R. Van de Vijver & Pether P. Mohler (Eds.). Hoboken, NJ: Wiley Interscience.

Soriano-Meier, Horacio, and Paul L. Forrester. 2002. A Model for Evaluating the Degree of Leanness of Manufacturing Firms. *Integrated Manufacturing Systems* 13 (2): 104–9.

Spear, Steven, and Kent H. Bowen. 1999. Decoding the DNA of the Toyota Production System. *Harvard Business Review* 77 (September-October): 96–108.

Statistics Canada. 2007. North American Industry Classification (NAICS) 2007 - Transportation Equipment Manufacturing. http://www.census.gov/cgi-bin/sssd/naics/naicsrch?code=336&search=2012%20NAICS%20Search. Accessed: February 15, 2014.

Sugimori, Y., F. Kusunoki, F. Cho, and S. Uchikawa. 1977. Toyota Production System and Kanban System Materialization of Just-in-Time and Respect-for-Human System. *The International Journal of Production Research* 15 (6): 553–64.

SurveyMonkey. 1999. SurveyMonkey. https://www.surveymonkey.com/. Accessed: March 2, 2014.

Swenson, Dan, Shahid Ansari, Janice Bell, and Il-Woon Kim. 2003. Best Practices in Target Costing. *Management Accounting Quarterly* 4 (2): 12–17.

Taylor, Frederick W. 1939. *The Principles of Scientific Management*. New York, NY: Harper & Row. pp. 80.

Trouteaud, Alex R. 2004. How You Ask Counts A Test of Internet-Related Components of Response Rates to a Web-Based Survey. *Social Science Computer Review* 22 (3): 385–92.

U.S. Bureau of Labor Statistics. 2014. Customer Price Index. http://www.bls.gov/cpi/. Accessed: March 07, 2014.

U.S. Census Bureau. 2007a. Transportation Equipment Manufacturing (NAICS 336) - Industry Facts Report 2007. http://thedataweb.rm.census.gov/TheDataWeb_HotReport2/econsnapshot/snapshot.hrml?NAICS=336. Accessed: February 15, 2014.

———. 2007b. Motor Vehicle Manufacturing (NAICS 3361) - Industry Facts Report 2007. https://www.census.gov/econ/census/snapshots_center/3361.html. Accessed: February 15, 2014.

———. 2007c. Automobile Manufacturing (NAICS 336111) - Industry Facts Report 2007. http://thedataweb.rm.census.gov/TheDataWeb_HotReport2/econsnapshot/snapshot.hrml?NAICS=336111. Accessed: February 15, 2014.

———. 2007d. Light Truck and Utility Vehicle Manufacturing (NAICS 336111) - Industry Facts Report 2007. http://thedataweb.rm.census.gov/TheDataWeb_HotReport2/econsnapshot/snapshot.hrml?NAICS=336112. Accessed: March 01, 2014.

———. 2007e. Heavy Duty Truck Manufacturing (NAICS 336120) - Industry Facts Report 2007. http://thedataweb.rm.census.gov/TheDataWeb_HotReport2/econsnapshot/snapshot.hrml?NAICS=33612. Accessed: March 02, 2014.

———. 2007f. Motor Vehicle Body and Trailer Manufacturing (NAICS 3362) - Industry Facts Report 2007. http://thedataweb.rm.census.gov/TheDataWeb_HotReport2/econsnapshot/snapshot.hrml?NAICS=3362. Accessed: March 02, 2014.

———. 2007g. Motor Vehicle Parts Manufacturing (NAICS 3363) - Industry Facts Report 2007. http://thedataweb.rm.census.gov/TheDataWeb_HotReport2/econsnapshot/snapshot.hrml?NAICS=3363. Accessed: March 02, 2014.

———. 2007h. Motor Vehicle Gasoline Engine and Engine Parts Manufacturing (NAICS 336310) - Industry Facts Report 2007. http://thedataweb.rm.census.gov/TheDataWeb_HotReport2/econsnapshot/snapshot.hrml?NAICS=33631. Accessed: March 02, 2014.

———. 2007i. Motor Vehicle Electrical and Electronic Equipment Manufacturing (NAICS 336320) - Industry Facts Report 2007. http://thedataweb.rm.census.gov/TheDataWeb_HotReport2/econsnapshot/snapshot.hrml?NAICS=33632. Accessed: March 02, 2014.

———. 2007j. Motor Vehicle Steering and Suspension Components Manufacturing (NAICS 336330) - Industry Facts Report 2007. http://thedataweb.rm.census.gov/TheDataWeb_HotReport2/econsnapshot/snapshot.hrml?NAICS=33633. Accessed: March 02, 2014.

———. 2007k. Motor Vehicle Brake System Manufacturing (NAICS 336340) - Industry Facts Report 2007. http://thedataweb.rm.census.gov/TheDataWeb_HotReport2/econsnapshot/snapshot.hrml?NAICS=33634. Accessed: March 02, 2014.

———. 2007l. Motor Vehicle Transmission and Power Train Parts Manufacturing (NAICS 336350) - Industry Facts Report 2007. http://thedataweb.rm.census.gov/TheDataWeb_HotReport2/econsnapshot/snapshot.hrml?NAICS=33635. Accessed: March 02, 2014.

———. 2007m. Motor Vehicle Seating and Interior Trim Manufacturing (NAICS 336360) - Industry Facts Report 2007. http://thedataweb.rm.census.gov/TheDataWeb_HotReport2/econsnapshot/snapshot.hrml?NAICS=33636. Accessed: March 02, 2014.

———. 2007n. Motor Vehicle Metal Stamping (NAICS 336370) - Industry Facts Report 2007. http://thedataweb.rm.census.gov/TheDataWeb_HotReport2/econsnapshot/snapshot.hrml?NAICS=33637. Accessed: March 02, 2014.

———. 2014a. Light Truck and Utility Vehicle Manufacturing (NAICS 336112) - Industry Definition. http://www.naics.com/censusfiles/ND336112.HTM. Accessed: March 02, 2014.

———. 2014b. Heavy Duty Truck Manufacturing (NAICS 336120) - Industry Definition. http://www.naics.com/censusfiles/ND336120.HTM. Accessed: March 02, 2014.

Van Buuren, Stef, Hendriek C. Boshuizen, and Dick L. Knook. 1999. Multiple Imputation of Missing Blood Pressure Covariates in Survival Analysis. *Statistics in Medicine* 18 (6): 681–94.

Venkatraman, Natarjan 1989. The Concept of Fit in Strategy Research: Toward Verbal and Statistical Correspondence. *The Academy of Management Review* 14 (3): 423–44.

Vick, Timothy. 2000. *How to Pick Stocks like Warren Buffett: Profiting from the Bargain Hunting Strategies of the World's Greatest Value Investor*. 1 edition. New York, NY: McGraw-Hill. pp. 277.

Vinas, Tonya. 2008. Knife Company Hones Competitiveness by Bucking the Status Quo. https://www.lean.org/admin/km/documents/3e62c5ef-4c52-4ba1-9ee0-7c452a013aa8-BuckKnivesR2%20%283%29.pdf. Accessed: February 14, 2014.

Vorhies, Douglas W., and Neil A. Morgan. 2003. A Configuration Theory Assessment of Marketing Organization Fit with Business Strategy and Its Relationship with Marketing Performance. *Journal of Marketing* 67 (1): 100–115.

Ward, Peter T., Rebecca Duray, G. Keong Leong, and Chee-Chuong Sum. 1995. Business Environment, Operations Strategy, and Performance: An Empirical Study of Singapore Manufacturers. *Journal of Operations Management* 13 (2): 99–115.

Ward, Peter T., G. Keong Leong, and Kenneth K. Boyer. 1994. Manufacturing Proactiveness and Performance. *Decision Sciences* 25 (3): 337–58.

Ward, Yvonne, Valerie Crute, Cyril Tomkins, and Andrew Graves. 2003. Cost Management and Accounting Methods to Support Lean Aerospace Enterprises. *University of Bath, School of Management Working Paper Series* 1-43.

Ward's Automotive Group. 2010. *Ward's World Motor Vehicle Data*. 2010 edition. Houston, TX: Wards Communications. pp. 297.

Ware, Colin. 2004. *Information Visualization: Perception for Design*. 2nd edition. Interactive Technologies. San Francisco, CA: Morgan Kaufmann. pp. 486.

Wilks, Samuel S. 1932. Moments and Distributions of Estimates of Population Parameters from Fragmentary Samples. *The Annals of Mathematical Statistics* 3 (3): 163–95.

Womack, James P, Daniel T Jones, Daniel Roos. 1990. *The Machine That Changed the World : Based on the Massachusetts Institute of Technology 5-Million Dollar 5-Year Study on the Future of the Automobile*. 1st edition. New York, NY: Rawson Associates. pp. 336.

Womack, James P., and Daniel T. Jones. 1996. *Lean Thinking: Banish Waste and Create Wealth in Your Corporation*. 1st edition. New York, NY: Simon & Schuster. pp. 352.

Womack, James P., Daniel T. Jones, and John Shook. 2002. *Seeing the Whole Value Stream*. 1st edition. Cambridge, MA: Lean Enterprise Institute. pp. 108.

Womack, James P., and John Shook. 2011. *Gemba Walks*. 1st edition. Cambridge, MA: Lean Enterprise Institute. pp. 381.

Womack, James P. 2006. Mura, Muri, Muda? http://www.lean.org/womack/DisplayObject.cfm?o=743. Accessed: February 10, 2014.

Wood, Angela M., Ian R. White, and Simon G. Thompson. 2004. Are Missing Outcome Data Adequately Handled? A Review of Published Randomized Controlled Trials in Major Medical Journals. Clinical Trials 1 (4): 368–76.

Wood, Stephen J., Chris B. Stride, Toby D. Wall, and Chris W. Clegg. 2004. Revisiting the Use and Effectiveness of Modern Management Practices. *Human Factors and Ergonomics in Manufacturing & Service Industries* 14 (4): 415–32.

Xu, Shichun, Tamer S. Cavusgil, and Chris J. White. 2006. The Impact of Strategic Fit among Strategy, Structure, and Processes on Multinational Corporation Performance: A Multimethod Assessment. *Journal of International Marketing* 14 (2): 1–31.

Yash, Dave, and Sohani Nagendra. 2012. Single Minute Exchange of Dies: Literature Review. *International Journal of Lean Thinking* 3 (2): 27–37.

Yin, Robert K. 2009. *Case Study Research: Design and Methods*. 4th edition. Los Angeles, CA: Sage Publications, Inc. pp. 240.

3. Research Hypotheses

The following chapter presents the research hypotheses for empirical testing. Theoretical and empirical reinforcement for each hypothesis are provided to justify its inclusion in the study.

3.1. Lean Implementation in Transportation Equipment Manufacturing

The International Motor Vehicle Program (IMVP) was established in 1984 by the Massachusetts Institute of Technology (MIT) with help from the U.S. Federal Government to improve the competitiveness of the U.S. automotive industry by benchmarking automotive manufacturing worldwide (Womack et al. 1990). In their book, "The Machine that Changed the World," Womack et al. (1990) presented a new type of production system from suppliers to sales through the promotion of the Toyota Production System and later through the promotion of Lean principles and determinants.

Companies, to successfully implement Lean, must go through a series of developmental steps during their journey. Each step involves an expansion and more systematic integration of Lean into facility operations. As the level of implementation increases, it becomes necessary to expand the transformation from manufacturing to other areas of the business, such as sales and marketing, new product development, accounting, and beyond the walls of the facility to the customers and suppliers relationships to ensure continuous flow. While there are numerous different ways to describe the level of Lean implementation of a facility (Maskell and Baggaley 2003, Nightingale and Mize 2002, Womack and Jones 1996), this study uses Maskell and Baggaley's (2003) framework – called Lean maturity path – to define four levels of Lean implementation. In this ranking, the **first level** represents a traditional business management system without any Lean transformation having taken place, which serves as a basis for comparison in the model. Traditional business management systems typically are characterized by mechanization and automation to achieve high throughput of equal or similar products, a strict organization of material flow, quality control, extensive division of labor, and production schedules based on forecasts. This traditional business management system is also known as “Mass production”, “Batch and Queue production”, or “Repetitive flow production,” among others. The **second level** of Maskell and Baggaley’s (2003) ranking framework, referred to as “developing a Lean framework,” represents an initial stage of the Lean journey when companies get enthusiastic about Lean by doing pilot projects, participate in Lean trainings and Kaizen events, start to experiment with current and future state value stream mapping, and investigate cellular manufacturing. Developing the Lean framework also involves assessing the financial benefits of Lean transformations. The **third level**, the “managing business by value streams” level, represents the expansion of Lean from pilot projects to the entire facility, including manufacturing, sales and marketing, new product development, and accounting among other business areas. Value stream management not only requires changes in a company’s departmental structure, the role of people, and the business culture, but also requires fundamental changes by creating new measurements and financial reporting capabilities, such as value stream costing. Finally, the **fourth** and last **level** represents development of a Lean enterprise management system, e.g., Lean being implemented throughout one’s company and facilities and the entire value chain of the company. At this level, companies focus entirely on creating value for the customer and creating a culture where continuous improvement becomes a way of living.

This research study defines Lean as an alignment of a set of theoretically-derived determinants. The **co-alignment among Lean determinants is proposed in terms of five dimensions** to reflect a successful Lean transformation in a manufacturing facility as illustrated in Table 8. These five dimensions include leadership, manufacturing, accounting and finance, supplier relationship, and customer relationship. The first dimension (leadership) reflects the general domain of organization and management, while the remaining four dimensions (manufacturing, accounting and finance, supplier relationship, and customer relationship) capture important functional areas. The five dimensions collectively reflect a general conceptualization of a successful Lean transformation. The operationalization of Lean into a measurable format requires the development of Lean determinants that adequately and reliably capture the theoretical construct of interest for all five dimensions, and the development of the anchors for calibrating the responses for each determinant (Venkatraman 1990).

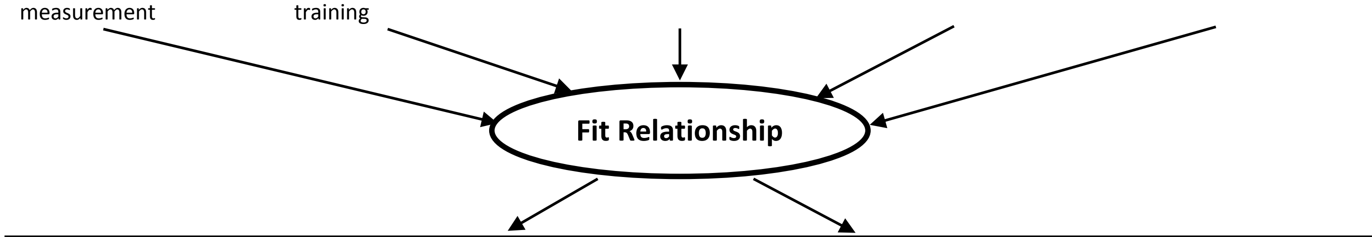
In this research, the **leadership dimension** is captured through eight Lean determinants, including Lean implementation planning, top management commitment, communication, training, employee involvement, knowledge management, employee incentives, and performance measurement. The **manufacturing dimension** is captured by nine Lean determinants including production flow, production quality, changeover procedures, maintenance procedures, pull system, one-piece flow, work procedures, workplace organization, and employee training. Similarly, the **accounting and finance dimension** is captured by nine Lean determinants including organization of administrative processes, transformation progress, budgeting, month-end closing, product costing, authorization process, accounts payable, accounts receivable, and inventory tracking. The **supplier relationship dimension** is captured by three Lean determinants including supplier relationship, inventory management, and supplier involvement in new product development. Finally, the **customer relationship dimension** is captured by three Lean determinants including customer relationship, customer demand, and customer involvement in new product development.

Operational performance is measured by the five categories of quality, time, delivery, capacity, and safety, where each of the five categories is comprised of individual measures that are used to compute an overall operational performance score. The quality performance category comprises of seven measures including first time through, inbound quality, outbound quality, customer reject rate, scrap cost, rework cost, and manual adjustment due to late data recording. Similarly, the time-based performance category comprises of seven measures including lead time on "long lead time" purchased materials, manufacturing lead time, order entry – cash in lead time, days of inventory, length of new product development cycle, length of closing process, and length of investment decision cycle. The delivery performance category is comprised of six measures including on-time delivery, supplier shipment delivery on time, percentage of customers in the JIT delivery program, percentage of suppliers in the JIT delivery program, overdue invoices from suppliers, and overdue invoices to customers. The capacity performance category comprises of four measures including OEE, reactive maintenance, overtime hours of production employees, and overtime hours of accounting/finance employees. Finally, safety performance is measured by lost time incident. The operational performance of a transportation equipment facility is calculated by adding up the numerators and denominators of all five measures reported above. Measurement scales were reverse coded and modified if necessary.

Financial performance measures are represented by five performance indicators, including productivity, return on assets, EBIT, market share, and R&D cost ratio, combined together into one metric.

Table 8: Proposed model to investigate the relationship between Lean implementation level and performance

Leadership	Manufacturing	Accounting/ Finance	Supplier relationship	Customer relationship
LQ1 – Lean implementation planning LQ2 – Top management commitment LQ3 – Communication LQ4 – Training LQ5 – Employee involvement LQ6 – Knowledge management LQ7 – Employee incentives LQ8 – Performance measurement	MQ1 – Production flow MQ2 – Production quality MQ3 – Changeover procedures MQ4 – Maintenance procedures MQ5 – Pull system MQ6 – One-piece flow MQ7 – Work procedures MQ8 – Workplace organization MQ9 – Employee training	AQ1 – Organization of administrative processes AQ2 – Transformation progress AQ3 – Budgeting AQ4 – Month-end closing AQ5 – Product costing AQ6 – Authorization process AQ7 – Accounts payable AQ8 – Accounts receivable AQ9 – Inventory tracking	SRQ1 – Supplier relationship SRQ2 – Inventory management SRQ3 – Supplier involvement in new product development	CRQ1 – Customer relationship CRQ2 – Customer demand CRQ3 – Customer involvement in new product development



	Operational performance	Financial performance
Quality	OMQ1 – First time through OMQ2 – Inbound quality OMQ3 – Outbound quality OMQ8 – Customer reject rate on shipped products OMQ9 – Scrap cost as a percentage of sales OMQ10 – Rework cost as a percentage of sales OMQ13 – Manual adjustments due to late recording	FMQ1 – Productivity FMQ2 – Return on assets FMQ3 – EBIT FMQ4 – Market share FMQ5 – R&D cost ratio
Time-based	OMQ18 – Lead-time on "long lead time" purchased materials OMQ19 – Manufacturing lead-time OMQ20 – Order entry – Cash-in time OMQ21 – Average days of inventory OMQ22 – Average length of a new product development cycle OMQ23 – Average length of an investment decision cycle OMQ24 – Average length of financial closing	
Delivery	OMQ4 – On-time delivery rate OMQ5 – Supplier shipments delivered on time OMQ11 – Customers for which the facility has implemented a JIT delivery program OMQ12 – Suppliers who provided JIT delivery to your facility OMQ14 – Overdue invoices from suppliers OMQ15 – Overdue invoices to customers	
Capacity	OMQ6 – Overall Equipment Effectiveness (OEE) OMQ7 – Reactive maintenance rate OMQ16 – Monthly overtime hours for production employees OMQ17 – Monthly overtime hours for accounting/finance employees	
Safety	OMQ25 – Lost time incident rate	

Implementing Lean along the above proposed five dimensions promises substantial improvements in productivity, quality, on-time delivery, and cost reduction among other things (Emiliani et al. 2003, Maskell and Baggaley 2003, Womack and Jones 1996, Womack et al. 1990). Since the 1990s, many U.S. companies have been introducing Lean in the U.S. transportation equipment industry; however, it has been difficult to demonstrate the financial benefits derived from Lean and correlating operational improvements due to Lean transformation efforts to financial performance. In addition, Lean implementations have often been undertaken without rigorous consideration of the support areas of business, such as the supply chain, customer service, or accounting, among others. In every business, those activities are needed to ensure that decisions are taken under consideration of all implications. Over the years, numerous industry participants and academic personnel expressed concerns that implementing Lean in the manufacturing area alone instead of throughout a firm's entire value chain would obstruct positive outcomes of the Lean transformation. Having traditional systems and mindset in place in the supporting functions of the business, e.g., having traditional accounting methods in place, may conflict with the objectives of Lean.

Therefore, the **first objective of this study** is to evaluate a subset of the U.S. transportation equipment manufacturing facilities as to their operational and financial performance and investigate if there is a correlation between the level of Lean implementation and operational and financial performance. Although, research on investigating the operational and financial outcome of Lean implementation exist (Harris 2012, Hofer et al. 2012, Fullerton et al. 2013, Fullerton and Wempe 2009, Olsen 2004), previous studies fall short on proofing that higher levels of Lean implementation throughout the organization correlate positively with the organization's operational and financial performance. Hence, the first and second hypotheses tested in this study are:

$H_0 1$: *The level of Lean implementation has no impact on operational performance.*

$H_0 2$: *The level of Lean implementation has no impact on financial performance.*

3.2. Lean Implementation in Transportation Equipment Manufacturing and the Role of Lean Accounting

While employees who work on implementing Lean may have a good understanding on the power of Lean in identifying and eliminating waste, data provided by traditional accounting systems may provide unreliable information when trying to quantify the financial implications of such Lean implementation efforts. Traditional accounting systems tend to advocate investment decisions that can be justified by directly quantifiable reductions, while they undervalue the importance of improvements to quality, time, delivery reliability, safety, or capacity. To better cope with such problems, Lean accounting was developed. Lean accounting supports Lean transformations by assessing the transformation's financial impact in a value stream structure, enabling management to see whether a dollar saved at some point in the process does not trigger two dollars to be spent elsewhere.

In this research, **Lean accounting** is captured by the same nine Lean determinants introduced in sub-chapter 3.1 (Table 8) including organization of administrative processes, transformation progress, budgeting, month-end closing, product costing, authorization process, accounts payable, accounts receivable, and inventory tracking, while accounting performance measures were developed using the frameworks of Cunningham et al. (2003) and Maskell and Baggaley (2003). In this study, **accounting performance** is measured by manual adjustment due to late recording, overdue invoices from suppliers, overdue invoices to customers, monthly overtime for accounting and financial employees, order entry – cash-in lead time, average length of an investment decision cycle, and average length of financial closing. Accounting performance is also calculated by adding up the numerators and denominators of all the above listed measures.

While there is no disagreement that Lean accounting supports Lean transformation, no empirical evidence exists on its impact on performance. Therefore, the **second objective of this study** is to evaluate a subset of the U.S. transportation equipment manufacturing facilities in respect to their accounting, operational, and financial performance and to correlate these results with the level of Lean implementation in the facility's accounting/financial area. Thus, hypotheses three to five are:

$H_0$3: *Lean implementation in accounting has no impact on operational performance.*

$H_0$4: *Lean implementation in accounting has no impact on financial performance.*

$H_0$5: *Lean implementation in accounting has no impact on accounting performance.*

3.3. Contextual Effects and Lean Accounting

Whether or not implementing Lean has a positive impact on accounting, operational, and financial performance, changing the traditional, mass production like system in support of other change initiatives in any company is a dramatic step as it requires severe structural and mindset changes. Manufacturing facilities investigated in this study operate in different contexts, e.g., in different environmental landscape and organizational structures. The literature recognizes the importance of these contextual factors and their impact on the implementation of new, state of the art management practices and on business performance (Cua 2000, Shah 2002, Olsen 2004). Therefore, in this study, contextual factors are represented by location, size, industry segment, and unionization as they may affect manufacturing performance.

Location is one of the most common cited contextual factors in the management literature as facilities located in different states or headquartering in different countries may need to adapt to different competitive landscapes that requires to implement different strategies, management and accounting practices. Furthermore, the implementation of dissimilar management and accounting practices may affect business performance. Location in this study is represented by four geographical regions (categorized as West, Midwest, Northeast, and South; U.S. Census Bureau 2000).

Size of a manufacturing facility may affect their organizational and communication structures, as well as their ability to invest in new technologies and human resources. The size of a manufacturing facility tends to be represented by either the number of employees, or the annual sales revenue. In this study, sales is represented by annual sales revenue (categorized as less than $2.6 million, $2.6 million to $13.1 million, $13.2 million to $65.6 million, $65.7 million to $262.8 million, more than $262.8 million; U.S. Census Bureau 2007).

Manufacturing facilities operating in different industry segments may possess different production diversity, product complexity, and technologies that can affect production cost and product quality and therefore business performance. The effect of industry segment as a contextual factor is investigated among the three industry sub-segments of the transportation equipment industry (categorized as NAICS 3361, NAICS 3362, NAICS 3363; Statistics Canada 2007).

Finally, being unionized (categorized as “yes” or “no”) may hinder or enhance the probability of success of a manufacturing facility as it may influence the managements’ effort in implementing change at a workplace, e.g., the implementation of new practices and cross-training (Shah and Ward 2007, Black and Lynch 2001).

Prior research (Fullerton et al. 2013, Fullerton and Wempe 2009, Kennedy and Widener 2008) shows that only a limited number of companies made the commitment to Lean initiatives that involved changing their traditional accounting system to a Lean accounting system. To investigate whether different contextual factors, such as industry segment, size, location, and unionization have an effect on the implementation of Lean principles and determinants in a facility and whether they prevent or encourage a facility's leadership and management in changing the accounting system in support of its Lean initiatives, the sixth to ninth hypotheses of this study are:

$H_0$6: C*ontextual factors have no impact on facility performance.*

$H_0$7: C*ontextual factors have no impact on Lean implementation-performance relationship.*

$H_0$8: C*ontextual factors have no impact on Lean implementation in accounting and finance.*

$H_0$9: C*ontextual factors have no impact on Lean implementation in accounting and finance – performance relationship.*

References

Black, Sandra E., and Lisa M. Lynch. 2001. How to Compete: The Impact of Workplace Practices and Information Technology on Productivity. *The Review of Economics and Statistics* 83 (3): 434–45.

Cua, Kristy O. 2000. A Theory of Integrated Manufacturing Practices: Relating Total Quality Management, Just-in-Time and Total Productive Maintenance. Doctor of Philosophy, Minneapolis, MN: University of Minnesota. pp. 224.

Cunningham, Jean E. 2003. *Real Numbers: Management Accounting in a Lean Organization*. Durham, NC: Managing Times Press. pp. 194.

Emiliani, Bob, David J. Stec, Lawrence Grasso, and James Stodder. 2003. *Better Thinking, Better Results: Using the Power of Lean as a Total Business Solution*. 1st edition. Kensington, CT: Center for Lean Business Management. pp. 313.

Fullerton, Rosemary R., and William F. Wempe. 2009. Lean Manufacturing, Non-Financial Performance Measures, and Financial Performance. *International Journal of Operations & Production Management* 29 (3): 214–40.

Fullerton, Rosemary R., Frances A. Kennedy, and Sally K. Widener. 2013. Management Accounting and Control Practices in a Lean Manufacturing Environment. *Accounting, Organizations and Society* 38 (1): 50–71.

Harris, Daniel C. 2012. The Adoption of Lean Operations and Lean Accounting on the Financial-Performance Measures of Publicly Traded Companies. Doctor of Philosophy, Oxford, MS: The University of Mississippi. pp. 162.

Hofer, Christian, Cuneyt Eroglu, and Adriana Rossiter Hofer. 2012. The Effect of Lean Production on Financial Performance: The Mediating Role of Inventory Leanness. *International Journal of Production Economics* 138 (2): 242–53.

Kennedy, Frances A., and Sally K. Widener. 2008. A Control Framework: Insights from Evidence on Lean Accounting. *Management Accounting Research* 19 (4): 301–23.

Maskell, Brian H., and Bruce L. Baggaley. 2003. *Practical Lean Accounting: A Proven System for Measuring and Managing the Lean Enterprise, Second Edition*. 1 edition. New York, NY: Productivity Press. pp. 359.

Nightingale, Deborah J., and Joe H. Mize. 2002. Development of a Lean Enterprise Transformation Maturity Model. *Information, Knowledge, Systems Management* 3 (1): 15–30.

Olsen, Eric Oscar. 2004. Lean Manufacturing Management: The Relationship between Practice and Firm Level Financial Performance. Doctor of Philosophy, Colombus, OH: The Ohio State University. pp. 220.

Shah, Rachna. 2002. A Configurational View of Lean Manufacturing and Its Theoretical Implications. Doctor of Philosophy, Colombus, OH: The Ohio State University. pp. 278.

Shah, Rachna, and Peter T. Ward. 2007. Defining and Developing Measures of Lean Production. *Journal of Operations Management* 25 (4): 785–805.

Statistics Canada. 2007. North American Industry Classification (NAICS) 2007. http://www.census.gov/cgi-bin/sssd/naics/naicsrch?code=336&search=2012%20NAICS%20Search. Accessed: February 15, 2014.

U.S. Census Bureau. 2000. Census Regions and Divisions of the United States. http://www.census.gov/geo/maps-data/maps/pdfs/reference/us_regdiv.pdf. Accessed: May 1, 2014.

———. 2007o. Receipt Size of Employer Firms. http://www.census.gov/econ/smallbus.html. Accessed: May 1, 2014.

Venkatraman, Natarjan. 1990. Performance Implications of Strategic Coalignment: A Methodological Perspective. *Journal of Management Studies* 27 (1): 19–41.

Womack, James P., Daniel T. Jones, Daniel Roos. 1990. *The Machine That Changed the World: Based on the Massachusetts Institute of Technology 5-Million Dollar 5-Year Study on the Future of the Automobile*. New York, NY: Rawson Associates. pp. 352.

Womack, James P., and Daniel T. Jones. 1996. *Lean Thinking : Banish Waste and Create Wealth in Your Corporation*. 1st edition. New York, NY: Simon & Schuster. Pp. 352.

4. Methodology

This chapter describes the basic design of this research project by providing information on the sampling procedure, the survey's content development process, and the surveying procedures used in data collection. Also, definitions of key concepts covered in the survey are explained. Finally, special attention is given to data preparation activities and methods of survey analysis.

4.1. Survey Design

Hypotheses $H1_0$ to $H9_0$ presented above are investigated by developing a mixed-mode survey (Dillman et al. 2009a) for a sub-segment of U.S. transportation equipment manufacturers. The survey was designed by using the Tailored Design Method (TDM; Dillman et al. 2009a) to increase survey response rate by establishing trust, highlighting the benefits of participation, and decreasing the expected cost of participation (Dillman et al. 2009a).

4.1.1. Population and Sampling

The population of the survey consists of the companies in the motor vehicle manufacturing industry (NAICS 3361), motor vehicle body and trailer manufacturing industry (NAICS 3362), and the motor vehicle parts manufacturing industry (NAICS 3363), to which survey results are generalized. Based on U.S. Census Bureau data from 2007 (U.S. Census Bureau 2007b, U.S. Census Bureau 2007f, U.S. Census Bureau 2007g), the survey population consists of 8,336 companies. The sample frame of the survey consists of a list of companies acquired from InfoGroup (InfoGroup 1972) and has been supplemented with a list of companies composed from various internet-based directories, such as WardsAuto, AmericanAutoWorker, and Manta. Also, additional contacts were received from the

Heavy Duty Truck Manufacturers Association, Truck Trailer Manufacturers Association, Tennessee Automotive Manufacturers Association, and from the Manufacturing Extension Partnership.

From the list above, a sample of 2,005 companies were randomly selected to represent the survey population. To be able to estimate the distribution of the characteristics in the population, the completed sample (N_s) should consist of a minimum of 239 responses. The completed sample size aimed in this study is calculated based on the following formula (Dillman et al. 2009a),

$$N_s = [(N_p)*(p)*(1-p)] / [(N_p-1)*(B/C)^2 + (p)*(1-p)]$$

$$N_s = [(8{,}336)*(0.2)*(0.8)] / [(8{,}336-1) * (0.05/1.96)^2 + (0.2)*(0.8)] = 239$$

where N_s represents the size of the completed sample, N_p represents the population size of 8,336, *p* represents the expected variation in responses to the Liker scale questions of interest of 20 and 80 percent, *B* represents the margin of error of +/- 5 percent, and *C* represents the Z-score of 1.96 associated with the statistical confidence.

4.1.2. Question and Questionnaire Design

The "Lean implementation in transportation equipment manufacturing" survey prepared for this study consists of a total of 57 questions and 82 variables. The survey was designed to be completed in approximately 20 minutes. Designing such a long survey may increase response burden on people sampled (Raghunathan and Grizzle 1995) and may result in a relatively low response rate (Dillman et al. 1993, Adams and Darwin 1982), and may decrease response quality (Herzog and Bachman 1981). Survey questions were adopted from various sources, including the Lean Enterprise Self-Assessment (Nightingale et al. 2012, Nightingale and Mize 2002), the Diagnostic Questionnaire of

Accounting, Control, and Measurement (Maskell 2007, Maskell and Baggaley 2003), and other literature sources (Olsen 2004, Shah 2002, Cua 2000, Womack and Jones 1996). The survey comprises of three sections: 1) Lean transformation efforts, 2) Performance measures, and 3) General firm characteristics.

The first section, dealing with a company's Lean transformation efforts, consists of 35 questions intended to collect information about participating companies' leadership activities; manufacturing, administrative, and accounting processes; customer and supplier relationships. The second section, the performance measures section, consists of 14 questions intended to collect information about the quality, time, delivery, safety, capacity, and accounting performance of participating companies. The third section, the general characteristics section of the questionnaire consists of 8 questions about the respondent's position, and about the size, location, and main product category of the company. Questions included closed-ended inquiries, both categorical (nominal and ordinal scale) and numerical (ratio scale); partial open-ended inquiries, such as nominal scale multiple choice questions with "Other" as an option; and open-ended inquiries with short answers.

