3-15-2013

Exploring lean implementation success factors in job shop, batch shop, and assembly line manufacturing settings

Daniela Todorova

Exploring Lean Implementation Success Factors in

Job Shop, Batch Shop, and Assembly Line Manufacturing Settings

by

Daniela Todorova

Dissertation

Submitted to the College of Technology

Eastern Michigan University

in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY IN TECHNOLOGY

Concentration in Engineering Management

Dissertation Committee:

Dr. Dugger, Ph. D, Dissertation chair

Dr. Haddad, Ph.D

Dr. Bellamy, Ph.D

Dr. Fields, Ph.D

Dr. Dobrzykowski, Ph.D

March 15, 2013

Ypsilanti, Michigan

Abstract

This study was motivated by the differences in manufacturing settings, which provide challenges for those organizations undertaking a lean implementation. The levels of applicability of sixteen lean tools were examined in three different manufacturing settings: a job shop, a batch shop, and an assembly line. Specifically, this study explored the perceptions of managers familiar with lean regarding which lean tools were associated with better operational performance. The level of satisfaction with the lean programs in each of the three manufacturing settings was explored as well. The data were collected through a survey that was emailed to one thousand managers working in manufacturing companies located in the US.

The results revealed that different lean tools are used at different levels in the three manufacturing settings, and the lean tools contributing most to the group differences were *Heijunka* (HEIJ), *Just in Time* (JIT) and *Kaizen* (KAIZ). The analysis revealed statistically significant positive relationships between the perceived operational performance of firms in job shop and batch shop settings and the implementation of *Workers Involvement* (WINV) and *Muda Elimination* (MUDA) *lean* tools. Assembly line settings had statistically significant positive relationships with the implementation of *Standardized Work* (STANDW) and *Value Stream Mapping* (VSM). The results highlighted the importance of *Workers Involvement* (WINV), which is consistent with prior work.

The managers' satisfaction with the *lean* program was most associated with the implementation of *Heijunka* (HEIJ) in a job shop setting, *Workers Involvement* (WINV) in a batch shop setting, and *Continuous Flow* (CONTFL) in an assembly line setting. This study presents a decision-making model which can be helpful in the successful implementation of the lean paradigm in each of the three manufacturing settings. A number of recommendations for future research are proposed.

Dedication

To my daughter, Iva; son, Tsvetoslav; husband, Ivo;

and parents, Vera and Ivan,

for their understanding

and support.

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to Dr. Dugger, chair of my dissertation committee, and to Dr. Dobrzykowski, member of my dissertation committee, for their support, guidance, encouragement, and valuable input throughout the dissertation process. I would also like to thank the other dissertation committee members: Dr. Fields, Dr. Bellamy, and Dr. Haddad for their valuable advice, support, and feedback throughout this process.

I am grateful to all faculty members at the College of Technology who taught me during the PhD program. Gratitude is extended to the judges in the Q-sort pilot testing, for their time and effort to provide assistance and expert advice during the instrument development. I am also grateful to Dennis Holmquist for his help with the data collection and to all lean professionals who took my survey and made this study possible.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1: Introduction and Background

Lean production is applicable in a variety of business contexts (Hong et al., 2010). The goal of lean was defined by Kim et al. (2006, p. 195) as "….transforming waste into value from the customer's perspective" and by Shah and Ward (2007) as eliminating waste by reducing variability of supply, processing time, and demand. The lean approach is "…a principle-based system of management whose objective is to change the way all work activities are performed, not just those in operations" (Emiliani & Stec, 2005, p. 384). However, the benefits of implementing lean may vary based on an individual organization's settings and goals (Mackelprang & Nair, 2010). Many companies are willing to implement lean manufacturing because of the improved competitive advantage, but creating a lean success trajectory is a difficult process because of the uniqueness of each lean implementation (Lewis, 2000). "Only 2 percent of companies who began a lean transformation have fully achieved their objectives" (Pay, 2008, p. 1).

The lean tools, supporting lean implementations, are Just in Time, Continuous Flow, Heijunka, Quick Set Up, Jidoka, Poke-Yoke, Andon, Standardized Work, the Five S's, Total Productive Maintenance, Visual Management, Kaizen, Multifunctional Teams, Workers Involvement, Value Stream Mapping, and Muda elimination (Dennis, 2007; Detty & Yingling, 2000; Fang & Kleiner, 2003; Fullerton & Watters 2001; Fullerton et al., 2003; Faizul & Lamb, 1996; Miltenburg, 2007; Liker, 2004; Veech, 2001).

Hayes and Wheelwright (1984) introduced four types of manufacturing settings: job shop, batch shop, assembly line, and continuous flow, each one with different characteristics. Hayes and Wheelwright (1984) felt that such a classification system would be useful in determining which process is the most appropriate for each product life cycle.

Statement of the Problem

Although a number of lean tools have been identified and generally accepted, these tools have not been sufficiently examined regarding their level of use in the various categories of manufacturing settings as identified by Hayes and Wheelwright (1984).

Elements of a Lean Implementation

Lean should be viewed more as a philosophy or condition than as a process (Bhasin & Burcher, 2004). A successful lean implementation requires dramatic changes at all organizational levels and departments involving work organization and culture (Sohal, 1996). Moreover, the firm who implements a lean approach will need a decision making system based on bottom up measures, quality reports and vendors reliability and adapted control system by "... linking compensation rewards to quality results" (Fullerton & McWatters, 2002, p. 730). *Lean* has to be seen as a direction, not as a reached after certain time state (Karlsson & Ahlstrom1996). In *Lean Thinking*, Womack and Jones (1996) identified five lean principles essential for successful lean implementation: (a) specify value, (b) identify the value stream, (c) flow, (d) pull, (e) perfection. In addition, Liker (2004, pp. 37-40) proposed the 14 Toyota principles listed in Table 1.

Table 1

Toyota's 14 Principles

	Sections		Principles
1	Long-term philosophy	1	Base your management decision on a long term philosophy (Customer is the starting point)
2	The right process will produce the right results	2 3 4 5 6 7 8	Continuous Flow Pull Level out the work load (Heijunka) Get quality right the first time (Jidoka) Standardized task Visual control Reliable Equipment
3	Add value to the organization by developing your people and partners	9 10 11	Grow leaders from within Develop exceptional people Respect your partners and help them improve
4	Continuously solving root problems drive organizational learning	12 13 14	Go and see for yourself Make decision slowly considering all options Become learning organization through reflection and Kaizen

Lean principles are defined by Womack and Jones (1996) and Liker (2004) as the basis for a successful lean implementation. Shah et al. (2008) wrote that lean principles reflect the flow and standardization and are crucial for the competitive advantage of a manufacturing firm.

Since the heart of the Toyota production system is elimination of the wastes at all levels (Liker, 2004; Dennis, 2007; Womack & Jones, 1996; Bhasin & Burcher, 2006), it is important to categorize the types of waste. Liker (2004) identified three types of waste: Muda, Muri, and Mura. *Muda* is defined as non-value adding operations. *Muri* and *Mura* are defined as overburden (of people and equipment) and unevenness respectively. The eight non value-adding operations of Muda are (a) correction/scrap, (b) over-production; (c) waiting; (d) conveyance; (e) processing; (f) inventory; (g) motion (Dennis, 2007; Womack & Jones, 1996; Liker, 2004); and (h) unused employees' creativities (Liker, 2004).

Several research efforts (Liker, 2004; Dennis, 2007; Womack & Jones, 1996) have addressed these eight wastes, but little attention has been paid to Muri—overburden of people and equipment—or Mura—unevenness (Liker, 2004). Lean is about the elimination of all three types of waste—Muda, Muri and Mura—not only the eight known wastes of Muda (Dennis, 2007; Liker, 2004).

The success of a lean implementation in an organization depends on the human element (Sawhney & Chason, 2005). Continuous improvement and respect for people are the two key principles of the Toyota production system (Emiliani & Stec, 2005), while the employees are the heart (Dennis, 2007). "The root of the Toyota way is encouraging people continuously to improve the process they work on. …It is the people who bring the system to life and make it work" (Liker 2004, p. 36). Recent research efforts listed in Table 2 have identified a few essentials that contribute to lean success.

Table 2

Lean Success Factors

Lean Success Factors	Literature
Leadership commitment	Achanga et al., 2006; Dickson et al., 2009; Scherrer-Rathje et al., 2009; Emiliani and Stec, 2005
Local culture	Achanga et al., 2006; Dickson et al., 2009; Emiliani and Stec, 2005
Skills and expertise	Achanga et al., 2006
Workforce's flexibility to change	Dickson et al., 2009
Autonomy	Scherrer-Rathje et al. 2009; Emiliani and Stec, 2005
Long-term lean goals	Scherrer-Rathje et al. 2009; Emiliani and Stec, 2005

To convert an organization into a lean learning organization, the right combination of a long-term philosophy, processes, people, and problem solving is needed (Liker, 2004). *Lean* is about changing corporate culture and reducing waste at all levels (Bhasin & Burcher, 2006).

Barriers to Success

According to Pay (2008), "Only 2 percent of companies who began a lean transformation have fully achieved their objectives and only 24 percent of these companies reported achieving significant results. That leaves 74 percent of the responding companies admitting that they are not making good progress with lean" (p. 1).

Dickson et al. (2009) reported that reasons for the failure of a lean implementation include (a) lean is not implemented properly or (b) the social context is not taken into account. In addition, the "bottom-up" approach to a lean implementation produces a cascading effect of problems such as "lack of senior management commitment, lack of team autonomy, and lack of organizational communication of, and interest in, lean" (Scherrer-Rathje, 2009, p. 81) or the company lacks the right people in the right positions (Pay, 2008).

"Cherry picking" single tools and practices in manufacturing and engineering without consideration of the environment within the system is a reason for failure or only partial success of many lean initiatives (Morgan & Liker, 2006). According to Liker (2004), the problem is that "…companies have mistaken a particular set of lean tools for deep 'lean thinking.' Lean thinking based on the Toyota Way involves a far deeper and more pervasive cultural transformation than most companies can begin to imagine" (pp. 10, 11). However, without "a total end-to-end view, companies often fail to migrate to a lean enterprise" (Loftus, 2006, p. 46).

Emiliani and Stec (2005) identified two types of lean manufacturing adopted by the companies: "real lean" and "imitation lean." "Real lean" refers to the faithful adoption of the lean management system across the entire enterprise, consistent with the lean principles even when modified to work with the specific company culture. “Imitation lean” occurs when only selected lean principles and practices are adopted. The author clarified that “imitation lean” focuses on continuous improvement just as a tool, and “respect for people” as part of the lean culture is missed.