The survey, which intended to be a web-based survey, was reviewed by University and federal scientists, industry participants, and Lean experts in regards to clarity, comprehensiveness, and overall quality. Based on the feedback received, minor changes to the questionnaire were implemented. The final version of the web-based survey, along with the cover letter email and follow-up emails, were submitted to the Institutional Review Board (IRB) and obtained approval on January 15, 2013. The web-based survey was sent out for a pre-test on February 26, 2013 by email to 200 randomly selected sampled facilities. These selected individuals were invited to complete the web-based "Lean implementation in transportation equipment manufacturing" survey by clicking on the survey link listed in the email. The survey link took these individuals to the survey that was hosted on the Virginia Tech server (https://virginiatech.qualtrics.com/). Eight valid responses (three percent) were received as a result of the pre-test. After the pre-test, no changes to the questionnaire were implemented; however, survey implementation procedures were reconsidered to receive a higher response rate and higher quality responses. Receiving only eight valid responses to the pre-test indicated that using merely a web-based survey may not be the most appropriate mode to reach out to senior company managers. Therefore, to reduce response burden and increase response rate and response quality a mixed-mode survey design rather than a web-based survey design was applied (Dillman et al. 2009a, Dillman and Parsons 2008, Dillman and Carley-Baxter 2000) by combining two different survey modes, e.g., Internet and mail, where both surveys are identical.

4.1.3. Implementation Procedure

The final version of the survey (Appendix A) was sent to all remaining individuals in the sample list (excluding the pre-tested respondents) on May 28, 2013. The survey was addressed to a senior company manager, preferably the CEO, the plant manager, or a financial representative. Each respondent received a personalized invitation letter (Appendix B) including the URL for the web-version of the survey (www.companyperformance.org, Appendix C). Two weeks after the invitation letter, thank you emails (for those who responded) and reminder cards for non-respondents (Appendix D and E) were sent out. Four weeks after the initial letter, a remainder letter containing the survey URL was sent to non-respondents to encourage participation. Six weeks after the initial letter a second round of thank you/reminder cards were sent to respondents/non-respondents. Eight weeks after the initial mailing, a last reminder letter with the survey URL were sent to non-respondents accompanied with a mail questionnaire and postage paid return envelope should the targeted individual prefer to answer by mail. Twelve weeks after the initial mailing on August 20, 2013, the survey was closed and information about non-respondents was collected by phone and fax to establish non-response bias.

4.1.4. Response Rate

From the original sample size of 2,005 companies, 17 companies rejected to participate in the research and an additional 161 surveys could not be delivered due to the businesses being closed or an address discrepancy. Thus, the adjusted sample size consists of 1827 companies. During the twelve-week-long duration of the survey, 69 valid responses were received resulting in a response rate of 3.78 percent as presented on Figure 5.

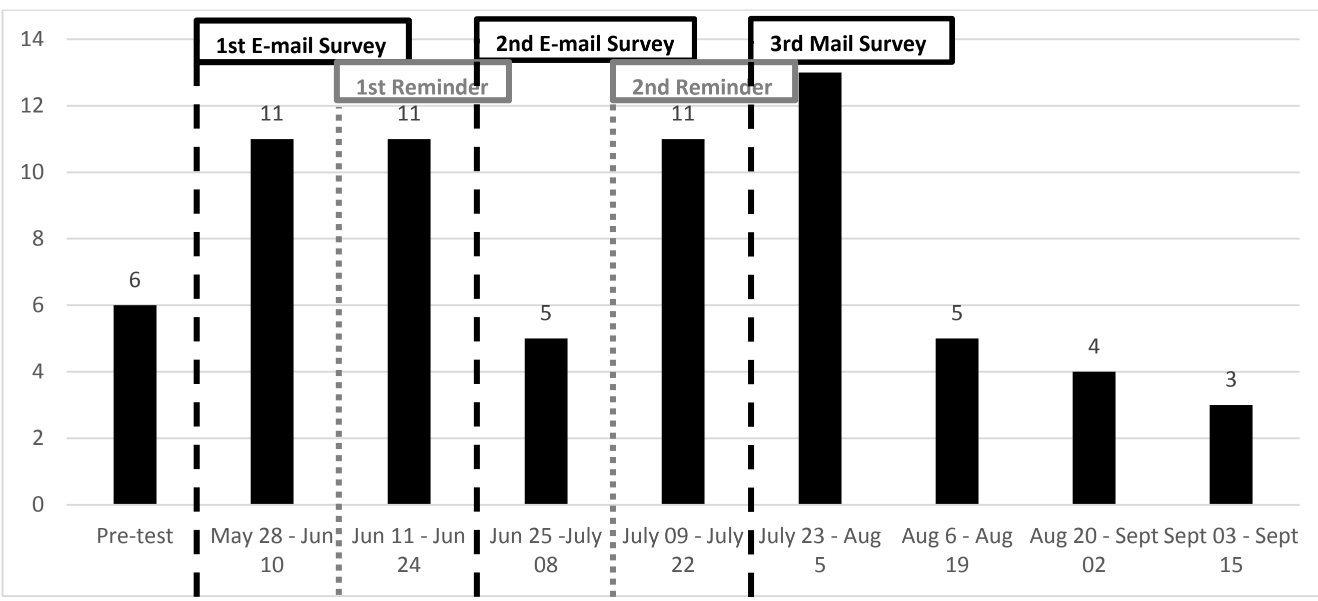


Figure 5: **Number of valid survey responses received during the survey process**

Given the number of valid responses received (n = 69) to the study, the survey population can only be represented with a +/- 10 percent margin of error:

$$N_s = [(8,336)*(0.2)*(0.8)] / [(8,336-1) * (0.1/1.96)^2 + (0.2)*(0.8)] = 61$$

4.2. Statistical Analysis

In this study, the conceptualization of Lean is proposed in terms of five dimensions including leadership, manufacturing, accounting and finance, supplier relationship and customer relationship. The theoretical logic is that having a successful Lean transformation requires consistent attention to all five dimensions as there is underlying logical linkage among them. Thus, it is proposed that co-alignment among these five dimensions will be positively and significantly related to performance. The major challenge is, however, to find the appropriate statistical model to test the hypotheses of the study.

One appropriate statistical analysis is using a second generation data analysis technique called covariance-based structural equation modelling (SEM; Jöreskog and Sörbom 1993, Jöreskog 1967). SEM enables modelling the relationship among multiple independent and dependent variables simultaneously as it provides a combined analysis of a structural model (e.g., the assumed interconnection among a set of dependent and independent variables) and a measurement model (e.g., loadings or observed variables on their expected latent variables (Jöreskog and Sörbom 1993, Jöreskog 1967). To perform SEM, however, requires meeting with numerous assumptions of specifying, fitting, testing, and interpreting the model, which provides numerous points for the process may fail, e.g., "… *the existing theory may not be sufficiently precise to suggest compelling causal models; in the process of model specification and identification compromises may be made that vitiate* *the assumptions of the original theory; observed data may be of insufficient quality or quantity to sustain the model fitting process; and the use of parameter estimates based on sample data rather than individual data may misrepresent the causal processes which are occurring in populations*, and the results *of the analysis may be compromised by design limitations and shortcomings in model fitting processes*…(Fergusson 2006, p.885)." The main liability of this approach in regards to this study arises from the fact that the available data are limited in both quantity (e.g., a total of 69 valid responses) and quality (e.g., a total of 7 percent missing values). Nunnally (1978) suggested that performing SEM would require working with at least 10 times as many responses as variables with such limited data can essentially hurt the credibility of research conclusions, while Boomsma (1982) suggested that the adequate response rate to perform SEM can be calculated based on the following formula,

$$n \geq 50r^2 - 450r + 1100$$

where r is the ratio of indicators to underlying variables. Therefore, for $r = 5$, at least 100 responses would be adequate to perform the analysis. To avoid weakening the credibility of research conclusions, an alternative method of analysis was explored.

The second appropriate statistical analysis is using a first generation statistical method, such as multiple regressions to analyze hypotheses of this study, as multiple regressions supports smaller sample sizes by requiring a minimum of 30 valid responses (Gefen et al. 2000). Covariance based SEM and multiple regression overlap in many ways, including analysis objectives, distribution assumptions, and correlational linearity assumptions among others; however, one major drawback of multiple regression over SEM is that it can only analyze one layer of linkages between independent and dependent variables at a time (Gefen et al. 2000, Venkatraman 1989). However, if the researcher examines data in a thorough and critical manner and possible counter-interactions are explored in depth, multiple regression may provide similar outcomes than SEM (Gefen et al. 2000, Brown et al. 1991). Therefore, multiple regressions are selected to test the hypotheses of this study. To achieve similar outcomes as from SEM with multiple regression, the analysis starts by examining how items load on the study dimensions to ensure that the measurement items form strong unities and represent good measurement properties of the study (via Principal Component Analysis and Cronbach's alpha; see sub-chapter 4.2.1). Then, a separate examination of the hypothesized paths is carried out by testing these factor loadings independently (Gefen et al. 2000).

The third appropriate statistical analysis is called a profile deviation analysis (Cua 2000, Doty et al. 1993, Venkatraman 1990, Venkatraman 1989). Conducting a profile deviation analysis requires defining how an ideal transportation equipment manufacturing facility practices Lean along its multiple business dimensions. Once this ideal Lean facility profile is defined, each respondent's degree of deviation from the ideal profile is measured. The degree of deviation from the ideal profile is calculated by using a weighted Euclidean distance formula of

$$Ek = \sqrt{\sum_{j=1}^{n} (Xji - Xjk)^2 * Wj}$$

where *Ek* represents the Euclidean distance between the ideal profile and respondent *k*; *Xji* represents the normalized mean score for the ideal profile for variable *j*; *Xjk* represents the normalized score of respondent *k*'s on variable *j*, *Wj* represents the weight for variable *j*. Calculating the weighted Euclidean distance establishes a profile deviation score for each respondent. The higher the profile deviation score is, the farther the responding facility is from an ideal Lean facility. Then, the calculated profile deviation scores are regressed onto operational, financial, and accounting performance.

4.3. Data Preparation for Statistical Analysis

Responses received to the e-mail survey were stored and organized in the Qualtrics system (Qualtrics 2002), while responses received to the mail survey were typed into a Microsoft Excel 2010 (Microsoft 2010) datasheet. Once the survey was closed on August 20, 2013, both e-mail and mail survey responses were transferred into a Microsoft Excel 2010 (Microsoft 2010) dataset for data preparation and further analysis. Data preparation included fixing the direction of reverse-coded variables, conducting multiple imputations to handle missing data, and assessing scale reliability and construct validity of the survey instrument.

4.3.1. Multiple Imputation

Sixty-nine valid responses were received during this study; however, not all survey questions were answered by all 69 respondents. To calculate the number of missing values in the dataset, for each variable, the data was converted to "0" if the value was missing and "1" otherwise. As a result, 372 missing values were found in the dataset, which accounts for approximately 8 percent of the total values in the dataset. Also, an average respondent missed a little more than five values, while 13 of the 69 respondents had no missing values. Therefore, responses (n=8) with more than 20 percent missing values were eliminated from further analysis.

For the remaining 61 valid responses, multiple imputations were used to deal with incomplete data (Rubin 1978, Schafer and Graham 2002). Further investigation of missing values revealed that the vast majority of the questions that had missing values were related to operational and financial performance, which raises the question of whether these missing values are related to the overall performance of responding companies. Conducting multiple imputations in SAS 9.3. (SAS Institute Inc. 2011) requires the data to be missing at random (MAR), which means that whether or not a value is missing depends on the observed values throughout the dataset, but not on the unobserved value itself. If missing values were highly related to company performance (e.g., lower performing companies had more missing values than higher performing ones), then it would have become questionable whether the data is MAR. Therefore, for the sake of this study, it is initially assumed that company performance has no effect on the amount of missing values.

Once the number of missing values was calculated, the pattern of missing values was examined. Specifically, it was determined if the pattern of the missing data was monotone or arbitrary. A monotone missing pattern means that if an observation (e.g., a survey response) has a missing value at a particular variable, then all subsequent variables also have missing values (Ault 2012). In other words, if the variables can be rearranged in a different order than as they originally appeared, the pattern is called to be monotone, but if such an arrangement is not possible, the pattern is called to be arbitrary (Ault 2012). In regards to the dataset used in this study, the data reflected arbitrary missing values.

Since the variables with missing values were ordinal in nature (e.g., they have a specific ordering but not necessarily on a continuous level) and there was no monotone-missing pattern, the multiple imputation was conducted by using the variables without missing values as predictors for each missing value variable in the model. Therefore, questions representing functional areas of the business, such as leadership, manufacturing, administrative support, supplier and customer relationship were added together to produce composite scores and were used as predictors. In addition, some of the contextual variables, such as location, and company position were also used as predictors.

The multiple imputation code, enlisted in Appendix F, followed a "PROC MI" procedure (Ault 2012) using the above described predictors. The first missing value variable imputed was the item called "Inbound quality (items coming in without any problem)," referred to as OMQ2 in the multiple imputation SAS code. The next missing value variable was imputed using the original predictors plus the previously imputed variable (OMQ2)*,* and then each subsequent missing value variable was imputed with the predictors being the originals plus all of the previously imputed variables.

4.3.2. Independent Variables

The "Lean implementation in transportation equipment manufacturing" survey developed in this study aims to obtain reliable and valid measures for Lean implementation as each measurement item was generated based on a thorough review of relevant empirical and conceptual literature. By measuring scale reliability (using Cronbach's alpha) and construct validity (using Principle Component Analysis, PCA), a decision can be made whether a particular survey item should be retained in further analysis.

4.3.2.1. Scale Reliability

In the "Lean implementation in transportation equipment manufacturing" survey conducted in this study, the observed variables consist of Lean implementation scores measured on the four level scale introduced in the Hypotheses chapter, which may or may not be a good measure of the underlying determinants of leadership, manufacturing, accounting and finance, and supplier and customer relationships.

Therefore, the reliability of responses to the scale needs to be determined. In this study, scale reliability is measured in terms of the consistency of the scores obtained on the observed variables using Cronbach's alpha (Cronbach 1951) in SAS 9.3. (SAS Institute Inc. 2011). The SAS code used to perform this analysis is enlisted in Appendix G. An estimate of internal consistency is best represented by a reliability coefficient (α) of 0.80 to 0.90 (Clark and Watson 1995, DeVellis 1991); however, researchers often consider 0.70 (Nunnally 1978) an acceptable reliability coefficient (α). Since Cronbach's alpha tends to underestimate the internal consistency of responses to scales with a few items (Lehman et al. 2005), for the sake of this test the measurement items of supplier relationship and customer relationship are grouped together. Results from assessing scale reliability are listed in Table 9. Since no missing values for independent variables have been identified, results for all five imputation cycles were identical and are therefore presented collectively for both, scale reliability and construct validity tests.

Table 9: Cronbach's Alpha Reliability Estimates for the Study's Independent Variables

Functional Areas	Original (Entire Set) Cronbach's alpha	Adjusted (Entire Set) Cronbach's alpha	Actions taken
Leadership	0.7923	0.7923	None
Manufacturing	0.8430	0.8430	None
Accounting and Finance	0.6230	0.7159	AQ3, AQ5, AQ6, and AQ8 removed
Supplier Relationship and Customer Relationship combined	0.5899	0.6802	SRQ2 and CRQ2 removed

Estimates of internal consistency as measured by Cronbach's alpha all exceeded α = 0.70 for the leadership (α = 0.79 for the entire set) and manufacturing (α = 0.84 for the entire set) dimensions, but did not exceeded α = 0.70 for the accounting and finance (α = 0.62 for the entire set) and customer and supplier relationship (α = 0.58 for the entire set) dimensions. Reliability of responses can be improved by dropping redundant items from the set (Lehman et al. 2005). Redundant items are the items that possess greater individual α-values than the α-values of the entire set (Lehman et al. 2005). Consequently, to improve scale reliability, the four items of "budgeting (AQ3)," "product costing (AQ5)," "authorization process (AQ6)," and "accounts receivable (AQ8)" representing determinants of the accounting and finance dimensions and the two items of "inventory management (SRQ2)" and "customer demand (CRQ2)" representing determinants of the supplier and customer relationship dimensions are suggested to be removed from the set. Removing these four variables would increase the reliability estimates of the accounting and finance dimension from α = 0.62 to 0.71 and the reliability estimates of the supplier and customer relationship dimensions from α = 0.58 to 0.68 (Table 9). However, before dropping the above mentioned four items permanently, it may be advisable to perform a principal component analysis on the responses of all independent variables to determine which items tend to group together empirically (Lehman et al. 2005).

4.3.2.2. Variance Reduction Using Principal Component Analysis

To investigate whether redundancy among Lean determinants representing the leadership, manufacturing, accounting and finance, and supplier and customer relationships dimensions exist, a principal component analysis (PCA) using SAS 9.3. (SAS Institute Inc. 2011) was performed. The SAS code used to perform this analysis is enlisted in Appendix H. PCA in this study was conducted for each of the four dimensions, rather than simultaneously across multiple dimensions given the small number (n=61) of observations in this study (Shah 2002). Responses to all four dimension categories were subject to a PCA analysis using the "eigenvalue > 1" criterion to determine the number of components to retain (Lehman et al. 2005). The principal axis method was used to extract the components, followed by a varimax (orthogonal) rotation (Lehman et al. 2005). From the leadership dimension, the first three determinants displayed eigenvalues greater than one, and the results of a scree-test also suggested that the first three determinants were meaningful; therefore, those three determinants were retained for rotation (Lehman et al. 2005). Combined, determinants one, two, and three accounted for 74 percent of the total variance. In interpreting the rotated factor pattern, an item was said to load on a given determinant if the factor loading was 0.40 or greater for that determinant, and was less than 0.40 for the other (Lehman et al. 2005). Using these criteria, the two items of "knowledge management (LQ6)" and "performance measurement (LQ8)" were found to be loaded on multiple determinants and got excluded from the model. Then, the analysis was repeated by keeping only the first two determinants for varimax rotation that represented 67 percent of the total variance. Results show that from the remaining six items, three-three items were loading on both, the first and second determinants as well.

Using the same procedure and criteria for the manufacturing dimension, it was revealed that determinants one and two accounted for 57 percent of the total variance and were therefore retained for the rotation. Results showed that the item called "maintenance procedures (MQ4)" had meaningful loading on both determinants and got deleted from the interpretation. Then the process was repeated again resulting in finding four items to be loaded on the first determinant and four items on the second determinant.

In regards to the accounting and finance dimension, the first two determinants were selected to be retained for the rotation. These two determinants accounted for 48 percent of the total variance in the accounting and finance dimension. The item called "organization of administrative processes (AQ1)" was found to have meaningful loading on both determinants and therefore being deleted from the interpretation. When repeating the analysis, five items were loaded on the first determinant, while three items were on the second determinant but no additional items showed meaningful loading on multiple determinants. Consequently, the original nine items representing the accounting and finance dimension have been reduced to eight items.

Lastly, the supplier and customer relationship dimensions were analyzed as one dimension due to the low number of items representing each individual dimensions. Three determinants displayed eigenvalues greater than one and got therefore retained for rotation. Combined, these two determinants accounted for 71 percent of the total variance. The item called "customer involvement in new product development (CRQ3)" was found to have meaningful loading on multiple determinants and therefore got deleted from the interpretation. When repeating the process, only the first two determinants, representing 60 percent of the total variance, were kept for the varimax rotation. The five remaining items did not show multiple loadings on any determinant; therefore, they were all kept for further analysis.

4.3.3. Dependent Variables

In this study, performance of a manufacturing facility is conceptualized as operational performance and financial performance as it is demonstrated in the Hypotheses chapter in Table 8. Operational performance measures were developed using the frameworks of Cua (2000), Shah (2002), Olsen (2004), and the Industry Week's best plant benchmarking database (Industry Week 2011).

4.3.3.1. Scale Reliability

Since dependent variables of this study are measured on a performance scale, the reliability of responses to the scale needs to be determined for dependent variables as well. Scale reliability is measured using Cronbach's alpha following the same procedure and criteria as for independent variables. However, as missing values for dependent variables exist, multiply imputed data is used as a base for the analysis. Since multiple imputations generates slightly different datasets in each imputation cycle, results from assessing scale reliability for all five imputation cycles (MI cycles one to five) are enlisted in Table 10. The SAS code used to perform the scale reliability test is enlisted in Appendix G.

Table 10: Cronbach's Alpha Reliability Estimates for the Study's Dependent Variables for All Five Imputation Cycles

Functional Areas	Original (Entire Set) Cronbach's alpha	Adjusted (Entire Set) Cronbach's alpha	Actions taken
Operational performance			
- MI cycle 1	0.6597	0.7890	OMQ7, OMQ10, OMQ11, OMQ12 removed
- MI cycle 2	0.6490	0.7848	
- MI cycle 3	0.6853	0.7919	
- MI cycle 4	0.6570	0.7844	
- MI cycle 5	0.6303	0.7802	
Accounting performance			
- MI cycle 1	0.7034	0.7034	None
- MI cycle 2	0.7429	0.7429	
- MI cycle 3	0.7592	0.7592	
- MI cycle 4	0.7757	0.7757	
- MI cycle 5	0.6847	0.6847	
Financial performance			
- MI cycle 1	0.7743	0.7743	None
- MI cycle 2	0.8343	0.8343	
- MI cycle 3	0.8187	0.8187	
- MI cycle 4	0.8055	0.8055	
- MI cycle 5	0.8149	0.8149	

Estimates of internal consistency as measured by Cronbach's alpha exceeded $\alpha = 0.70$ for the accounting performance ($\alpha = 0.70, 0.74, 0.75, 0.77, 0.68$ respectively for the entire set) and financial performance ($\alpha = 0.77, 0.83, 0.81, 0.80, 0.81$ respectively for the entire set) dimensions, but did not exceeded α = 0.70 for the operational performance (α = 0.65, 0.64, 0.68, 0.65, 0.63 for the entire set) dimension. Since the reliability of responses can be improved by dropping redundant items from the set (Lehman et al. 2005), the four items of "reactive maintenance (OMQ7)," "rework cost as a percentage of sales (OMQ10)," "customers for which the facility has implemented a JIT delivery program (OMQ11)," and "suppliers who provided JIT delivery to your facility (OMQ12)" representing determinants of the operational performance are suggested to be removed from the set. Removing these four variables would increase the reliability estimates of the operational performance dimension from α = 0.65, 0.64, 0.68, 0.65, 0.63 for the entire set to 0.78, 0.78, 0.79, 0.78, 0.78 respectively (Table 10). However, before dropping the above mentioned two items permanently, a principal component analysis on the responses of all dependent variables are performed as well to determine which items tend to group together empirically (Lehman et al. 2005).

4.3.3.2. Variance Reduction Using Principal Component Analysis

To investigate whether redundancy among items representing operational, financial, and accounting performance exist, a principal component analysis (PCA) using SAS 9.3. (SAS Institute Inc. 2011) was performed. Conducting PCA on a multiple imputed dataset, however, raises some concerns as having five imputed datasets generate five separate varimax-rotated solutions that must be analyzed and combined. Simply averaging these varimax-rotated solutions, however, may provide incorrect results if 1) the order of the components is not the same for all imputed datasets, 2) the signs of loading is reversed in any of the imputed datasets compared to the other imputed datasets, 3) the average solution is computed across solutions that have more variation among each other than necessary (van Ginkel 2014). Although, a more appropriate and state-of-the-art analysis, called generalized procrustes analysis (GPA; van Ginkel 2014), for combining PCA outcomes for multiple imputed datasets exist, as of today, this option is not included in the SAS 9.3 software. Therefore, the average varimax-rotated solutions are used to analyze PCA outcomes for the five imputation cycles of this study. The SAS code used to perform this analysis is enlisted in Appendix H.

Since operational performance is measured by the five categories of quality, time, delivery, capacity, and safety, PCA was conducted for each of these categories individually, rather than simultaneously across operational performance measures in general given the small number (n=61) of observations in this study (Shah 2002). Responses to all five operational performance categories were subject to a PCA analysis using the "eigenvalue > 1" criterion to determine the number of components to retain (Lehman et al. 2005). The principal axis method was used to extract the components, followed by a varimax (orthogonal) rotation (Lehman et al. 2005). From the quality performance measures, the first three determinants displayed eigenvalues greater than one, and the results of a scree-test also suggested that the first three determinants were meaningful; therefore, those three determinants were retained for rotation in all imputation cycles (Lehman et al. 2005). The first three determinants combined accounted for 67 percent of the total variance. In interpreting the rotated factor pattern, an item was said to load on a given determinant if the factor loading was 0.40 or greater for that determinant, and was less than 0.40 for the other (Lehman et al. 2005). In four out of the five imputation cycles, the item called "scrap cost as a percentage of sales (OMQ9)" was found to be loading on multiple determinants, while in three out of the five imputation cycles the item called "rework cost as a percentage of sales (OMQ10)" was found not to be loaded on any determinants; therefore, they got removed from the model. When repeating the analysis, it was revealed that in one out of the five imputation cycles the item called "customer reject rate on shipped products (OMQ8)" was not loading on any dimension. Further investigation of the item OMQ8 revealed that the variance among responses to that item was very low; therefore, the item also got removed from further analysis. Since the item called “manual adjustments due to late recording (OMQ13)” remained the only item loading on the second dimension, it also got removed from further analysis. Using the same procedure and criteria for the time-based performance measures, it was revealed that determinants one and two accounted for 51 percent of the total variance and were therefore retained tor the rotation. Results showed that the item called “manufacturing lead time (OMQ19)” had meaningful loading on both determinants and got deleted from the interpretation. All remaining items representing time-based performance measures are kept for further analysis. In regards to delivery performance measures, the first three determinants were selected to be retained for the rotation. These three determinants accounted for 81 percent of the total variance in the delivery performance dimension. Since two items were found to be loaded on each of the three determinants, no items representing the delivery performance dimension were found to be redundant and got excluded from the model. In regards to capacity performance measures, the first two determinants were selected to be retained for the rotation. These two determinants accounted for 72 percent of the total variance in the delivery performance dimension. Since the item called “overall equipment effectiveness (OMQ6)” did not load on any determinants in any of the five imputation cycles, it got removed from the model. Consequently, the item called “reactive maintenance rate (OMQ7)” was the only remaining item loading on the second determinant; therefore, it had been removed from the model. Lastly, no PCA on the safety dimensions was conducted as it possessed only one determinant.

PCA was also conducted for financial performance measures. Results showed that only the first determinant displayed eigenvalues greater than one and the results of a scree-test also suggested that only the first determinant was meaningful. Although, all five financial performance measures loaded on the same determinant in all five imputation cycles, the item called “R&D cost ratio (FMQ5)” had very low loading scores compared to the other four items; therefore, it had been removed from the interpretation.

The outcomes of the PCA for the accounting performance dimension showed notable differences among different imputation cycles. In all imputation cycles, the first two determinants were meaningful and retained for the varimax rotation. In imputation cycles one, two and three the item called “monthly overtime hours for accounting/finance employees (OMQ17)” loaded on both determinants, while in imputation cycle four the item called “order entry – Cash-in lead time (OMQ20)” did not load on any determinant. Further investigation of the item OMQ20 showed that its loading values tend to be very low for all imputation cycles; therefore, the item have been removed from further interpretation.

4.3.4. Reduced Model

Independent variables in this study were originally aligned to the five dimensions of leadership, manufacturing, accounting and finance, supplier relationship, and customer relationship to collectively measure the level of Lean implementation in transportation equipment manufacturing facilities for the year of 2012. Each of these dimensions was represented by three to nine measurement items, resulting in a total of 32 measurement items. These 32 items along four dimensions (supplier relationship and customer relationship dimensions were combined due to the low number of measurement items) were then tested for reliability using Cronbach’s alpha and construct validity using PCA. As a result, 5 (LQ6, LQ8, MQ4, AQ1, CRQ3) out of the 32 items were dropped from the original model due to high factor-loadings on more than one component. As the number of items representing Lean implementation along the five dimensions got reduced from 32 to 27 items, the number of dimensions also had to be adjusted by combining the supplier relationship dimension and the customer relationship dimension into one final dimension, called supplier and customer relationship dimension, as displayed in Table 11.

Three dependent variables, including operational performance, financial performance, and accounting performance formed the basis of this study. Operational performance was originally aligned to the five measurement dimensions of quality (OMQ_P1), time (OMQ_P2), delivery (OMQ_P3), capacity (OMQ_P4), and safety (OMQ_P5). Each of these five dimensions was then represented by one to seven measurement items, resulting in a total of 25 measurement items. Financial performance was originally represented by 5 measurement items along one single dimension, while accounting performance was originally represented by 7 measurement items representing one dimension. All three dependent variable categories were then individually tested for reliability using Cronbach's alpha and construct validity using PCA. As a result, 2 items (OMQ9, OMQ19) out of the 25 items representing operational performance were dropped from the original model due to high factor-loadings on more than one component, 3 items (OMQ6, OMQ8, OMQ10) were dropped because they did not load on any dimension, while an additional 2 items (OMQ7, OMQ13) were dropped due to being the only loading on an investigated component. One item (FMQ5) representing financial performance was dropped from the model due to its low loading values. One (OMQ17) out of the seven items representing accounting performance were dropped from the original model due to high factor-loadings on more than one component, while another item (OMQ20) was dropped because it was not loading on any dimension. Consequently, the number of items representing operational performance along the five dimensions got reduced from 25 to 18 items, while the number of items representing financial performance was reduced from 5 to 4 items as represented in Table 11. Finally, the number of items representing accounting performance got reduced from 7 to 5.

Table 11: Reduced model to investigate the relationship between Lean implementation level and performance

Leadership	Manufacturing	Accounting/ Finance	Supplier and Customer relationship
LQ1 – Lean implementation planning	MQ1 – Production flow	AQ2 – Transformation progress	SRQ1 – Supplier relationship
LQ2 – Top management commitment	MQ2 – Production quality	AQ3 – Budgeting	SRQ2 – Inventory management
LQ3 – Communication	MQ3 – Changeover procedures	AQ4 – Month-end closing	SRQ3 – Supplier involvement in new product development
LQ4 – Training	MQ5 – Pull system	AQ5 – Product costing	CRQ1 – Customer relationship
LQ5 – Employee involvement	MQ6 – One-piece flow	AQ6 – Authorization process	CRQ2 – Customer demand
LQ7 – Employee incentives	MQ7 – Work procedures	AQ7 – Accounts payable	CRQ3 – Customer involvement in new product development
	MQ8 – Workplace organization	AQ8 – Accounts receivable	
	MQ9 – Employee training	AQ9 – Inventory tracking	

Fit Relationship

	Operational performance	Accounting performance	Financial performance
Quality	OMQ1 – First time through OMQ2 – Inbound quality OMQ3 – Outbound quality	OMQ13 – Manual adjustments due to late recording OMQ14 – Overdue invoices from suppliers OMQ15 – Overdue invoices to customers OMQ23 – Average length of an investment decision cycle OMQ24 – Average length of financial closing	FMQ1 – Productivity FMQ2 – Return on assets FMQ3 – EBIT FMQ4 – Market share
Time-based	OMQ18 – Lead-time on "long lead time" purchased materials OMQ20 – Order entry – Cash-in time OMQ21 – Average days of inventory OMQ22 – Average length of a new product development cycle OMQ23 – Average length of an investment decision cycle OMQ24 – Average length of financial closing		
Delivery	OMQ4 – On-time delivery rate OMQ5 – Supplier shipments delivered on time OMQ11 – Customers for which the facility has implemented a JIT delivery program OMQ12 – Suppliers who provided JIT delivery to your facility OMQ14 – Overdue invoices from suppliers OMQ15 – Overdue invoices to customers		
Capacity	OMQ16 – Monthly overtime hours for production employees OMQ17 – Monthly overtime hours for accounting/finance employees		
Safety	OMQ25 – Lost time incident rate		

4.4. Multiple Regression Assumption Testing

Before pursuing further with the regression analysis, it is necessary to make sure that assumptions for the multiple regression models are met. Assumption testing was performed using SAS 9.3 (SAS Institute Inc. 2011) for each multiply imputed dataset. The SAS codes used to perform the analysis are enlisted in Appendix I. To examine whether error terms are independent, plots of residual values versus dependent variable values of Y and independent variable values of X were examined. Since residuals are randomly scattered around the reference line of 0 and no patterns appear in the residual plot, the model does not violate either the assumption of constant variance or of independence of the error terms.

To verify normality of the residuals, distribution analysis using normal quantile plots and Shapiro-Wilk tests (Shapiro and Wilk 1965) were performed for each imputation cycle. Results of the Shapiro-Wilk tests along with the distribution analysis using normal quantile plots revealed that the random error terms of the model for the dependent variables of operational, financial, and accounting performance do not follow a normal distribution. A Box-Cox method (Box and Cox 1964, Box and Cox 1982) was used to identify the appropriate transformation for each of the dependent variables based on a set of independent variables (e.g., leadership, manufacturing, accounting and finance, and supplier and customer relationship). Results of the Box-Cox analysis revealed that the recommended transformation for each three dependent variables are the square-transformation as data tend to be skewed to the left and the Lambda values tend to be larger than 1.75 for all dependent variable in each imputation cycle (Ngo 2012). Once the square-transformation was completed, the Shapiro-Wilk tests was run again and results showed that in general the random error terms of all three models tend to follow a normal distribution. Individual *p*-values of the Shapiro-Wilk tests before and after the square-transformation for all three dependent variables for each imputation cycles are enlisted in Table 12.

Table 12: Results of the Shapiro-Wilk test before and after the square-transformation of all dependent variables for each imputation cycles.

	Shapiro-Wilk test (p-values) for Operational Performance		Shapiro-Wilk test for (p-values) Financial Performance		Shapiro-Wilk test (p-values) for Accounting Performance	
	Before the Square-transformation	After the Square-transformation	Before the Square-transformation	After the Square-transformation	Before the Square-transformation	After the Square-transformation
IM Cycle 1	0.0061	0.1344	0.0004	0.0341	0.0026	0.1424
IM Cycle 2	0.0090	0.1189	0.0006	0.0866	0.0170	0.2118
IM Cycle 3	0.0051	0.0772	0.0004	0.0738	0.0015	0.1912
IM Cycle 4	0.0300	0.3171	0.0002	0.0506	0.0242	0.1799
IM Cycle 5	0.0347	0.3464	0.0002	0.0533	0.0076	0.2368

Besides verifying assumptions, the data is also examined to detect potential outliers that fall away from the overall pattern of the remaining data by examining the Studentized residuals (calculated by dividing the residual values by their standard error) of the model. No Studentized residuals with the absolute value of 3.0 were identified. Studentized residuals with the absolute values of 2.0 to 3.0 were further examined but no outliers got detected or deleted from the model.

4.5. Non-Response Bias

After closing the survey on August 20, 2013, 30 randomly selected non-respondents from the adjusted mailing list were contacted by phone and fax to obtain answers to five survey questions including geographical region (categorized as West, Midwest, Northeast, South, Great-Lake, and Souteast regions; U.S. Census Bureau 2000), main product (categorized as NAICS 3361, NAICS 3362, NAICS 3363; Statistics Canada 2007), annual sales revenue (categorized as less than $2.6 million, $2.6 million to $13.1 million, $13.2 million to $65.6 million. $65.7 million to $262.8 million, more than $262.8 million; Census Bureau 2007o), whether or not they have ever started a Lean journey (categorized as yes and no), and the type of communication respondents have in their facility (categorized as 1) communication is largely top-down and limited, 2) basic communication procedures to openly and timely inform work-teams are in place but they are not uniform, 3) communication between management and employees is timely and information can be pulled as required in the facility, and 4) two-way and open communication exists throughout the extended value chain). Responses from these phone and fax surveys were used to test for non-response bias (Malhotra 1996, Armstrong and Overton 1977). Verbal and fax responses to these questions were recorded and entered into the database.

Since five data points were missing in regards to two response categories (e.g., main product and annual sales revenue categories) from the original 69 responses received to the survey, the 30 responses extracted from non-respondents for the five questions were analyzed using nominal logistic regression on the multiply-imputed data in SAS 9.3. (SAS Institute Inc. 2011) at $\alpha = 0.05$. The SAS code and for non-response bias analysis is enlisted in Appendix J. No statistically significant differences between respondents and non-respondents were found in any of the five investigated response categories for any of the five multiple imputation cycles (MI cycles). Individual *p*-values for MI cycles one to five ranged from p = 0.4698, 0.4893, 0.4836, 0.4678, 0.4716 for geographical region, p = 0.3959, 0.3239, 0.3682, 0.3939, 0.3970 for main product, p = 0.2699, 0.2428, 0.2812, 0.2558, 0.2769 for annual sales revenue, p = 0.1103, 0.1436, 0.1128, 0.1140, 0.1084 for communication, and to p = 0.3510, 0.3149, 0.3472, 0.3446, 0.3574 for whether or not they have ever started a Lean journey.

4.6. Limitations of the Study

Generalizing the results of a survey to the population of interest is based on the assumption that survey respondents provide a representative sample of the population; however, all sample surveys are exposed to some kind of survey errors.

All estimates produced by the "Lean implementation in transportation equipment manufacturing" survey are somewhat subject to sampling errors. Sampling error in this study reflects the natural variability in the estimates that occur because data are only collected from a subset of the population. To cope with the low response rate of the survey, results will be generalized with a 10 percent margin of error.

The study may have been exposed to some coverage error. Considering the limited number of valid responses received to the survey, using a mixed mode design (combination of an internet and mail surveys) may not have been the most appropriate mode of reaching top management personnel of transportation equipment manufacturers.

Non-response bias occurs if respondents and non-respondents differ from each other on the variables that are of interest to the study, e.g., geographical region, main product, annual sales revenue, type of communication, and whether or not the facility has ever started a Lean journey. Although, the response rate to this study was low, no evidence of non-response bias was detected. Therefore, non-respondents in this study can be considered a random subset of the full survey sample with respect to the variables being measured.

The estimates may also be subject to measurement error, as data on Lean implementation and performance were obtained using assessments by senior managers. External verification could not be achieved in regards to this study due to the single business unit level focus of this study, where corresponding secondary (e.g., published) data are not directly available. However, previous studies have established that managerial assessments correspond closely to internally obtained objective performance indicators (Dess and Robinson 1984) and externally obtained secondary data (Venkatraman and Ramanujam 1987). Thus, the expectation is that the data are free from serious measurement error.

References

Adams, La Mar L., and Gale Darwin. 1982. Solving the Quandary between Questionnaire Length and Response Rate in Educational Research. *Research in Higher Education* 17 (3): 231–40.

Armstrong, J. Scott, and Terry S. Overton. 1977. Estimating Nonresponse Bias in Mail Surveys. *Journal of Marketing Research* 14 (3): 396–402.

Ault, Kimberly. 2012. Multiple Imputation for Ordinal Variables: A Comparison of SUDAAN PROC IMPUTE and SAS PROC MI. SAS Institute, Inc. http://analytics.ncsu.edu/sesug/2012/SD-12.pdf. Accessed: April 6, 2014.

Boomsma, Anne. 1982. Robustness of LISREL against Small Sample Sizes in Factor Analysis Models. In *Systems under Indirect Observations, Causality, Structure, Prediction (part 1)*, Karl G. Jöreskog and H. Wold (eds.), 149 - 173. Amsterdam: North Holland.

Box, George E.P., and David R. Cox. 1964. An analysis of transformations. *Journal of the Royal Statistical Society. Series B (Methodological)* 26 (2): 211-252.

Box, George E.P., and David R. Cox. 1982. An analysis of transformation revisited, rebutted. *Journal of the American Statistical Association* 77 (377): 209-210.

Brown, George W., Tirril O. Harris, and Louise Lemyre. 1991. Now You See It, Now You Don't - Some Considerations on Multiple Regression. In *Problems and Methods in Longitudinal Research:*

Stability and Change, Magnusson David, Bergman Lars R., Rudinger George, and Torestad Bertil (eds.), 67–94. Cambridge, UK: Cambridge University Press.

Clark, Lee Anna, and David Watson. 1995. Constructing Validity: Basic Issues in Objective Scale Development. *Psychological Assessment* 7 (3): 309–19.

Cronbach, Lee J. 1951. Coefficient Alpha and the Internal Structure of Tests. *Psychometrika* 16 (3): 297–334.

Cua, Kristy O. 2000. A Theory of Integrated Manufacturing Practices: Relating Total Quality Management, Just-in-Time and Total Productive Maintenance. Doctor of Philosophy, Minneapolis, MN: University of Minnesota. pp. 224.

Dess, Gregory G., and Richard B. Robinson. 1984. Measuring Organizational Performance in the Absence of Objective Measures: The Case of the Privately-Held Firm and Conglomerate Business Unit. *Strategic Management Journal* 5 (3): 265–73.

DeVellis, Robert F. 1991. *Scale Development: Theory and Applications*. Newbury Park, CA: SAGE Publications. pp. 217.

Dillman, Don A., and Lisa R. Carley-Baxter. 2000. Structural Determinants of Mail Survey Response Rates over a 12 Year Period, 1988–1999. In *Proceedings of the Survey Research Methods Section*, 1–6. Alexandria, VA: American Statistical Association.

Dillman, Don A., and Nicholas L. Parsons. 2008. Self-Administered Paper Questionnaire. In *The SAGE Handbook of Public Opinion Research*, Wolfgand Donsbach and Michael W. Traugott (Eds.), 262–70. London, UK: SAGE Publications, Inc.

Dillman, Don A., Michael D. Sinclair, and Jon R. Clark. 1993. Effects of Questionnaire Length, Respondent-Friendly Design, and a Difficult Question on Response Rates for Occupant-Addressed Census Mail Surveys. *Public Opinion Quarterly* 57 (3): 289–304.

Dillman, Don A., Jolene D. Smyth, and Leah M. Christian. 2009a. *Internet, Mail, and Mixed-Mode Surveys: The Tailored Design Method*. 3 edition. Hoboken, N.J: Wiley and Sons, Inc. pp. 512.

Doty, D. Harold, William H. Glick, and George P. Huber. 1993. Fit, equifinality, and organizational effectiveness: A test of two configurational theories. *Academy of Management Journal* 36 (6): 1196-1250.

Fergusson, David M. 1997. Annotation: Structural Equation Models in Developmental Research. *Journal of Child Psychology and Psychiatry* 38 (8): 877–87.

Gefen, David, Detmar W. Straub, and Marie-Claude Boudreau. 2000. Structural Equation Modeling and Regression: Guidelines for Research Practice. *Communications of the Association for Information Systems* 4 (7): 1–77.

Herzog, A. Regula, and Jerald G. Bachman. 1981. Effects of Questionnaire Length on Response Quality. *Public Opinion Quarterly* 45 (4): 549–59.

Industry Week. 2011. IW Best Plants Benchmarking Database. http://www.industryweek.com/benchmarking/bestplants. Accessed: January 18, 2013.

InfoGroup. 1972. Infogroup - Leader in High Value Data and Multichannel Services. http://www.infogroup.com/. Accessed: December 13, 2012.

Jöreskog, Karl G. 1967. Some Contributions to Maximum Likelihood Factor Analysis. *Psychometrika* 32 (4): 443 - 482.

Jöreskog, Karl G., and Dag Sörbom. 1993. *LISREL 8: Structural Equation Modeling with the SIMPLIS Command Language*. Chicago, IL: Scientific Software International. pp. 262.

Lehman, Ann, Norm O'Rourke, Larry Hatcher, and Edward J. Stepanski. 2005. *JMP for Basic Univariate and Multivariate Statistics - A Step-by-Step Guide*. Cary, NC: SAS Institute, Inc. pp. 481.

Malhotra, Naresh K. 1996. *Marketing Research: An Applied Orientation*. 2nd edition. Upper Saddle River, NJ: Prentice Hall. pp. 890.

Maskell, Brian H. 2007. *The Diagnostic Questionnaire of Accounting, Control, and Measurement*. Cherry Hill, NJ: BMA, Inc.

Maskell, Brian H., and Bruce L. Baggaley. 2003. *Practical Lean Accounting: A Proven System for Measuring and Managing the Lean Enterprise, Second Edition*. 1 edition. New York, NY: Productivity Press. pp. 359.

Microsoft. 2010. *Microsoft Excel 2010*. http://office.microsoft.com/en-us/excel/. Accessed: July 21, 2014.

Ngo, Theresa H. D. 2012. The Steps to Follow in a Multiple Regression Analysis. http://support.sas.com/resources/papers/proceedings12/333-2012.pdf. Accessed: August 8, 2014.

Nightingale, Deborah J., Leyla Abdimomunova, Thomas Shields, Nathan L. Perkins, Jayakanth Srinivasan, and Ricardo Valerdi. 2012. *LAI Enterprise Self-Assessment Tool (LESAT) Version 2.0*. Massachusetts, MA: Massachusetts Institute of Technology, Lean Advancement Initiative.

Nightingale, Deborah J., and Joe H. Mize. 2002. Development of a Lean Enterprise Transformation Maturity Model. *Information, Knowledge, Systems Management* 3 (1): 15–30.

Nunnally, Jum C. 1978. *Psychometric Theory*. 2nd edition. New York, NY: McGraw-Hill. pp. 640.

Olsen, Eric Oscar. 2004. Lean Manufacturing Management: The Relationship between Practice and Firm Level Financial Performance. Doctor of Philosophy, Colombus, OH: The Ohio State University. pp. 220.

Qualtrics. 2002. Qualtrics Online Survey Software and Insight Platform. http://www.qualtrics.com/. Accessed: March 2, 2104.

Raghunathan, Trivellore E., and James E. Grizzle. 1995. A Split Questionnaire Survey Design. *Journal of the American Statistical Association* 90 (429): 54–63.

Rubin, Donald B. 1978. Multiple Imputations in Sample Surveys — a Phenomenological Bayesian Approach to Nonresponse. In *In Proceedings of the Section on Survey Research Methods*, 20–28. The American Statistical Association.

SAS Institute, Inc. 2011. *SAS® 9.3 Software*. http://support.sas.com/software/93/. Accessed: July 21, 2014.

Schafer, Joseph L., and John W. Graham. 2002. Missing Data: Our View of the State of the Art. *Psychological Methods* 7 (2): 147–77.

Shah, Rachna. 2002. A Configurational View of Lean Manufacturing and Its Theoretical Implications. Doctor of Philosophy, Colombus, OH: The Ohio State University. pp. 278.

Shapiro, Samuel Sanford, and Martin B. Wilk. An analysis of variance test for normality (complete samples). *Biometrika* 52 (3 and 4): 591-611.

Statistics Canada. 2007. North American Industry Classification (NAICS) 2007. http://www.census.gov/cgi-bin/sssd/naics/naicsrch?code=336&search=2012%20NAICS%20Search. Accessed: February 15, 2014.

U.S. Census Bureau. 2000. Census Regions and Divisions of the United States. http://www.census.gov/geo/maps-data/maps/pdfs/reference/us_regdiv.pdf. Accessed: May 1, 2014.

———. 2007b. Motor Vehicle Manufacturing (NAICS 3361) - Industry Facts Report 2007. https://www.census.gov/econ/census/snapshots_center/3361.html. Accessed: February 15, 2014.

———. 2007f. Motor Vehicle Body and Trailer Manufacturing (NAICS 3362) - Industry Facts Report 2007. http://thedataweb.rm.census.gov/TheDataWeb_HotReport2/econsnapshot/snapshot.hrml?NAICS=3362. Accessed: March 2, 2014.

———. 2007g. Motor Vehicle Parts Manufacturing (NAICS 3363) - Industry Facts Report 2007. http://thedataweb.rm.census.gov/TheDataWeb_HotReport2/econsnapshot/snapshot.hrml?NAICS=3363. Accessed: March 2, 2014.

———. 2007o. Receipt Size of Employer Firms. http://www.census.gov/econ/smallbus.html. Accessed: May 1, 2014.

Van Ginkel, Joost R., and Pieter M. Kroonenberg. 2014. Using Generalized Procrustes Analysis for multiple imputation in principal component analysis. *Journal of Classification* 31 (2): 242-269.

Venkatraman, Natarjan. 1990. Performance Implications of Strategic Coalignment: A Methodological Perspective. *Journal of Management Studies* 27 (1): 19–41.

Venkatraman, Natarjan. 1989. The Concept of Fit in Strategy Research: Toward Verbal and Statistical Correspondence. *Academy of Management Review* 14 (3): 423–44.

Venkatraman, Natarjan, and Vasudevan Ramanujam. 1987. Measurement of Business Economic Performance: An Examination of Method Convergence. *Journal of Management* 13 (1): 109–22.

Womack, James P., and Daniel T. Jones. 1996. *Lean Thinking : Banish Waste and Create Wealth in Your Corporation*. 1st edition. New York, NY: Simon & Schuster. Pp. 352.

5. Results

In the previous chapter, different approaches and their associated statistical methods for testing hypotheses were collected from which multiple regression and profile deviation analysis were selected. This chapter presents the results of the multiple regression and profile deviation analysis used to test the hypotheses of this study using data from 61 transportation equipment manufacturers.

5.1. Lean Implementation's Impact on Manufacturing Performance

The first objective of this study is to evaluate a segment of the U.S. transportation equipment manufacturing facilities as to their operational and financial performance and to investigate if there is a relationship between the level of Lean implementation and operational and financial performance. To evaluate the relationship between the level of Lean implementation of a facility and its operational and financial performance, an understanding of the levels of Lean implementation in responding facilities has to be obtained.

5.1.1. Level of Lean Implementation in Transportation Equipment Manufacturing

In this study, the level of Lean implementation of a transportation equipment manufacturing facility is measured on a four point scale, where 1 represents a traditional, mass production like management system, 2 represents the beginning of a transformation by developing a Lean framework, 3 represents a more advanced stage of a transformation by managing facility processes through value streams, and 4 represents a Lean enterprise like management system.

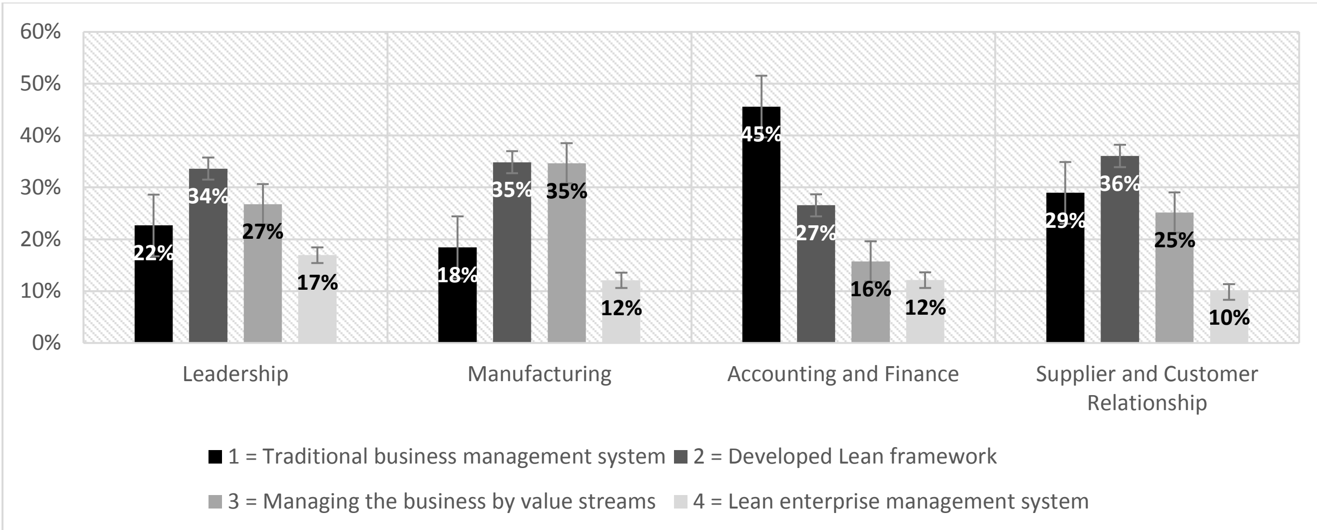


Figure 6: **Level of Lean implementation in transportation equipment facilities in 2012**

Results of this study (Figure 6) show that, on average, 22 percent of all respondents employed a traditional business management **leadership philosophy**, 34 percent of the respondents indicated that they started to experiment with a Lean leadership philosophy, 27 percent reported that they were enhancing their leadership philosophy by managing by value streams, while 17 percent reported to lead their facilities using a Lean enterprise leadership philosophy. Based on the results shown in Figure 6, the level of Lean implementation tends to be higher in the **manufacturing area** of the participating transportation equipment facilities, than in any other business areas. In regards to the manufacturing area, on average, 18 percent of the responding transportation equipment facilities possess traditional manufacturing operations, 35 percent started to experiment with Lean pilot projects, 35 percent advanced their Lean implementation into managing the shop-floor by value streams, while 12 percent reported to integrate Lean into manufacturing operations as an enterprise management system. Despite the relatively high level of Lean implementation in manufacturing, very few transportation equipment manufacturers reported to extend their Lean implementation to the **administrative, accounting and financial areas** of their businesses. Results show that, on average, 45 percent of the respondents organize their administrative processes by functional departments and use traditional accounting systems to manage the administrative side of their businesses, 27 percent reported to experiment with Lean pilot projects in administration, accounting, and finance, 16 percent reported to align the administrative side of their businesses to value streams, while 12 percent reported to align their administrative, accounting, and financial processes to value streams throughout the extended value chain. The investigation of the **supplier and customer relationship** dimension resulted in 29 percent reporting to manage that dimension based on a business mentality of not keeping close relationships with any suppliers and customers of the facility, 36 percent reported to experiment with Lean by introducing the concept to their suppliers and customers, 25 percent reported to develop mutually beneficial partnerships with their suppliers and customers throughout the Lean value stream, while 10 percent reported to integrate their suppliers and customers into their daily operations as part of their Lean enterprise management system.

5.1.2. Lean Implementation and Performance Relationship

Two different statistical analysis, multiple regression analysis and profile deviation analysis, were used parallel to investigate whether the higher level of Lean implementation along the four business dimensions of leadership, manufacturing, accounting and finance, and supplier and customer relationship together are correlated to better operational and financial performance in transportation equipment manufacturing facilities for the year of 2012.

To conduct a **multiple regression analysis**, a scale score of 1 to 4 was assigned to each question item measuring the facility’s level of Lean implementation in the four business dimensions, as demonstrated in Table 11 in the Methodology chapter. Then a final Lean implementation score representing the integration of Lean into facility operations was derived from the sum of the scale scores of each dimension's representative question items. The indicators used to measure operational and financial performance were also introduced in the Methodology chapter (Table 11) and will not be explained here again. Based on the responses provided to each performance related question, a scale score of 1 to 5 was established for each question variables, where one represented the worst performance and five the best performance. These individual scale scores were then summed up to calculate each facilities' overall operational and financial performance scores, which were then used as a base for conducting correlation and regression analysis. Since the final dataset (n = 61) used to perform the analysis contained missing values, a multiple imputation procedure was run to handle the incomplete data. Dependent variables with missing values (e.g., operational performance and financial performance) were imputed using logistic regression. A total of five imputation cycles were run in the model resulting in five different multiple imputed datasets. The PROC REG procedure was then used in SAS 9.3 to perform a multiple regression analysis on each of the five multiply imputed datasets (code for the analysis is shown in Appendix K). To pool and report results from the five generated multiple regression models, the PROC MIANALYZE procedure was used in SAS 9.3.

To conduct a **profile deviation analysis**, a scale score of 1 to 4 was assigned to each question item that measures the facility's level of Lean implementation in the four business dimensions of leadership, manufacturing, accounting and finance, and supplier and customer relationship, while a scale score of 1 to 5 was established for each performance variables. In this study, the ideal Lean facility profile is represented by the scale score of 4, which corresponds to the highest level of Lean implementation in all four business dimensions, while an ideal Lean facility performance profile is represented by the scale score of 5, which corresponds to best facility performance. The Euclidean distance from the ideal Lean facility profile as well as from the ideal Lean performance profile was then calculated for all five imputations using the normalized mean scores of variables, which were then weighted by their degrees of contribution to the fit relationship (e.g., the leadership dimension is represented by six underlying variables resulting in an assigned weight of 1/6 = 0.167). Once the Euclidean distance is calculated, the fit relationship investigates whether higher deviations from an ideal Lean facility profile results in higher deviations from an ideal Lean performance profile using a multiple regression analysis for all five imputations. The SAS 9.3 codes used to perform the analysis are enlisted in Appendix L.

5.1.2.1. Level of Lean Implementation and Operational Performance

The **multiple regression analysis** conducted to regress the dependent variable, operational performance, on the predictor variables of Lean implementation levels in the four business dimensions of leadership, manufacturing, accounting and finance, and supplier and customer relationship did not show enough evidence to reject the null hypotheses for *H1* stating that "*the level of Lean implementation has no impact on operational performance.*" Results of the multiple regression analysis, as displayed in Table 13, indicated that the level of Lean implementation in leadership (p = 0.9549), manufacturing (p = 0.1751), accounting and finance (p = 0.3100), and supplier and customer relationship (p = 0.6466) has no statistically significant influence on operational performance at α = 0.05 as measured by the performance metrics enlisted in Table 11 in the Methodology chapter. The "relative increase in variance" value enlisted in Table 13 shows the increase of variance due to having missing data imputed compared to a condition where no data are missing, while the "fraction of missing information" index indicates how much more precise the parameter estimate would have been if there have been no missing data. The relative efficiency presented in Table 13 shows the power of the test for the five imputations, which in this analysis is larger than 0.99 for each independent variables, indicating a robust imputation model.

Table 13: Results of multiple regression analysis on the dependent variable, operational performance, on all of the predictor variables in the data set

Model Information	
Data Set	REGRESSION_OP_PERF
Number of Imputations	5

Variance Information							
Parameter	Variance			DF	Relative Increase in Variance	Fraction Missing Information	Relative Efficiency
	Between	Within	Total				
leadership	55.7418	2475.8224	2542.7126	5780	0.0270	0.0266	0.9947
manufacturing	18.2370	1785.5432	1807.4276	27284	0.0122	0.0121	0.9975
accounting	17.0189	2850.7739	2871.1967	79060	0.0071	0.0071	0.9985
sup_and_cust_rel	115.0373	3866.9826	4005.0275	3366.9	0.0356	0.0350	0.9930

Parameter Estimates										
Parameter	Estimate	Std Error	95% Confidence Limits		DF	Minimum	Maximum	Theta0	t for H0: Parameter=Theta0	Pr > |t|
Leadership	-2.8537	50.4253	-101.706	95.9987	5780	-9.3803	8.4856	0	-0.06	0.9549
Manufacturing	57.6522	42.5138	-25.677	140.9816	27284	53.3835	64.7910	0	1.36	0.1751
Accounting	54.3968	53.5835	-50.627	159.4203	79060	49.7748	60.6530	0	1.02	0.3100
sup_and_cust_rel	-29.0146	63.2852	-153.096	95.0668	3366.9	-46.3696	-19.6614	0	-0.46	0.6466

Results of the **profile deviation analysis** were consistent with the results of the multiple regression analysis above showing no statistically significant relationship between the level of Lean implementation (as measured by the deviations from an ideal Lean facility profile in four business dimensions) and operational performance (as measured by the deviations from an ideal Lean operational performance profile). Profile deviation analysis results, as displayed in Table 14, indicated that the deviations from an ideal Lean facility profile in leadership (p = 0.9724), manufacturing (p = 0.2281), accounting and finance (p = 0.5395), and supplier and customer relationship (p = 0.7322) has no statistically significant influence on the deviations from an ideal Lean operational performance profile at α = 0.05. Consequently, there is not enough evidence to reject the null hypotheses for *H1* stating that "*the level of Lean implementation has no impact on operational performance.*" The relative increase in variance enlisted in Table 14 due to using multiple imputation to handle missing values is 2.95 for the leadership dimension, 2.12 percent for the manufacturing dimension, 1.44 percent for the accounting dimension, and somewhat larger, 7.27 percent, for the supplier and customer relationship dimension, while the relative efficiencies of 0.98 and 0.99 for all dimensions indicate a reliable and robust imputation model.

Table 14: Results of the regression analysis between the deviations from an ideal Lean facility profile and the deviations from an ideal Lean operational performance profile

Model Information	
Data Set	PDA_REG_OP_PERF
Number of Imputations	5

Variance Information							
Parameter	Variance			DF	Relative Increase in Variance	Fraction Missing Information	Relative Efficiency
	Between	Within	Total				
w_leadership	0.0004	0.0185	0.0191	4851.5	0.0295	0.0291	0.9942
w_manufacturing	0.0003	0.0216	0.0220	9208	0.0212	0.0210	0.9958
w_accounting	0.0001	0.0023	0.0023	19830	0.0144	0.0143	0.9971
w_sup_and_cust_rel	0.0013	0.0222	0.0239	870.83	0.0727	0.0699	0.9862

Parameter Estimates										
Parameter	Estimate	Std Error	95% Confidence Limits		DF	Minimum	Maximum	Theta0	t for H0: Parameter=Theta0	Pr > |t|
w_leadership	0.0047	0.1383	-0.2664	0.2759	4851.5	-0.0219	0.0332	0	0.03	0.9724
w_manufacturing	0.1790	0.1485	-0.1121	0.4702	9208	0.1610	0.2121	0	1.21	0.2281
w_accounting	0.0297	0.0485	-0.0653	0.1248	19830	0.0233	0.0368	0	0.61	0.5395
w_sup_and_cust_rel	-0.0529	0.1546	-0.3564	0.2505	870.83	-0.1142	-0.0240	0	-0.34	0.7322

Since the dependent variable of operational performance in this study was examined through different groups of performance measures, including quality, time, delivery, capacity, and safety related measures, the relationship between the level of Lean implementation in the four business dimensions and these individual performance groups were also examined. Results of the **multiple regression analysis** performed to investigate those relationships are displayed in Table 15. Results revealed that no statistically significant relationship could be obtained between the level of Lean implementation in any of the four business dimension and these individual performance groups. Although, the overall model performed on quality-related performance was not statistically significant (e.g., overall *p*-values of quality-related performance for the five imputation cycles were listed as p = 0.1786, 0.0653, 0.1854, 0.0976, and 0.1601 respectively), it was revealed that the level of Lean implementation in the manufacturing dimension has a statistically significant (p = 0.0214, Table 15) positive effect on quality-related performance.

Table 15: Results of multiple regression analysis on the dependent variables of time-, delivery-, capacity-, and safety-related performance on all of the predictor variables in the data set

Parameter	Quality-Related Performance P-values	Time-Related Performance P-values	Delivery-Related Performance P-values	Capacity-Related Performance P-values	Safety-Related Performance P-values
Leadership	0.8951	0.9729	0.7283	0.3202	0.9332
manufacturing	**0.0214**	0.7786	0.0932	0.7675	0.1968
Accounting	0.2299	0.1262	0.5110	0.5680	0.8148
sup_and_cust_rel	0.5652	0.6260	0.4233	0.4351	0.8245

Profile deviation analysis was also run to further investigate the fit relationship between the level of Lean implementation (as measured by the deviations from an ideal Lean facility profile in four business dimensions) and quality, time, delivery, capacity, and safety related performance (as measured by the deviations from an ideal Lean performance profiles). Results of the profile deviation analysis, as displayed in Table 16, were consistent with the results of the multiple regression analysis above showing no statistically significant relationship between the deviations from an ideal Lean facility profile in four business dimensions and the deviations from an ideal Lean quality, time, delivery, capacity, and safety related performance profiles. However, results of the profile deviation analysis also highlighted that the lower the deviation from the ideal Lean facility profile in manufacturing is, the lower the deviation from the ideal Lean quality performance tends to be (p = 0.0371, Table 16).

Table 16: Results of the regression analysis between the deviations from an ideal Lean facility profile and the deviations from an ideal time, delivery, capacity, and safety related performance profile

Parameter	Quality-Related Performance P-values	Time-Related Performance P-values	Delivery-Related Performance P-values	Capacity-Related Performance P-values	Safety-Related Performance P-values
w_leadership	0.6333	0.9321	0.7180	0.2366	0.7796
w_manufacturing	**0.0371**	0.7659	0.2119	0.7538	0.9520
w_accounting	0.1068	0.3151	0.8654	0.5100	0.4539
w_sup_and_cust_rel	0.5214	0.4419	0.3035	0.5387	0.1481

5.1.2.2. Level of Lean Implementation and Financial Performance

The **multiple regression analysis** conducted to regress the dependent variable, financial performance, on the predictor variables of Lean implementation levels in the four business dimensions of leadership, manufacturing, accounting and finance, and supplier and customer relationship did not show enough evidence to reject the null hypotheses for *H2* stating that "*the level of Lean implementation has no impact on financial performance.*" Results of the multiple regression analysis, as displayed in Table 17, indicated that the level of Lean implementation in leadership (p = 0.9332), manufacturing (p = 0.1968), accounting and finance (p = 0.8148), and supplier and customer relationship (p = 0.8245) has no statistically significant influence on financial performance at $\alpha = 0.05$ as measured by productivity, return on assets, EBIT, and market share. Although, the overall results of the multiple regression analysis did not show any statistically significant relationship between the Level of Lean implementation and financial performance, conclusions must be drawn with careful considerations, as the relative efficiency (0.94 for leadership, 0.93 for manufacturing, 0.93 for accounting and finance, and 0.96 for supplier and customer relationship), and therefore the power of the regression model, for the five imputations tend to be weaker than in the previous models due to the higher percentage of missing values in financial performance variables. Moreover, for the accounting and manufacturing dimensions, Table 17 displays 48 and 43 percent relative increase in variance respectively due to having missing data imputed compared to a condition where no data are missing.

Table 17: Results of the analysis run to regress the dependent variable, financial performance, on all of the predictor variables in the data set

Model Information	
Data Set	REGRESSION FIN_PERF
Number of Imputations	5

Variance Information							
Parameter	**Variance**			**DF**	**Relative Increase in Variance**	**Fraction Missing Information**	**Relative Efficiency**
	Between	**Within**	**Total**				
leadership	5.7146	17.6704	24.5280	51.173	0.3880	0.3061	0.9422
manufacturing	4.6352	12.7437	18.3060	43.326	0.4364	0.3339	0.9374
accounting	8.2043	20.3465	30.1917	37.617	0.4838	0.3592	0.9329
sup_and_cust_rel	4.5216	27.5994	33.0253	148.19	0.1965	0.1753	0.9661

Parameter Estimates										
Parameter	**Estimate**	**Std Error**	**95% Confidence Limits**		**DF**	**Minimum**	**Maximum**	**Theta0**	**t for H0: Parameter=Theta0**	**Pr > |t|**
Leadership	0.4172	4.9525	-9.5247	10.3591	51.173	-1.9900	3.567399	0	0.08	0.9332
manufacturing	5.6091	4.2785	-3.0175	14.2358	43.326	3.9213	9.110199	0	1.31	0.1968
Accounting	-1.2957	5.4947	-12.4230	9.8313	37.617	-4.7264	3.182813	0	-0.24	0.8148
sup_and_cust_rel	1.2768	5.7467	-10.0794	12.6330	148.19	-1.9035	3.610363	0	0.22	0.8245

The **profile deviation analysis** performed to investigate the relationship between the level of Lean implementation (measured by the deviations from an ideal Lean facility profile in the four business dimensions) and financial performance (measured by the deviations from an ideal Lean financial performance profile) also did not provide enough evidence to reject the null hypotheses for *H2* stating that "*the level of Lean implementation has no impact on financial performance.*" Findings of the profile deviation analysis, as summarized in Table 18, revealed that the deviations from an ideal Lean facility profile in the four business dimensions of leadership (p = 0.8586), manufacturing (p = 0.0907), accounting and finance (p = 0.5187), and supplier and customer relationship (p = 0.9999) has no statistically significant influence on the deviations from an ideal financial performance profile at α = 0.05. Although, the overall profile deviation model did not reveal any significant relationship between Lean implementation and financial performance, the effect of manufacturing was found to be significant in three out of the five imputation cycles (p = 0.0033, p = 0.0864, p = 0.1152, p = 0.0422, and p = 0.0807 respectively). Conclusions about this relationship, however, must also be drawn with careful considerations since the relative increase in variance, respectively due to having missing data imputed compared to a condition where no data are missing, in regards to the manufacturing dimension is approximately 43 percent and the relative efficiency is listed as 0.93 which is considerably lower than in all of the other models.