Implementing “real lean” is a long and difficult process involving a commitment from all management levels (Emiliani, 2004). An important key for a successful implementation is that the first team member has to be the company CEO (Raymond, 2006). In addition, lean implementation success depends on the “….relationship between the external facilitator, internal line managers and the sponsor of the lean project, including those who work the processes” (Atkinson, 2010, p. 41).

Rationale for the Study

Lean is popular in a variety of manufacturing and service businesses and has been the focus of many scholarly investigations. Lewis (2000) stated that creating a lean success trajectory is a difficult process because of the uniqueness of each individual lean implementation. The lean research efforts identified many reasons why companies fail to implement lean, but many questions remain. The relationship between organizational culture and radical changes required for a lean implementation is not clear (Nahm et al., 2003), nor is the effect of size and industry type on a lean implementation (Shah & Ward, 2003).

Four types of manufacturing settings have been identified by Hayes and Wheelwright (1984): job shop, batch shop, assembly line and continuous flow. The job shop relies on knowledge of the workers and is characterized by high flexibility, many different products, and low volumes (NetMBA, 2011), such as a machine tool shop, a machining center, or a paint shop.

Hayes and Wheelwright (1984) described a job shop as producing “small batches of a large number of different products” requiring different processing steps. In addition, Montreuil et al. (1999, p. 501) defined a job shop as “manufacturing units that process a variety of individual products requiring diverse workstation types in varied sequences” with different product routes and lack of a dominant flow pattern. Characteristics of a job shop are variability in the job demand, constantly changing product mix, and small to medium volume, which makes a production line uneconomical to set up.

The batch shop is characterized with moderate flexibility, several products, and moderate volumes. The products are produced in batches with disconnected activities; usually set-up time is required for change from one product to another (NetMBA, 2011). Examples of this include injection-molding manufacturing. Hayes and Wheelwright (1984) described the batch shop as a standardized job shop with stable line of products. A batch production process is useful for highly customized products in low volumes; it enables the buffering of the manual work into the production system leading to innovation (Cooney, 2002).

The assembly line is associated with low flexibility, a few products, and high volumes. The sequence of activities is fixed (NetMBA, 2011), such as in an automobile plant. Moreover, the assembly line consists of sequenced workstations producing highly similar products (Hayes & Wheelwright, 1984) with operators performing assembly tasks, and product moving from workstation to workstation (Eswaramoorthi et al., 2011).

Continuous flow is characterized by very low flexibility, one product, and very high volume. The sequence of action is fixed; usually the product is measured with weight or volume (NetMBA, 2011), like petroleum refinery or sugar refinery. In process manufacturing, the materials flow from one machine to another without stopping (Ha, 2007).

Most of the lean success stories are from companies with market and product technology similar to Toyota's: limited product offerings, with only cosmetic customization, high volume production, repetitive manufacturing and stable or predictive demand (Lander & Liker, 2007), which is an assembly line production. Safizadeh et al. (1996) found that firms with different process choices have a different competitive priority. As an example: Job shop and batch organizations stress flexibility and speed of response, while mass and process production emphasize reliability, productivity, and lower cost (Han, 1997). Moreover, according to Cua et al. (2001), the "….process type plays a significant role in differentiating performance" (p. 688). Despite the uniqueness of the individual implementations, there is a possibility for "…generating useful, contingent descriptions of the lean production development trajectory" (Lewis, 2000, p. 971). Kim et al. (2006) clarified that lean is unique because of the specified value from the customer's perspective. The "universality" of lean applications depends upon business conditions (Cooney, 2002). Moreover, Shingo (1981) explained that the lean is universally applicable after adaptation to the characteristics of each industry or plant.

White and Prybutok (2001) found out that an association between the type of production system and lean manufacturing implementation exists. Lean manufacturing as a concept is well understood and addressed by many research efforts, but its applicability to high value, low volume complex products has not been determined (James-Moore & Gibbons, 1997). The unchanged lean formula is applicable to a small sector of manufacturers; for most manufacturers, good judgment is needed to adapt to the company's circumstances (Jina et al., 1997). In addition, which of the lean principles and tools are relevant to a specific environment is important for successful lean implementations (Corbett, 2007). Consequently, if the appropriate fit between the manufacturing processes and lean tools is defined, the companies will be able to implement lean, sustain the results, and improve organizational performance.

Purposes of the Research

One purpose of this study was to examine the level of use of the sixteen lean tools as defined by Liker (2004), Dennis (2007), and Womack and Jones (1996) in the different settings of manufacturing operations identified by Hayes and Wheelwright (1984): job shop, batch shop, and assembly line. The relationship between the type of manufacturing category and the levels of use of the lean tools in each manufacturing category was tested through Hypothesis 1 (See Figure 1). Moreover, a prioritization of the lean tools on which the different types of manufacturing settings could emphasize during a successful lean implementation was proposed.

Another purpose of this study was to explore whether a relationship exists between the perceived operational performance and the alignment of the identified lean tools with the type of manufacturing category. In addition, this study investigated whether a relationship exists between the perceived satisfaction with a lean program and the alignment of the identified lean tools with the type of manufacturing category. The moderating effect of the type of manufacturing settings on the relationships between the levels of use of the lean tools and the perceived operational performance was tested through Hypothesis 2. The moderating effect of the type of manufacturing settings on the relationships between the levels of utilization of the lean tools and the satisfaction with the lean program was tested through Hypothesis 3 (See Figure 1). For definitions, please refer to Chapter 2.

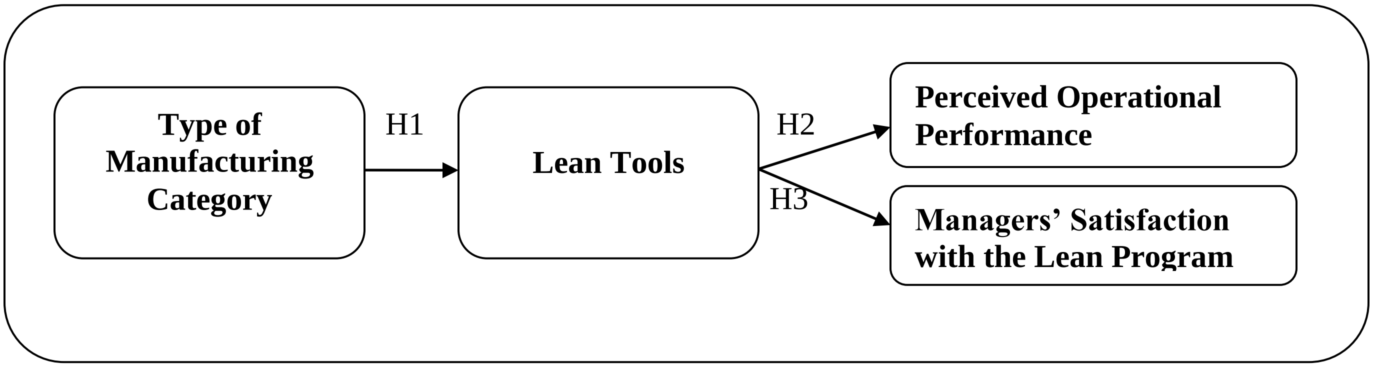

Figure 1. Theoretical Model

Research Questions

Lander and Liker (2007) suggested that the successful lean implementation depends on designing and implementing specific tools for your organization, achieving the lean objectives, and supporting your people. Based on the literature review, the level of use of the different lean tools to the different categories of manufacturing organizations is crucial for a successful lean implementation (Corbett, 2007). This study addressed three research questions related to successful lean implementation in job shop, batch shop, and assembly line manufacturing settings:

RQ1: Are the sixteen lean tools perceived by respondents to be equally used in job shop, batch shop, and assembly line manufacturing settings?

RQ2: Is there a relationship between the operational performance of the firm as perceived by the respondents and the perceived alignment of the lean tools with the type of manufacturing setting?

RQ3: Is there a relationship between the reported satisfaction with the lean program and the perceived alignment of the lean tools with the type of manufacturing setting?

Research hypothesis. Grounded in the contingency theory and in the universality of lean dependent on different contextual factors (Chapter 2), the present study hypothesized:

H1 (Null): There will be no significant difference between the degrees of utilization of each lean tool, when the companies are grouped by the three manufacturing settings: job shop, batch shop, and assembly line.

This study hypothesized:

H2 (Null): The type of manufacturing setting will not have a significant moderating effect on the relationship between the lean tools and the operational performance as perceived by the respondents.

H3 (Null): The type of manufacturing setting will not have a significant moderating effect on the relationship between the lean tools and the respondents' satisfaction with the lean program.

Delimitations and Limitations

The study was limited to manufacturing companies located in the US that were in some stage of lean implementation. Data were collected using an electronic survey-questionnaire using a checklist and a rating scale. A limitation of this survey research was that it captured a fleeting moment in time and relied on self-reported data (Leedy & Ormrod, 2005). In addition, surveys rely on participant honesty, and the quality of data obtained depends on how well the respondents understand the survey item or question (Passmore & Parchman, 2002). Another limitation was that the personal biases could not be controlled. Moreover, when using an online survey, there was a probability of sampling bias issues (Selm & Jankowski, 2006). A delimitation was that only three of the four settings identified by Hayes and Wheelwright (1984) were used for this study. The study was further delimitated to Lean Enterprise Institute members and LinkedIn Continuous Improvement group members.

Assumptions

It was assumed that all survey takers would provide honest answers to the survey questions and that the chosen instrument would reflect accurately the lean implementations and the perceptions of the respondents.

Definition of Terms

Continuous flow: The product flow, at rate one piece at a time, from one process to another without WIP inventory between the processes (Dennis, 2007; Liker, 2004).

Five S: S-sort, S-set in order, S-shine, S-standardize, and S-sustain (Dennis, 2007).

Heijunka: Production leveling (Dennis, 2007).

Jidoka: automation with human touch (Dennis, 2007).

Kaizen: continuous improvement through employees' contribution to the company's development (Brunet & New, 2003).

Kanban: system of visual tools synchronizing the production (Dennis, 2007).

Muda: Waste (Dennis, 2007).

Mura: Unevenness (Dennis, 2007).

Muri: Overburden of people and equipment (Dennis, 2007).

Poka-yoke: Error-proofing device (Dennis, 2007).

Pull: product is manufactured when is placed the actual order (Haaster et al., 2010).

Standardization: current best practices for each process (Detty & Yingling, 2000).

Total productive maintenance (TPM): progressive maintenance methodologies in which shop floor employees perform basic maintenance work (Dennis, 2007).

Value Stream Map: material and information flow diagram (Dennis, 2007).

Work-in-process (WIP): inventory between the different processes (Dennis, 2007).