Table 18: Results of the regression analysis between the deviations from an ideal Lean facility profile and the deviations from an ideal Lean financial performance profile

Model Information	
Data Set	PDA_REG_FIN_PERF
Number of Imputations	5

Variance Information							
Parameter	Variance			DF	Relative Increase in Variance	Fraction Missing Information	Relative Efficiency
	Between	Within	Total				
w_leadership	0.0156	0.0688	0.0876	87.102	0.2727	0.2317	0.9557
w_manufacturing	0.0275	0.0800	0.1130	46.93	0.4123	0.3203	0.9397
w_accounting	0.0021	0.0085	0.0111	76.849	0.2955	0.2474	0.9528
w_sup_and_cust_rel	0.0047	0.0825	0.0883	946.53	0.0695	0.0669	0.9867

Parameter Estimates										
Parameter	Estimate	Std Error	95% Confidence Limits		DF	Minimum	Maximum	Theta0	t for H0: Parameter=Theta0	Pr > |t|
w_leadership	0.0529	0.2960	-0.5354	0.6413	87.102	-0.0580	0.2363	0	0.18	0.8586
w_manufacturing	0.5808	0.3362	-0.0957	1.2573	46.93	0.4301	0.8519	0	1.73	0.0907
w_accounting	-0.0684	0.1055	-0.2785	0.1417	76.849	-0.1292	-0.0007	0	-0.65	0.5187
w_sup_and_cust_rel	0.0001	0.2972	-0.5832	0.5833	946.53	-0.1068	0.0772	0	0.00	0.9999

Overall, analyzing the data using multiple regressions versus profile deviation analysis resulted in very similar results.

5.2. Performance Impact of Lean Accounting

To keep up with today’s highly competitive business environment, accounting and finance employees are under pressure to deliver a growing array of filings, reports, and critical information to meet business demands for faster turnaround and lower costs. As facilities change their production systems from mass to Lean production, alternative approaches to traditional accounting and financial systems, such as Lean accounting are also considered to be implemented.

5.2.1. Level of Lean Implementation in Transportation Equipment Manufacturing Facilities' Accounting and Finance Dimension

In Chapter 5.1.1., Figure 6 already showed that the level of Lean implementation tend to be the least frequent in the accounting and finance dimension. To get a better understanding about this finding, responses to individual question variables of the accounting and finance dimension are further examined in Figure 7.

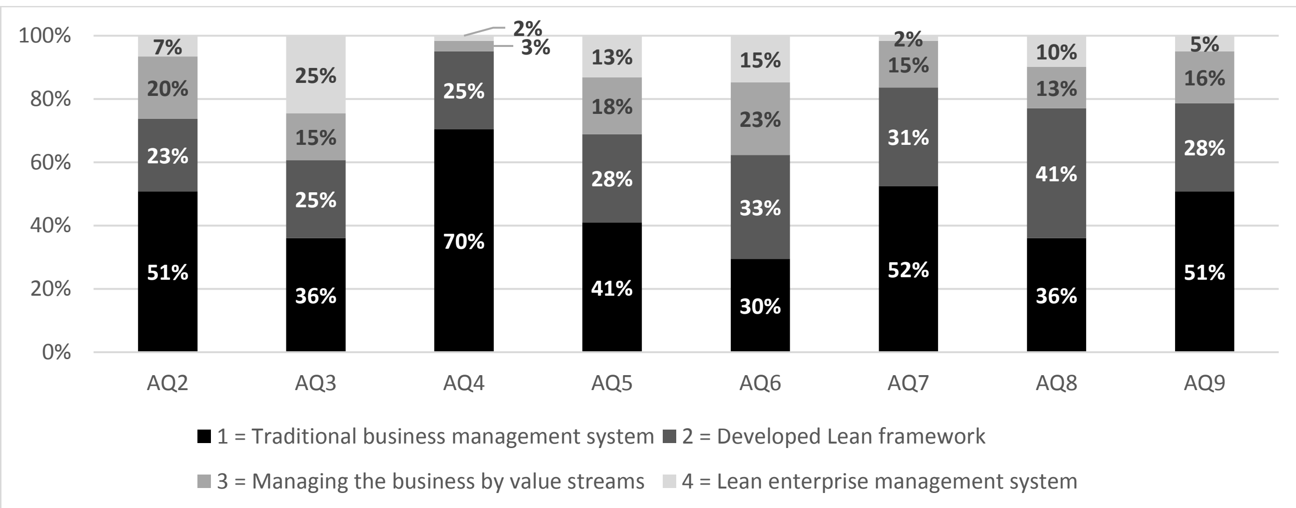


Figure 7: Level of Lean implementation in accounting and finance of transportation equipment manufacturers in 2012

At first, study participants were asked how accounting and financial personnel **evaluate the facility's manufacturing program (AQ2)**. Fifty-one percent of the respondents reported that their evaluation is based on cost reductions and efficiency, 23 percent reported that their Lean transformation progress is reviewed against predetermined success criteria for some continuous improvement projects, 20 percent reported that they have a formal process in place to analyze Lean transformation progress for all continuous improvement projects, and 7 percent reported that their

Lean transformation progress is judged by the aggregate benefits rather than individual or localized improvements.

In every budget review, accounting and financial employees spend a large amount of time preparing applications, rewriting reports, and reworking exceptions, and aligning documentations to division and corporate standards. When respondents were asked about their accounting **budgeting process (AQ3)**, 36 percent of the respondents reported that in their facility every department submits its budget which is then consolidated across the operation and rolled up to the division and corporate levels, 25 percent reported that their facility re-casted its chart of accounts and submits annual budgets from functional departments to value streams, 15 percent stated that their value stream budgets are results of the monthly operational planning of each value stream, while 25 percent stated that in their facility budgeting is eliminated and investment decisions are made based on consolidated monthly operational planning.

One of the big challenges employees deal with when implementing Lean in the accounting and finance dimension is the transformation of **product costing (AQ4)**. In fact, a vast majority (70 percent) of the respondents reported to calculate the standard costs for each item and report the variances against actual values, while 25 percent reported to calculate standard and value-stream costs parallel to help decision making. Only 3 percent of the respondents went beyond that step by replacing standard costing with value stream costing, and only 2 percent (e.g., 1 respondent) reported to apply value stream costing throughout the extended value chain.

In many facilities, accounting and financial employee's returning monster is **month-end closing (AQ5)** as necessary data are often not executed with adequate consistency and frequency to be readily observed. When respondents were asked about their month-end closing process, 41 percent reported to prepare a full package of month-end reports for corporate accounting, 28 percent reported to pursue a simplified month-end closing by using standardized charts of accounts and cost centers, 18 percent stated that in their facility month-end closing requires only short preparation time and reviews are brief and conducted only for important issues, while 13 percent stated that no month end closing is necessary in their facility as their financial statements are continuously updated and can be pulled at any time.

In numerous facilities, conducting activities, events, and transactions require validation and permissions, which can considerably slow down both administrative and manufacturing processes. When respondents were asked about **authorization processes (AQ6)**, 30 percent reported that in their facility multiple approvals and sign-offs are required from multiple managers to authorize transactions, 33 percent reported to reduce the number of approvals and sign-offs and strengthen budgetary accountability of departmental managers, 23 percent reported to minimize the number of approvals and sign-offs and push down the authority of spending money is in the organization, while 15 percent stated that multiple approvals and sign-offs are eliminated in their facility and value stream managers are responsible to authorize transactions.

Another crucial part of the Lean implementation in accounting is the transformation of the **accounts payable (AQ7)** and **accounts receivable (AQ8)** processes. In regards to accounts payable (AQ7), 52 percent of the 61 respondents reported that all materials received in their facility are documented with a purchase order, receiver, and an invoice, 31 percent reported to use accounts payable credit cards for small purchases and develop master purchase agreements with selected supplier(s) as a pilot project. An additional 11 percent of the respondents reported that in their facility, payment authorization based on receivers and invoices is initiated at the point of receiving and purchase orders are eliminated due to master purchase agreements for all key suppliers. Only 2 percent (one respondent) reported that their accounts payable processes are completely electronic using pick and pay systems. In regards to accounts receivable (AQ8), 36 percent reported that invoices are mailed to customers after each product shipment by the accounts receivable department, 41 percent indicated that master sales orders are used from our key customers and invoicing happens directly from shipping, 13 percent stated that invoicing needs are reduced by encouraging key customers to pay when products are received, while 10 percent indicated that their customers automatically wire payments to our bank accounts based on usage of products.

Inventory tracking (AQ9) is another pressing issue in the accounting and finance world; therefore, respondents were asked about their way of handling this task. A total of 51 percent of the respondents reported conducting a full physical inventory annually and making adjustments in the books accordingly. Twenty-eight percent of the respondents reported to replace their annual physical inventory with cycle counting to reduce errors, 16 percent reported to use cycle counting while introducing Kanban based inventory control throughout the value stream, and 5 percent reported to step forward by eliminating cycle count in favor of visual inventory control via Kanban system.

5.2.2. Lean Accounting and Performance

The second objective of this study focuses on Lean implementation in accounting and finance and the examination on its effect on manufacturing performance. At first, following the procedure described in Chapter 5.1.2, **single and multiple linear regression analysis** was performed to investigate whether the level of Lean implementation in accounting and finance effects operational, financial, and accounting performance of a transportation equipment manufacturer. The SAS 9.3 code used to perform the analysis is enlisted in Appendix K. Then, following the procedure described in Chapter 5.1.2, **profile deviation analysis** was performed to investigate whether higher deviation from an ideal Lean accounting profile correlates to higher deviation from an ideal Lean performance. The SAS 9.3 code used to perform the analysis is enlisted in Appendix L.

5.2.2.1. Lean Accounting and Operational Performance

In Chapter 5.1.2.1, when multiple regression analysis was conducted to regress the dependent variable, operational performance, on the predictor variable of Lean implementation levels in four business dimensions including accounting and finance, the relationship between operational performance and the level of Lean implementation in accounting and finance was not found to be significant (p = 0.3100, Table 13). Therefore, in this chapter, a **single linear regression analysis** was performed to regress the dependent variable, operational performance, on the single predictor variable of Lean implementation in the accounting and finance dimension. Results of the single linear regression analysis, as displayed in Table 19, revealed the higher level of Lean implementation in the accounting and finance dimension has a positive effect on operational performance (p = 0.0351) at α = 0.05, thereby, providing enough evidence to reject the null hypotheses for *H3* of this study stating "*Lean implementation in accounting has no impact on operational performance.*" The relative efficiency of 0.99 and relative increase in variance due to missing values of 0.3 percent displayed in Table 19 indicated a strong imputation model.

Table 19: Results of the analysis run to regress operational performance on the accounting and finance dimension

Model Information	
Data Set	REGRESSION2_OP_PERF
Number of Imputations	5

Variance Information							
Parameter	Variance			DF	Relative Increase in Variance	Fraction Missing Information	Relative Efficiency
	Between	Within	Total				
accounting	4.3673	1369.0833	1374.3241	275069	0.0038	0.0038	0.9992

Parameter Estimates										
Parameter	Estimate	Std Error	95% Confidence Limits		DF	Minimum	Maximum	Theta0	t for H0: Parameter=Theta0	Pr > |t|
Accounting	78.1161	37.0718	5.4562	150.7760	275069	74.5844	79.8386	0	2.11	**0.0351**

In Chapter 5.1.2.1, when **profile deviation analysis** was conducted to regress the dependent variable, operational performance (as measured by the deviations from an ideal Lean operational performance profile), on the level of Lean implementation (as measured by the deviations from an ideal Lean facility profile in four business dimensions including accounting and finance), the relationship between the deviation from an ideal Lean operational performance profile and the deviation from an ideal Lean facility profile in accounting and finance was not found to be significant ($p = 0.5395$, Table 14). In this chapter, when the deviation from an ideal Lean facility profile in accounting and finance was regressed as a **single predictor variable** on the deviation from an ideal Lean operational performance profile, the findings were consistent with the aforementioned ones, indicating no statistically significant effect between the deviation from an ideal Lean operational performance profile and the deviation from an ideal Lean accounting profile ($p = 0.0938$, Table 20) at $\alpha = 0.05$. Therefore, the results displayed in Table 20 confirmed that there is not enough evidence to reject the null hypotheses for *H3* stating "*Lean implementation in accounting has no impact on* *operational performance.*" The relative efficiency of 0.99 and relative increase in variance due to missing values of 4.83 percent displayed in Table 20 indicated a stable imputation model.

Table 20: Results of the regression analysis between the deviations from an ideal Lean facility profile for accounting and finance and the deviations from an ideal Lean operational performance profile

Model Information	
Data Set	PDA_REG2_OP_PERF
Number of Imputations	5

Variance Information							
Parameter	Variance			DF	Relative Increase in Variance	Fraction Missing Information	Relative Efficiency
	Between	Within	Total				
w_accounting	0.0001	0.0010	0.0010	14970	0.0166	0.0164	0.9967

Parameter Estimates										
Parameter	Estimate	Std Error	95% Confidence Limits		DF	Minimum	Maximum	Theta0	t for H0: Parameter=Theta0	Pr > |t|
w_accounting	0.0544	0.0325	-0.0092	0.1181	14970	0.0483	0.0578	0	1.68	0.0938

Since the dependent variable of operational performance in this study was examined through different groups of performance measures, including quality, time, delivery, capacity, and safety related measures, the relationship between the level of Lean implementation in the accounting and finance dimension and these individual performance groups were also examined. Results of **single linear regression analysis** performed to investigate those relationships are displayed in Table 21. Results revealed that no statistically significant relationship could be obtained between the level of Lean implementation in the accounting and finance dimension and quality, capacity, and safety related performance. However, a statistically significant relationship was found between the level of Lean implementation in the accounting and finance dimension and time-related performance (p = 0.0389, Table 21) as measured by lead-time on "long lead time" purchased materials, order entry – cash-in time, average days of inventory, average length of a new product development cycle, average length of an investment decision cycle, and average length of financial closing. Furthermore, a statistically significant relationship was found between the level of Lean implementation in the accounting and finance dimension and delivery-related performance (*p* = 0.0023, Table 21) as measured by on-time delivery rate, supplier shipments delivered on time, customers for which the facility has implemented a JIT delivery program, suppliers who provided JIT delivery to your facility, overdue invoices from suppliers, and overdue invoices to customers.

Table 21: Results of the single linear regression analysis performed on the level of Lean implementation in accounting and finance on time, delivery, capacity, and safety related performance

Parameter	Quality-Related Performance P-values	Time-Related Performance P-values	Delivery-Related Performance P-values	Capacity-Related Performance P-values	Safety-Related Performance P-values
accounting	0.7604	**0.0389**	**0.0023**	0.4429	0.5149

Profile deviation analysis was also run to further investigate the fit relationship between the level of Lean implementation in the accounting and finance dimension (as measured by the deviations from an ideal Lean accounting profile) and quality, time, delivery, capacity, and safety related performance (as measured by the deviations from those ideal Lean performance profiles). Results of the profile deviation analysis, as displayed in Table 22, results showed that no statistically significant relationship could be obtained between the deviation from an ideal Lean accounting profile and the deviation from an ideal operational performance profile as represented by quality, time, capacity, and safety related performance. However, a statistically significant relationship was found between the deviation from an ideal Lean accounting profile and the deviation from an ideal Lean delivery-related performance (*p* = 0.0140, Table 22) as measured by on-time delivery rate, supplier shipments delivered on time, customers for which the facility has implemented a JIT delivery program, suppliers who provided JIT delivery to your facility, overdue invoices from suppliers, and overdue invoices to customers.

Table 22: Results of the single linear regression analysis performed on the level of Lean implementation in accounting and finance on time, delivery, capacity, and safety related performance

Parameter	Quality-Related Performance P-values	Time-Related Performance P-values	Delivery-Related Performance P-values	Capacity-Related Performance P-values	Safety-Related Performance P-values
w_accounting	0.4651	0.2362	**0.0140**	0.4148	0.8104

5.2.2.2. Lean Accounting and Financial Performance

In Chapter 5.1.2.2, when **multiple regression analysis** was conducted to regress the dependent variable, financial performance, on the predictor variable of Lean implementation levels in four business dimensions including accounting and finance, the relationship between financial performance and the level of Lean implementation in the accounting and finance dimension was not found to be significant (p = 0.8148, Table 17). Therefore, in this chapter, **a single linear regression analysis** was performed to regress the dependent variable, financial performance, on the single predictor variable of Lean implementation in the accounting and finance dimension. Results of the single linear regression analysis, as displayed in Table 23, supported the above findings that the higher level of Lean implementation in the accounting and finance dimension does not have a statistically significant effect on financial performance (p = 0.3190, Table 23) as measured by productivity, return on assets, EBIT, and market share, at α = 0.05. Therefore, there is not enough evidence to reject the null hypotheses for *H4* stating "*Lean implementation in accounting has no impact on financial performance.*" The relative efficiency of 0.96 and the relative increase in variance due to missing values of 17.31 percent displayed in Table 23, however, indicated a weak imputation model.

Table 23: Results of the analysis run to regress financial performance on the accounting and finance dimension

Model Information	
Data Set	REGRESSION2_FIN_PERF
Number of Imputations	5

Variance Information							
Parameter	Variance			DF	Relative Increase in Variance	Fraction Missing Information	Relative Efficiency
	Between	Within	Total				
accounting	1.4522	10.0657	11.8084	183.65	0.1731	0.1567	0.9696

Parameter Estimates										
Parameter	Estimate	Std Error	95% Confidence Limits		DF	Minimum	Maximum	Theta0	t for H0: Parameter=Theta0	Pr > |t|
Accounting	3.4337	3.4363	-3.3460	10.2135	183.65	1.7847	4.4594	0	1.00	0.3190

In Chapter 5.1.2.2, when **profile deviation analysis** was conducted to regress the dependent variable, financial performance (as represented by the deviation from an ideal Lean financial performance profile), on the predictor variable of Lean implementation levels in four business dimensions (as represented by the deviation from an ideal Lean facility profile in four business dimensions including accounting and finance), the relationship between the deviation from an ideal Lean financial performance profile and the deviation from an ideal Lean accounting profile was not found to be significant (p = 0.5395, Table 18). In this chapter, when the deviation from an ideal Lean accounting profile was regressed as a **single predictor variable** on the deviation from an ideal Lean financial performance profile, the findings were consistent with the aforementioned ones showing no statistically significant relationship (p = 0.4433, Table 24) at $\alpha = 0.05$. Therefore, the results displayed in Table 24 confirmed that there is not enough evidence to reject the null hypotheses for *H4* stating "*Lean implementation in accounting has no impact on financial performance.*" The relative efficiency of 0.97 and relative increase in variance due to missing values of 11.95 percent displayed in Table 24 indicated a somewhat fragile imputation model.

Table 24: Results of the regression analysis between the deviations from an ideal Lean facility profile in accounting and finance and the deviations from an ideal Lean financial performance profile

Model Information	
Data Set	PDA_REG2_FIN_PERF
Number of Imputations	5

Variance Information							
Parameter	Variance			DF	Relative Increase in Variance	Fraction Missing Information	Relative Efficiency
	Between	Within	Total				
w_accounting	0.0004	0.0041	0.0046	350.79	0.1195	0.1118	0.9781

Parameter Estimates										
Parameter	Estimate	Std Error	95% Confidence Limits		DF	Minimum	Maximum	Theta0	t for H0: Parameter=Theta0	Pr > |t|
w_accounting	0.0520	0.0678	-0.0814	0.1855	350.79	0.0237	0.0760	0	0.77	0.4433

5.2.2.3. Lean Accounting and Accounting Performance

First, a **multiple regression analysis** was conducted to regress the dependent variable, **accounting performance**, on the predictor variables of **Lean implementation levels along** the **four business dimensions** of leadership, manufacturing, accounting and finance, and supplier and customer relationship. Results of the multiple regression analysis did not show enough evidence to reject the null hypotheses for *H5* stating that "*Lean implementation in accounting has no impact on accounting performance.*" Results of the multiple regression analysis, as displayed in Table 25, indicated that the level of Lean implementation in leadership ($p = 0.3471$), manufacturing ($p = 0.9559$), accounting and finance ($p = 0.1031$), and supplier and customer relationship ($p = 0.1779$) has no statistically significant influence on accounting performance at $\alpha = 0.05$ as measured by manual adjustments due to late recording, overdue invoices from suppliers, overdue invoices to customers, average length of an investment decision cycle, and average length of financial closing. The Relative efficiency of 0.99 and the relative increase in variance due to missing data handling of 3 percent for the accounting and finance dimension suggest a strong imputation model.

Table 25: Results of multiple regression analysis on the dependent variable, accounting performance, on all of the predictor variables in the data set

Model Information	
Data Set	REGRESSION_ACC_PERF
Number of Imputations	5

Variance Information							
Parameter	**Variance**			**DF**	**Relative Increase in Variance**	**Fraction Missing Information**	**Relative Efficiency**
	Between	**Within**	**Total**				
leadership	1.4494	13.7070	15.4464	315.44	0.1268	0.1181	0.9769
manufacturing	1.0276	9.8854	11.1185	325.19	0.1247	0.1163	0.9772
accounting	0.3959	15.7829	16.2580	4683.4	0.0301	0.0296	0.9941
sup_and_cust_rel	1.0129	21.4090	22.6246	1385.6	0.0567	0.0550	0.9891

Parameter Estimates										
Parameter	**Estimate**	**Std Error**	**95% Confidence Limits**		**DF**	**Minimum**	**Maximum**	**Theta0**	**t for H0: Parameter=Theta0**	**Pr > |t|**
Leadership	3.7004	3.9301	-4.0322	11.4331	315.44	2.3647	5.4902	0	0.94	0.3471
manufacturing	0.1845	3.3344	-6.3752	6.7443	325.19	-0.8442	1.6415	0	0.06	0.9559
Accounting	6.5739	4.0321	-1.3309	14.4788	4683.4	6.0318	7.3543	0	1.63	0.1031
sup_and_cust_rel	-6.4120	4.7565	-15.7428	2.9187	1385.6	-7.3417	-4.6970	0	-1.35	0.1779

Second, **a single linear regression analysis** was performed to regress the dependent variable, accounting performance, on the single predictor variable of Lean implementation in the accounting and finance dimension. Results of the single linear regression analysis, as displayed in Table 26, contradicted the above findings by revealing that the higher level of Lean implementation in the accounting and finance dimension shows a positive effect on accounting performance (p = 0.0485,

Table 26) at α = 0.05. Therefore, the results displayed in Table 26 suggest that there is enough evidence to reject the null hypotheses for *H5* stating "*Lean implementation in accounting has no impact on accounting performance.*" The relative efficiency of 0.99 and relative increase in variance due to missing values of 4.24 percent displayed in Table 26 indicate a strong imputation model.

Table 26: Results of the analysis run to regress accounting performance on the accounting and finance dimension

Model Information	
Data Set	REGRESSION2_ACC_PERF
Number of Imputations	5

Variance Information							
Parameter	**Variance**			**DF**	**Relative Increase in Variance**	**Fraction Missing Information**	**Relative Efficiency**
	Between	**Within**	**Total**				
accounting	0.2700	7.6255	7.9496	2406.9	0.0424	0.0415	0.9917

Parameter Estimates										
Parameter	**Estimate**	**Std Error**	**95% Confidence Limits**		**DF**	**Minimum**	**Maximum**	**Theta0**	**t for H0: Parameter=Theta0**	**Pr > |t|**
Accounting	5.5665	2.8195	0.0376	11.0955	2406.9	4.9616	6.3139	0	1.97	**0.0485**

Third, a **p**rofile deviation analysis was also run to regress the dependent variable, accounting performance (as represented by the deviation from an ideal Lean accounting performance profile), on the predictor variable of Lean implementation levels in four business dimensions (as represented by the deviation from an ideal Lean facility profile in four business dimensions including accounting and finance). Results of the profile deviation analysis, as displayed in Table 27, indicated no statistically significant relationship for the accounting and finance dimension in the model (p = 0.2195, Table 27). Therefore, based on the profile deviation analysis results, there is not show enough evidence to reject the null hypotheses for *H5* stating that "*Lean implementation in accounting has no impact on accounting performance.*" The relative efficiency of 0.98 and the relative increase in variance due to missing data handling of 5.43 percent displayed in Table 27 for the accounting and finance dimension suggest a stable imputation model.

Table 27: Results of the regression analysis between the deviations from an ideal Lean facility profile and the deviations from an ideal Lean accounting performance profile

Model Information	
Data Set	PDA_REG_ACC_PERF
Number of Imputations	5

Variance Information							
Parameter	Variance			DF	Relative Increase in Variance	Fraction Missing Information	Relative Efficiency
	Between	Within	Total				
w_leadership	0.0045	0.0513	0.0567	441.58	0.1051	0.0992	0.9805
w_manufacturing	0.0084	0.0596	0.0698	188.2	0.1706	0.1547	0.9699
w_accounting	0.0002	0.0064	0.0067	1507.9	0.0543	0.0527	0.9895
w_sup_and_cust_rel	0.0018	0.0615	0.0638	3194.1	0.0366	0.0359	0.9928

Parameter Estimates										
Parameter	Estimate	Std Error	95% Confidence Limits		DF	Minimum	Maximum	Theta0	t for H0: Parameter=Theta0	Pr > |t|
w_leadership	0.1874	0.2381	-0.2806	0.6556	441.58	0.1160	0.2875	0	0.79	0.4316
w_manufacturing	0.0650	0.2643	-0.4564	0.5865	188.2	-0.0259	0.2071	0	0.25	0.8058
w_accounting	0.1009	0.0821	-0.0602	0.2622	1507.9	0.0760	0.1235	0	1.23	0.2195
w_sup_and_cust_rel	-0.4203	0.2526	-0.9157	0.0749	3194.1	-0.4511	-0.3444	0	-1.66	0.0962

Lastly, a profile deviation analysis was also used to investigate whether the higher level of Lean implementation in the accounting and finance dimension (as represented by the deviation from an ideal Lean accounting profile) results in better accounting performance (as represented by the deviation from an ideal Lean accounting performance). Results of the profile deviation analysis are enlisted in Table 28 revealing This indicates no relationship between the deviation from an ideal Lean accounting profile and the deviation from an ideal Lean accounting performance profile (p = 0.2365, Table 28). Therefore, the results displayed in Table 28 suggest that there is not enough evidence to reject the null hypotheses for *H5* stating "*Lean implementation in accounting has no impact on accounting performance.*" The relative efficiency of 0.97 and relative increase in variance due to missing values of 11.21 percent displayed in Table 28 indicate a somewhat fragile imputation model.

Table 28: Results of the regression analysis between the deviations from an ideal Lean facility profile in accounting and finance and the deviations from an ideal Lean accounting performance profile

Model Information	
Data Set	PDA_REG2_ACC_PERF
Number of Imputations	5

Variance Information							
Parameter	**Variance**			**DF**	**Relative Increase in Variance**	**Fraction Missing Information**	**Relative Efficiency**
	Between	**Within**	**Total**				
w_accounting	0.0002	0.0029	0.0032	393.17	0.1121	0.1054	0.9793

Parameter Estimates										
Parameter	**Estimate**	**Std Error**	**95% Confidence Limits**		**DF**	**Minimum**	**Maximum**	**Theta0**	**t for H0: Parameter=Theta0**	**Pr > |t|**
w_accounting	0.0678	0.0572	-0.0446	0.1802	393.17	0.0503	0.0883	0	1.19	0.2365

5.3. The Effect of Contextual Variables

The third objective of this study was to investigate whether and how contextual factors, such as industry segment, location, annual sales revenue, and unionization effect 1) transportation equipment manufacturing performance, 2) transportation equipment manufacturing facilities' level of Lean adaptation in accounting and finance, and 3) the link between the level of Lean implementation and performance. Multiply imputed data of the 61 responses received from transportation equipment manufacturers were used to test the aforementioned research objectives using multiple regression analysis and hierarchical regression analysis. The SAS 9.3 codes used to perform those analyses are enlisted in Appendix M.

5.3.1. Contextual Variables' Effect on Facility Performance

5.3.1.1. Operational Performance

When the effect of contextual variables on operational performance was investigated, it was revealed that industry segment (CCQ2), location (CCQ3), and unionization (CCQ7) do not tend to have a statistically significant effect on the operational performance of transportation equipment manufacturing facilities. However, pooled results from the five imputations showed that the size of a facility, represented by annual sales volume (CCQ6), tend to have a statistically significant negative relationship on operational performance (p = 0.0178, Table 29, Column 1), indicating that smaller transportation equipment facilities reported to have better operational performance than larger ones. Individual test results of all five imputations for the contextual variable of annual sales volume (p = 0.0245, 0.0141, 0.0262, 0.0234, and 0.0191 respectively) supported the aforementioned outcome. The relative efficiency of 0.99 and the relative increase in variance due to missing data handling of 0.41 percent for the contextual variable of annual sales volume indicate a robust imputation model.

Table 29: Results of the multiple regression analysis performed on facility performance and the four contextual variables of industry segment, location, annual sales volume, and unionization

	Operational Performance	Financial Performance	Accounting Performance
CCQ2 - Industry Segment	0.0604	0.4264	0.6075
CCQ3 - Location	0.5562	0.3030	0.0174
CCQ6 - Annual Sales	**0.0178**	0.4691	**0.0027**
CCQ7 - Unionization	0.8963	0.1706	0.6342
Average R-Square	14.02%	10.59%	25.82%

To investigate whether the aforementioned four contextual variables contribute to the Lean implementation – operational performance relationship, a hierarchical regression analysis was performed for each contextual variable. At first, industry segment's (CCQ2) effect on the Lean implementation – operational performance relationship was examined, and pooled results of the five imputations reported no significant effect. Further investigation of the results in each imputation cycle however revealed that in imputation cycle one and four, industry segment (as represented by NAICS 3361, 3362, and 3363) tend to have a statistically significant effect (p = 0.0487 in IM cycle 1 and p = 0.0229 in IM cycle 4) on the manufacturing – operational performance relationship. More specifically, it was revealed that significantly more motor vehicle part manufacturers (NAICS 3363) tend to show a positive relationship in the Level of Lean implementation in manufacturing and operational performance, than do motor vehicle manufacturers (NAICS 3361). When location's (CCQ3) effect on the Lean implementation – operational performance relationship was examined, the pooled results of the five imputations, as well as individual imputation models, presented no significant effect on the Lean implementation – operational performance relationship. Next, the effect of facility size represented by annual sales volume (CCQ6) was investigated on the Lean implementation – operational performance relationship. Although, the relationship between annual sales volume and operational performance was found to be significant, the effect of annual sales volume on the Lean implementation – operational performance relationship does not show any significance in any of the five imputation cycles, or in the pooled results. Finally, the effect of unionization (CCQ7) on the Lean implementation – operational performance relationship also did not show any statistically significant relationship in any of the five imputation cycles or in the pooled results.

5.3.1.2. Financial Performance

The investigation of the effect of contextual variables on financial performance revealed no statistically significant influence (Table 29, Column 2). Individual test results of all five imputations for all contextual variables of financial performance (p = 0.4324, 0.0970, 0.2758, 0.1739, and 0.0635 respectively) also supported the aforementioned outcome. The relative efficiency of 0.98 and 0.98, coupled with the relative increase in variance due to missing data handling of 5.85 percent and 7.23 percent for industry segment (CCQ2) and unionization (CCQ7) respectively indicate a stable imputation model for those two variables. However, the relative efficiency of 0.93 and 0.92 and the relative increase in variance due to missing data handling of 51.57 percent and 56.06 percent for the contextual variables of location (CCQ3), and annual sales volume (CCQ6) respectively, indicate a weak imputation model. Consequently, conclusions must be drawn when taking the volatility of the imputation model for those two variables (CCQ3 and CCQ6) into account.

When the aforementioned four contextual variables of industry segment (CCQ2), location (CCQ3), annual sales volume (CCQ6), and unionization (CCQ7)'s effects on the Lean implementation – financial performance relationship were investigated using hierarchical regression analysis, none of these relationships resulted to be statistically significant. Both, pooled results of the five imputations, as well as the individual imputation results showed no relationship in the investigated models.

5.3.1.3. Accounting Performance

The effect of contextual variables on accounting performance was also investigated, and it was revealed that while industry segment (CCQ2), location (CCQ3), and unionization (CCQ7) do not tend to have a statistically significant effect on the operational performance of transportation equipment manufacturing facilities, annual sales volume (CCQ6) does. Pooled results from the five imputations showed that the size of the facility, represented by annual sales volume, tend to have a statistically significant negative relationship with accounting performance (p = 0.0027, Table 29, Column 3), indicating that smaller transportation equipment facilities tend to have better accounting performance than larger ones. Surprisingly, when individual test results of the overall model for all five imputations were examined, none of the individual imputation models were statistically significant; however, individual *p*-values for three out of the five imputations for the contextual variable of annual sales volume (p = 0.0392, 0.0210, 0.0716, 0.0509, and 0.0406 respectively) supported the aforementioned outcome. The relative efficiency of 0.99 and the relative increase in variance due to missing data handling of 2.50 percent for the contextual variable of annual sales volume indicate a robust imputation model.

Next, the aforementioned four contextual variables effect on the Lean implementation – accounting performance relationship was investigated using a hierarchical regression analysis. Regardless of the significant relationship found between annual sales volume (CCQ6) and accounting performance, results of the hierarchical regression did not indicate that any of the four contextual variables would affect the Lean implementation – accounting performance relationship. Both, pooled results of the five imputations, as well as the individual imputation results showed no such relationship in the investigated models.

Consequently, there is enough evidence to reject the null hypotheses for *H6* stating that "*contextual factors have no impact on facility performance*" for operational and accounting performance, as the size of a facility represented by annual sales volume (CCQ6) has a statistically significant influence on both (p = 0.0178 and 0.0027, respectively) at $\alpha = 0.05$. However, there is not enough evidence to reject the null hypotheses for *H6* stating that "*contextual factors have no impact on facility performance*" for financial performance. Moreover, outcomes of the hierarchical regression revealed that there is not enough evidence to reject the null hypotheses for *H7* stating that "c*ontextual factors have no impact on Lean implementation-performance relationship."*

5.3.2. Contextual Variables' Effect on Lean Implementation in Accounting and Finance

The investigation of the effect of industry segment (CCQ2), location (CCQ3), annual sales volume (CCQ6), and unionization (CCQ7) on the level of Lean implementation in accounting and finance indicated that location tend to have a statistically significant effect (p = 0.0024) on the level of Lean implementation in accounting and finance at α = 0.05 (pooled results are enlisted in Table 30), while the remaining three contextual variables do not. Individual test results of all five imputations for the contextual variable of location (p = 0.0031, 0.0039, 0.0047, 0.0034, and 0.0029 respectively) supported the aforementioned outcome, indicating that facilities located in the Southern States tend to have a higher level of Lean implementation in accounting and finance than companies in the Midwest. The relative efficiency of 0.99 and the relative increase in variance due to missing data handling of 0.47 percent for the contextual variable of location enlisted in Table 30 indicate a robust imputation model.

Table 30: Multiple regression results of the effect of contextual variables on Lean implementation in Accounting and Finance

Model Information	
Data Set	REG_CONTEXT_LEAN_ACC
Number of Imputations	5

Variance Information							
Parameter	Variance			DF	Relative Increase in Variance	Fraction Missing Information	Relative Efficiency
	Between	Within	Total				
CCQ2	0.0360	0.4953	0.5385	621.41	0.0872	0.0831	0.9836

Variance Information							
Parameter	Variance			DF	Relative Increase in Variance	Fraction Missing Information	Relative Efficiency
	Between	Within	Total				
CCQ3	0.0010	0.2600	0.2612	175690	0.0047	0.0047	0.9990
CCQ6	0.0120	0.2498	0.2643	1330.1	0.0580	0.0562	0.9888
CCQ7	0.0021	1.2771	1.2797	1.03E6	0.0019	0.0019	0.9996

Parameter Estimates										
Parameter	Estimate	Std Error	95% Confidence Limits		DF	Minimum	Maximum	Theta0	t for H0: Parameter=Theta0	Pr > |t|
CCQ2	0.7028	0.7338	-0.7383	2.1440	621.41	0.4521	0.8846	0	0.96	0.3386
CCQ3	1.5516	0.5111	0.5498	2.5535	175690	1.5119	1.5857	0	3.04	**0.0024**
CCQ6	-0.4241	0.5141	-1.4327	0.5845	1330.1	-0.5988	-0.2992	0	-0.82	0.4096
CCQ7	-0.5882	1.1312	-2.8054	1.6289	1.03E6	-0.6328	-0.5148	0	-0.52	0.6031

To investigate whether the aforementioned four contextual variables of industry segment (CCQ2), location (CCQ3), annual sales volume (CCQ6), and unionization (CCQ7) contribute to the Lean implementation in accounting and finance – operational performance relationship, a hierarchical regression analysis was performed for each contextual variable at $\alpha = 0.05$. Results revealed that only the contextual variable of industry segment tend to have a statistically significant effect on the Lean implementation in accounting and finance – operational performance relationship (p = 0.0114), indicating that significantly more motor vehicle part manufacturers (NAICS 3363) tend to have a positive relationship between their level of Lean implementation in accounting and finance and their operational performance, than do motor vehicle manufacturers (NAICS 3361). When individual p-values (p = 0.0097, 0.0075, 0.0136, 0.0020, and 0.0284 respectively) were analyzed, all five imputations for the contextual variable of industry segment confirmed the aforementioned outcome. The relative efficiency of 0.97 and the relative increase in variance of 11.93 percent due to having missing values in the dataset indicate a reliable imputation model. None of the remaining three contextual variables (e.g., location, annual sales volume, and unionization) showed any influence on the Lean implementation in accounting and finance – operational performance relationship.

Next, the aforementioned four contextual variables of industry segment (CCQ2), location (CCQ3), annual sales volume (CCQ6), and unionization (CCQ7) were investigated in respect to their influence on the Lean implementation in accounting and finance – financial performance relationship, and as a result, none of the aforementioned contextual variables reported any significant relationships at $\alpha = 0.05$.

When the same four contextual variables' impact on the Lean implementation in accounting and finance – accounting performance relationship was investigated, outcomes of the hierarchical regression also reported that none of the contextual variables of industry segment (CCQ2), location (CCQ3), annual sales volume (CCQ6), and unionization (CCQ7) tend to have a significant effect on the aforementioned relationship at $\alpha = 0.05$. Although pooled results of the industry segment variable did not show a statistically significant impact on the Lean implementation in accounting and finance – accounting performance relationship at $\alpha = 0.05$ ($p = 0.0666$), further investigation of individual imputation cycles revealed (p = 0.0548, 0.0430, 0.0859, 0.1137, and 0.0570) that in imputation cycle two, industry segment showed to be significant, while in imputation cycles one and five, the industry segment variable was on the edge of having a significant effect at $\alpha = 0.05$.

Thus, the overall results indicate that there is enough evidence to reject the null hypotheses for *H8* stating that "c*ontextual factors have no impact on Lean implementation in accounting and finance,*" since location (CCQ6) shows a statistically significant influence on the level of Lean implementation in accounting and finance ($p = 0.0024$) at $\alpha = 0.05$. In addition, there is enough evidence to reject the null hypotheses for *H9* stating that "*contextual factors have no impact on Lean implementation in accounting and finance – performance relationship,*" since the impact of industry segment tend to be statistically significant on the Lean implementation in accounting and finance – operational performance relationship (p = 0.0114) at α = 0.05.

6. Discussion

The following chapter provides an in-depth discussion about the research findings on 1) whether a higher level of Lean implementation in transportation equipment manufacturing facilities results in better operational and financial performance, 2) whether a higher level of Lean implementation in accounting and finance results in better accounting, operational, and financial performance, and 3) whether facilities' contextual variables influence any of the above described relationships.

6.1. Lean Implementation's Impact on Manufacturing Performance

Inspired by the exceptional performance of the Toyota Motor Corporation (Liker 2003), U.S. transportation equipment manufacturers have been experimenting with implementing Lean principles and determinants for decades in the anticipation of achieving better operational and financial performance (Crute et al. 2003, Kochan et al. 1997). Transforming a facility to Lean, however, comes with numerous challenges and has proven to be difficult for many companies, maybe explaining why U.S. transportation equipment manufacturers have been slow to implement Lean. In many cases, these manufacturers have only made modest progress on improving their performance. Numerous companies relapsed, got discouraged, and reverted to traditional mass production (Crute et al. 2003, Kochan et al. 1997). This study, therefore, tried to establish if there indeed were gains (better operational and financial performance, better quality, higher customer satisfaction, to name a few) to be won from introducing Lean into a facility of the transportation equipment manufacturing industry and continuously elevating it to the highest extent.

This study builds on prior research studies that have identified key principles and determinants of successful Lean transformations (Womack and Jones 1996, Ahlstrom and Karlsson 1996, Sanchez and Perez 2001, Soriano-Meier and Forrester 2002, Shah 2002, Olsen 2004, Shah and Ward 2007) and demonstrated that these principles and determinants can act as an integrated, synergic set affecting operational (Cua 2000, Shah 2002, Olsen 2004) and financial performance (Olsen 2004, Harris 2012). However, no conclusive findings on the relationship between Lean implementation and operational and financial performance have been found, yet. Shah (2002) and Olsen (2004) both used cluster analysis to categorize facilities as Lean or Non-Lean facilities based on pre-selected key principles and determinants and compared them on selected operational and financial performance measures; while Harris (2012) used publicly available data to "hand-pick" a given number of Lean and Non-Lean facilities for comparison. This dissertation takes a different approach to investigating the relationship between Lean implementation and operational and financial performance by developing an assessment type questionnaire that allows randomly selected transportation equipment manufacturers to evaluate themselves as "being Non-Lean" in a sense of having a traditional, mass production-like system, or "being Lean" in the sense of being at their early, intermediate, or complete stages of their Lean transformation in the four business dimensions of leadership, manufacturing, accounting and finance, and supplier and customer relationship. By doing so, this study tests whether implementing Lean principles and practices and advancing them over multiple stages have a positive additive effect on performance.

Results of this study show that the *level of Lean implementation* of transportation equipment manufacturers greatly fluctuates across the four business dimensions investigated (Figure 6). Most frequently, Lean principles and determinants were implemented in manufacturing, while Lean was least frequently implemented in accounting and finance. These results are not surprising as the usual practice is that Lean initially focuses on the implementation of Lean principles and practices in manufacturing as the area with the highest need and the largest payback. Only as facilities have become more proficient in Lean in manufacturing, have they extended these ideas throughout their supply chain and to other support functions of their businesses. Consequently, Lean implementation in the supplier and customer relationship, as well as in support functions of the business as the accounting and finance dimensions, may not yet have come as far along the learning curve as in manufacturing. However, as the Lean movement started out from the transportation equipment industry in the 1990s, it is rather surprising that, on average, only 13 percent of the respondents reported to work with a Lean enterprise management system, which represents the highest level of Lean implementation as defined for the purpose of this study. These results suggest that the transformation of the transportation equipment industry is incomplete and that room for further improvement exists.

This study did not find any evidence that a higher level of Lean implementation does result in better *operational performance* as represented by quality, time-based, delivery, capacity, and safety performance (Tables 15 and Table 16); however, a positive relationship was found between the level of Lean implementation in the manufacturing dimension and quality performance. This positive finding between the level of Lean implementation in manufacturing and quality performance is in-line with Cua's (2000) and Fullerton and McWatters's (2001) studies. However, these two studies also found that implementing Lean in manufacturing results in better delivery, time-based, inventory, and customer service performance as well, which this study failed to do.

This study also found no linear relationship between the level of Lean implementation and *financial performance* as represented by productivity, return on asset, EBIT, and market share (Tables 17 and 18). On the Lean – productivity performance relationship, mixed results were found in prior studies. For example, Olsen (2004) did not find any difference between Lean and Non-Lean companies in regards to employee productivity, while Shah (2002) found that Lean companies tend to have better productivity than Non-Lean companies. Similarly to Olsen (2004), this study could not prove the existence of improvements to employee productivity. The facts are similar to the impact of Lean on return on assets, where prior studies found mixed results. For example, Olsen (2004) found no difference between Lean and Non-Lean companies in respect to asset productivity, a result that this study conforms to. However, Harris (2012) was able to show that Lean companies tend to have better asset productivity than Non-Lean companies. Earnings before interest and tax (EBIT) were not selected as a performance measure in any of the literature cited (Cua 2000, Shah 2002, Olsen 2004, Harris 2012) here, except for Emiliani's (2003) case study, which showed a continuous increase in EBIT as the Wiremold Company progressed on its Lean journey. This study, however, was not able to support Emiliani's (2003) results. Finally, in regards to the Lean – market share relationship, similarly to this study, Olsen (2004) did not find any significant differences between Lean and Non-Lean companies.

Not being able to show a positive relationship between the level of Lean implementation and operational and financial performance raises numerous questions. At first, it raises the question whether there is a noticeable linear progression through the traditional, early, intermediate, and full stage of a Lean transformation, or not. Second, it draws attention on the reliability of the questionnaire. For example, the accuracy of the results depend on the accuracy of the assessment; therefore, if the response intervals developed to measure operational and financial performance were too wide or too narrow, it could lead to erroneous results. Third, there is a concern in regards to the survey method, i.e., the self-assessment asked for by respondents Individuals tend to be imperfect in appraising themselves and their achievements by reporting overly favorable views on certain subjects, e.g., the “above-average effect” (Kruger and Dunning 1999), which can lead to erroneous conclusions. In this study, if respondents have miscalibrated either their level of Lean implementation or their company’s performance, results could be biased.

Another concern is the number and the quality of responses received for this study. A total of 69 respondents returned the questionnaire. Eight responses were removed from further investigation, as they possessed a large amount of missing data (more than 20 percent). For the remaining 61 responses, multiple imputations were applied to handle missing values. Although, multiple imputation is a state-of-the-art methodology for handling missing data handling and it comes highly recommended by numerous statisticians (Enders 2010, Raghunathan and Grizzle 1995, Rubin 1976), its application in this study raises additional concerns. Most importantly, multiple imputations requires the data to be missing at random (MAR, Enders 2010, Raghunathan and Grizzle 1995, Rubin 1976). For this study, it was assumed that performance had no effect on the amount of missing values (e.g., lower performing companies did not have more missing values than higher performing ones). However, if that assumption does not stand, and study participants refused to provide their response due to having lower performance in certain areas, the imputation outcomes could be biased. Second, the predictor variables of Lean implementation in the investigated business dimension carried information about the missing values of the outcome variables of operational, financial, and accounting performance, which may falsely, weakened the association between the level of Lean implementation and performance (Sterne et al. 2009). Third, in this study, some variables presented highly-skewed distributions, which were square-transformed before performing the regression analysis to investigate the relationship between the level of Lean implementation and performance. However, conducting the imputation including non-normally distributed variables, may have introduced bias in the output data (Sterne et al. 2009). Moreover, the higher the proportion of missing values, the more pronounced the issues described above may become. For example, the high proportion of missing values in financial measures weakened the multiple imputation models considerably, as shown by the high percentages of relative increases in variances and therefore may have distorted the results of the regression analysis (Tables 17 and 18).

6.2. Performance Impact of Lean Implementation in Accounting and Finance

To achieve and maintain a competitive advantage in today's rapidly changing business environments, implementing Lean principles and determinants solely in the manufacturing dimension of transportation equipment manufacturers are not sufficient (Maskell and Baggaley 2003, Ward 2003). Maskell and Baggaley's (2003) pioneering framework on Lean accounting argues that a *Lean transformation in the accounting and finance* dimension should move parallel with changes being implemented in other business dimensions of a transportation equipment facility. Ward (2003) states, it is critically important to develop a holistic, enterprise-wide view of Lean implementation to reach the desired performance impact. This study aims to investigate the role of Lean accounting in businesses of transportation equipment manufacturers and to detect possible contributions to accounting, operational, and financial performance.

This study shows that more than 50 percent of the respondents are aware of the existence of Lean accounting and have, to a certain extent, implemented it in their manufacturing facility. Findings of this study (Figure 6 and Figure 7), however, contradict that argument by revealing that transportation equipment manufacturers fall behind in implementing Lean principles and determinants in their accounting and finance dimension compared to other business dimensions, such as manufacturing or leadership. These findings are not surprising since the accounting discipline is continuously being blamed for not recognizing the need of aligning accounting and financial practices to Lean principles and determinants (Fullerton et al. 2013). Results of this study reveal (Figure 7) that within the accounting and finance dimension, Lean implementation tends to be the most progressive in respect to authorization, budgeting, and month-end closing processes; while Lean implementation is least progressive in the product costing, accounts payable, and inventory tracking processes (Figure 7). These findings are in line with Fullerton et al.'s (2013) study, which found that the extent of Lean implementation is low in inventory tracking, and product costing. One possible explanation of having low levels of Lean implementation in product costing, accounts payable, and inventory tracking processes may be that the directions provided by Maskell and Baggaley (2003) and McVay et al. (2013) on how to transform those processes may not be specific enough for practitioners to follow them or the task may be too difficult and time-consuming to execute. Another explanation may be that, often, these product costing, accounts payable and receivable, and inventory tracking systems are corporate functions and individual facilities do not have the authority to implement changes in those areas as it would interfere with corporate reporting standards.

There is little empirical evidence that provides insights on the level of Lean implementation in accounting and finance with Fullerton et al. (2013) and Kennedy and Widener (2008) being the exceptions. The evidence of the impact of Lean accounting on performance shown by Maskell and Baggaley (2003) and Cunningham (2003) are the only ones known to have addressed the issue. Moreover, none of the aforementioned studies have investigated as to how the level of Lean implementation in accounting and finance impacts operational, financial, and accounting performance. A fact that was changed by this study used two different statistical approaches, namely a multiple imputation approach and a profile deviation approach, to investigate the aforementioned relationship. Both statistical approaches were found to be applicable to test the hypotheses of this study; however, they both rely on different mathematical calculations to obtain results. Therefore, it is not surprising that the outcomes produced by these two approaches are slightly different. The regression approach revealed that the *level of Lean implementation in accounting and finance*, represented by the eight items introduced in the methodology chapter (Table 11) combined, have a direct positive effect *on operational performance* (p = 0.0351, Table 19) at α = 0.05, while the profile deviation approach did not support that finding at α = 0.05 (p = 0.0938, Table 20). Furthermore, when the effect of the level of Lean implementation in accounting and finance on operational performance was further investigated, the regression approach revealed that the level of Lean implementation in accounting and finance is positively correlated to time (p = 0.0389, Table 21) and delivery performance (p = 0.0023, Table 21). The profile deviation analysis only highlighted the correlation to delivery performance (p = 0.0140, Table 22) but not to time-related performance (p = 0.2362, Table 22). Results of the two statistical approaches also differed when the effect of the level of Lean implementation in accounting and finance *on accounting performance* was investigated. While the regression approach showed a significant relationship at α = 0.05 (p = 0.0485, Table 26), the profile deviation analysis did not (p = 0.2365, Table 28). Finally, none of the two approaches showed any relationship between the level of

Lean implementation in accounting and finance and *financial performance*. Differing results may also stem from the multiple imputation procedure as well. For example, the relative increase in variance due to having missing values in the model when investigating accounting performance were 4.24 percent and 11.21 percent for the regression and profile deviation approaches, respectively.

The level of Lean implementation in accounting and finance was found to be influential on operational and accounting performance when only the accounting and finance dimensions were included in the regression model as a predictor variable. However, it was not found to be influential when other business dimensions were also included in the model and suggests that the level of Lean implementation in accounting and finance may only indirectly affect overall company performance. Regardless, the revealed linear relationship between the level of Lean implementation in accounting and finance and accounting and operational performance (Table 19 and Table 20) suggests that transportation equipment manufacturing facilities should aim to implement Lean accounting principles and determinants at the highest extent to achieve the desired success.

6.3. The Effect of Contextual Variables

In general, environmental and organizational contexts tend to impact the success of any business (Gurowka and Lawson 2007). In this study, the effects of contextual variables, as represented by industry segment, location, annual sales volume, and unionization, were examined in three different contexts: their effect on performance, on Lean implementation, and on the Lean implementation and performance relationship.

Results of this study showed that the contextual variable of *industry segment*, as represented by motor vehicle manufacturers (NAICS 3361), motor vehicle body and trailer manufacturers (NAICS 3362), and motor vehicle part manufacturers (NAICS 3363), did not have any effect on either performance, or the Lean implementation of transportation equipment manufacturers in 2012. However, this study found that the industry sub-segment influences the Lean accounting – operational performance relationship. Results from this study indicated that significantly more motor vehicle part manufacturers (NAICS 3363) tend to have a positive relationship between their level of Lean implementation in accounting and finance and operational performance, than do motor vehicle manufacturers (NAICS 3361).

When the effect of *location*, e.g., West, Midwest, Northeast, and South, was investigated, results did not reveal any relationship between location and performance or between location and Lean implementation. This study, however, found that facilities located in the South tend to have a higher level of Lean implementation in accounting and finance than companies located in the Midwest. This phenomenon may be related to the fact that many new transportation equipment manufacturing facilities have been opening in the South, while facilities in the Midwest are older and possibly more traditional (Hill 2003). One could also speculate that, as the facilities being opened in the South are mainly opened by foreign suppliers, that those foreign companies are more aggressive in the use of Lean practices.

The contextual variable of facility *size*, as represented by annual sales volume, was found to have a significant effect on performance. Findings of this study revealed that smaller transportation equipment facilities reported to have better operational and accounting performance than larger ones;

however. The U.S Census Bureau reported that for 2012, transportation equipment manufacturing facilities showed an average of 11.2 percent increase in their annual sales volume compared to 2011 (U.S. Census Bureau 2012). One could speculate that the trend of smaller facilities over-performing their larger competitors may arise from the fact that smaller companies tend to have fewer layers of management and less complex organizational structures than their larger competitors, which may provide them some competitive advantage.

The last contextual variable investigated was unionization. Although, some researchers (Machin 1995, Meador and Walters 1994, Bronars et al. 1994) were able to show a significant negative correlation between being unionization and facility performance, this study did not find any evidence supporting those results. Results of this study indicated that unionization do not tend to have any effect on facility performance, Lean implementation, and performance – Lean implementation relationship. These findings were in line with the findings of Shah and Ward (2003), who also found lack of significant relationship.

6.4. Directions for Future Research

The questionnaire developed in this study assumed that there is a linear progression through a traditional, mass production-like system; a developed Lean framework; an intermediate, facility-wide Lean transformation; and a Lean enterprise like management system. Results of this study however revealed that responding transportation equipment manufacturers often displayed elements of all four levels simultaneously for each business dimension investigated.

No one Lean implementation journey is exactly the same, as companies operating in different business environments (e.g., different competitive landscapes, market stability, technology platforms) and possessing different organizational structures (e.g., organizational size, diversity, level of centralization, product diversity, product complexity, customer diversity, channel diversity). Different companies may have different purposes of implementing Lean and therefore they may follow different paths to transform. Therefore, as a future research, longitudinal case studies should be conducted with companies having different contextual, structural, and strategic requirements and needs to pursue their Lean journey to closely investigate how they relate changes in each of their business dimension to the overall purpose of their Lean transformation. Based on the case study results, multiple ideal-type Lean companies can be identified, where each ideal-type of Lean company represents a unique configuration of contextual, structural, and strategic factors. These ideal-type of Lean companies also represent the most effective forms of implementing Lean under those given circumstances. Then, deviations of a real company from its ideal-type can be accessed using profile deviation analysis (Doty et al. 1993, Venkatraman 1990, Venkatraman 1989). Regardless of each company's initial condition, they can all reach the same final state of operational and financial success.

References

Ahlstrom, Par, and Christer Karlsson. 1996. Change Processes towards Lean Production - The Role of the Management Accounting System. *International Journal of Operations & Production Management* 16 (11): 42–56.

Bronars, Stephen G., Donald R. Deere, and Joseph S. Tracy. 1994. The Effects of Unions on Firm Behavior: An Empirical Analysis Using Firm-Level Data. *Industrial Relations: A Journal of Economy and Society* 33 (4): 426-51.

Cua, Kristy O. 2000. A Theory of Integrated Manufacturing Practices: Relating Total Quality Management, Just-in-Time and Total Productive Maintenance. Doctor of Philosophy, Minneapolis, MN: University of Minnesota. pp. 224.

Crute, Valerie, Yvonne Ward, Steve Brown, and Andrew Graves. Implementing Lean in aerospace—challenging the assumptions and understanding the challenges. *Technovation* 23 (12): 917-28.

Cunningham, Jean E. 2003. *Real Numbers: Management Accounting in a Lean Organization*. Durham, NC: Managing Times Press. pp. 194.

Doty, D. Harold, William H. Glick, and George P. Huber. 1993. Fit, equifinality, and organizational effectiveness: A test of two configurational theories. *Academy of Management Journal* 36 (6): 1196-1250.

Emiliani, Bob, David J. Stec, Lawrence Grasso, and James Stodder. 2003. *Better Thinking, Better Results: Using the Power of Lean as a Total Business Solution*. 1st edition. Kensington, CT: Center for Lean Business Management. pp. 313.

Enders, Craig K. 2010. *Applied Missing Data Analysis*. 1st edition. Methodology in the Social Sciences. New York, NY: The Guilford Press. pp. 377.

Fullerton, Rosemary R., and Cheryl S. McWatters. 2001. The production performance benefits from JIT implementation. *Journal of Operations Management* 19 (1): 81-96.

Fullerton, Rosemary R., Frances A. Kennedy, and Sally K. Widener. 2013. Management Accounting and Control Practices in a Lean Manufacturing Environment. *Accounting, Organizations and Society* 38 (1): 50–71.

Gurowka, Jim, Lawson, Raef A. 2007. Selecting the Right Costing Tool for Your Business Needs. *The Journal of Corporate Accounting & Finance* 18 (3): 21-27.

Harris, Daniel C. 2012. The Adoption of Lean Operations and Lean Accounting on the Financial-Performance Measures of Publicly Traded Companies. Doctor of Philosophy, Oxford, MS: The University of Mississippi. pp. 162.

Hill, Kim. 2003. The Auto Industry Moving South: An Examination of Trends. http://www.cargroup.org/?module=Publications&event=Download&pubID=56&fileID=65. Accessed: September 8, 2014.

Kennedy, Frances A., and Sally K. Widener. 2008. A Control Framework: Insights from Evidence on Lean Accounting. *Management Accounting Research* 19 (4): 301–23.

Kochan, Thomas A., Russell D. Lansbury, and John Paul Macduffie. 1997. *After lean production: evolving employment practices in the world auto industry*. Ithaca, NY: Cornell University Press. pp. 368.

Kruger, Justin, and David Dunning. 1999. Unskilled and unaware of it: how difficulties in recognizing one's own incompetence lead to inflated self-assessments. *Journal of personality and social psychology* 77 (6): 1121-34.

Machin, Stephen. 1995. Plant closures and unionization in British establishments. *British Journal of Industrial Relations* 33 (1): 55-68.

Maskell, Brian H., and Bruce L. Baggaley. 2003. *Practical Lean Accounting: A Proven System for Measuring and Managing the Lean Enterprise*. New York, NY: Productivity Press. pp. 359.

Meador, Mark, and Stephen JK Walters. 1994. Unions and productivity: evidence from academe. *Journal of Labor Research* 15 (4): 373-86.

McVay, Gloria, Frances A. Kennedy, and Rosemary R. Fullerton. 2013. *Accounting in the Lean Enterprise*. Boca Raton, FL: CRC Press, Taylor and Francis Group. pp. 184.

Olsen, Eric Oscar. 2004. Lean Manufacturing Management: The Relationship between Practice and Firm Level Financial Performance. Doctor of Philosophy, Columbus, OH: The Ohio State University. pp. 220.

Raghunathan, Trivellore E., and James E. Grizzle. 1995. A Split Questionnaire Survey Design. *Journal of the American Statistical Association* 90 (429): 54–63.

Rubin, Donald B. 1976. Inference and Missing Data. *Biometrika* 63 (3): 581–92.

Sánchez, Angel M., and Manuela P. Pérez. 2001. Lean Indicators and Manufacturing Strategies. *International Journal of Operations & Production Management* 21 (11): 1433–52.

Shah, Rachna. 2002. A Configurational View of Lean Manufacturing and Its Theoretical Implications. Doctor of Philosophy, Colombus, OH: The Ohio State University. pp. 278.

Shah, Rachna, and Peter T. Ward. 2003. Lean Manufacturing: Context, Practice Bundles, and Performance. *Journal of Operations Management* 21 (2): 129–49.

Shah, Rachna, and Peter T. Ward. 2007. Defining and Developing Measures of Lean Production. *Journal of Operations Management* 25 (4): 785–805.

Soriano-Meier, Horacio, and Paul L. Forrester. 2002. A Model for Evaluating the Degree of Leanness of Manufacturing Firms. *Integrated Manufacturing Systems* 13 (2): 104–9.

Sterne, Jonathan A.C., Ian R. White, John B. Carlin, Michael Spratt, Patrick Royston, Michael G. Kenward, Angela M. Wood, and James R. Carpenter. Multiple imputation for missing data in epidemiological and clinical research: potential and pitfalls. *BMJ* 338.

U.S. Census Bureau. 2012. Full report on manufacturers' shipments, inventories, and orders. http://www.census.gov/manufacturing/m3/historical_data/pressreleases/prel/2012/dec12prel .pdf Accessed: September 18, 2014.

Venkatraman, Natarjan. 1990. Performance Implications of Strategic Coalignment: A Methodological Perspective. *Journal of Management Studies* 27 (1): 19–41.

Venkatraman, Natarjan. 1989. The Concept of Fit in Strategy Research: Toward Verbal and Statistical Correspondence. *Academy of Management Review* 14 (3): 423–44.

Ward, Yvonne, Valerie Crute, Cyril Tomkins, and Andrew Graves. 2003. Cost Management and Accounting Methods to Support Lean Aerospace Enterprises. *University of Bath, School of Management Working Paper Series* 1-43.

Womack, James P., and Daniel T. Jones. 1996. *Lean Thinking : Banish Waste and Create Wealth in Your Corporation*. 1st edition. New York, NY: Simon & Schuster. Pp. 352.

7. Summary and Conclusions

The following chapter summarizes the outcomes of this study, highlights its contributions to the body of knowledge, and provides directions for future research.

7.1. Overview

Starting in the early 1990's, the implementation of Lean in the U.S. transportation equipment manufacturing industry was a response to continuously increasing foreign, especially Japanese, competition and continuously strengthened governmental regulations for emission, energy consumption, and safety controls (Shimokawa et al. 2009, Womack et al. 1990). Both academics and practitioners expected that the implementation of Lean in the U.S. transportation equipment manufacturing industry would increase industry competitiveness and performance, as it made Japanese motor vehicle manufacturers one of the most successful automotive manufacturers of the world (Shimokawa et al. 2009, Womack et al. 1990). However, many U.S. companies were and still are struggling with the fact that Lean must be fully integrated into the extended value chain and must be fully supported by a company's administration and leadership philosophies (Emiliani et al. 2003, Maskell and Baggaley 2003, Womack and Jones 1996). Prior research shows that only a limited number of companies implementing Lean were able to show operational and financial success in the long-term (Cua 2000, Shah 2002, Olsen 2004, Harris 2012).

By developing a mixed-mode survey (Dillman et al. 2009) and inquiring participants about their Lean transformation efforts, performance, and general characteristics, this study provides a snapshot on how far transportation equipment manufacturing companies got in their Lean journey. Results show that 29 percent of the responding transportation equipment companies possessed a traditional, mass production like management system. Thirty-three percent had begun their Lean transformation by developing a Lean framework in their facilities, 26 percent stood at a more advanced stage of the lean transformation, where a facility's processes are managed through value streams, and 13 percent possessed a Lean enterprise like management system. This study did not find any evidence that a higher level of Lean implementation in the leadership, manufacturing, accounting and finance, and supplier and customer relationship dimensions collectively would result in better operational and/or financial performance. The study, however, revealed that a higher level of Lean implementation in the manufacturing dimension resulted in better quality performance as measured by first-time through, inbound quality, and outbound quality.

Although, U.S. transportation equipment companies show high levels of Lean implementations in manufacturing, their implementation in the accounting and finance, and supplier and customer relationship dimensions still fall behind. Results of this study showed that 46 percent of the respondents organize their administrative processes by functional departments and use traditional accounting systems to manage the administrative side of their businesses. Twenty-seven percent reported to conduct pilot projects on introducing Lean in administration, accounting, and finance, 16 percent reported to move forward with their Lean implementation by aligning the administrative side of their businesses to value streams, while 12 percent reported to align their administrative, accounting, and financial processes to value streams throughout the extended value chain. This study revealed that a higher level of Lean implementation in the accounting and finance dimension resulted in better accounting performance as well as in better operational performance. No evidence was found, however, that a higher level of implementing Lean in the accounting and finance dimension does have any effect on a facility's financial performance.

The U.S. transportation equipment manufacturing industry consists of a wide range of micro, small, medium, and large-size businesses that may or may not be members of the union, and provide a wide variety of end-products ranging from trucks and automobiles to bodies and trailers and to motor vehicle parts (Statistics Canada 2007). To take the aforementioned differences into account, the effects of contextual variables (such as industry segment, location, annual sales volume, and unionization) on Lean implementation in the transportation equipment manufacturing industry and its relationship with *performance* were also examined. Annual sales volume was found to be a significant factor in regards to performance as smaller transportation equipment facilities reported to have better operational and accounting performance than larger ones; while none of the four contextual variables were found to have a significant effect on financial performance. When the effect of contextual variables on *the level of Lean implementation in accounting and finance* was examined, results showed that location had a significant effect. More specifically, facilities located in the Southern States revealed to have a higher level of Lean implementation in accounting and finance than companies located in the Midwest. When the effect of contextual variables on the *Lean implementation and performance relationship* was investigated, no significant relationship was found (alpha = 0.05). Finally, when the effect of contextual variables on the *Lean implementation in accounting and finance and performance relationship* was investigated, results showed that industry segment has a significant effect. More specifically, significantly more motor vehicle part manufacturers (NAICS 3363) tend to have a positive relationship between their level of Lean implementation in accounting and finance and operational performance, than do motor vehicle manufacturers (NAICS 3361).

7.2. Contributions of This Study

The questionnaire developed in this study provides conceptual clarity and specificity on Lean principles and determinants, and can be used as a roadmap for manufacturing facilities' journey on the road towards continuous improvement.

The study contributes to the Lean accounting literature by providing a snapshot of transportation equipment manufacturers' level of Lean implementation in their accounting and finance dimension, as of 2012. This study also provides empirical evidence that the systematic implementation of Lean principles and determinants in the manufacturing dimension of transportation equipment manufacturing facilities results in better quality performance and that the expansion of Lean principles and determinants to the accounting and finance dimension results in better accounting and operational performance.

This study also demonstrates the value of multiple imputations for handling missing data in operational research. Moreover, using multiple regression and profile deviation analysis parallel to examine study hypotheses provides complementary assessment of the same relationship, and brings out relevant details that may have been overlooked by a single method of analysis.