Summary

This chapter introduced the background of lean manufacturing and described the problems encountered when implementing lean and justified the need to explore the level of utilization of the different lean tools in the three manufacturing settings: job shop, batch shop, and assembly line. In the next chapter, a review of related to the topic literature provides more information about the lean manufacturing and the types of manufacturing categories.

Chapter 2: Review of the Literature

This chapter provides a summary of the current literature relevant to the definition and purpose of lean manufacturing, the difficulty when implementing and sustaining lean, the benefits achieved when lean is successfully implemented, the need for lean in order to keep more manufacturing in the US, and the universality of lean when implemented in different types of businesses. Moreover, this chapter provides information about the three types of manufacturing settings: job shop, batch shop, and assembly line.

Lean Manufacturing

Researchers defined lean as a philosophy, a process, a systems approach, a method and a business strategy. "Lean manufacturing is a comprehensive philosophy for structuring, operating, controlling, managing, and continuously improving industrial production systems" (Detty & Yingling, 2000, p. 429). Moreover, lean is a collection of tools and techniques, incorporated in the business processes with goal optimizing time, human resources, assets, productivity, and improving the quality level (Becker, 1998). Lean is a systems approach with integrated value delivery processes (Allen, 2000), a total lean enterprise system concentrated on elimination of non-value added activity (Haaster et al., 2010) and a dynamic process driven by set of principles and practices (Womack et al., 1990). According to the National Institute of Standards and Technology Manufacturing Extension Partnership's Lean Network, "Lean manufacturing is a systematic approach to identifying and eliminating waste through continuous improvement, flowing the product at the pull of the customer in pursuit of perfection" (Kilpatrick, 2003, p. 1)

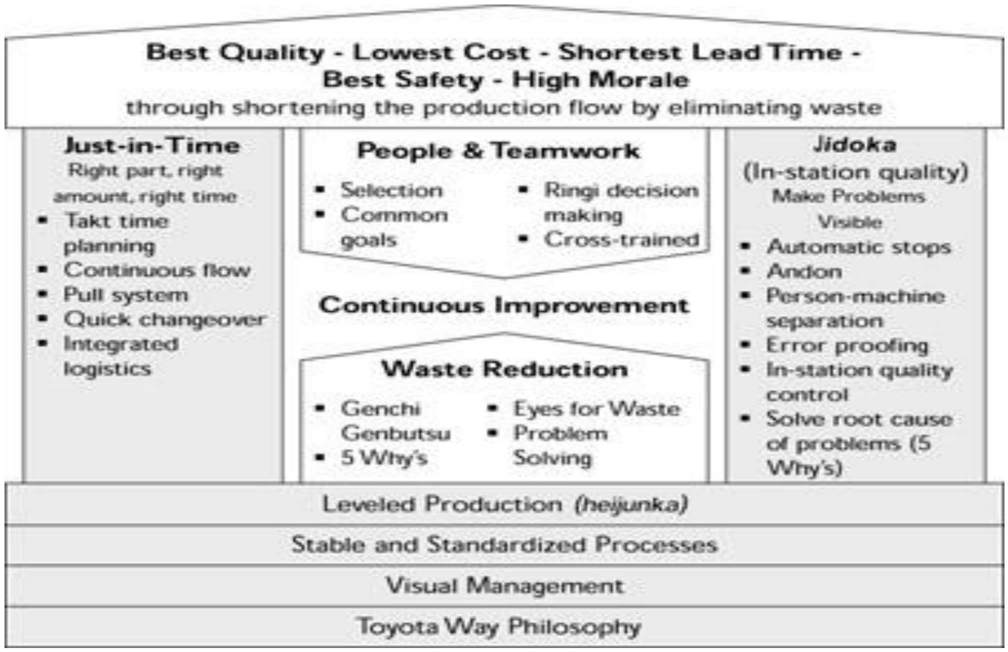

Figure 2. Toyota Production System house

Source: Liker, J. K. (2004, p. 33). *Toyota way 14 management principles from the world's greatest manufacturer*. New York: McGraw-Hill

Lean manufacturing has synonyms such as lean production and just-in-time (Kilpatrick, 2003). Moreover, in a manufacturing environment, the term lean also refers to the Toyota Production System (TPS) established by the Toyota Corporation (Chen et al., 2010).

At the present time, lean is the most effective way of manufacturing (Kristjuhan, 2010). However, lean is not the application of a few lean tools on the shop floor but a complete change of the way everyone relates in an organization when performing their daily work (Melton, 2005). The adoption of lean involves "…complex evolutionary process of organizational learning and interpretation" (Lee & Jo, 2007, p. 3665). The focus of lean manufacturing is based on the combination of human and technological subsystems, because Kanban, heijunka, and autonomaton are part of the technological system, while creative thinking, problem solving, and team work are part of the human system (Paez et al., 2004).

The three underlying lean elements are philosophical underpinnings, managerial culture, and technical tools (Dibia & Onuh, 2010). Other lean characteristics are team-based work, organization with cross-functional teams, shop floor problem solving, lean operations, high employee commitment, involved suppliers, and make-to-order strategy (Sohal & Egglestone, 1994). In addition, lean manufacturing combines product development, supplier management, customer management, and policy focusing processes for the whole organization (Holweg, 2007). Finally, lean manufacturing coordinates all processes in the chain from the customer to the supplier (Smeds, 1994).

Implementing lean. "Optimal lean implementation depends on using effective lean mechanisms within the boundaries of system constraints and strategic goals" (Deif, 2011, pp. 11-12). For a successful lean implementation, a decision-making system is needed which is based on bottom-up measures, quality reports, vendors' reliability, and an adapted control system linking compensation rewards to quality results (Fullerton & McWatters, 2002). Moreover, essential is the development of comprehensive in scope and content, plant specific manufacturing strategies (Crute et al., 2003). A successful lean implementation requires dramatic changes at all organizational levels and departments, involving work organizational and cultural issues (Sohal, 1996).

Black (2007, p. 3645) proposed seven preliminary steps for successful lean implementation:

1. Education of everybody in the plant on lean production philosophy and concepts,
2. Top-down commitment,

3. Financial decision based on the lean practices as lean accounting,
4. Selection of measurable parameters that track organizational changes,
5. Full involvement of production workers,
6. The company must share the gains with those who contributed, and
7. The middle management reward structure must support the system design.

Liker et al. (1998) grouped Toyota managerial practices into six organizational mechanisms: mutual adjustment, close supervision, integrative leadership from product heads, standard skills, standard work processes, and design standards, which are working well as a whole, but alone each one of them would accomplish little. On the other hand, Allen (2000) defined the five phases of lean implementation as stability, continuous flow, synchronized production, pull system, and leveled production. “Activities, connections, and production flows are standardized and rigidly specified to provide the necessary performance and flexibility to supply a wide range of standardized products at low costs” (Alfnes & Strandhagen, 2000, p. 5).

According Crute et al. (2003), the lean capabilities are plant specific. In order to work, the Toyota product development system must be redesigned to suit the uniqueness of each organization and must be integrated in the overall system, realizing the potential of the best practiced and tools (Liker et al., 1998).

Sohal (1996) wrote that employees’ education and training is a foundation of all change initiatives and is critical for successful lean implementation. Other success factors are management’s commitment to changes and active involvement in the improvement initiatives (Sohal & Egglestone, 1994) and culture supporting autonomous working (Crute et al., 2003), or in other words, a leadership dedicated to lean. Becoming lean requires tremendous learning and a high level of commitment to the process (Chen et al., 2010).

Hines and Holwe (2004) believed that many companies focused on lean implementations on the shop floor, while to be successful, lean must be implemented in the entire organization. Moreover, when implementing lean, the focus usually is on the tangible aspects, overlooking the most important human aspects (Dibia & Onuh, 2010).The benefits of lean are attained through creating a lean learning culture, not by a few quick fixes to reduce the cycle time and cost and increase quality (Liker & Morgan, 2005). Lean is a direction, not a reached-after-a-certain time state (Karlsson & Ahlstrom, 1996).

The starting point of every lean implementation is the identification and definition of the value from the customer's perspective (Melton, 2005; Kim et al., 2006). Identifying value-added activities (Pepper & Spedding, 2010) and resources (Poppendieck, 2002) is the next step. The development of standardized work instructions, reducing wastes and involving the entire work force in the optimization process, is also important (Burg, 2009). Spear (2004) suggested four rules for successful lean implementation:

1. There is not another replacement for direct observation.
2. Proposed changes should be tested as an experiment before implementing.
3. Experiment as frequently as possible.
4. Managers should use coaching style management.

Respect for people and continuous improvement are the most important business principles of TPS, because the Toyota success dependents on the effort of every team member to identify problems, reduce inventory, and eliminate waste (Smith, 2006). Lean manufacturing relies on the shop floor workers to coordinate production flow through minimizing work in process inventory and throughput times (Alfnes & Strandhagen, 2000). Human resources are important factors contributing to the successful lean implementation; they are the initiative of processes, business, and continuous improvement activities (Dibia & Onuh, 2010). In the lean environment, variances and uncertainty are easily managed through teamwork and group problem solving, leading to decentralized decision-making (Forza, 1996).

Sustaining lean. Sustaining a lean culture is not easy because it requires workers dedicated to continuous improvement, accepting that there exists a better way of doing everything (Flinchbaugh, 2006). According Liker and Rother (n.d.), "The Shingo Prize committee, which gives awards for excellence in lean manufacturing, went back to past winners and found that many had not sustained their progress after winning the award" (p. 1). The lean system functions properly in a social collaborative environment with foreseeable and reliable production resources (Forza, 1996). An open environment of timely information sharing, communication, trust, and openness between the employees is necessary (Sohal, 1996).

The lean achievement is sustainable through implementing teamwork for problem solving, employees' suggestion program, quality feedback, statistical process control, standardized procedures, and employees performing a variety of tasks (Forza, 1996). In addition, everyone must be involved in the transformation changes and must understand that the well-being of the firm means job security for everyone (Sohal, 1996).

The TPS is working with a flat hierarchy, democratic culture, understanding that the employees and managers have a common interest in the well-being of organization (Fang & Kleiner, 2003). Lean culture characteristics are the decentralization of responsibility to the production workers and the decrease of hierarchic levels in the company (Sanchez & Perez, 2001).