References

Cua, Kristy O. 2000. A Theory of Integrated Manufacturing Practices: Relating Total Quality Management, Just-in-Time and Total Productive Maintenance. Doctor of Philosophy, Minneapolis, MN: University of Minnesota. pp. 224.

Dillman, Don A., Jolene D. Smyth, and Leah M. Christian. 2009. *Internet, Mail, and Mixed-Mode Surveys: The Tailored Design Method*. 3 edition. Hoboken, N.J: Wiley and Sons, Inc. pp. 512.

Emiliani, Bob, David J. Stec, Lawrence Grasso, and James Stodder. 2003. *Better Thinking, Better Results : Using the Power of Lean as a Total Business Solution*. 1st edition. Kensington, CT: Center for Lean Business Management. pp. 313.

Harris, Daniel C. 2012. The Adoption of Lean Operations and Lean Accounting on the Financial-Performance Measures of Publicly Traded Companies. Doctor of Philosophy, Oxford, MS: The University of Mississippi. pp. 162.

Maskell, Brian H., and Bruce L. Baggaley. 2003. *Practical Lean Accounting: A Proven System for Measuring and Managing the Lean Enterprise*. New York, NY: Productivity Press. pp. 359.

Olsen, Eric Oscar. 2004. Lean Manufacturing Management: The Relationship between Practice and Firm Level Financial Performance. Doctor of Philosophy, Columbus, OH: The Ohio State University. pp. 220.

Shah, Rachna. 2002. A Configurational View of Lean Manufacturing and Its Theoretical Implications. Doctor of Philosophy, Colombus, OH: The Ohio State University. pp. 278.

Shimokawa, Koichi, Takahiro Fujimoto, Brian Miller, and John Shook. 2009. *The Birth of Lean - Conversations with Taiichi Ohno, Eiji Toyoda, and Other Figures Who Shaped Toyota Management.* 1st edition. Cambridge, MA: The Lean Enterprise Institute. pp. 284.

Statistics Canada. 2007. North American Industry Classification (NAICS) 2007. http://www.census.gov/cgi-bin/sssd/naics/naicsrch?code=336&search=2012%20NAICS%20Search. Accessed: February 15, 2014.

Womack, James P., and Daniel T. Jones. 1996. *Lean Thinking : Banish Waste and Create Wealth in Your Corporation*. 1st edition. New York, NY: Simon & Schuster. Pp. 352.

Womack, James P., Daniel T. Jones, Daniel Roos, and Massachusetts Institute of Technology. 1990. *The Machine That Changed the World : Based on the Massachusetts Institute of Technology 5-Million Dollar 5-Year Study on the Future of the Automobile*. 1st edition. New York, NY: Rawson Associates. pp. 352.

APPENDIX A

Lean Implementation in the Transportation Equipment Manufacturing Industry Survey

Department of Sustainable Biomaterials
Brooks Center (0503)
Virginia Tech
Blacksburg, VA 24061

If you have any questions, please contact:
Adrienn Andersch
Phone: (540)231-9759
Fax: (540)231-8868
E-mail: andersch@vt.edu

INFORMED CONSENT FORM

INTRODUCTION: The transportation equipment manufacturing industry is influenced by the cyclical nature of the U.S. economy, rising global competition, and changing customer habits. This complex environment has fostered new business practices and created an interest in new management concepts such as Lean management. To better understand these trends, Virginia Tech is in the process of conducting research to examine the extent of Lean implementation in the transportation equipment manufacturing industry.

OBJECTIVE: The purpose of this research is to evaluate transportation equipment manufacturing facilities in respect to their operational and financial performance and to correlate these results with the level of Lean implementation of the facility in question.

PROCEDURE: Filling out the questionnaire will take approximately 20 minutes or less. The questionnaire comprises of three sections: 1) Lean transformation efforts, 2) Performance measures, and 3) General characteristics. Please answer ALL questions for your manufacturing facility by selecting the most appropriate response or by filling out the blanks as indicated. Your approximate response is far more useful than no response. Any support from colleagues, such as from financial or operational personnel are welcomed.

BENEFITS: Participating facilities will gain a better understanding of the benefits of their Lean transformation efforts compared to other industry participants. The research will also provide mutual performance metrics, enabling them to benchmark and improve their facilities in the future. A summary of the results will be made available to all participants.

PARTICIPATION: Participation in this research is voluntary and you have the right to withdraw at any time or to refuse to participate without any penalty. If you desire to withdraw, please close your internet browser or notify the researcher via email (andersch@vt.edu).

CONFIDENTIALITY: All data obtained from participants will be kept strictly confidential and will only be reported in aggregate format. Your operation will not be identified in connection with your data. All questionnaires will be concealed, and no one other than the primary investigator and his assistant researcher will have access to them. The data collected will be stored in the Qualtrics-secure database until it has been deleted by the primary investigator.

RISKS/DISCOMFORT: Risks are minimal for involvement in this study. Although, we do not expect any harm to come upon any participants due to electronic malfunction of the computer, it is possible though extremely rare and uncommon.

CONTACT INFORMATION: If you have any questions about the research or if you have any problem in loading or accessing the study, please contact us by phone at (540) 231-9759, fax at (540) 231-8868, or e-mail: andersch@vt.edu.

LEAN TRANSFORMATION EFFORTS

All TERMS that are marked with a " * " are explained in the Glossary at the end of the document.

1) Was your facility ever involved in a LEAN TRANSFORMATION*?

☐ Yes
☐ No (If no, please follow with question 4)

2) Please indicate the YEAR your facility STARTED the LEAN TRANSFORMATION.

______

3) Is the LEAN TRANSFORMATION in your facility ONGOING?

☐ Yes
☐ No, please indicate the reason:

____

LEADERSHIP

Please select the ONE CATEGORY THAT BEST DESCRIBES your facility's status for each of the following questions. NOTE that categories represent progress in Lean transformation.
All TERMS that are marked with a " * " are explained in the Glossary at the end of the document.

4) Lean implementation planning

☐ Senior managers do not plan to implement Lean* in the facility.
☐ Senior managers started initial Lean projects but no transformation plan has yet been defined.
☐ Senior managers formulated a facility wide plan for the Lean transformation across all value streams* with timeline and measurements.
☐ Senior managers rolled out Lean transformation plans throughout the extended (upstream and downstream) value chains*.

5) Top management commitment

☐ Senior managers do not show interest in Lean transformation.
☐ Senior managers understand the importance of the Lean transformation and show commitment towards it.
☐ Senior managers lead the Lean transformation by personally practicing and mentoring Lean in the facility.
☐ Senior managers practice and mentor Lean throughout the extended value chain.

6) Communication

☐ Communication is largely top-down and limited.
☐ Basic communication procedures to openly and timely inform work-teams are in place but they are not uniform.
☐ Communication between management and employees is timely and information can be pulled as required in the facility.
☐ Two-way and open communication exists throughout the extended value chain.

7) Training

☐ Lean is not part of education and training programs.
☐ Basic Lean training is provided to all employees.
☐ Extensive Lean training of skills required for transformation projects is provided to all employees in the facility.
☐ Advanced Lean training focusing on skills, capabilities, and Lean principles is provided throughout the extended value chain.

8) Employee involvement

☐ Employees are required to fulfill their job description but nothing more.
☐ Employees are required to participate in continuous improvement* (Kaizen) activities.
☐ Employees are internalizing continuous improvement (Kaizen) activities as the basis of operation in the facility.
☐ Employee involvement and commitment to continuous improvement has become a habit throughout the extended value chain.

9) Knowledge management

☐ No documentation is kept about lessons learned.
☐ Sparse documentation is kept about lessons learned.
☐ Proper documentation exists for capturing and reusing lessons learned in the facility.
☐ Proper documentation of best practices exist and includes knowledge captured from all parties throughout the extended value chain.

10) Employee incentives

☐ No incentives are provided to encourage employees.☐ Primarily monetary rewards are used to encourage employees.
☐ A balance of monetary rewards, non-monetary rewards, and recognition are used to encourage Lean transformation activity.
☐ Profit sharing, non-monetary rewards, and recognition are used to fairly reward employees for the achievement of Lean goals.

11) Performance measurement

☐ Performance measures are inconsistent and focus on functional areas.
☐ Performance measures are being collected but they are not aligned with Lean goals.
☐ Key performance measures have been selected to align with Lean goals and they are available throughout the facility.
☐ A balanced and minimal set of key performance measures are used to track transformation progress throughout the extended value chain in real-time.

MANUFACTURING

All TERMS that are marked with a " * " are explained in the Glossary at the end of the document.

12) Production Flow

☐ Equipment and workstations are organized by functional departments.
☐ Equipment and workstations are arranged close together in the sequence of processing steps.
☐ All processes are aligned to value streams in the facility.
☐ Value streams are extended to suppliers and customers to enable better flow*.

13) Production quality

☐ Production encompasses final inspection and rework to repair defective items.
☐ Final inspection is eliminated and each employee is responsible for continuously detecting and analyzing quality issues in a pilot cell(s)*/line(s).
☐ Built-in-quality (individuals detect, analyze, permanently resolve quality issues and assure proper product and process designs) is achieved in the facility.
☐ Built-in-quality is achieved in the facility and rolled out for the extended value chain.

14) Changeover procedures

☐ Long set-up times are dealt with by producing large batches.
☐ Continuous improvement (Kaizen) teams are reducing setup times and increasing operational efficiency on a pilot machine(s).
☐ Modified machines and time-improved changeover procedures are rolled out to multiple machines.
☐ All machines have systematic changeovers and are continuously improved throughout the facility.

15) Maintenance procedures

☐ Maintenance work is done only upon machine breakdown or when safety issues are detected.
☐ Total Productive Maintenance (TPM)* is introduced in a pilot cell(s) to reduce breakdowns, quality defects, and minor stoppages.
☐ TPM is rolled out to multiple machines and conducted on a schedule.
☐ TPM became a habit in the facility and operators play a prominent role in achieving zero defects and breakdowns.

16) Pull system

☐ Production is based on forecasts only and parts are pushed* through the process.
☐ Production is “pulled” from subsequent stations based on customer demand in a pilot cell(s)/line(s).
☐ Pull* production is extended to the entire facility.
☐ Production is pulled throughout the extended value stream (including suppliers and customers).

17) One-piece flow

☐ Parts are moved from functional area to functional area in large batches.
☐ Small batches of parts are moved through a sequence of process steps in a pilot cell(s)/line(s).
☐ Small batch production in a sequence of process steps are rolled out to several value streams.
☐ Parts are moved through a sequence of process steps in all value streams with no work-in-process in between, one piece at a time.

18) Work procedures

☐ No work instructions can be found near machines.
☐ Work charts and job element sheets are visually posted in a pilot cell(s).
☐ Visual work charts and job element sheets are rolled out to multiple cells.
☐ Work and processes are standardized throughout the facility and are continuously updated based on employees' suggestions.

19) Workplace organization

☐ Work areas, supply and tool locations are disorganized.
☐ Necessary tools and supplies are identified and have assigned locations close to work area in a pilot cell(s).
☐ Assigned location for tools and supplies are rolled out to multiple cells.
☐ Work areas are organized; supplies and tools are standardized throughout the facility.

20) Employee training

☐ Each employee is assigned to a single job at any given time.
☐ Some employees are cross-trained to help each other to keep production going.
☐ Almost all employees are cross-trained and are assigned to a specific value stream.
☐ Cross-functional teams became the primary form of continuous improvement across value streams and throughout the facility.

ADMINISTRATIVE SUPPORT

21) Organization of administrative processes

☐ Administrative processes of the facility are organized by functional departments.
☐ Administrative processes are arranged close together in sequence of processing steps.
☐ Administrative processes are aligned to value streams in the facility.
☐ Administrative processes are aligned to value streams throughout the extended value chain.

ACCOUNTING/FINANCE PROCESSES

22) Transformation progress

☐ The manufacturing program is evaluated based on cost reductions and efficiency.
☐ Lean transformation progress is reviewed against predetermined success criteria for some continuous improvement (Kaizen) projects.
☐ A formal process exists to analyze Lean transformation progress for all continuous improvement projects (Kaizen) in the facility.
☐ Lean transformation progress is judged by the aggregate benefits rather than individual or localized improvements.

23) Budgeting

☐ Every department submits its budget which is then consolidated across the operation and rolled up to the division and corporate levels.
☐ The facility re-casted its chart of accounts and submits annual budgets from functional departments to value streams.
☐ Value stream budgets are results of the monthly operational planning of each value stream.
☐ Budgeting is eliminated and investment decisions are made based on consolidated monthly operational planning.

24) Product costing

☐ Standard cost is calculated for each item and variances are reported against actual values.
☐ Standard cost and value-stream cost* are calculated parallel to help decision making.
☐ Standard costing is replaced with value stream costing and value stream rather than unit costs are calculated in the facility.
☐ Value stream costing is applied throughout the extended value chain.

25) Month-end closing

☐ Full package of month-end reports are prepared for corporate accounting.
☐ Month-end closing is simplified due to standardized charts of accounts and cost centers.
☐ Month-end closing requires short preparation time; reviews are brief and conducted only for important issues.
☐ No month end closing is necessary, financial statements are continuously updated and can be pulled at any time.

26) Authorization process

☐ Multiple approvals and sign-offs are required from multiple managers to authorize transactions.
☐ Number of approvals and sign-offs are reduced and budgetary accountability of departmental managers are strengthened.
☐ Number of approvals and sign-offs are minimized and the authority of spending money is pushed down in the organization.
☐ Multiple approvals and sign-offs are eliminated and value stream managers are responsible to authorize transactions.

27) Accounts payable / Procurement

☐ All materials received are documented with a purchase order, receiver, and an invoice.
☐ Accounts payable credit cards are used for small purchases and master purchase agreements are developed with selected supplier(s) as a pilot project.
☐ Payment authorization based on receivers and invoices is initiated at the point of receiving and purchase orders are eliminated due to master purchase agreements for all key suppliers.
☐ Accounts payable processes are completely electronic using pick and pay systems.

28) Accounts receivable

☐ Invoices are mailed to customers after each product shipment by the accounts receivable department.
☐ Master sales orders are used from our key customers and invoicing happens directly from shipping.
☐ Invoicing needs are reduced by encouraging key customers to pay when products are received.
☐ Customers automatically wire payments to our bank accounts based on usage of products.

29) Inventory tracking

☐ Full physical inventory is conducted annually and adjustments are made in the books accordingly.
☐ Annual physical inventory is replaced with cycle counting to reduce errors.
☐ Cycle counting is in-use and Kanban* based inventory control is introduced throughout the value stream.
☐ Cycle counting is eliminated due to visual inventory control via Kanban system.

SUPPLIER RELATIONSHIP

30) Supplier relationship

☐ No close relationship is kept with suppliers.
☐ Key suppliers are identified and engaged in learning about Lean.
☐ Mutually beneficial partnerships facilitating Lean improvements are established with key suppliers.
☐ Suppliers are integrated part of daily operations and an agreement is in place for allocating risks and rewards.

31) Inventory management

☐ Internal material withdrawal from inventory is optimized without consideration of supplier processes.
☐ Key suppliers ship to stock based on predetermined minimum and maximum stocking levels.
☐ Key suppliers ship directly to the production line based on Kanban systems.
☐ No inventory is kept; suppliers deliver to point of use when needed.

32) Supplier involvement in new product development

☐ Suppliers are not involved in new product development.
☐ Pilot projects are conducted to involve key suppliers in new product development.
☐ Innovation capabilities of key suppliers are utilized in designing and engineering new products.
☐ Key suppliers are involved at all stages and all activities of product life cycles.

CUSTOMER RELATIONSHIP

All TERMS that are marked with a "*" are explained in the Glossary at the end of the document.

33) Customer relationship

☐ Essentially no contact with customers exists outside of the sales department.
☐ Key customers are engaged in learning about Lean.
☐ Mutually beneficial partnerships facilitating Lean improvements are established with key customers.
☐ Customers are integrated part of daily operations and an agreement is in place for allocating risks and rewards.

34) Customer demand

☐ Production reflects forecasts and may be revised in reaction to customer demand.
☐ The facility ships to stock for customers based on predetermined minimum and maximum stocking levels.
☐ The facility ships directly to its customers' production line (or customers' hands) based on a Kanban system.
☐ The facility produces to customer demand and ships just-in-time (JIT)*.

35) Customer involvement in new product development

☐ New products are developed based on market research and market analysis reports.
☐ Pilot projects are conducted to involve key customers in new product development.
☐ Key customer's inputs are actively considered in designing and engineering new products.
☐ Customers are represented on integrated product teams to ensure incremental product improvements

PERFORMANCE MEASURES - OPERATIONAL MEASURES

36) For 2012, please indicate the percentage for the following questions in regards to your facility.

	1-40 %	41-75 %	76-85 %	86-92 %	93-100 %	Not measured
First time through (items moving through the process without any problem)						
Inbound quality (items coming in without any problem)						
Outbound quality (items leaving the facility without any problem)						
On-time delivery rate						
Supplier shipments delivered on time						
Overall Equipment Effectiveness (OEE)						
Reactive maintenance rate						

37) For 2012, please indicate the percentage for the following questions in regards to your facility.

	1-5 %	6-10 %	11-25 %	26-50 %	More than 50%	Not measured
Customer reject rate on shipped products						
Scrap cost as a percentage of sales						
Rework cost as a percentage of sales						

38) For 2012, please indicate the percentage for the following JUST IN TIME (JIT) DELIVERY questions in regards to your facility.

	1-5 %	6-10 %	11-25 %	26-50 %	More than 50%	Not measured
Customers for which the facility has implemented a JIT delivery program						
Suppliers who provided JIT delivery to your facility						

39) For 2012, please indicate the percentage for the following questions in regards to your facility's ACCOUNTING PROCESSES.

	Less than 1%	1-2 %	3-4 %	5-7 %	More than 7%	Not measured
Manual adjustments due to late recording						
Overdue invoices from suppliers						
Overdue invoices to customers						

40) For 2012, please indicate the MONTHLY OVERTIME HOURS in your facility.

	1-3 hrs /month	4-6 hrs /month	7-10 hrs /month	11-15 hrs /month	More than 15 hrs /month	Not measured
For production employees						
For accounting / finance employees						

41) Please indicate the typical LEAD-TIME on "long lead time" PURCHASED MATERIALS to your facility in 2012.

- ☐ 15 - 30 days
- ☐ 31 - 70 days
- ☐ 71 - 140 days
- ☐ 141 - 280 days
- ☐ Other, please specify: ________________
- ☐ Not measured

42) Please indicate the MANUFACTURING LEAD TIME (the average length of time it takes a new set of inputs to move all the way through the operation) for a typical product in your facility in 2012.

- ☐ Less than 3 hour
- ☐ 4 - 6 hours
- ☐ 7 – 9 hours
- ☐ 10 - 12 hours
- ☐ More than 12 hours
- ☐ Not measured

43) Please indicate the average ORDER ENTRY - CASH-IN TIME in your facility in 2012.

- ☐ 15 - 30 days
- ☐ 31 - 60 days
- ☐ 61 - 90 days
- ☐ 91 - 180 days
- ☐ Other, please specify: ________________
- ☐ Not measured

44) Please indicate the AVERAGE DAYS OF INVENTORY of finished goods in your facility in 2012.

- ☐ 1 - 15 days
- ☐ 16 - 30 days
- ☐ 31 - 45 days
- ☐ 45 - 60 days
- ☐ More than 60 days
- ☐ Not measured

45) Please indicate the AVERAGE LENGTH OF A NEW PRODUCT DEVELOPMENT CYCLE in your facility in 2012.

- ☐ 1-3 Months
- ☐ 4 - 6 Months
- ☐ 7 - 9 Months
- ☐ 10 - 12 Months
- ☐ More than 12 Months
- ☐ Not measured

46) Please indicate the AVERAGE LENGTH OF AN INVESTMENT DECISION CYCLE (for large investments, from need arising until request approved) in your facility in 2012.

- ☐ Less than 5 days
- ☐ 5 - 14 days
- ☐ 15 - 30 days
- ☐ 31 - 60 days
- ☐ More than 60 days
- ☐ Not measured

47) Please indicate the AVERAGE LENGTH OF FINANCIAL CLOSING in your facility in 2012.

- ☐ 1 day or less
- ☐ 2 - 3 days
- ☐ 4 - 5 days
- ☐ 6 - 7 days
- ☐ More than 7 days
- ☐ Not measured

48) Please, indicate the LOST TIME INCIDENT rate of your facility in 2012 (total lost time incidents per million hours worked).

- ☐ 0 - 0.3
- ☐ 0.4 - 1.0
- ☐ 1.1 - 3.0
- ☐ 3.1 - 6.0
- ☐ More than 6.0
- ☐ Not measured

FINANCIAL MEASURES

49) For 2012, please indicate by what percentage the following MEASURES CHANGED in your facility in the PAST 5 YEARS.

	Decreased with more than 20 %	Decreased 11-20 %	Decreased 6-10 %	Decreased 1-5 %	Stayed the same	Not measured	Increased 1-5 %	Increased 6-10 %	Increased 11-20 %	Increased with more than 20 %	Not measured
Productivity (sales per full time employees)											
Return on assets (net income per total assets)											
EBIT											
Market share											
R&D cost ratio (R&D cost per sales)											

GENERAL CHARACTERISTICS

50) Please indicate your POSITION in your facility.

☐ Senior management (CEO, COO, CFO, etc.)
☐ Accountant / Financial analyst
☐ Lean manager
☐ Industrial engineer
☐ Product engineer
☐ Sales personnel
☐ Buyer / Purchasing agent
☐ Other, please specify: ________________

51) Please indicate the ONE category that best describes the MAIN PRODUCT your facility produces.

☐ Automobile Manufacturing
☐ Light Truck and Utility Vehicle Manufacturing
☐ Heavy Duty Truck Manufacturing
☐ Motor Vehicle Body Manufacturing
☐ Truck Trailer Manufacturing
☐ Motor Home Manufacturing
☐ Travel Trailer and Camper Manufacturing
☐ Motor Vehicle Gasoline Engine and Engine Parts Manufacturing
☐ Motor Vehicle Electrical and Electronic Equipment Manufacturing
☐ Motor Vehicle Steering and Suspension Components
☐ Motor Vehicle Brake System Manufacturing
☐ Motor Vehicle Transmission and Power Train Parts Manufacturing
☐ Motor Vehicle Seating and Interior Trim
☐ Motor Vehicle Metal Stamping
☐ Other, please specify: ________________

52) Please indicate the STATE your facility is located in.

_____

53) Please indicate the TOTAL NUMBER OF EMPLOYEES in your facility in 2012.

☐ Less than 11
☐ 11 – 50
☐ 51 – 250
☐ 251 - 1,000
☐ More than 1,000

54) Please indicate the NUMBER OF ACCOUNTING / FINANCE EMPLOYEES in your facility's in 2012.

☐ Less than 3
☐ 3 - 4
☐ 5 - 6
☐ 7 - 8
☐ More than 8

55) Please indicate the approximate ANNUAL SALES REVENUE of your facility in 2012.

☐ Less than $2.6 million
☐ $2.6 million - $13.1 million
☐ $13.2 million - $65.6 million
☐ $65.7 million - $262.8 million
☐ More than $262.8 million

56) Were employees of your facility organized in UNIONS in 2012?

☐ Yes
☐ No
☐ Partially, please explain: ________________

57) Please indicate if you would like to receive a summary of the survey results.

☐ Yes, please send the results for the following e-mail address: ______________________________
☐ No

GLOSSARY

All TERMS that are marked with a " * " are explained in the Glossary.

CELL: A collection of employees with various skills, techniques, machinery, tooling, support, material and sub-processes; committed to a product with similar function or manufacturer or model, item, part, assembly or asset.

CONSOLIDATED FINANCIAL REPORT: Shows the impact of the changes in each value stream, rolls them up together with any non-value stream (sustaining) departments to create a rolling budget for the facility.

CONTINUOUS IMPROVEMENT: A culture of ongoing improvement of any and all elements within the enterprise, including processes, products, and services. Improvements seek to increase efficiency, effectiveness, and value-creation.

EXTENDED VALUE CHAIN: Holistic and comprehensive view of the value chain that enables identification of opportunities for greater efficiency and greater value delivery.

FLOW: The progressive achievement of tasks along a value stream so that a product proceeds from order to delivery with no stoppages, scrap, or back-flows.

JUST IN TIME (JIT): Producing or conveying only the items that are needed by the next process when they are needed and in the quantity needed.

KANBAN: Signaling system to trigger action, replenishment is based on consumption.

LEAN: Lean is a management philosophy. It stipulates to maximize customer value derived from products and/or services, while minimizing waste. Lean requires a shift in management's focus from optimizing technologies, assets, and departments to holistically optimize the flow of products and services along value streams that flow horizontally across technologies, assets, and departments to customers. Lean is known by various names, such as "Toyota Production System (TPS)", "Lean manufacturing", "Lean production", or "Lean management" among others.

LEAN TRANSFORMATION: Term used to characterize a company moving from traditional ways of doing things (batch and queue) to leaner ways of doing things (Lean). Takes a long-term perspective and perseverance.

PULL: A planning system based on communication of actual real-time needs from downstream operations, ultimately from the end user.

PUSH: A planning system that schedules upstream operations according to some forecasted plan of downstream needs.

REACTIVE MAINTENANCE RATE: Percentage of unscheduled maintenance actions performed as a result of system or product failure compared to all maintenance activities.

ROLLING BUDGET: Method in which a budget established at the beginning of an accounting period is continually amended to reflect variances that arise due to changing circumstances.

TOTAL PRODUCTIVE MAINTENANCE (TPM): A series of techniques used to improved machine availability through better utilization of maintenance and production resources.

VALUE STREAM: The specific activities required to design, order, and provide a specific product, from concept to

428429

NO POSTAGE
NECESSARY
IF MAILED
IN THE
UNITED STATES

BUSINESS REPLY MAIL
FIRST-CLASS MAIL PERMIT NO. 10 BLACKSBURG, VA

POSTAGE WILL BE PAID BY ADDRESSEE

ATTN: URS BUEHLMANN
DEPARTMENT OF SUSTAINABLE BIOMATERIALS
PO BOX 850
VA TECH
BLACKSBURG VA 24063-9960

Please complete
the questionnaire,
fold, tape at top and
return.
Postage is prepaid.

Thank You!

APPENDIX B

VirginiaTech | *College of* Natural Resources and Environment

November 6, 2014

<Company Name>
<Address>
<City>, <State> <Zip>

Dear <Prefix> <Last Name>,

During the past decade, the U.S. transportation equipment manufacturing industry has been greatly affected by the economic downturn, new and emerging technologies, changing laws and regulations, and new initiatives to improve performance by improving manufacturing processes and management systems.

Virginia Tech is conducting research to **evaluate transportation equipment manufacturing facilities in respect to their operational and financial performance and to correlate these results with the level of Lean implementation.** We are asking for your help with this research study by completing the below listed online questionnaire:

URL address to the Survey:
www.companyperformance.org

Upon completion of our research, participating facilities will **gain a better understanding of the benefits of Lean transformation efforts** compared to other industry participants. The research will also provide mutual performance metrics, enabling individual operations to **benchmark** and improve their facilities in the future. A summary of the results will be made available to all participants.

Please note that all **data** obtained from participants **will be kept strictly confidential** and will only be reported in aggregate format. We really appreciate your taking the time in filling out this survey and look forward to your response. If you have any questions about the study or have any problem in loading or accessing the web-site, please contact us by phone at (540) 231-9759, fax at (540) 231-8868, or e-mail: andersch@vt.edu.

Thank you very much for your time and assistance.

Sincerely,

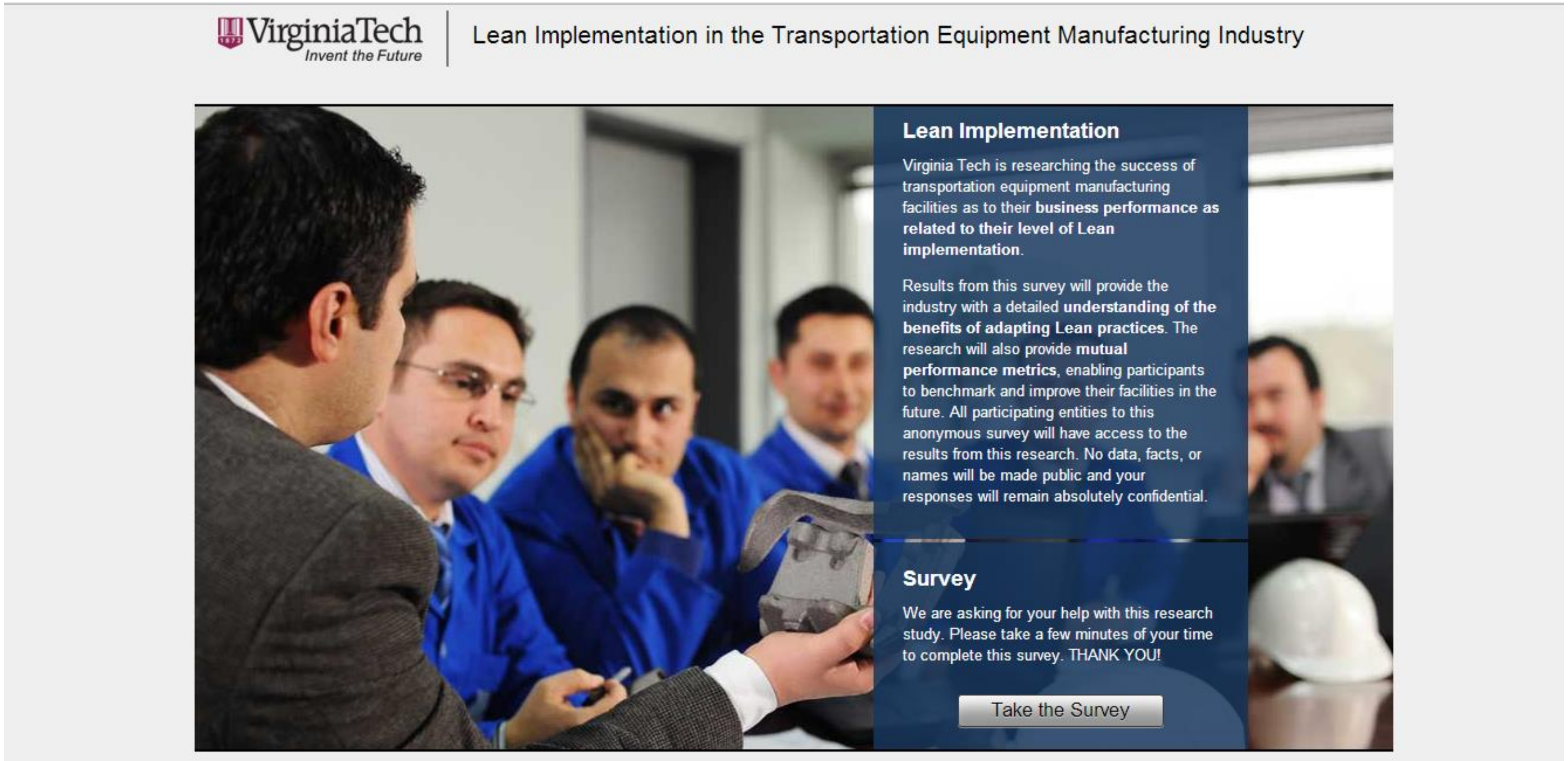
Adrienn Andersch
PhD. Candidate

Invent the Future

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

APPENDIX C

www.companyperformance.org



APPENDIX D

VirginiaTech | *College of* Natural Resources and Environment

Good morning,

I would like to say THANK YOU for providing your insight and opinion into our "Lean implementation in transportation equipment manufacturing" survey and THANK YOU for enabling us to reach our goal of receiving high quality and quantity responses.

Final report of the findings will be issued at the end of 2013, which will be distributed to your email address.

Thank you very much again for the time and effort you contributed towards this survey.

Sincerely,

Adrienn Andersch

Adrienn Andersch
PhD. Candidate

Invent the Future

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

APPENDIX E

My work is incomplete without YOUR HELP!

Please help my research by filling out the questionnaire!

Virginia Tech
College of Natural Resources and Environment

We need your help! Recently, you were invited to help our research by providing your input on **"Lean implementation in transportation equipment manufacturing"**. I am contacting you to ask for your help by completing a web-based survey that can be accessed at:

www.companyperformance.org

Your participation is critical for the success of the study. The information you provide will be kept strictly confidential. If you have any questions or concerns, please do not hesitate to contact us at (540) 231-9759. Our fax number is (540) 231-8868. Thank you for your participation in advance.