Sustainable lean improvement is achieved when the local culture adapts to and embraces the lean principles (Dickson et al., 2009). A sustainable lean culture is contingent on the "training and development targeted at learning and knowledge sharing, compensation and reward schemes, and focus on lean as a means towards career development" (Jorgensen et al., 2007, p. 377). Similarly, lean should be seen as a direction, not as a state, reached after a certain time (Karlsson & Ahlstrom, 1996). Moreover, sustainable success of lean depends on the appropriate assessment tool taking into account technical and organizational perspectives (Jorgensen et al., 2007). Toyota culture is built and sustained through company uniforms, songs, after-work social gathering (Fang & Kleiner 2003), and a high level of continuous leadership commitment to lean (Dickson et al., 2009). The lean implementation is a long-term strategy with incorporated continuous improvement (Loftus, 2006).

Benefits of lean. Lean manufacturing is a very effective management system, achieving better results while using less of everything: half the human effort, half the manufacturing space, half the engineering hours, and decreased labor cost (Dibia & Onuh 2010; Sohal & Egglestone, 1994). The lean manufacturing companies design and distribute products in less than half the time that other companies do (Sohal, 1996).

The goal of lean is reduction of labor, space, capital, and delivery time (Taninecz, 2005). The benefits of implementing lean are achieved through associated improvement techniques and methodologies (Katayama & Bennett, 1996), but they vary in different manufacturing systems (Lima et al., n.d.). "Companies which have adopted the lean production concepts can typically design, manufacture, and distribute products in less than half the time taken by other companies" (Sohal, 1996, p. 92).

Table 3

Lean Benefits

Lean Benefits	Literature
Reduction of lead time	Koenigsaecker, 2005; Pavnaskar et al., 2010
Reduction of accidents	Koenigsaecker, 2005;
Reduction in customers complaint	Koenigsaecker, 2005;
Reduction in floor space	Koenigsaecker, 2005; Pavnaskar et al., 2010
Improved quality	Chen et al., 2010; Pavnaskar et al., 2010
Reduced processing time	Chen et al., 2010;
Reduction of WIP inventory level	Chen et al., 2010; Cudney, 2010;
Easily traceable quality problems	Chen et al., 2010;
Simplified communication	Chen et al., 2010;
Time-based responses	Fullerton and Watters, 2001;
Employee flexibility	Fullerton and Watters, 2001;
Accounting simplification	Fullerton and Watters, 2001;
Increased firm profitability	Fullerton and Watters, 2001;
Inventory reductions	Fullerton and Watters, 2001; Cudney, 2010;
Reduced scraps cost	Cudney, 2010; Pavnaskar et al., 2010
Improved delivery time	Cudney, 2010; Pavnaskar et al., 2010
Increased flexibility	Sohal and Egglestone, 1994;
Lowering of cycle times	Sohal and Egglestone, 1994;
Greater sensitivity to market changes	Sohal and Egglestone, 1994;
Increased productivity levels	Sohal and Egglestone, 1994; Cudney, 2010; Pavnaskar et al., 2010
Stronger focus on performance	Sohal and Egglestone, 1994;
Improved supplier bonds	Sohal and Egglestone, 1994;
Reduced labor	Cudney, 2010; Pavnaskar et al., 2010
Increased machine utilization	Cudney, 2010; Pavnaskar et al., 2010

Need for lean. During the past decade, the U.S. manufacturing companies have faced increased pressure from customers and competitors (Chen et al., 2010). In order to meet the customers' high expectations, manufacturers have to increase product quality, reduce delivery time, and minimize the product cost or implement new production strategy (George, 2002). Quality products with varying production requirements, short lead-time, and small delivery lots are today customer's demands, forcing manufacturers to adopt lean initiatives such as setup time reduction, continuous flow, and quality improvements (Fullerton & Wempe, 2008).

Despite the natural and economic resources (Fullerton & Watters, 2001), the U.S. manufacturing companies do not have a big choice when competing with low-cost foreign suppliers (Flinchbaugh, 2005). However, the competitiveness of the current market place and globalization has forced the U.S. firms to look for better ways of doing business (Fullerton & Watters, 2001; Flinchbaugh, 2005). Different firms take different approaches: investing in new equipment, eliminating job positions, or using what they already have in a more efficient manner (Flinchbaugh, 2005; Reeb & Leavengood, 2010). The increased customer expectations require implementing a new production strategy: some manufacturing companies have moved their production over the border, while others have decided to implement lean and increase their competitiveness in the global arena (Chen et al., 2010)

The most important fact about lean is that it can save jobs and the company can keep manufacturing in the USA (Burg, 2009). Even the public sector of the US is aiming to become lean (Comm & Mathaisel, 2000). "Today lean production has become the goal of manufacturers aiming for world-class status" (Sohal, 1996, p. 92).

The competitive advantage of the manufacturing firms is dependent on greater product variety, customer focus, and mass customization at reasonable prices (Alfnes & Strandhagen, 2000). In addition, the competitive advantage of manufacturing firms is accomplished through quality beyond the competition and technology before the competition or, on the other hand, better, faster, and cheaper, which is a characteristic of lean (Comm & Mathaisel, 2000). “Achieving long term competitive advantage depends on the firm understanding how to position its manufacturing skills vis a vis its competitors” (Fine & Hax, 1985, p. 30).

Dibia and Onuh (2010) explained that lean is a significant enabler in the manufacturing world because new customers’ expectations are high quality, customer-driven products, cost effectiveness, technology, and new human resources practices. Powerful business drivers, delivering value to shareholders, are cost reduction and innovations (Dlott, 2011). The U.S. manufacturing landscape is transforming itself through the lean production paradigm (Fullerton & Wempe, 2008). “Lean manufacturing has proved to be one of the most successful tools that manufacturing facilities can employ” (Green et al., 2010, p. 2992). Because of the increased global competition, almost every manufacturing industry is willing to implement lean (Pavnaskary et al., 2003; Vinodh & Chintha, 2011).

Applicability of lean to different businesses. The lean principles, developed by TPS, are not restricted to only large multinational companies, but they are also applicable to small and medium-sized firms (Karlsson & Ahlstrom, 1996). Incidentally, different aspects of lean are implemented in larger and small firms (White et al., 1999). Quality controls, total preventive maintenance, set-up time reduction, and kanban are implemented in the large businesses, while the multifunction employee concept is implemented in the small businesses (Shah & Ward, 2003).

Lean manufacturing is applicable to the aerospace industry, resulting in a high level of process and product quality along with low cost and significant reduction in lead times (Crute et al., 2003; Cudney, 2010). However, the problems when implementing lean in aerospace are very similar to high volume sectors such as automobiles (Crute et al., 2003). Moreover, lean is well understood and successfully applied in the software development practices, resulting in many benefits (Poppendieck, 2002). Similarly, lean when applied in the construction and forest products industries improves efficiency and competitiveness (Reeb & Leavengood, 2010; Höök & Stehn, 2008). The application of lean in many industry sectors has resulted in performance improvement (Reichhart & Holweg, 2007). Finally, the lean principles are applied to a range of business processes, although there continues to be the existing challenges of transferring lean from the production floor to the service area (Taninecz, 2005).

Lean measures. "Leanness" is a lean performance measure, defined by Vinodh and Balaji (2011). For this reason Wan and Chen (2008) proposed a "unit- invariant" leanness measure quantifying the leanness of the manufacturing systems through extracting "….the value-adding investments from a production process to determine the leanness frontier as a benchmark" (p. 6567). Moreover, the application of lean principles is measured by "…faster throughput times for in-bound, work in progress (WIP) and out-bound material; smaller manufacturing batch sizes; shorter set-up and change-over times and greater 'up time'; greater schedule stability; lower rework and rectification costs" (Jina et al., 1997, p. 5).

On the other hand, Jing and Xuejun (2009) explained that lean production is an integrated social technology system, where the implementation can be measured by measuring the implementation degree of "…. team work, simple structure, multi skill, employee involvement, visualization, training, skill based and group based performance pay, organizational support, kanban, set up time reduction, cell manufacturing, group technology, statistical process control, preventive maintenance, supplier involvement, and customer focus" (p. 549).

Lean tool and construct definitions. *Just in Time* (JIT) is one of the pillars of the Lean House (Liker, 2004; Dennis, 2007) and a key lean production element (Hines, 1996). JIT is defined as the extent to which the parts are delivered in the right quantity at the right time using the minimum necessary resources (Sanchez & Perez, 2001; Haak, 2006; Detty & Yingling, 2000, Kasul & Motwani, 1997). JIT is also called a “pull system,” in which the product is manufactured when the actual order is placed and the firm produces only what is needed in requested quantities and time (Haaster et al., 2010; Dennis, 2007). The purpose of pull production is to match production with demand (Detty & Yingling, 2000; Kilpatrick, 2003).

The benefits of JIT are lower inventory, space and cost savings, reduced risk of obsolesce, and reduced response time (Beard & Butler, 2000; Haak, 2006; Haaster et al., 2010; Billesbach & Hayen, 1994). According Fullerton et al. (2003), positive relationships exist between the degrees to which waste reduction practices, profitability of the firm, and marginal return to long-term JIT investment are implemented.

Beard and Butler (2000) explained that actually JIT theory differs from JIT practice, because different industries have different manufacturing processes, and JIT is not applicable to all of them. For successful implementation of JIT, human resources support and understanding is a crucial factor (Gupta et al., 2000). Moreover, the master production schedule is very deterministic for the JIT system (Faizul & Lamb, 1996). JIT is supported through Kanban, a card or other visual control, pulling production through the manufacturing process (Melton, 2005). Kanban is a pull signal, controlling work in process inventory (de Araujo & de Queiroz, 2005) and indicating how much material is needed and when (Kilpatrick, 2003). Adler et al. (1997) explained that NUMMI did not use a computer production schedule, but instead used kanban, signaling that the downstream needed something to be produced.

Kanban is a scheduling system replacing what has been used by the next process, resulting in minimum inventory and shorter lead-time (Kasul & Motwani, 1997). Two kinds of Kanban are identified by Kasul and Motwani (1997): (a) Withdrawal Kanban “specifies the kind and quantity of product which the subsequent process should withdraw from the preceding process” (p. 277) and (b) Production Kanban “specifies the kind and quantity of product which the preceding process must produce” (p. 277). In cases when pure flow is not possible because of different cycle times between processes or another reason, the Kanban system is the next choice (Liker, 2004).

Continuous Flow (CONTFL) is defined as the extent to which the product flows one piece at a time, from one process to another without WIP inventory between the processes (Dennis, 2007; Liker, 2004). Flow is the most difficult concept to understand, because first one needs an understanding of the linkage of events and activities delivering value to the customer (Melton, 2005). Continuous flow is achieved through the implementation of work cells, which is a technique arranging operations in a cell with one piece flow and better use of people and equipment (Kilpatrick, 2003). Disconnected processes and people or areas with material stagnation are signs that the workflow has to increase through cells implementation (Lander & Liker, 2007).