Sincerely,

Adrienn Andersch

Adrienn Andersch
PhD. Candidate

«Company_Name»
«Prefix» «First_Name» «Last_Name» «F11»
«Address»
«City», «State» «Zip»

Invent the Future

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

APPENDIX F

Multiple Imputation in SAS 9.3:

```
proc import datafile="F:\Adri\Dissertation\Original Survey Data_Reduced
Model_Adrienn Andersch.csv"
out=MIdata
dbms=csv
replace;
getnames=yes;
run;

data MIdata1;
set MIdata;
array a(*) LQ1--LQ8;
leadership=sum(of a[*]);
array b(*) MQ1--MQ9;
manufacturing=sum(of b[*]);
array c(*) AQ1--AQ9;
accounting=sum(of c[*]);
array d(*) SRQ1--SRQ3;
supplier_relationship=sum(of d[*]);
array e(*) CRQ1--CRQ3;
customer_relationship=sum(of e[*]);
run;

data reorder;
retain leadership manufacturing accounting supplier_relationship
customer_relationship CCQ3
OMQ1 OMQ2 OMQ3 OMQ4 OMQ5 OMQ6 OMQ7 OMQ8 OMQ9 OMQ10 OMQ11 OMQ12 OMQ13
OMQ14 OMQ15 OMQ16 OMQ17 OMQ18 OMQ19 OMQ20 OMQ21 OMQ22 OMQ23 OMQ24 OMQ25
FMQ1 FMQ2 FMQ3 FMQ4 FMQ5 CCQ2 CCQ6 CCQ7;
set MIdata1;
run;

proc mi data=reorder nimpute=5 seed=12345678 out=mob;
class CCQ3 OMQ2;
var leadership manufacturing accounting supplier_relationship
customer_relationship OMQ1 CCQ3 OMQ2;
monotone logistic (OMQ2=leadership manufacturing accounting
supplier_relationship customer_relationship OMQ1);
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 OMQ3;
var leadership manufacturing accounting supplier_relationship
customer_relationship CCQ3 OMQ1 OMQ2 OMQ3;
monotone logistic (OMQ3=leadership manufacturing accounting
supplier_relationship customer_relationship OMQ1 OMQ2);
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 OMQ4;
```

```
var leadership manufacturing accounting supplier_relationship
customer_relationship CCQ3 OMQ1 OMQ2 OMQ3 OMQ4;
monotone logistic (OMQ4=leadership manufacturing accounting
supplier_relationship customer_relationship OMQ1 OMQ2 OMQ3);
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 OMQ5;
var leadership manufacturing accounting supplier_relationship
customer_relationship CCQ3 OMQ1 OMQ2 OMQ3 OMQ4 OMQ5;
monotone logistic (OMQ5=leadership manufacturing accounting
supplier_relationship customer_relationship OMQ1 OMQ2 OMQ3 OMQ4);
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 OMQ6;
var leadership manufacturing accounting supplier_relationship
customer_relationship CCQ3 OMQ1 OMQ2 OMQ3 OMQ4 OMQ5 OMQ6;
monotone logistic (OMQ6=leadership manufacturing accounting
supplier_relationship customer_relationship OMQ1 OMQ2 OMQ3 OMQ4 OMQ5);
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 OMQ7;
var leadership manufacturing accounting supplier_relationship
customer_relationship CCQ3 OMQ1 OMQ2 OMQ3 OMQ4 OMQ5 OMQ6 OMQ7;
monotone logistic (OMQ7=leadership manufacturing accounting
supplier_relationship customer_relationship OMQ1 OMQ2 OMQ3 OMQ4 OMQ5
OMQ6);
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 OMQ8;
var leadership manufacturing accounting supplier_relationship
customer_relationship CCQ3 OMQ1 OMQ2 OMQ3 OMQ4 OMQ5 OMQ6 OMQ7 OMQ8;
monotone logistic (OMQ8=leadership manufacturing accounting
supplier_relationship customer_relationship OMQ1 OMQ2 OMQ3 OMQ4 OMQ5
OMQ6 OMQ7);
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 OMQ9;
var leadership manufacturing accounting supplier_relationship
customer_relationship CCQ3 OMQ1 OMQ2 OMQ3 OMQ4 OMQ5 OMQ6 OMQ7 OMQ8
OMQ9;
monotone logistic (OMQ9=leadership manufacturing accounting
supplier_relationship customer_relationship OMQ1 OMQ2 OMQ3 OMQ4 OMQ5
OMQ6 OMQ7 OMQ8);
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 OMQ10;
var leadership manufacturing accounting supplier_relationship
customer_relationship CCQ3 OMQ1 OMQ2 OMQ3 OMQ4 OMQ5 OMQ6 OMQ7 OMQ8 OMQ9
OMQ10;
```

```
monotone logistic (OMQ10=leadership manufacturing accounting
supplier_relationship customer_relationship OMQ1 OMQ2 OMQ3 OMQ4 OMQ5
OMQ6 OMQ7 OMQ8 OMQ9);
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 OMQ11;
var leadership manufacturing accounting supplier_relationship
customer_relationship CCQ3 OMQ1 OMQ2 OMQ3 OMQ4 OMQ5 OMQ6 OMQ7 OMQ8 OMQ9
OMQ10 OMQ11;
monotone logistic (OMQ11=leadership manufacturing accounting
supplier_relationship customer_relationship OMQ1 OMQ2 OMQ3 OMQ4 OMQ5
OMQ6 OMQ7 OMQ8 OMQ9 OMQ10);
run;

data mob;
set mob;
Qtot=OMQ1+OMQ2+OMQ3+OMQ4+OMQ5+OMQ6+OMQ7+OMQ8+OMQ9+OMQ10+OMQ11;
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 OMQ12;
var leadership manufacturing accounting supplier_relationship
customer_relationship CCQ3 Qtot OMQ12;
monotone logistic (OMQ12=leadership manufacturing accounting
supplier_relationship customer_relationship Qtot);
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 OMQ13;
var leadership manufacturing accounting supplier_relationship
customer_relationship CCQ3 Qtot OMQ12 OMQ13;
monotone logistic (OMQ13=leadership manufacturing accounting
supplier_relationship customer_relationship Qtot OMQ12);
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 OMQ14;
var leadership manufacturing accounting supplier_relationship
customer_relationship CCQ3 Qtot OMQ12 OMQ13 OMQ14;
monotone logistic (OMQ14=leadership manufacturing accounting
supplier_relationship customer_relationship Qtot OMQ12 OMQ13);
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 OMQ15;
var leadership manufacturing accounting supplier_relationship
customer_relationship CCQ3 Qtot OMQ12 OMQ13 OMQ14 OMQ15;
monotone logistic (OMQ15=leadership manufacturing accounting
supplier_relationship customer_relationship Qtot OMQ12 OMQ13 OMQ14);
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 OMQ16;
var leadership manufacturing accounting supplier_relationship
customer_relationship CCQ3 Qtot OMQ12 OMQ13 OMQ14 OMQ15 OMQ16;
```

```
monotone logistic (OMQ16=leadership manufacturing accounting
supplier_relationship customer_relationship Qtot OMQ12 OMQ13 OMQ14
OMQ15);
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 OMQ17;
var leadership manufacturing accounting supplier_relationship
customer_relationship CCQ3 Qtot OMQ12 OMQ13 OMQ14 OMQ15 OMQ16 OMQ17;
monotone logistic (OMQ17=leadership manufacturing accounting
supplier_relationship customer_relationship Qtot OMQ12 OMQ13 OMQ14
OMQ15 OMQ16);
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 OMQ18;
var leadership manufacturing accounting supplier_relationship
customer_relationship CCQ3 Qtot OMQ12 OMQ13 OMQ14 OMQ15 OMQ16 OMQ17
OMQ18;
monotone logistic (OMQ18=leadership manufacturing accounting
supplier_relationship customer_relationship Qtot OMQ12 OMQ13 OMQ14
OMQ15 OMQ16 OMQ17);
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 OMQ19;
var leadership manufacturing accounting supplier_relationship
customer_relationship CCQ3 Qtot OMQ12 OMQ13 OMQ14 OMQ15 OMQ16 OMQ17
OMQ18 OMQ19;
monotone logistic (OMQ19=leadership manufacturing accounting
supplier_relationship customer_relationship Qtot OMQ12 OMQ13 OMQ14
OMQ15 OMQ16 OMQ17 OMQ18);
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 OMQ20;
var leadership manufacturing accounting supplier_relationship
customer_relationship CCQ3 Qtot OMQ12 OMQ13 OMQ14 OMQ15 OMQ16 OMQ17
OMQ18 OMQ19 OMQ20;
monotone logistic (OMQ20=leadership manufacturing accounting
supplier_relationship customer_relationship Qtot OMQ12 OMQ13 OMQ14
OMQ15 OMQ16 OMQ17 OMQ18 OMQ19);
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 OMQ21;
var leadership manufacturing accounting supplier_relationship
customer_relationship CCQ3 Qtot OMQ12 OMQ13 OMQ14 OMQ15 OMQ16 OMQ17
OMQ18 OMQ19 OMQ20 OMQ21;
monotone logistic (OMQ21=leadership manufacturing accounting
supplier_relationship customer_relationship Qtot OMQ12 OMQ13 OMQ14
OMQ15 OMQ16 OMQ17 OMQ18 OMQ19 OMQ20);
run;
data mob;
set mob;
Qtot1=Qtot+OMQ12+OMQ13+OMQ14+OMQ15+OMQ16+OMQ17+OMQ18+OMQ19+OMQ20+OMQ21;
run;
```

```
proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 OMQ22;
var leadership manufacturing accounting supplier_relationship
customer_relationship CCQ3 Qtot1 OMQ22;
monotone logistic (OMQ22=leadership manufacturing accounting
supplier_relationship customer_relationship Qtot1);
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 OMQ23;
var leadership manufacturing accounting supplier_relationship
customer_relationship CCQ3 Qtot1 OMQ22 OMQ23;
monotone logistic (OMQ23=leadership manufacturing accounting
supplier_relationship customer_relationship Qtot1 OMQ22);
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 OMQ24;
var leadership manufacturing accounting supplier_relationship
customer_relationship CCQ3 Qtot1 OMQ22 OMQ23 OMQ24;
monotone logistic (OMQ24=leadership manufacturing accounting
supplier_relationship customer_relationship Qtot1 OMQ22 OMQ23);
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 OMQ25;
var leadership manufacturing accounting supplier_relationship
customer_relationship CCQ3 Qtot1 OMQ22 OMQ23 OMQ24 OMQ25;
monotone logistic (OMQ25=leadership manufacturing accounting
supplier_relationship customer_relationship Qtot1 OMQ22 OMQ23 OMQ24);
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 FMQ1;
var leadership manufacturing accounting supplier_relationship
customer_relationship CCQ3 Qtot1 OMQ22 OMQ23 OMQ24 OMQ25 FMQ1;
monotone logistic (FMQ1=leadership manufacturing accounting
supplier_relationship customer_relationship Qtot1 OMQ22 OMQ23 OMQ24
OMQ25);
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 FMQ2;
var leadership manufacturing accounting supplier_relationship
customer_relationship CCQ3 Qtot1 OMQ22 OMQ23 OMQ24 OMQ25 FMQ1 FMQ2;
monotone logistic (FMQ2=leadership manufacturing accounting
supplier_relationship customer_relationship Qtot1 OMQ22 OMQ23 OMQ24
OMQ25 FMQ1);
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 FMQ3;
var leadership manufacturing accounting supplier_relationship
customer_relationship CCQ3 Qtot1 OMQ22 OMQ23 OMQ24 OMQ25 FMQ1 FMQ2
FMQ3;
```

```
monotone logistic (FMQ3=leadership manufacturing accounting
supplier_relationship customer_relationship Qtot1 OMQ22 OMQ23 OMQ24
OMQ25 FMQ1 FMQ2);
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 FMQ4;
var leadership manufacturing accounting supplier_relationship
customer_relationship CCQ3 Qtot1 OMQ22 OMQ23 OMQ24 OMQ25 FMQ1 FMQ2 FMQ3
FMQ4;
monotone logistic (FMQ4=leadership manufacturing accounting
supplier_relationship customer_relationship Qtot1 OMQ22 OMQ23 OMQ24
OMQ25 FMQ1 FMQ2 FMQ3);
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 FMQ5;
var leadership manufacturing accounting supplier_relationship
customer_relationship CCQ3 Qtot1 OMQ22 OMQ23 OMQ24 OMQ25 FMQ1 FMQ2 FMQ3
FMQ4 FMQ5;
monotone logistic (FMQ5=leadership manufacturing accounting
supplier_relationship customer_relationship Qtot1 OMQ22 OMQ23 OMQ24
OMQ25 FMQ1 FMQ2 FMQ3 FMQ4);
run;

data mob;
set mob;
Qtot2=Qtot1+OMQ22+OMQ23+OMQ24+OMQ25+FMQ1+FMQ2+FMQ3+FMQ4+FMQ5;
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 CCQ2;
var leadership manufacturing accounting supplier_relationship
customer_relationship CCQ3 Qtot2 CCQ2;
monotone logistic (CCQ2=leadership manufacturing accounting
supplier_relationship customer_relationship Qtot2);
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 CCQ6;
var leadership manufacturing accounting supplier_relationship
customer_relationship CCQ3 Qtot2 CCQ2 CCQ6;
monotone logistic (CCQ6=leadership manufacturing accounting
supplier_relationship customer_relationship Qtot2);
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 CCQ7;
var leadership manufacturing accounting supplier_relationship
customer_relationship CCQ3 Qtot2 CCQ2 CCQ6 CCQ7;
monotone logistic (CCQ7=leadership manufacturing accounting
supplier_relationship customer_relationship Qtot2);
run;

data reorder;
retain leadership manufacturing accounting supplier_relationship
customer_relationship CCQ3
```

```
OMQ1 OMQ2 OMQ3 OMQ4 OMQ5 OMQ6 OMQ7 OMQ8 OMQ9 OMQ10 OMQ11 OMQ12 OMQ13
OMQ14 OMQ15 OMQ16 OMQ17 OMQ18 OMQ19 OMQ20 OMQ21 OMQ22 OMQ23 OMQ24 OMQ25
FMQ1 FMQ2 FMQ3 FMQ4 FMQ5 CCQ2 CCQ6 CCQ7;
set MIdata1;
run;
```

APPENDIX G

Scale Reliability Test in SAS 9.3.:

Independent variables:

```
proc corr data=mob alpha plots;
var LQ1 LQ2 LQ3 LQ4 LQ5 LQ6 LQ7 LQ8;
by _imputation_;
run;

proc corr data=mob alpha plots;
var MQ1 MQ2 MQ3 MQ4 MQ5 MQ6 MQ7 MQ8 MQ9;
by _imputation_;
run;

proc corr data=mob alpha plots;
var AQ1 AQ2 AQ3 AQ4 AQ5 AQ6 AQ7 AQ8 AQ9;
by _imputation_;
run;

proc corr data=mob alpha plots;
by _imputation_;
var AQ1 AQ2 AQ4 AQ7 AQ9;
run;

proc corr data=mob alpha plots;
var SRQ1 SRQ2 SRQ3 CRQ1 CRQ2 CRQ3;
by _imputation_;
run;

proc corr data=mob alpha plots;
var SRQ1 SRQ3 CRQ1 CRQ3;
by _imputation_;
run;
```

Dependent variables:

```
proc corr data=mob alpha plots;
var OMQ1 OMQ2 OMQ3 OMQ4 OMQ5 OMQ6 OMQ7 OMQ8 OMQ9 OMQ10 OMQ11 OMQ12
OMQ13 OMQ14 OMQ15 OMQ16 OMQ17 OMQ18 OMQ19 OMQ20 OMQ21 OMQ22 OMQ23 OMQ24
OMQ25;
by _imputation_;
run;

proc corr data=mob alpha plots;
var OMQ1 OMQ2 OMQ3 OMQ4 OMQ5 OMQ6 OMQ8 OMQ9 OMQ13 OMQ14 OMQ15 OMQ16
OMQ17 OMQ18 OMQ19 OMQ20 OMQ21 OMQ22 OMQ23 OMQ24 OMQ25;
by _imputation_;
run;
```

```
proc corr data=mob alpha plots;
var FMQ1 FMQ2 FMQ3 FMQ4 FMQ5;
by _imputation_;
run;

proc corr data=mob alpha plots;
var OMQ13 OMQ14 OMQ15 OMQ17 OMQ20 OMQ23 OMQ24;
by _imputation_;
run;
```

APPENDIX H

Construct Validity Test in SAS 9.3:

Independent variables:

```
proc factor data=mob
method=prin
priors=one
mineigen=1
scree
rotate=varimax
round
flag=.40;
var LQ1 LQ2 LQ3 LQ4 LQ5 LQ6 LQ7 LQ8;
by _imputation_;
run;

proc factor data=mob
method=prin
priors=one
mineigen=1
scree
rotate=varimax
round
flag=.40;
var LQ1 LQ2 LQ3 LQ4 LQ5 LQ7;
by _imputation_;
run;

proc factor data=mob
method=prin
priors=one
mineigen=1
scree
rotate=varimax
round
flag=.40;
var MQ1 MQ2 MQ3 MQ4 MQ5 MQ6 MQ7 MQ8 MQ9;
by _imputation_;
run;

proc factor data=mob
method=prin
priors=one
mineigen=1
scree
rotate=varimax
round
flag=.40;
var MQ1 MQ2 MQ3 MQ5 MQ6 MQ7 MQ8 MQ9;
by _imputation_;
run;
```

```
proc factor data=mob
method=prin
priors=one
mineigen=1
scree
rotate=varimax
round
flag=.40;
var AQ1 AQ2 AQ3 AQ4 AQ5 AQ6 AQ7 AQ8 AQ9;
by _imputation_;
run;

proc factor data=mob
method=prin
priors=one
mineigen=1
scree
rotate=varimax
round
flag=.40;
var AQ2 AQ3 AQ4 AQ5 AQ6 AQ7 AQ8 AQ9;
by _imputation_;
run;

proc factor data=mob
method=prin
priors=one
mineigen=1
scree
rotate=varimax
round
flag=.40;
var SRQ1 SRQ2 SRQ3 CRQ1 CRQ2 CRQ3;
by _imputation_;
run;

proc factor data=mob
method=prin
priors=one
mineigen=1
scree
rotate=varimax
round
flag=.40;
var SRQ1 SRQ2 SRQ3 CRQ1 CRQ2;
by _imputation_;
run;
```

Dependent variables:

```
proc factor data=mob
method=prin
priors=one
mineigen=1
```

```
scree
rotate=varimax
round
flag=.40;
var OMQ1 OMQ2 OMQ3 OMQ8 OMQ9 OMQ10 OMQ13;
by _imputation_;
run;

proc factor data=mob
method=prin
priors=one
mineigen=1
scree
rotate=varimax
round
flag=.40;
var OMQ1 OMQ2 OMQ3 OMQ8 OMQ13;
by _imputation_;
run;

proc factor data=mob
method=prin
priors=one
mineigen=1
scree
rotate=varimax
round
flag=.40;
var OMQ1 OMQ2 OMQ3;
by _imputation_;
run;

proc factor data=mob
method=prin
priors=one
mineigen=1
scree
rotate=varimax
round
flag=.40;
var OMQ18 OMQ19 OMQ20 OMQ21 OMQ22 OMQ23 OMQ24;
by _imputation_;
run;

proc factor data=mob
method=prin
priors=one
mineigen=1
scree
rotate=varimax
round
flag=.40;
var OMQ18 OMQ20 OMQ21 OMQ22 OMQ23 OMQ24;
by _imputation_;
run;

proc factor data=mob
```

```
method=prin
priors=one
mineigen=1
scree
rotate=varimax
round
flag=.40;
var OMQ4 OMQ5 OMQ11 OMQ12 OMQ14 OMQ15;
by _imputation_;
run;


proc factor data=mob
method=prin
priors=one
mineigen=1
scree
rotate=varimax
round
flag=.40;
var OMQ6 OMQ7 OMQ16 OMQ17;
by _imputation_;
run;

proc factor data=mob
method=prin
priors=one
mineigen=1
scree
rotate=varimax
round
flag=.40;
var OMQ16 OMQ17;
by _imputation_;
run;

proc factor data=mob
method=prin
priors=one
mineigen=1
scree
rotate=varimax
round
flag=.40;
var FMQ1 FMQ2 FMQ3 FMQ4 FMQ5;
by _imputation_;
run;

proc factor data=mob
method=prin
priors=one
mineigen=1
scree
rotate=varimax
round
flag=.40;
var FMQ1 FMQ2 FMQ3 FMQ4;
```

```
by _imputation_;
run;

proc factor data=mob
method=prin
priors=one
mineigen=1
scree
rotate=varimax
round
flag=.40;
var OMQ13 OMQ14 OMQ15 OMQ17 OMQ20 OMQ23 OMQ24;
by _imputation_;
run;

proc factor data=mob
method=prin
priors=one
mineigen=1
scree
rotate=varimax
round
flag=.40;
var OMQ13 OMQ14 OMQ15 OMQ23 OMQ24;
by _imputation_;
run;
```

APPENDIX I

Multiple Regression Assumption Test in SAS 9.3:

```
proc import datafile="F:\Adri\Dissertation\Original Survey Data_Reduced
Model_Regression.csv"
out=MIdata
dbms=csv
replace;
getnames=yes;
run;

data MIdata1;
set MIdata;
array a(*) LQ1--LQ7;
leadership=sum(of a[*]);
array b(*) MQ1--MQ9;
manufacturing=sum(of b[*]);
array c(*) AQ2--AQ9;
accounting=sum(of c[*]);
array d(*) SRQ1--CRQ2;
sup_and_cust_rel=sum(of d[*]);
run;

data reorder;
retain leadership manufacturing accounting sup_and_cust_rel CCQ3
OMQ1 OMQ2 OMQ3 OMQ4 OMQ5 OMQ11 OMQ12 OMQ14 OMQ15 OMQ16 OMQ17 OMQ18
OMQ20 OMQ21 OMQ22 OMQ23 OMQ24 OMQ25 FMQ1 FMQ2 FMQ3 FMQ4 CCQ2 CCQ6 CCQ7;
set MIdata1;
run;

proc mi data=reorder nimpute=5 seed=12345678 out=mob;
class CCQ3 OMQ2;
var leadership manufacturing accounting sup_and_cust_rel CCQ3 OMQ1
OMQ2;
monotone logistic (OMQ2=leadership manufacturing accounting
sup_and_cust_rel OMQ1);
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 OMQ3;
var leadership manufacturing accounting sup_and_cust_rel CCQ3 OMQ1 OMQ2
OMQ3;
monotone logistic (OMQ3=leadership manufacturing accounting
sup_and_cust_rel OMQ1 OMQ2);
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 OMQ4;
var leadership manufacturing accounting sup_and_cust_rel CCQ3 OMQ1 OMQ2
OMQ3 OMQ4;
monotone logistic (OMQ4=leadership manufacturing accounting
sup_and_cust_rel OMQ1 OMQ2 OMQ3);
```

```
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 OMQ5;
var leadership manufacturing accounting sup_and_cust_rel CCQ3 OMQ1 OMQ2
OMQ3 OMQ4 OMQ5;
monotone logistic (OMQ5=leadership manufacturing accounting
sup_and_cust_rel OMQ1 OMQ2 OMQ3 OMQ4);
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 OMQ11;
var leadership manufacturing accounting sup_and_cust_rel CCQ3 OMQ1 OMQ2
OMQ3 OMQ4 OMQ5 OMQ11;
monotone logistic (OMQ11=leadership manufacturing accounting
sup_and_cust_rel OMQ1 OMQ2 OMQ3 OMQ4 OMQ5);
run;

data mob;
set mob;
Qtot=OMQ1+OMQ2+OMQ3+OMQ4+OMQ5+OMQ11;
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 OMQ12;
var leadership manufacturing accounting sup_and_cust_rel CCQ3 Qtot
OMQ12;
monotone logistic (OMQ12=leadership manufacturing accounting
sup_and_cust_rel Qtot);
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 OMQ14;
var leadership manufacturing accounting sup_and_cust_rel CCQ3 Qtot
OMQ12 OMQ14;
monotone logistic (OMQ14=leadership manufacturing accounting
sup_and_cust_rel Qtot OMQ12);
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 OMQ15;
var leadership manufacturing accounting sup_and_cust_rel CCQ3 Qtot
OMQ12 OMQ14 OMQ15;
monotone logistic (OMQ15=leadership manufacturing accounting
sup_and_cust_rel Qtot OMQ12 OMQ14);
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 OMQ16;
var leadership manufacturing accounting sup_and_cust_rel CCQ3 Qtot
OMQ12 OMQ14 OMQ15 OMQ16;
monotone logistic (OMQ16=leadership manufacturing accounting
sup_and_cust_rel Qtot OMQ12 OMQ14 OMQ15);
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 OMQ17;
```

```
var leadership manufacturing accounting sup_and_cust_rel CCQ3 Qtot
OMQ12 OMQ14 OMQ15 OMQ16 OMQ17;
monotone logistic (OMQ17=leadership manufacturing accounting
sup_and_cust_rel Qtot OMQ12 OMQ14 OMQ15 OMQ16);
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 OMQ18;
var leadership manufacturing accounting sup_and_cust_rel CCQ3 Qtot
OMQ12 OMQ14 OMQ15 OMQ16 OMQ17 OMQ18;
monotone logistic (OMQ18=leadership manufacturing accounting
sup_and_cust_rel Qtot OMQ12 OMQ14 OMQ15 OMQ16 OMQ17);
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 OMQ20;
var leadership manufacturing accounting sup_and_cust_rel CCQ3 Qtot
OMQ12 OMQ14 OMQ15 OMQ16 OMQ17 OMQ18 OMQ20;
monotone logistic (OMQ20=leadership manufacturing accounting
sup_and_cust_rel Qtot OMQ12 OMQ14 OMQ15 OMQ16 OMQ17 OMQ18);
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 OMQ21;
var leadership manufacturing accounting sup_and_cust_rel CCQ3 Qtot
OMQ12 OMQ14 OMQ15 OMQ16 OMQ17 OMQ18 OMQ20 OMQ21;
monotone logistic (OMQ21=leadership manufacturing accounting
sup_and_cust_rel Qtot OMQ12 OMQ14 OMQ15 OMQ16 OMQ17 OMQ18 OMQ20);
run;

data mob;
set mob;
Qtot1=Qtot+OMQ12+OMQ14+OMQ15+OMQ16+OMQ17+OMQ18+OMQ20+OMQ21;
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 OMQ22;
var leadership manufacturing accounting sup_and_cust_rel CCQ3 Qtot1
OMQ22;
monotone logistic (OMQ22=leadership manufacturing accounting
sup_and_cust_rel Qtot1);
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 OMQ23;
var leadership manufacturing accounting sup_and_cust_rel CCQ3 Qtot1
OMQ22 OMQ23;
monotone logistic (OMQ23=leadership manufacturing accounting
sup_and_cust_rel Qtot1 OMQ22);
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 OMQ24;
var leadership manufacturing accounting sup_and_cust_rel CCQ3 Qtot1
OMQ22 OMQ23 OMQ24;
monotone logistic (OMQ24=leadership manufacturing accounting
sup_and_cust_rel Qtot1 OMQ22 OMQ23);
```

```
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 OMQ25;
var leadership manufacturing accounting sup_and_cust_rel CCQ3 Qtot1
OMQ22 OMQ23 OMQ24 OMQ25;
monotone logistic (OMQ25=leadership manufacturing accounting
sup_and_cust_rel Qtot1 OMQ22 OMQ23 OMQ24);
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 FMQ1;
var leadership manufacturing accounting sup_and_cust_rel CCQ3 Qtot1
OMQ22 OMQ23 OMQ24 OMQ25 FMQ1;
monotone logistic (FMQ1=leadership manufacturing accounting
sup_and_cust_rel Qtot1 OMQ22 OMQ23 OMQ24 OMQ25);
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 FMQ2;
var leadership manufacturing accounting sup_and_cust_rel CCQ3 Qtot1
OMQ22 OMQ23 OMQ24 OMQ25 FMQ1 FMQ2;
monotone logistic (FMQ2=leadership manufacturing accounting
sup_and_cust_rel Qtot1 OMQ22 OMQ23 OMQ24 OMQ25 FMQ1);
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 FMQ3;
var leadership manufacturing accounting sup_and_cust_rel CCQ3 Qtot1
OMQ22 OMQ23 OMQ24 OMQ25 FMQ1 FMQ2 FMQ3;
monotone logistic (FMQ3=leadership manufacturing accounting
sup_and_cust_rel Qtot1 OMQ22 OMQ23 OMQ24 OMQ25 FMQ1 FMQ2);
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 FMQ4;
var leadership manufacturing accounting sup_and_cust_rel CCQ3 Qtot1
OMQ22 OMQ23 OMQ24 OMQ25 FMQ1 FMQ2 FMQ3 FMQ4;
monotone logistic (FMQ4=leadership manufacturing accounting
sup_and_cust_rel Qtot1 OMQ22 OMQ23 OMQ24 OMQ25 FMQ1 FMQ2 FMQ3);
run;

data mob;
set mob;
Qtot2=Qtot1+OMQ22+OMQ23+OMQ24+OMQ25+FMQ1+FMQ2+FMQ3+FMQ4;
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 CCQ2;
var leadership manufacturing accounting sup_and_cust_rel CCQ3 Qtot2
CCQ2;
monotone logistic (CCQ2=leadership manufacturing accounting
sup_and_cust_rel Qtot2);
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 CCQ6;
```

```
var leadership manufacturing accounting sup_and_cust_rel CCQ3 Qtot2
CCQ2 CCQ6;
monotone logistic (CCQ6=leadership manufacturing accounting
sup_and_cust_rel Qtot2);
run;

proc mi data=mob nimpute=1 seed=12345678 out=mob;
class CCQ3 CCQ7;
var leadership manufacturing accounting sup_and_cust_rel CCQ3 Qtot2
CCQ2 CCQ6 CCQ7;
monotone logistic (CCQ7=leadership manufacturing accounting
sup_and_cust_rel Qtot2);
run;

data reorder;
retain leadership manufacturing accounting sup_and_cust_rel CCQ3
OMQ1 OMQ2 OMQ3 OMQ4 OMQ5 OMQ11 OMQ12 OMQ14 OMQ15 OMQ16 OMQ17 OMQ18
OMQ20 OMQ21 OMQ22 OMQ23 OMQ24 OMQ25
FMQ1 FMQ2 FMQ3 FMQ4 CCQ2 CCQ6 CCQ7;
set MIdata1;
run;

data Analysis;
set mob;
array a(*) LQ1--LQ7;
leadership=sum(of a[*]);
array b(*) MQ1--MQ9;
manufacturing=sum(of b[*]);
array c(*) AQ2--AQ9;
accounting=sum(of c[*]);
array d(*) SRQ1--CRQ2;
sup_and_cust_rel=sum(of d[*]);
array e(*) OMQ1 OMQ2 OMQ3;
quality=sum(of e[*]);
array f(*) OMQ18 OMQ20 OMQ21 OMQ22 OMQ23 OMQ24;
time=sum(of f[*]);
array g(*) OMQ4 OMQ5 OMQ11 OMQ12 OMQ14 OMQ15;
delivery=sum(of g[*]);
array h(*) OMQ16 OMQ17;
capacity=sum(of h[*]);
array i(*) OMQ25;
safety=sum(of i[*]);
array j(*) OMQ1--OMQ25;
operational_performance=sum(of j[*]);
array k(*) FMQ1--FMQ4;
financial_performance=sum(of k[*]);
array m(*) OMQ13 OMQ14 OMQ15 OMQ23 OMQ24;
accounting_performance=sum(of m[*]);
run;

proc univariate data=Analysis normal plot;
var operational_performance leadership manufacturing accounting
sup_and_cust_rel;
qqplot operational_performance /normal(mu=est sigma=est color=RED l=1);
by _imputation_;
run;
```

```
proc univariate data=Analysis normal plot;
var quality leadership manufacturing accounting sup_and_cust_rel;
qqplot quality /normal(mu=est sigma=est color=RED l=1);
by _imputation_;
run;

proc univariate data=Analysis normal plot;
var time leadership manufacturing accounting sup_and_cust_rel;
qqplot time /normal(mu=est sigma=est color=RED l=1);
by _imputation_;
run;

proc univariate data=Analysis normal plot;
var delivery leadership manufacturing accounting sup_and_cust_rel;
qqplot delivery /normal(mu=est sigma=est color=RED l=1);
by _imputation_;
run;

proc univariate data=Analysis normal plot;
var capacity leadership manufacturing accounting sup_and_cust_rel;
qqplot capacity /normal(mu=est sigma=est color=RED l=1);
by _imputation_;
run;

proc univariate data=Analysis normal plot;
var safety leadership manufacturing accounting sup_and_cust_rel;
qqplot safety /normal(mu=est sigma=est color=RED l=1);
by _imputation_;
run;

proc univariate data=Analysis normal plot;
var financial_performance leadership manufacturing accounting
sup_and_cust_rel;
qqplot financial_performance /normal(mu=est sigma=est color=RED l=1);
by _imputation_;
run;

proc univariate data=Analysis normal plot;
var accounting_performance leadership manufacturing accounting
sup_and_cust_rel;
qqplot accounting_performance /normal(mu=est sigma=est color=RED l=1);
by _imputation_;
run;

proc univariate data=Analysis normal plot;
var accounting_performance accounting;
qqplot accounting_performance /normal(mu=est sigma=est color=RED l=1);
by _imputation_;
run;

proc transreg data=Analysis;
model boxcox(operational_performance)=identity(leadership manufacturing
accounting sup_and_cust_rel);
by _imputation_;
run;

proc transreg data=Analysis;
```

```
model boxcox(quality)=identity(leadership manufacturing accounting
sup_and_cust_rel);
by _imputation_;
run;

proc transreg data=Analysis;
model boxcox(time)=identity(leadership manufacturing accounting
sup_and_cust_rel);
by _imputation_;
run;

proc transreg data=Analysis;
model boxcox(delivery)=identity(leadership manufacturing accounting
sup_and_cust_rel);
by _imputation_;
run;

proc transreg data=Analysis;
model boxcox(capacity)=identity(leadership manufacturing accounting
sup_and_cust_rel);
by _imputation_;
run;

proc transreg data=Analysis;
model boxcox(safety)=identity(leadership manufacturing accounting
sup_and_cust_rel);
by _imputation_;
run;

proc transreg data=Analysis;
model boxcox(financial_performance)=identity(leadership manufacturing
accounting sup_and_cust_rel);
by _imputation_;
run;

proc transreg data=Analysis;
model boxcox(accounting_performance)=identity(leadership manufacturing
accounting sup_and_cust_rel);
by _imputation_;
run;

data Analysis2;
set Analysis;
operational_performance2=operational_performance*operational_performanc
e;
financial_performance2=financial_performance*financial_performance;
accounting_performance2=accounting_performance*accounting_performance;
quality2=quality*quality;
time2=time*time;
delivery2=delivery*delivery;
capacity2=capacity*capacity;
safety2=safety*safety;
by _imputation_;
run;

proc univariate data=Analysis2 normal plot;
```

```
var operational_performance2 leadership manufacturing accounting
sup_and_cust_rel;
qqplot operational_performance2 /normal(mu=est sigma=est color=RED
l=1);
by _imputation_;
run;

proc univariate data=Analysis2 normal plot;
var quality2 leadership manufacturing accounting sup_and_cust_rel;
qqplot quality2 /normal(mu=est sigma=est color=RED l=1);
by _imputation_;
run;

proc univariate data=Analysis2 normal plot;
var time2 leadership manufacturing accounting sup_and_cust_rel;
qqplot time2 /normal(mu=est sigma=est color=RED l=1);
by _imputation_;
run;

proc univariate data=Analysis2 normal plot;
var delivery2 leadership manufacturing accounting sup_and_cust_rel;
qqplot delivery2 /normal(mu=est sigma=est color=RED l=1);
by _imputation_;
run;

proc univariate data=Analysis2 normal plot;
var capacity2 leadership manufacturing accounting sup_and_cust_rel;
qqplot capacity2 /normal(mu=est sigma=est color=RED l=1);
by _imputation_;
run;

proc univariate data=Analysis2 normal plot;
var safety2 leadership manufacturing accounting sup_and_cust_rel;
qqplot safety2 /normal(mu=est sigma=est color=RED l=1);
by _imputation_;
run;

proc univariate data=Analysis2 normal plot;
var financial_performance2 leadership manufacturing accounting
sup_and_cust_rel;
qqplot financial_performance2 /normal(mu=est sigma=est color=RED l=1);
by _imputation_;
run;

proc univariate data=Analysis2 normal plot;
var accounting_performance2 leadership manufacturing accounting
sup_and_cust_rel;
qqplot accounting_performance2 /normal(mu=est sigma=est color=RED l=1);
by _imputation_;
run;

proc univariate data=Analysis2 normal plot;
var accounting_performance2 accounting;
qqplot accounting_performance2 /normal(mu=est sigma=est color=RED l=1);
by _imputation_;
run;
```