Because the ideal batch size, one, is not always applicable, when working in batches, the goal is to decrease the batch size as low as possible (Kilpatrick, 2003). As a first step in the lean journey, Liker (2004) recommended creating continuous flow whenever applicable to the processes. Continuous flow is created through defining value from the customers’ perspective and moving machines and people together (Dennis, 2007). “Flow is at the heart of the lean message that shortening the elapsed time from raw materials to finished goods will lead to the best quality, lowest cost, and shortest delivery time" (Liker, 2004 pp. 87, 88).

Heijunka (HEIJ) is defined as the extent to which the production is leveled over a defined period in order to achieve constant flow of mixed parts and to minimize peaks and valleys in the workload (Furmans, 2005., Haaster et al., 2010, Adler et al., 1997; Coleman & Vaghefi, 1994; Deif, 2011; Hampson, 1999; Huttmeir et al., 2009). In addition, *heijunka* is defined as a production planning method, taking into account process leads, capacities, external demand, and *takt time* to mix the items' sequence in the most efficient way (Coleman & Vaghefi, 1994). On the other hand, *heijunka* is defined as a manufacturing strategy eliminating the overproduction and synchronizing all production operations to match customer demand (Deif, 2011, Detty & Yingling, 2000). Heijunka prevents uneven workloads or having too many of one part and not enough of another (Kasul & Motwani, 1997).

Production leveling aims to smooth the product line utilization, to level the workload, and to set up standardized processes (Průša & Schacherl, 2007). Consequently, even work distribution results in stable and even output and creates a continuous flow, which is required for lean manufacturing (Haaster et al., 2010). Leveling production is achieved through quick change over small lots and mixed model-sequenced product scheduling (Detty & Yingling, 2000).

Quick Set Up (QSETUP) is defined as the extent to which the amount of time for change-over is reduced from running one product to another (Kilpatrick, 2003). The leveling of production quantity requires that one product be manufactured for a specific time, called *takt time* (Art of Lean, Inc., n.d.). According to Melton (2005), the single-minute exchange of dies is a change over reduction technique. Reduced "change over" time is necessary to avoid costs associated with heijunka (Adler et al., 1997).

The other pillar of the lean house is called automation with a human touch or Jidoka. *Jidoka* (JID) is defined as the extent to which quality is built into the process through people and machine detection of abnormal conditions, preventing defective parts passing to the next process and determining and eliminating the root cause (Hinckley, 2007; Art of lean, Inc., n.d.; Veech, 2001; Dennis, 2007). Moreover, jidoka refers to machine autonomous monitoring for defects. With automatic stopping devices triggered by a defect or poor quality products, in the case of continuous flow, the whole production line can stop until the defect is fixed (Haak, 2006; Haaster et al., 2010; Detty & Yingling, 2000). Jidoka is an interaction of team members and machinery, bringing attention to the problems (Veech, 2001). The best automation is achieved through constantly revised manufacturing strategies (Morey, 2008). Suzuki (2004) identified two kinds of jidoka: the first one stops a machine when a problem occurs, while the second one stops a machine when the processing is complete. The main purpose of jidoka is to produce defect-free products (Kasul & Motwani, 1997). High quality is achieved through implementation of mistake-proofing devices and inspecting one hundred percent of the time (Hinckley, 2007).

Poka-Yoke (PYOKE) is defined as the extent to which the error-proofing device has low cost, high reliability, and is designed for specific work place conditions (Melton, 2005; Dennis, 2007). In the lean manufacturing environment, the mistakes are controlled through mistake-proofing devices, which are the most cost efficient and quality reliable alternative (Hinckley, 2007). Poke-yoke is a low cost simple device, detecting abnormal situations before they occur, or stopping the line to prevent a defect. The poke-yoke requirement is long life, low maintenance, high reliability, low cost and designed for the specific work place conditions (Dennis, 2007).

Andon (AND) is defined as the extent to which the device allows everyone working on the production line to stop the production if a defect is detected (Kasul & Motwani, 1997).

Standardized Work (STANDW) is defined as the extent to which the best practices are standardized and used as a basis for improvement (Detty & Yingling, 2000; Dennis, 2007; Liker, 2004). Standardization is the responsibility of the shop floor employees to identify the current best practices for each process and use them as a benchmark for improvement (Detty & Yingling, 2000). Standardized work, guiding the workers responsible for cell performance and output, is the foundation of lean manufacturing (Whitmore, 2008). The primary purpose of standardization is providing a basis for improvement; it stands on the beliefs that there is no one best way to do the work and that the employees doing the work are able to create the best work design (Dennis, 2007). Moreover, the standardization is constantly changing because of improvement suggestions from Muda elimination (Dennis, 2007). A Standardized Work Analysis Chart is a document combining the job elements in a waste-free work sequence (Dennis, 2007; Art of Lean, Inc., n.d.). On the other hand, Quality Check sheets define required quality checks (Art of Lean, Inc., n.d.)

5 S system (FIVES) is defined as the extent to which the workplace is organized and standardized (Dennis, 2007; Liker, 2004). According to Melton (2005), 5S is a visual housekeeping technique, transferring control to the shop floor. Kilpatrick (2003) described the 5S as “systematic method for organizing and standardizing the workplace” (p. 3). Moreover, in a lean transformation, 5S is the first tool implemented, providing immediate return on investments and applicable to every function in the organization (Kilpatrick, 2003). The purpose of 5S is to create a visual workplace: self-explaining, self-ordering, and self-improving (Dennis, 2007). The first S stands for Sort—keep only what is needed; the second S stands for Straighten—create a place for everything; the third S stands for Shine—cleaning so that abnormal and pre-failure conditions are exposable; the fourth S stands for Standardize—to create rules to maintain and monitor the first 3s, and the fifth S stands for Sustain—create self-discipline for continuous improvement (Liker, 2004).

Total Productive Maintenance (TPM) is defined as the extent to which everyone on the shop floor is involved in preventive basic maintenance work (Dennis, 2007; Liker, 2004). TPM is a progressive maintenance methodology dependent on the knowledge and cooperation of operators and support personal, with a goal of achieving longer equipment life, reliable equipment, lower maintenance costs, and improved utilization and quality (Kilpatrick, 2003). Moreover, “TPM assigns basic maintenance work such as inspection, cleaning, lubricating, and tightening to production team members” (Dennis, 2007, p. 45).

Visual management (VISM) is the extent to which value-added information is displayed to everyone (Hogan, 2009; Dennis, 2007). With visual management, the problems are apparent to all because the production operations status is displayed to all workers. The visual information creates a self-directing, self-explaining and self-improving workplace (Hogan, 2009). Information distribution is essential for the manufacturing teams, in order to perform according to the company’s goals (Karlsson & Ahlstrom, 1996). TPS visual management communicates information to all employees (Kasul & Motwani, 1997). Kilpatrick (2003) defined visual management as simple signals providing immediate and obvious understanding of a situation within a short period. Visual management is a communication aid, a tool driving real time operations and processes (Parry & Turnerz, 2006), and a method for a shop floor performance measurement (Melton, 2005).

Toyota strategy is based on lasting cost reduction, with high quality, availability, and customer satisfaction, achieved through continuous improvement (Alukal, 2007). *Kaizen* (continuous improvement; KAIZ) is defined as the extent to which employees contribute to the company's development through suggestions aimed at elimination of all kinds of waste (Boyer, 1996; Alukal, 2007; Dennis, 2007; Imai, 1997). Kaizen is a Toyota management philosophy involving everyone working for the company contributing to continuous improvement of the structures and systems with the goal of eliminating all kinds of waste (Haak, 2006). Kaizen "….consists of pervasive and continual activities, outside the contributor's explicit contractual roles, to identify and achieve outcomes he believes contribute to the organizational goals" (Brunet & New, 2003, p. 1428). Employees' creativity and idea generation is the basis of continuous improvement (Alukal, 2007). The connection between lean and growth is Kaizen, which eliminates manufacturing and administrative wastes and depends on employees' engagement (Hettler, 2008).

The workers' training in problem solving is a very important element of continuous improvement (Adler et al., 1997). The base of lean production is well trained and multi-skilled workers, creating an environment which promotes continuous improvement (Boyer, 1996). The goal of continuous improvement is improving safety, quality, and productivity through working in employee teams (Detty & Yingling, 2000). Kaizen refers to the gradual improvement made over time (Manos, 2007).

According Adler et al. (1997), workers' participation in the suggestion program is a reliable measure of plant performance. Kaizen-oriented suggestions are applicable to organizations with process- and result-oriented employees, empowered and committed to company's long-term viability, with free flow of information (Recht & Wilderom, 1998).

A Team (TEAM) is defined as the extent to which employees with complementary skills work together to achieve a common goal (Sanchez & Perez, 2001; Karlsson & Ahlstrom, 1996). At Toyota, teamwork is promoted through shared vision and purpose (Alukal, 2007), and the workers rotate every two hours and share their mistakes with their fellow workers (Bodek, 2008). The purpose of teamwork is the transferring of responsibilities to the production workers and reducing indirect labor costs, because beside the production, the teamwork requires maintenance and material handling (Sanchez & Perez, 2001). The success of NUMMI is based on cross-trained workers rotating between different tasks (Adler et al., 1997). The success and sustainability of the TPS depends on the team members, the power of highly skilled motivated workforce as the most competitive advantage of any company, because satisfying and motivating the team members is the primary goal of a lean company (Veech, 2001).

In a lean environment, product teams and personnel management are working together to achieve common goals (Haak, 2006). Manufacturing teamwork is essential for a successful lean organization, resulting in improved quality, shorter cycle time, and lower costs (Jina et al., 1997). Cross training is a method for achieving multi-skilled employees, which is the requirement for increasing flexibility in meeting fluctuating demand, creating a shared sense of responsibility, and balancing the workload in a lean manufacturing organization (McDonald et al., 2009). At the beginning, the training of employees reduces the profit margin, but it is a long-term investment, resulting in the achievement of the lean benefits (Fullerton et al., 2003). When implementing lean, the first step is improving people's skills, because this step is directly related to the success of continuous process improvement (Veech, 2001).

Workers involvement (WINV) is defined as the extent to which employees are motivated to participate in continuous improvement and problem-solving activities (Bodek, 2010; Fullerton & Wempe, 2008). The human side of lean is very important in implementing a team-based environment in which employees follow the standards and use all tools and lean techniques (Alukal, 2007). All of the keys to lean manufacturing are dependent on people doing the work

(Dibia & Onuh, 2010). The successful implementation of TPS depends on creating and sustaining high level of worker involvement because employees decide when to stop the line, develop the standardization, and generate the kaizen ideas (Adler et al., 1997). Moreover, Fullerton and Wempe (2008) confirmed in their study that successful adoption of lean manufacturing depends on the shop floor employee involvement. Only the front line workers can identify and fix small problems (Dennis, 2007). Working out a plan for a personal growth is a good motivator because the employees feel that they are in charge of their own lives, and by contributing to the organization they are contributing to their growth (Bodek, 2010).

The most important for Kaizen success is employees' motivation to participate and implement small but constant improvements to the shop-floor activities (Imai, 1997). Self-efficiency motivates team members to participate in problem-solving and continuous improvement activities (Veech, 2001). Another motivator is the involvement of "production line workers in the identification and adjustment of defective parts, in order to prevent defective parts from arriving at the quality control department" (Sanchez & Perez, 2001, p. 1436). Confidence in job security is essential for workers to bring ideas (Detty & Yingling, 2000).

Value Stream Mapping (VSM) is defined as the extent to which the current process is mapped to make the improvement opportunities obvious (Dennis, 2007; Hettler, 2008). When improving a process, the first step is to create a baseline value stream map (Jovag, 2011). A value stream map makes the wastes in the process obvious and is a visual representation of the value- and no-value-added materials and information moving through the process (Hettler, 2008). If implemented correctly, *Value Stream Mapping* (VSM) defines the current and desirable state of the system, provides a reliable analysis tool (Pepper & Spedding, 2010), tracks the redesign of the production system (Serrano et al., 2008), and helps in identifying and eliminating wastes (Seth & Gupta, 2005)

The value stream map is a communication tool and the foundation for decision-making (Hettler, 2008). The current value stream is mapped to serve as a basis for improvement; the ideal value stream is mapped as a future direction with only value added processes (Hettler, 2008).

Muda (MUDA) is defined as the extent to which the activity or the process is not value-added (Dennis, 2007). There are eight types of Muda within lean:

1. Overproduction Muda is defined as the extent to which unordered items are produced (Liker, 2004). Overproduction generates storage, transportation, inventory, maintenance, labor, and energy costs (Liker, 2004).
2. Overprocessing Muda is defined as the extent to which the items are processed more than is the customer's requirement, producing higher than necessary quality parts (Dennis, 2007; Liker, 2004).
3. Excess inventory Muda is defined as the extent to which unnecessary raw materials, parts, and WIP are kept. Problems as production imbalance, late delivery from suppliers, long set-up times, and equipment downtime are hidden behind the excess inventory (Liker, 2004).
4. Correction/scrap Muda is defined as the extent to which defective parts are reworked or corrected (Liker, 2004).
5. Conveyance Muda is defined as the extent to which work in process inventory is conveyed long distances or parts are moved between processes (Dennis, 2007; Liker, 2004).

6. Waiting Muda is defined as the extent to which the workers wait for material or for the next processing steps, parts, and so on (Dennis, 2007; Liker, 2004).
7. Motion Muda is defined as the extent to which employees perform unnecessary motion (Dennis, 2007; Liker, 2004).
8. Unused employees creativity Muda is defined as the extent to which improvement and learning opportunities are lost (Liker, 2004)

Operational Performance (OPPER) is defined as the extent to which the firm's operational performance indicators focus on the key operational success factors leading to financial performance (Venkatrama & Ramanujam, 1986). The implication of the lean practices is related to improvements in the firm operational performance measures as quality cost scrap and rework cost, productivity costs, cycle time and customer lead-time (Shah & Ward, 2003).

Satisfaction (SATISF) is defined as the extent to which "one's feelings or attitudes toward a variety of factors affecting the situation" are summed (Legris et al., 2003, p. 192; Bailey & Pearson, 1983, p. 531). Three categories of variables measuring satisfaction were identified by Cheney (1986): uncontrollable, partly controllable, and fully controllable. Ives et al. (1983) linked satisfaction with the needs addressed by the system. However, the satisfaction is a critical factor in determining the success or failure of the system implementation (Doll & Torkzadeh, 1988; Bailey & Pearson, 1983). "Satisfaction cannot be evaluated directly using an objective measure" (Dehghan & Shahin, 2011, p. 3; Dehghan & Trafalis, 2012, p. 154). Palvia (1996) proposed a comprehensive model measuring user satisfaction with technology.

Table 4

Construct Definitions

Construct	Construct Definition	Literature
Just in Time (JIT)	The extent to which is produced the right item, at right time, in right quantity when is placed an actual order.	Dennis, 2007; Detty and Yingling, 2000; Fang and Kleiner, 2003; Fullerton and Watters, 2001; Fullerton et al., 2003; Faizul and Lamb, 1996; Miltenburg, 2007; Liker, 2004; Veech, 2001
Continuous Flow (CONTFL)	The extent to which, the product flow, at rate one piece at a time from one process to another without WIP inventory between the processes.	Dennis, 2007; Liker, 2004; Fullerton and Wempe, 2008; Allen, 2000; Veech, 2001; Haaster et al., 2010
Heijunka (HEIJ)	The extent to which the workload and production is leveled over defined period in order to achieve constant flow of mixed parts and to minimize the peaks and valleys in the workload.	Furmans, 2005; Haaster et al., 2010; Adler et al., 1997; Coleman and Vaghefi, 1994; Deif, 2011; Hampson, 1999; Huttmeir et al., 2009
Quick Set Up (QSETUP)	The extent to which is reduced the amount of time for change over from running one product to another.	Kilpatrick, 2003; Dennis, 2007; Detty and Yingling, 2000;
Jidoka (JID)	The extent to which quality is built into the process through people and machine detecting abnormal conditions, preventing defective parts of passing to the next process and determining and eliminating the root cause.	Dennis, 2007; Haak, 2006; Haaster et al., 2010; Detty and Yingling, 2000; Hinckley, 2007; Kasul and Motwani,1997; Morey, 2008; Sugimorit et al., 1997; Liker, 2004; Suzuki, 2004;
Poke Yoke (PYOKE)	The extent to which the error proofing device is low cost, high reliability, and designed for specific work place conditions.	Melton, 2005; Dennis, 2007
Andon (AND)	the extent to which the devise allows everyone working on the production line to stop the production if defect is detected	Kasul and Motwani, 1997
Standardized Work (STANDW)	the extent to which the best practices are standardized and used as a base for improvement	Höök and Stehn, 2008; Dennis, 2007; Detty and Yingling, 2000; Melton, 2005; Whitmore, 2008; Liker, 2004;

5 S system (FIVES)	The extent to which the workplace is organized and standardized.	Dennis, 2007; Liker, 2004; Veech, 2001; Melton, 2005; Kilpatrick, 2003
Total Productive Maintenance (TPM)	The extent to which everyone on the shop floor is involved in preventive basic maintenance work.	Dennis, 2007; Liker, 2004; Kilpatrick, 2003; Shah and Ward, 2007
Visual Management (VISM)	The extent to which value added information is displayed to everyone.	Hogan, 2009; Dennis, 2007; Adler et al., 1997; Kasul and Motwani, 1997; Parry and Turnerz, 2006; Melton, 2005; Kilpatrick, 2003
Kaizen (Continuous Improvement) (KAIZ)	The extent to which employees contribute to the company's development through suggestions aiming elimination of all kinds of wastes.	Alukal, 2007; Bernett and Nentl, 2010; Adler et al., 1997; Boyer, 1996; Sanchez and Perez, 2001; Brunet and New, 2003; Detty and Yingling, 2000; Haak, 2006; Harari, 1997
Teams (TEAM)	The extent to which team members with supplementary skills work together to achieve common goals.	Sanchez and Perez, 2001; Karlsson and Ahlstrom, 1996; Detty and Yingling, 2000; Haak, 2006; Dennis, 2007; Liker, 2004
Workers Involvement (WINV)	The extent to which employees are motivated to participate in continuous improvement and problem-solving activities.	Bodek, 2010; Fullerton and Wempe, 2008; Alukal, 2007; Dibia and Onuh, 2010; Adler et al., 1997; Boyer, 1996; Dennis, 2007
Value Stream Mapping (VSM)	The extent to which the current process is mapped to make the improvement opportunities obvious.	Dennis, 2007; Hettler, 2008; Jovag, 2011; Hettler, 2008; Pepper and Spedding, 2010; Serrano et al., 2008; Seth and Gupta, 2005
Muda (MUDA)	The extent to which the process is not value added.	Dennis, 2007; Liker, 2004; Womack and Jones, 1996
Operational Performance (OPPERF)	The extent to which the firm's operational performance indicators focus on the key operational success factors leading to financial performance.	Venkatrama and Ramanujam, 1986
Satisfaction with the lean program (SATISF)	The extent to which "one's feelings or attitudes toward a variety of factors affecting the situation" are summed.	Legris et al., 2003; Bailey and Pearson, 1983

Production Processes

According to Fine and Hax (1985), the manufacturing operations element is the most complex and difficult for management. Consequently, when developing integrated business strategy, the most important is the interaction between manufacturing and rest of the management functions (Fine & Hax, 1985). The range of products and processes is one of the reasons that the management of manufacturing tasks is more difficult (Skinner, 1969).

Hayes and Wheelwright (1979) proposed the first product–process matrix linking the process life cycle with the product life cycle. Consequently, the most appropriate manufacturing process depends on the number of products, degree of standardization, and product volume. The traditional approach for managing process and technology is matching the process type: job shop, batch shop, assembly line, and continuous flow with the product characteristics, despite matching processes having become more complicated because of the new technologies such as computer-aided design (Fine & Hax, 1985).