APPENDIX J

Non-Response Bias Analysis in SAS 9.3:

```
proc import datafile="I:\Adri\Dissertation\Nonresponse Imputation
Data.csv"
out=nonresponse
dbms=csv
replace;
getnames=yes;
run;

data reorder;
retain response location lean communication
product sales;
set nonresponse;
run;

proc mi data=reorder nimpute=5 seed=87654321 out=mob;
class location product;
var response location lean communication product;
monotone logistic (product=response location lean communication);
run;

proc mi data=mob nimpute=1 seed=87654321 out=mob;
class location sales;
var response location lean communication product sales;
monotone logistic (sales= response location lean communication
product);
run;

proc print data=mob;
run;

proc logistic data=mob descending outest=newvalue covout;
class location product;
model response = location lean communication product sales;
by _imputation_;
run;

proc mianalyze data=newvalue;
modeleffects location1 location2 location3 lean communication product1
product2 sales;
run;
```

APPENDIX K

Multiple Regression Analysis in SAS 9.3:

```
proc reg data=Analysis2 outest=Regression2 covout;
model operational_performance2=leadership manufacturing accounting
sup_and_cust_rel;
by _imputation_;
run;

proc mianalyze data=Regression2;
modeleffects leadership manufacturing accounting sup_and_cust_rel;
run;

proc reg data=Analysis2 outest=Regression2 covout;
model quality2=leadership manufacturing accounting sup_and_cust_rel;
by _imputation_;
run;

proc mianalyze data=Regression2;
modeleffects leadership manufacturing accounting sup_and_cust_rel;
run;

proc reg data=Analysis2 outest=Regression2 covout;
model time2=leadership manufacturing accounting sup_and_cust_rel;
by _imputation_;
run;

proc mianalyze data=Regression2;
modeleffects leadership manufacturing accounting sup_and_cust_rel;
run;

proc reg data=Analysis2 outest=Regression2 covout;
model delivery2=leadership manufacturing accounting sup_and_cust_rel;
by _imputation_;
run;

proc mianalyze data=Regression2;
modeleffects leadership manufacturing accounting sup_and_cust_rel;
run;

proc reg data=Analysis2 outest=Regression2 covout;
model capacity2=leadership manufacturing accounting sup_and_cust_rel;
by _imputation_;
run;

proc mianalyze data=Regression2;
modeleffects leadership manufacturing accounting sup_and_cust_rel;
run;

proc reg data=Analysis2 outest=Regression2 covout;
model safety2=leadership manufacturing accounting sup_and_cust_rel;
by _imputation_;
run;
```

```
proc mianalyze data=Regression2;
modeleffects leadership manufacturing accounting sup_and_cust_rel;
run;

proc reg data=Analysis2 outest=Regression2 covout;
model financial_performance2=leadership manufacturing accounting
sup_and_cust_rel;
by _imputation_;
run;

proc mianalyze data=Regression2;
modeleffects leadership manufacturing accounting sup_and_cust_rel;
run;

proc reg data=Analysis2 outest=Regression2 covout;
model operational_performance2=accounting;
by _imputation_;
run;

proc mianalyze data=Regression2;
modeleffects accounting;
run;

proc reg data=Analysis2 outest=Regression2 covout;
model quality2=accounting;
by _imputation_;
run;

proc mianalyze data=Regression2;
modeleffects accounting;
run;

proc reg data=Analysis2 outest=Regression2 covout;
model time2=accounting;
by _imputation_;
run;

proc mianalyze data=Regression2;
modeleffects accounting;
run;

proc reg data=Analysis2 outest=Regression2 covout;
model delivery2=accounting;
by _imputation_;
run;

proc mianalyze data=Regression2;
modeleffects accounting;
run;

proc reg data=Analysis2 outest=Regression2 covout;
model capacity2=accounting;
by _imputation_;
run;

proc mianalyze data=Regression2;
```

```
modeleffects accounting;
run;

proc reg data=Analysis2 outest=Regression2 covout;
model safety2=accounting;
by _imputation_;
run;

proc mianalyze data=Regression2;
modeleffects accounting;
run;

proc reg data=Analysis2 outest=Regression2 covout;
model financial_performance2=accounting;
by _imputation_;
run;

proc mianalyze data=Regression2;
modeleffects accounting;
run;

proc reg data=Analysis2 outest=Regression2 covout;
model accounting_performance2=leadership manufacturing accounting
sup_and_cust_rel;
by _imputation_;
run;

proc mianalyze data=Regression2;
modeleffects leadership manufacturing accounting sup_and_cust_rel;
run;

proc reg data=Analysis2 outest=Regression2 covout;
model accounting_performance2=accounting;
by _imputation_;
run;

proc mianalyze data=Regression2;
modeleffects accounting;
run;
```

APPENDIX L

Profile Deviation Analysis in SAS 9.3:

```
proc import datafile="F:\Adri\Dissertation\Original Survey Data_Reduced
Model_PDA.csv"
out=PDA
dbms=csv
replace;
getnames=yes;
run;

title'Profile Deviation Analysis - Weighted_Leadership';
proc distance data=PDA out=PDAWLeader method=Euclid;
var interval(LQ1 LQ2 LQ3 LQ4 LQ5 LQ7 / std=mean weights=0.167);
by imputation;
id Response;
run;

title'Profile Deviation Analysis - Weighted_Manufacturing';
proc distance data=PDA out=PDAWMFG method=Euclid;
var interval(MQ1 MQ2 MQ3 MQ5 MQ6 MQ7 MQ8 MQ9 / std=mean weights=0.125);
by imputation;
id Response;
run;

title'Profile Deviation Analysis - Weighted_Accounting';
proc distance data=PDA out=PDAWACC method=Euclid;
var interval(AQ2 AQ3 AQ4 AQ5 AQ6 AQ7 AQ8 AQ9 / std=mean weights=0.125);
by imputation;
id Response;
run;

title'Profile Deviation Analysis - Weighted_S&C';
proc distance data=PDA out=PDAWSC method=Euclid;
var interval(SRQ1 SRQ2 SRQ3 CRQ1 CRQ2 / std=mean weights=0.2);
by imputation;
id Response;
run;

title'Profile Deviation Analysis - Weighted_Operational Results';
proc distance data=PDA out=YWOP method=Euclid;
var interval(OMQ1--OMQ25 / std=mean weights=0.056);
by imputation;
id Response;
run;

title'Profile Deviation Analysis - Weighted_Quality Results';
proc distance data=PDA out=YWQual method=Euclid;
var interval(OMQ1 OMQ2 OMQ3 / std=mean weights=0.334);
by imputation;
id Response;
run;
```

```
title'Profile Deviation Analysis - Weighted_Time Results';
proc distance data=PDA out=YWTime method=Euclid;
var interval(OMQ18 OMQ20 OMQ21 OMQ22 OMQ23 OMQ24 / std=mean
weights=0.167);
by imputation;
id Response;
run;

title'Profile Deviation Analysis - Weighted_Delivery Results';
proc distance data=PDA out=YWDel method=Euclid;
var interval(OMQ4 OMQ5 OMQ11 OMQ12 OMQ14 OMQ15 / std=mean
weights=0.167);
by imputation;
id Response;
run;

title'Profile Deviation Analysis - Weighted_Capacity Results';
proc distance data=PDA out=YWCap method=Euclid;
var interval(OMQ16 OMQ17 / std=mean weights=0.5);
by imputation;
id Response;
run;

title'Profile Deviation Analysis - Weighted_Safety Results';
proc distance data=PDA out=YWSaf method=Euclid;
var interval(OMQ25 / std=mean weights=1);
by imputation;
id Response;
run;

title'Profile Deviation Analysis - Weighted_Financial Results';
proc distance data=PDA out=YWFinanc method=Euclid;
var interval(FMQ1--FMQ4 / std=mean weights=0.25);
by imputation;
id Response;
run;

title'Profile Deviation Analysis - Weighted_Accounting Results';
proc distance data=PDA out=YWAcc method=Euclid;
var interval(OMQ13 OMQ14 OMQ15 OMQ23 OMQ24 / std=mean weights=0.2);
by imputation;
id Response;
run;

proc import datafile="F:\Adri\Dissertation\Original Survey Data_Reduced
Model_PDAOutcomes.csv"
out=PDA_Results
dbms=csv
replace;
getnames=yes;
run;

proc univariate data=PDA_Results normal plot;
var w_operational_performance w_leadership w_manufacturing w_accounting
w_sup_and_cust_rel;
```

```
qqplot w_operational_performance /normal(mu=est sigma=est color=RED
l=1);
by _imputation_;
run;

proc univariate data=PDA_Results normal plot;
var w_quality w_leadership w_manufacturing w_accounting
w_sup_and_cust_rel;
qqplot w_quality /normal(mu=est sigma=est color=RED l=1);
by _imputation_;
run;

proc univariate data=PDA_Results normal plot;
var w_time w_leadership w_manufacturing w_accounting
w_sup_and_cust_rel;
qqplot w_time /normal(mu=est sigma=est color=RED l=1);
by _imputation_;
run;

proc univariate data=PDA_Results normal plot;
var w_delivery w_leadership w_manufacturing w_accounting
w_sup_and_cust_rel;
qqplot w_delivery /normal(mu=est sigma=est color=RED l=1);
by _imputation_;
run;

proc univariate data=PDA_Results normal plot;
var w_capacity w_leadership w_manufacturing w_accounting
w_sup_and_cust_rel;
qqplot w_capacity /normal(mu=est sigma=est color=RED l=1);
by _imputation_;
run;

proc univariate data=PDA_Results normal plot;
var w_safety w_leadership w_manufacturing w_accounting
w_sup_and_cust_rel;
qqplot w_safety /normal(mu=est sigma=est color=RED l=1);
by _imputation_;
run;

proc univariate data=PDA_Results normal plot;
var w_financial_performance w_leadership w_manufacturing w_accounting
w_sup_and_cust_rel;
qqplot w_financial_performance /normal(mu=est sigma=est color=RED l=1);
by _imputation_;
run;

proc univariate data=PDA_Results normal plot;
var w_accounting_performance w_accounting;
qqplot w_accounting_performance /normal(mu=est sigma=est color=RED
l=1);
by _imputation_;
run;

data PDA_Results2;
set PDA_Results;
w_accounting2=w_accounting*w_accounting;
```

```
w_financial_performance2=w_financial_performance*w_financial_performanc
e;
w_quality2=w_quality*w_quality;
w_delivery2=w_delivery*w_delivery;
w_capacity2=w_capacity*w_capacity;
w_safety2=w_safety*w_safety;
by _imputation_;
run;

proc univariate data=PDA_Results2 normal plot;
var w_operational_performance w_leadership w_manufacturing
w_accounting2 w_sup_and_cust_rel;
qqplot w_operational_performance /normal(mu=est sigma=est color=RED
l=1);
by _imputation_;
run;

proc univariate data=PDA_Results2 normal plot;
var w_quality2 w_leadership w_manufacturing w_accounting2
w_sup_and_cust_rel;
qqplot w_quality2 /normal(mu=est sigma=est color=RED l=1);
by _imputation_;
run;

proc univariate data=PDA_Results2 normal plot;
var w_time w_leadership w_manufacturing w_accounting2
w_sup_and_cust_rel;
qqplot w_time /normal(mu=est sigma=est color=RED l=1);
by _imputation_;
run;

proc univariate data=PDA_Results2 normal plot;
var w_delivery2 w_leadership w_manufacturing w_accounting2
w_sup_and_cust_rel;
qqplot w_delivery2 /normal(mu=est sigma=est color=RED l=1);
by _imputation_;
run;

proc univariate data=PDA_Results2 normal plot;
var w_capacity2 w_leadership w_manufacturing w_accounting2
w_sup_and_cust_rel;
qqplot w_capacity2 /normal(mu=est sigma=est color=RED l=1);
by _imputation_;
run;

proc univariate data=PDA_Results2 normal plot;
var w_safety2 w_leadership w_manufacturing w_accounting2
w_sup_and_cust_rel;
qqplot w_safety2 /normal(mu=est sigma=est color=RED l=1);
by _imputation_;
run;

proc univariate data=PDA_Results2 normal plot;
var w_financial_performance w_leadership w_manufacturing w_accounting2
w_sup_and_cust_rel;
qqplot w_financial_performance /normal(mu=est sigma=est color=RED l=1);
by _imputation_;
```

```
run;

proc univariate data=PDA_Results2 normal plot;
var w_accounting_performance w_accounting2;
qqplot w_accounting_performance /normal(mu=est sigma=est color=RED
l=1);
by _imputation_;
run;

proc reg data=PDA_Results2 outest=Regression covout;
model w_operational_performance=w_leadership w_manufacturing
w_accounting2 w_sup_and_cust_rel;
by _imputation_;
run;

proc mianalyze data=Regression;
modeleffects w_leadership w_manufacturing w_accounting2
w_sup_and_cust_rel;
run;

proc reg data=PDA_Results2 outest=Regression covout;
model w_quality2=w_leadership w_manufacturing w_accounting2
w_sup_and_cust_rel;
by _imputation_;
run;

proc mianalyze data=Regression;
modeleffects w_leadership w_manufacturing w_accounting2
w_sup_and_cust_rel;
run;

proc reg data=PDA_Results2 outest=Regression covout;
model w_time=w_leadership w_manufacturing w_accounting2
w_sup_and_cust_rel;
by _imputation_;
run;

proc mianalyze data=Regression;
modeleffects w_leadership w_manufacturing w_accounting2
w_sup_and_cust_rel;
run;

proc reg data=PDA_Results2 outest=Regression covout;
model w_delivery2=w_leadership w_manufacturing w_accounting2
w_sup_and_cust_rel;
by _imputation_;
run;

proc mianalyze data=Regression;
modeleffects w_leadership w_manufacturing w_accounting2
w_sup_and_cust_rel;
run;

proc reg data=PDA_Results2 outest=Regression covout;
model w_capacity2=w_leadership w_manufacturing w_accounting2
w_sup_and_cust_rel;
by _imputation_;
```

```
run;

proc mianalyze data=Regression;
modeleffects w_leadership w_manufacturing w_accounting2
w_sup_and_cust_rel;
run;

proc reg data=PDA_Results2 outest=Regression covout;
model w_safety2=w_leadership w_manufacturing w_accounting2
w_sup_and_cust_rel;
by _imputation_;
run;

proc mianalyze data=Regression;
modeleffects w_leadership w_manufacturing w_accounting2
w_sup_and_cust_rel;
run;

proc reg data=PDA_Results2 outest=Regression covout;
model w_financial_performance=w_leadership w_manufacturing
w_accounting2 w_sup_and_cust_rel;
by _imputation_;
run;

proc mianalyze data=Regression;
modeleffects w_leadership w_manufacturing w_accounting2
w_sup_and_cust_rel;
run;

proc reg data=PDA_Results2 outest=Regression covout;
model w_operational_performance=w_accounting2;
by _imputation_;
run;

proc mianalyze data=Regression;
modeleffects w_accounting2;
run;

proc reg data=PDA_Results2 outest=Regression covout;
model w_quality2=w_accounting2;
by _imputation_;
run;

proc mianalyze data=Regression;
modeleffects w_accounting2;
run;

proc reg data=PDA_Results2 outest=Regression covout;
model w_time=w_accounting2;
by _imputation_;
run;

proc mianalyze data=Regression;
modeleffects w_accounting2;
run;

proc reg data=PDA_Results2 outest=Regression covout;
```

```
model w_delivery2=w_accounting2;
by _imputation_;
run;

proc mianalyze data=Regression;
modeleffects w_accounting2;
run;

proc reg data=PDA_Results2 outest=Regression covout;
model w_capacity2=w_accounting2;
by _imputation_;
run;

proc mianalyze data=Regression;
modeleffects w_accounting2;
run;

proc reg data=PDA_Results2 outest=Regression covout;
model w_safety2=w_accounting2;
by _imputation_;
run;

proc mianalyze data=Regression;
modeleffects w_accounting2;
run;

proc reg data=PDA_Results2 outest=Regression covout;
model w_financial_performance=w_accounting2;
by _imputation_;
run;

proc mianalyze data=Regression;
modeleffects w_accounting2;
run;

proc reg data=PDA_Results2 outest=Regression covout;
model w_accounting_performance=w_leadership w_manufacturing
w_accounting2 w_sup_and_cust_rel;
by _imputation_;
run;

proc mianalyze data=Regression;
modeleffects w_leadership w_manufacturing w_accounting2
w_sup_and_cust_rel;
run;

proc reg data=PDA_Results2 outest=Regression covout;
model w_accounting_performance=w_accounting2;
by _imputation_;
run;

proc mianalyze data=Regression;
modeleffects w_accounting2;
run;
```

APPENDIX M

Hierarchical Regression Analysis in SAS 9.3:

```
data Hierarchical;
set Analysis2;
if CCQ2='3' then CCQ23='1';
else CCQ23='0';
if CCQ2='2' then CCQ22='1';
else CCQ22='0';
if CCQ3='4' then CCQ34='1';
else CCQ34='0';
if CCQ3='3' then CCQ33='1';
else CCQ33='0';
if CCQ3='2' then CCQ32='1';
else CCQ32='0';
if CCQ6='5' then CCQ65='1';
else CCQ65='0';
if CCQ6='4' then CCQ64='1';
else CCQ64='0';
if CCQ6='3' then CCQ63='1';
else CCQ63='0';
if CCQ6='2' then CCQ62='1';
else CCQ62='0';
LEAD_CCQ23_int=CCQ23*leadership;
LEAD_CCQ22_int=CCQ22*leadership;
MFG_CCQ23_int=CCQ23*manufacturing;
MFG_CCQ22_int=CCQ22*manufacturing;
ACC_CCQ23_int=CCQ23*accounting;
ACC_CCQ22_int=CCQ22*accounting;
SCR_CCQ23_int=CCQ23*sup_and_cust_rel;
SCR_CCQ22_int=CCQ22*sup_and_cust_rel;
CCQ23_num=CCQ23+0;
CCQ22_num=CCQ22+0;
LEAD_CCQ34_int=CCQ34*leadership;
LEAD_CCQ33_int=CCQ33*leadership;
LEAD_CCQ32_int=CCQ32*leadership;
MFG_CCQ34_int=CCQ34*manufacturing;
MFG_CCQ33_int=CCQ33*manufacturing;
MFG_CCQ32_int=CCQ32*manufacturing;
ACC_CCQ34_int=CCQ34*accounting;
ACC_CCQ33_int=CCQ33*accounting;
ACC_CCQ32_int=CCQ32*accounting;
SCR_CCQ34_int=CCQ34*sup_and_cust_rel;
SCR_CCQ33_int=CCQ33*sup_and_cust_rel;
SCR_CCQ32_int=CCQ32*sup_and_cust_rel;
CCQ34_num=CCQ34+0;
CCQ33_num=CCQ33+0;
CCQ32_num=CCQ32+0;
LEAD_CCQ65_int=CCQ65*leadership;
LEAD_CCQ64_int=CCQ64*leadership;
LEAD_CCQ63_int=CCQ63*leadership;
```

```
LEAD_CCQ62_int=CCQ62*leadership;
MFG_CCQ65_int=CCQ65*manufacturing;
MFG_CCQ64_int=CCQ64*manufacturing;
MFG_CCQ63_int=CCQ63*manufacturing;
MFG_CCQ62_int=CCQ62*manufacturing;
ACC_CCQ65_int=CCQ65*accounting;
ACC_CCQ64_int=CCQ64*accounting;
ACC_CCQ63_int=CCQ63*accounting;
ACC_CCQ62_int=CCQ62*accounting;
ACC_CCQ7_int=CCQ7*accounting;
SCR_CCQ65_int=CCQ65*sup_and_cust_rel;
SCR_CCQ64_int=CCQ64*sup_and_cust_rel;
SCR_CCQ63_int=CCQ63*sup_and_cust_rel;
SCR_CCQ62_int=CCQ62*sup_and_cust_rel;
CCQ65_num=CCQ65+0;
CCQ64_num=CCQ64+0;
CCQ63_num=CCQ63+0;
CCQ62_num=CCQ62+0;
LEAD_CCQ7_int=CCQ7*leadership;
MFG_CCQ7_int=CCQ7*manufacturing;
ACC_CCQ7_int=CCQ7*accounting;
SCR_CCQ7_int=CCQ7*sup_and_cust_rel;
run;

proc reg data=Hierarchical outest=Results covout;
model operational_performance2=CCQ2 CCQ3 CCQ6 CCQ7;
by _imputation_;
run;

proc mianalyze data=Results;
modeleffects CCQ2 CCQ3 CCQ6 CCQ7;
run;

proc reg data=Hierarchical outest=Results covout;
model operational_performance2=leadership manufacturing accounting
sup_and_cust_rel CCQ23_num CCQ22_num LEAD_CCQ23_int MFG_CCQ23_int
ACC_CCQ23_int SCR_CCQ23_int;
by _imputation_;
run;

proc mianalyze data=Results;
modeleffects leadership manufacturing accounting sup_and_cust_rel
CCQ23_num CCQ22_num LEAD_CCQ23_int MFG_CCQ23_int ACC_CCQ23_int
SCR_CCQ23_int;
run;

proc reg data=Hierarchical outest=Results covout;
model operational_performance2=leadership manufacturing accounting
sup_and_cust_rel CCQ34_num CCQ33_num CCQ32_num LEAD_CCQ34_int
MFG_CCQ34_int ACC_CCQ34_int SCR_CCQ34_int;
by _imputation_;
run;

proc mianalyze data=Results;
modeleffects leadership manufacturing accounting sup_and_cust_rel
CCQ34_num CCQ33_num CCQ32_num LEAD_CCQ34_int MFG_CCQ34_int
ACC_CCQ34_int SCR_CCQ34_int;
```

```
run;

proc reg data=Hierarchical outest=Results covout;
model operational_performance2=leadership manufacturing accounting
sup_and_cust_rel CCQ65_num CCQ64_num CCQ63_num CCQ62_num LEAD_CCQ65_int
MFG_CCQ65_int ACC_CCQ65_int SCR_CCQ65_int;
by _imputation_;
run;

proc mianalyze data=Results;
modeleffects leadership manufacturing accounting sup_and_cust_rel
leadership manufacturing accounting sup_and_cust_rel CCQ65_num
CCQ64_num CCQ63_num CCQ62_num LEAD_CCQ65_int MFG_CCQ65_int
ACC_CCQ65_int SCR_CCQ65_int;
run;

proc reg data=Hierarchical outest=Results covout;
model operational_performance2=leadership manufacturing accounting
sup_and_cust_rel LEAD_CCQ7_int MFG_CCQ7_int ACC_CCQ7_int SCR_CCQ7_int;
by _imputation_;
run;

proc mianalyze data=Results;
modeleffects leadership manufacturing accounting sup_and_cust_rel
LEAD_CCQ7_int MFG_CCQ7_int ACC_CCQ7_int SCR_CCQ7_int;
run;

proc reg data=Hierarchical outest=Results covout;
model financial_performance2=CCQ2 CCQ3 CCQ6 CCQ7;
by _imputation_;
run;

proc mianalyze data=Results;
modeleffects CCQ2 CCQ3 CCQ6 CCQ7;
run;

proc reg data=Hierarchical outest=Results covout;
model financial_performance2=leadership manufacturing accounting
sup_and_cust_rel CCQ23_num CCQ22_num LEAD_CCQ23_int MFG_CCQ23_int
ACC_CCQ23_int SCR_CCQ23_int;
by _imputation_;
run;

proc mianalyze data=Results;
modeleffects leadership manufacturing accounting sup_and_cust_rel
CCQ23_num CCQ22_num LEAD_CCQ23_int MFG_CCQ23_int ACC_CCQ23_int
SCR_CCQ23_int;
run;

proc reg data=Hierarchical outest=Results covout;
model financial_performance2=leadership manufacturing accounting
sup_and_cust_rel CCQ34_num CCQ33_num CCQ32_num LEAD_CCQ34_int
MFG_CCQ34_int ACC_CCQ34_int SCR_CCQ34_int;
by _imputation_;
run;

proc mianalyze data=Results;
```

```
modeleffects leadership manufacturing accounting sup_and_cust_rel
CCQ34_num CCQ33_num CCQ32_num LEAD_CCQ34_int MFG_CCQ34_int
ACC_CCQ34_int SCR_CCQ34_int;
run;

proc reg data=Hierarchical outest=Results covout;
model financial_performance2=leadership manufacturing accounting
sup_and_cust_rel CCQ65_num CCQ64_num CCQ63_num CCQ62_num LEAD_CCQ65_int
MFG_CCQ65_int ACC_CCQ65_int SCR_CCQ65_int;
by _imputation_;
run;

proc mianalyze data=Results;
modeleffects leadership manufacturing accounting sup_and_cust_rel
leadership manufacturing accounting sup_and_cust_rel CCQ65_num
CCQ64_num CCQ63_num CCQ62_num LEAD_CCQ65_int MFG_CCQ65_int
ACC_CCQ65_int SCR_CCQ65_int;
run;

proc reg data=Hierarchical outest=Results covout;
model financial_performance2=leadership manufacturing accounting
sup_and_cust_rel LEAD_CCQ7_int MFG_CCQ7_int ACC_CCQ7_int SCR_CCQ7_int;
by _imputation_;
run;

proc mianalyze data=Results;
modeleffects leadership manufacturing accounting sup_and_cust_rel
LEAD_CCQ7_int MFG_CCQ7_int ACC_CCQ7_int SCR_CCQ7_int;
run;

proc reg data=Hierarchical outest=Results covout;
model accounting_performance2=CCQ2 CCQ3 CCQ6 CCQ7;
by _imputation_;
run;

proc mianalyze data=Results;
modeleffects CCQ2 CCQ3 CCQ6 CCQ7;
run;

proc reg data=Hierarchical outest=Results covout;
model accounting_performance2=leadership manufacturing accounting
sup_and_cust_rel CCQ23_num CCQ22_num LEAD_CCQ23_int MFG_CCQ23_int
ACC_CCQ23_int SCR_CCQ23_int;
by _imputation_;
run;

proc mianalyze data=Results;
modeleffects leadership manufacturing accounting sup_and_cust_rel
CCQ23_num CCQ22_num LEAD_CCQ23_int MFG_CCQ23_int ACC_CCQ23_int
SCR_CCQ23_int;
run;

proc reg data=Hierarchical outest=Results covout;
model accounting_performance2=leadership manufacturing accounting
sup_and_cust_rel CCQ34_num CCQ33_num CCQ32_num LEAD_CCQ34_int
MFG_CCQ34_int ACC_CCQ34_int SCR_CCQ34_int;
by _imputation_;
```

```
run;

proc mianalyze data=Results;
modeleffects leadership manufacturing accounting sup_and_cust_rel
CCQ34_num CCQ33_num CCQ32_num LEAD_CCQ34_int MFG_CCQ34_int
ACC_CCQ34_int SCR_CCQ34_int;
run;

proc reg data=Hierarchical outest=Results covout;
model accounting_performance2=leadership manufacturing accounting
sup_and_cust_rel CCQ65_num CCQ64_num CCQ63_num CCQ62_num LEAD_CCQ65_int
MFG_CCQ65_int ACC_CCQ65_int SCR_CCQ65_int;
by _imputation_;
run;

proc mianalyze data=Results;
modeleffects leadership manufacturing accounting sup_and_cust_rel
leadership manufacturing accounting sup_and_cust_rel CCQ65_num
CCQ64_num CCQ63_num CCQ62_num LEAD_CCQ65_int MFG_CCQ65_int
ACC_CCQ65_int SCR_CCQ65_int;
run;

proc reg data=Hierarchical outest=Results covout;
model accounting_performance2=leadership manufacturing accounting
sup_and_cust_rel LEAD_CCQ7_int MFG_CCQ7_int ACC_CCQ7_int SCR_CCQ7_int;
by _imputation_;
run;

proc mianalyze data=Results;
modeleffects leadership manufacturing accounting sup_and_cust_rel
LEAD_CCQ7_int MFG_CCQ7_int ACC_CCQ7_int SCR_CCQ7_int;
run;

proc reg data=Hierarchical outest=Results covout;
model accounting=CCQ2 CCQ3 CCQ6 CCQ7;
by _imputation_;
run;

proc mianalyze data=Results;
modeleffects CCQ2 CCQ3 CCQ6 CCQ7;
run;

proc reg data=Hierarchical outest=Results covout;
model operational_performance2=accounting CCQ23_num CCQ22_num
ACC_CCQ23_int;
by _imputation_;
run;

proc mianalyze data=Results;
modeleffects accounting CCQ23_num CCQ22_num ACC_CCQ23_int;
run;

proc reg data=Hierarchical outest=Results covout;
model operational_performance2=accounting CCQ34_num CCQ33_num CCQ32_num
ACC_CCQ34_int;
by _imputation_;
run;
```

```
proc mianalyze data=Results;
modeleffects accounting CCQ34_num CCQ33_num CCQ32_num ACC_CCQ34_int;
run;

proc reg data=Hierarchical outest=Results covout;
model operational_performance2=accounting CCQ65_num CCQ64_num CCQ63_num
CCQ62_num ACC_CCQ65_int;
by _imputation_;
run;

proc mianalyze data=Results;
modeleffects accounting CCQ65_num CCQ64_num CCQ63_num CCQ62_num
ACC_CCQ65_int;
run;

proc reg data=Hierarchical outest=Results covout;
model operational_performance2=accounting ACC_CCQ7_int;
by _imputation_;
run;

proc mianalyze data=Results;
modeleffects accounting ACC_CCQ7_int;
run;

proc reg data=Hierarchical outest=Results covout;
model financial_performance2=accounting CCQ23_num CCQ22_num
ACC_CCQ23_int;
by _imputation_;
run;

proc mianalyze data=Results;
modeleffects accounting CCQ23_num CCQ22_num ACC_CCQ23_int;
run;

proc reg data=Hierarchical outest=Results covout;
model financial_performance2=accounting CCQ34_num CCQ33_num CCQ32_num
ACC_CCQ34_int;
by _imputation_;
run;

proc mianalyze data=Results;
modeleffects accounting CCQ34_num CCQ33_num CCQ32_num ACC_CCQ34_int;
run;

proc reg data=Hierarchical outest=Results covout;
model financial_performance2=accounting CCQ65_num CCQ64_num CCQ63_num
CCQ62_num ACC_CCQ65_int;
by _imputation_;
run;

proc mianalyze data=Results;
modeleffects accounting CCQ65_num CCQ64_num CCQ63_num CCQ62_num
ACC_CCQ65_int;
run;

proc reg data=Hierarchical outest=Results covout;
```

```
model financial_performance2=accounting ACC_CCQ7_int;
by _imputation_;
run;

proc mianalyze data=Results;
modeleffects accounting ACC_CCQ7_int;
run;

proc reg data=Hierarchical outest=Results covout;
model accounting_performance2=accounting CCQ23_num CCQ22_num
ACC_CCQ23_int;
by _imputation_;
run;

proc mianalyze data=Results;
modeleffects accounting CCQ23_num CCQ22_num ACC_CCQ23_int;
run;

proc reg data=Hierarchical outest=Results covout;
model accounting_performance2=accounting CCQ34_num CCQ33_num CCQ32_num
ACC_CCQ34_int;
by _imputation_;
run;

proc mianalyze data=Results;
modeleffects accounting CCQ34_num CCQ33_num CCQ32_num ACC_CCQ34_int;
run;

proc reg data=Hierarchical outest=Results covout;
model accounting_performance2=accounting CCQ65_num CCQ64_num CCQ63_num
CCQ62_num ACC_CCQ65_int;
by _imputation_;
run;

proc mianalyze data=Results;
modeleffects accounting CCQ65_num CCQ64_num CCQ63_num CCQ62_num
ACC_CCQ65_int;
run;

proc reg data=Hierarchical outest=Results covout;
model accounting_performance2=accounting ACC_CCQ7_int;
by _imputation_;
run;

proc mianalyze data=Results;
modeleffects accounting ACC_CCQ7_int;
run;
```