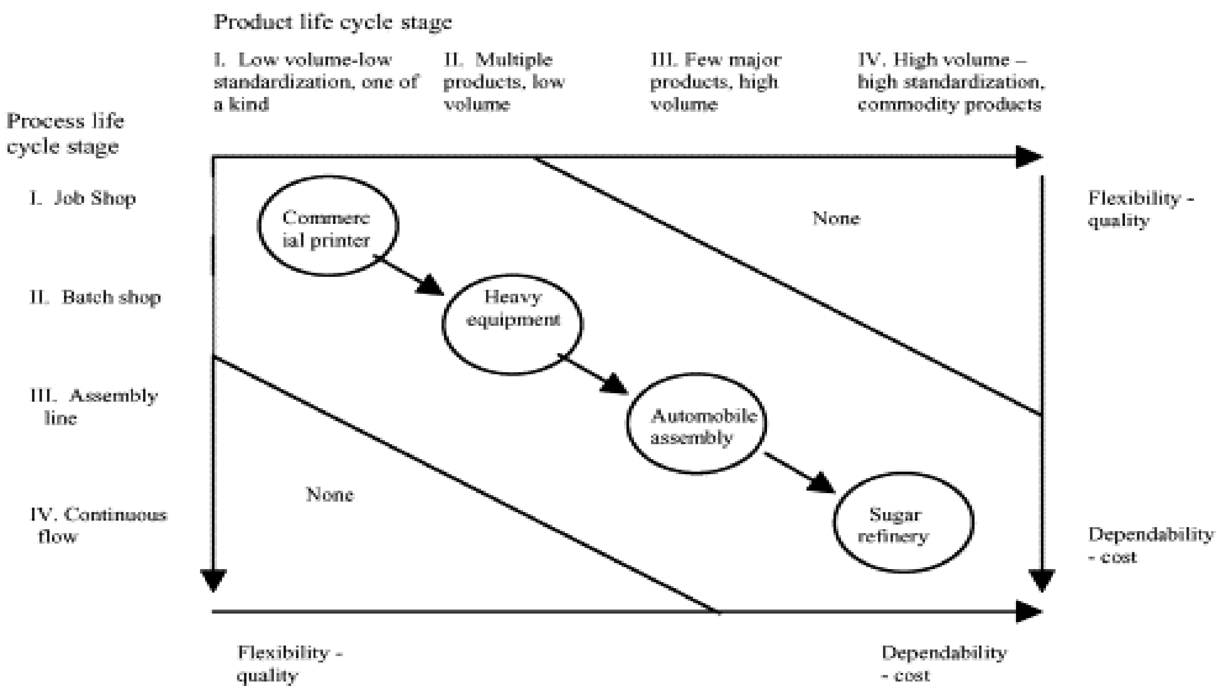

Figure 3. The product-process matrix

Source: Hayes, R., and Wheelwright, S. (1979). Link manufacturing process and product life cycles. *Harvard Business Review 57 (1): 133-140*

Different combinations of technology are needed for every one of the different production processes: job shop, batch shop, assembly line, and continuous flow (Han, 1997). Burack (1967) viewed the industrial units along a technological field as follows: at one end, low volume and general purpose equipment; in the middle is the “mass production” as final assembly line and high volume assembling; and at the other end, quasi-process and product types using process flow with high volume and product standardization.

Ballard and Howell (1998) categorized job shops and batch shops as fabricators, and assembly line and continuous flow as assemblers. Moreover, job shop and batch shop organizations stress flexibility and speed of response; on the other hand, mass and process production emphasize reliability, productivity, and lower cost (Han, 1997).

Job shop. The job shop is a firm producing small batches of a large number of different products requiring a different set of sequences of processing steps (Hayes & Wheelwright, 1984; Chase & Aquilano, 1995). Moreover, a job shop is a flexible production facility, producing variety of individual products (Graves, 1986), requiring diverse workstation types with different product routes and the lack of a dominant flow pattern (Montreuil et al., 1999).

One of the job shop characteristics is a large amount of in-process inventory, making it difficult to know the exact location of a specific job at a specific time (Hayes & Wheelwright, 1984). Other job shop characteristics are variability in the job demand, constantly changing product mix, and small to medium volume, which makes it uneconomical to set up a production line (Montreuil et al., 1999; Hayes & Wheelwright, 1984). Calculating a job shop’s capacity is very difficult because of their flexible flow path, products produced, and resources used (Hayes & Wheelwright, 1984). The processing requirement dictates the route of each job through the machine center; consequently, some pattern in the workflow cannot be distinguished because of the wide variety of jobs and processing requirements (Graves, 1986).

Graves (1986) reported that in the job shop, production control is difficult and cannot be sophisticated because there is not a dominant workflow. On the other hand, according Oosterman et al. (2000), pure job shops do not exist because there is a more or less dominant flow. Some lean principles such as JIT and production leveling are very difficult to apply to a high-level mass customization environment; as an alternative, the company can increase efficiency of MC operations through integrating other lean strategies (Stump & Badurdeen, 2009). Moreover, the implementation of heijunka is very challenging in a high variety production (Huttmeir et al., 2009). The Toyota production system is working for low variety and high volume productions, but when applied to a high variety and low volume, kanban and heijunka are not manageable, machine cells cannot be dedicated to one product, and more complex scheduling techniques are needed (Masson et al., 2007).

According to Hogan (2005), in order to be profitable, the low volume production needs the implementation of lean manufacturing. Howard and Newman (1993) described a conversion of job shop to a just-in-time environment, resulting in labor saving, reduced customer lead-time, and inventory reduction. With the implementation of JIT, the job shop can convert to a continuous manufacturing process (Faizul & Lamb, 1996).

Batch Shop. The batch shop is a standardized job shop (Chase & Aquilano, 1995; Hayes & Wheelwright, 1984). A batch shop process is implemented when the business has a reasonably stable line of products produced in periodic batches to meet customer requirements or for inventory (Chase & Aquilano, 1995; Hayes & Wheelwright, 1984). Brown and Mitchell (1997) described batch shop manufacturing as involving the "….movement of large lots of goods between functionally specialized departments or work centers" (p. 907) with group of employees performing similar tasks in each department and each batch having different routine and different process requirements. A batch shop is a standardized job shop with less variety in the product flow path (Hayes & Wheelwright, 1984). According to Susman and Chase (1986), in the typical batch system, the parts are usually queued up at workstations. "Batch systems may be subject to excess work in process, long lead times, scheduling problems, and large rework quantities" (Brown & Mitchell, 1991, p. 907).

In batch production, the work planning and controlling depends on the degree of "….complexity and uncertainty inherent in production scheduling tasks" (Reeves & Turner 1972, p. 81). Woodward (1965) found that in batch production, the way work is controlled is important, because the link between technology and organization is not clear. In addition, the technical center is a major source of uncertainty; consequently, coordination and standardization are not well applicable (Reeves & Turner, 1972). Batch production processes are useful for highly customized products in low volumes (Cooney 2002) because of the high flexibility of the production resources (Reeves & Turner 1972). In a batch shop environment, production lead-times are shorter, work in process is less, and forecasting batch completion is easier (Hayes & Wheelwright, 1984).

In a decision to use batch production, the low production volume is a significant factor (Cooney, 2002). Batch production may adopt some lean principles, but there is not a lean transition because producing low volumes of diverse products makes it difficult to balance the flow, and production leveling is not applicable (Cooney, 2002).

Assembly Line. Eswaramoorthi et al. (2011) described the typical assembly line as a group of workstations with a material handling system and operators performing the assembly tasks in which the product is moving from workstation to workstation with a goal of achieving continuous workflow. In an assembly line, the workstations are arranged in the needed sequence, producing groups of highly similar products (Hayes & Wheelwright, 1984) moving from workstation to workstation at a controlled rate (Chase & Aquilano, 1995). The assembly line plays a significant role in both mass production and lean production (Parker, 2003).

High volume, low variety production organizations level the production schedule through decoupling the internal supply chain from the outbound supply chain (Jina et al., 1997). A mixed model assembly line refers to producing a variety of given products at the same time (Hayes & Wheelwright, 1984). The Toyota final assembly lines are mixed product lines, with calculated production per day (Sugimorit et al., 1997). In some cases, "assembly line is employed as a final step in a long series of production activities" (Hayes & Wheelwright, 1984, p.178).

Very good performance is achieved through implementing lean in high volume, low variety situations (Jina et al., 1997). The Toyota production system is developed to solve problems in such an environment.

Universality of Lean Depends on Different Contextual Factors

Unit and small batch production is characterized by production schedules based on the firm's orders; the financial planning is a short term and relies on skills and experiences of the labor forces (Woodward, 1965, p. 128). Implementing cellular manufacturing in small batch and one-of-a-kind manufacturing facilities is not an acceptable solution because of the diverse demand pattern, so Zijm and Kals (1995, p. 429) proposed using flexible planning and control to manage those complexities. Some of the characteristics of large batch and mass production are longer-term planning, production schedules not dependent on firm orders, and long terms plans made based on a sales forecast (Woodward, 1965, p. 135).

Most of the lean success stories are from companies with production technology similar to Toyota: limited product offering, cosmetic customization, high volume, repetitive manufacturing, and stable or predictable demand (Lander & Liker, 2007). The lean implementations have not been as successful in low volume-high variety productions because each job is different and production approaches cannot be standardized; characteristics of the product create production constraints, and small firms do not possess as many resources as the large ones, resulting in less flexibility (Pepper & Spedding, 2010). Applicability of lean principles depends on the level of mass customization and customer's involvement, despite the fact that most of the lean principles and tools are applicable to most manufacturing environments (Stump & Badurdeen, 2009).

The universality of lean applications is dependent upon business conditions (Cooney, 2002). White and Prybutok (2001) found evidence that the implementation of JIT practices is influenced by the type of production system. According Poppendieck (2002), the principles of lean are universal, successfully applied in many industries, and successful in improving results. On the other hand, Shingo (1981) explained that the TPS is universally applicable after adaptation to the characteristics of each industry or plant. Defined by Toyota, lean tools are solving Toyota's problems, but for a specific organization's problems, specific tools must be designed and implemented (Lander & Liker 2007).

Contingency Theory

"Contingency theories are a class of behavioral theory that contends that there is no one best way of organizing/leading and that an organizational/leadership style that is effective in some situations may not be successful in others" (Fiedler, 1964, p./n.a.). The contingency model is one of the major theories for leadership effectiveness (Mitchell et al., 1970). The effectiveness of an organization is contingent upon the motivation system of the leader and the "degree to which the situation itself gives the leader power and influence" (Fiedler, 1972, p. 454); the different leaders perform well under different conditions. Moreover, using the contingency model, Leister et al. (1977, p. 645) predicted that the leaders can learn how to "modify their situational control." The contingency model suggests that providing human relations training will improve the leader's ability to work better with the coworkers and will improve leader-member relations (Fiedler, 1972). The contingency theory has led to new insights into the leadership process (Mitchell et al., 1970). The leader's experience is the major factor determining how favorable one system is (Fiedler, 1972).

In order for an organization to perform well, the context and structure must somehow fit together (Drazin & Ven, 1985), or the effectiveness of one organization is contingent on goodness of fit between structural and environmental variables (Shenhar, 2001). "Contingency theory assumes that the better the 'fit' among contingency variables (e.g., between technology and organizational structure), the better the performance of the organization" (Weill & Olson, 1989, p. 61). Environment and strategic conditions influence the performance of one particular organizational structure. Moreover, there is no single structure equally appropriate for all environmental circumstances, and "no single structure will produce equally good performances on all performance dimensions; there is typically a trade-off between short run efficiency and effectiveness, on the one hand, and the adaptability necessary for longer term effectiveness, on the other" (Ruekert et al., 1985, p. 19). "Each business activity should be categorized by the characteristic of the task itself, by the nature of the environment, and by the relative importance of alternative performance dimensions" (Ruekert et al., 1985, p. 23). The structural characteristic of an organizational subunit is dependent on the managerial selection switching rules contingent on task uncertainty (Drazin & Ven, 1985). Shenhar (2001) proved that "one size does not fit all" because the different projects have a wide range of variations, and the managerial style is affected by technological uncertainty and system scope. Higher performing organizations have strong relationships between structure and context (Drazin & Ven, 1985).

The success of lean is contingent on the organization's environment context; consequently, the lean practices will need customization to the organization's environment (Browning & Heath, 2009). There is not a "best approach" appropriate for all organizations, and building a theory of lean has to take into account the moderating factor of contextual variables, because the lean success is contingent on the organization environmental context (Browning & Heath, 2009). For successful lean implementation, it is very important to know which of the lean tools are relevant to which specific environment (Corbett, 2007). Grounded in the contingency theory and in the universality of lean dependent on different contextual factors (Chapter 2), the present study hypothesizes the following.

Appropriate Alignment

Different perspectives of the lean concept have to be taken into account when implementing the lean approach; the organizations must find a production concept that aligns with the contextual factors and existing production practices (Pettersen, 2009). The alignment between context and structure is "…adherence to a linear relationship between dimensions of context and structure" (Drazin & Ven, 1985, p. 519), and "….the degrees to which operational elements match the business strategy" (Smith & Reece, 1998: p. 158). Moreover, alignment is the interaction effect that the organizational context and structure have on the organizational performance, with purpose identifying the organizational processes effective for different context configurations (Drazin & Ven, 1985).

The effectiveness of an organization depends on the quality of fit between structural and environmental variables, because as contingency theory states: different external conditions may require different organizational characteristics (Shenhar, 2001). In addition, the organization’s performance is dependent on the internal alignment (Venkatraman & Camillus, 1984), the alignment between the organization’s product’s market domain, technology, and organizational structure and performance (Miles & Snow, 2003), and proper external alignment between business and manufacturing strategy (Smith & Reece 1998). Higher-performing organizations have stronger relationships between structure and contest than low-performing organizations (Drazin & Ven, 1985). The alignment between operational elements and strategy is very important for organizational performance (Smith & Reece, 1998). The alignment of appropriate variables results in internally consistency, matching the contextual settings pattern of processes and structure (Drazin & Ven, 1985).

Because the nature of the alignment is dependent on different contextual factors, the different industry types have different forms of alignment (Drazin & Ven, 1985).

Summary

This chapter provides a comprehensive literature review of the lean manufacturing philosophy, the lean tools supporting the system, the need for lean, and the three types of production processes: job shop, batch shop, and assembly line. The next chapter provides information on the research methods used for this study, instrument development, validation, data collection, and data analysis.

Chapter 3: Methods

The objectives of this chapter are to discuss the choice of research design and methods, population and sample, instrument development, pilot testing, validation, data collection procedure, and appropriate data analysis steps.

Research Methods

This study determined the differences in the level of utilization of the sixteen lean tools for the three different categories of manufacturing organizations: job shop, batch shop, and assembly line. In addition, this research investigated which lean tools play major roles for lean implementation success in the three different categories of manufacturing organizations. In order to identify the lean tools on which the operational performance of a firm depends, a survey questionnaire was used for data collection. “Survey research involves acquiring information about one or more groups of people by asking them questions and tabulating their answers” (Leedy & Ormrod, 2005; p. 183). Developing a quality instrument is the biggest challenge in survey research (Passmore & Parchman, 2002). Conducting an online survey has some advantages: Anonymity facilitates sharing of the participants’ experience, and respondents directly entered the data in the electronic file (Selm & Jankowski, 2006).

The data analysis for this study involved three major steps: data preparation, descriptive statistics, and inferential statistics (Trochim, 2006). Use of descriptive statistics is appropriate when exploring a possible correlation among two or more phenomena or when identifying the characteristics of the observed phenomena (Leedy & Ormrod, 2005). Inferential statistics is appropriate for hypothesis testing (Trochim, 2006). Therefore, for the purposes of this study, descriptive and inferential statistical tools were used.

This research consisted of five phases: instrument development, Q-sort pilot testing, instrument validation, data collection, and data analysis.

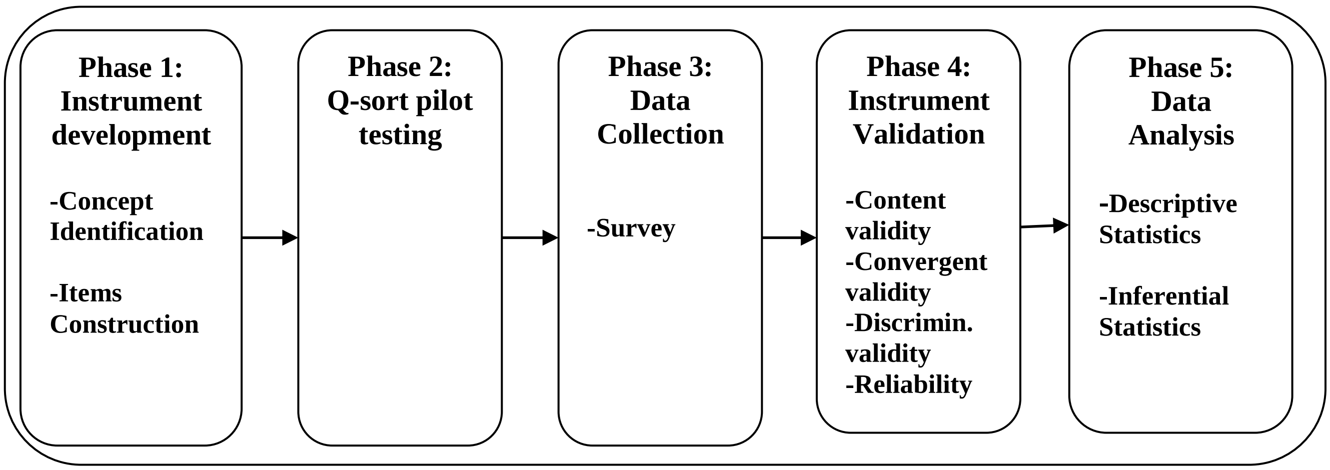

Figure 4. Research phases

Population and Sample

The population is defined by Leedy and Ormrod (2005, p. 205) as "…generally homogenous group of individual units." The first step when conducting a study is to identify the population (Creswell, 2009). Consequently, the population for this study was manufacturing leaders, managers or engineers with knowledge of lean manufacturing, working for manufacturing companies located in US, that were in some stage of implementing lean and were not involved in any operations that could be categorized as continuous flow manufacturing. Because of the limited number of companies in the continuous flow manufacturing setting, researchers did not expect to collect the number of survey responses needed for data analysis.

The sampling technique used for this study was non-probability convenience sampling: "it takes people or units that are readily available…" (Leedy & Ormrod, 2005, p. 201). The sample for this study was manufacturing leaders, managers, and/or engineers of U.S.

manufacturing companies, who were members of the Lean Enterprise Institute (LEI) or members of Continuous Improvement, Six Sigma, and Lean LinkedIn groups. An introductory email and a hyperlink to the web-based survey were posted in the LEI manufacturing forum and emailed to 700 members of the Continuous Improvement, Six Sigma, and Lean group in LinkedIn.

Instrument Development

To examine the level of use of the lean tools in the different types of manufacturing categories and to investigate on which lean tools the perceived operational performance of the firm and the satisfaction with the lean transformation depend, an instrument was developed. A valid and reliable instrument that was easily understood by the sample was the goal of this step. The four steps for instrument development, suggested by Davis (1996), included concept identification, item construction, validity testing, and reliability testing.

Concept identification. The first step of instrument development was identifying what the tool would measure (Davis, 1996). Moreover, according to Aladwania and Palvia (2002), the starting point for the measuring process is conceptualization, defining the domain of construct, and generating items representing the concepts under reflection. Therefore, based on the process defined in Chapter 2 constructs, the proposed instrument measured (a) the level of adoption of the sixteen different lean tools identified by the literature review: *Just in Time* (JIT), *Continuous Flow* (CONTFL), *Heijunka* (HEIJ), *Quick set up* (QSETUP), *Jidoka* (JID), *Poke-Yoke* (PYOKE), *Andon* (AND), *Standardized Work* (STANDW), the *Five S's* (FIVES), *Total Productive Maintenance* (TPM), *Visual Management* (VISM), *Kaizen* (KAIZ), *Teams* (TEAM), *Workers Involvement* (WINV), *Value Stream Mapping* (VSM) and *Muda elimination* (MUDA); (b) the satisfaction with the firm's *lean* transformation (SATISF); and (c) the perceived operational performance of the firm (OPPER). Moreover, questions about the company size, company revenue, number of employees, type of industry, and duration of the lean implementation were added.

Items construction. The next step of instrument development was item construction, during which a framework of the instrument was created, reflecting the content area that needed to be tested (Davis, 1996). Based on the comprehensive review of literature in Chapter 2, a framework of the instrument was developed (See Table 5) and, as recommended, an item format was chosen (Davis, 1996). To reflect the purpose of this instrument, researchers selected a Likert-type scale. When using a Likert-type scale, the responses are numerical, and the respondents make an evaluation of the statement based on magnitude (Leedy & Ormrod, 2005). The coding chosen for the Likert-type scale was: 1-strongly disagree, 2-disagree, 3-neutral, 4-agree, and 5-strongly agree.

Table 5

Framework of the Instrument

Constructs	Literature
Just in Time (JIT)	Dennis, 2007; Detty and Yingling, 2000; Fang and Kleiner, 2003; Fullerton and Watters, 2001; Fullerton et al., 2003; Faizul and Lamb, 1996; Miltenburg, 2007; Liker, 2004; Veech, 2001
Continuous Flow (CONTFL)	Dennis, 2007; Liker, 2004; Fullerton and Wempe, 2008; Allen, 2000; Veech, 2001; Haaster et al., 2010
Heijunka (HEIJ)	Furmans, 2005., Haaster et al., 2010, Adler et al., 1997; Coleman and Vaghefi, 1994; Deif, 2011; Hampson, 1999; Huttmeir et al., 2009
Quick set up (QSETUP)	Kilpatrick, 2003; Dennis, 2007; Detty and Yingling, 2000
Jidoka (JID)	Dennis, 2007; Haak, 2006; Haaster et al., 2010; Detty and Yingling, 2000; Hinckley, 2007; Kasul and Motwani, 1997; Morey, 2008; Sugimorit et al., 1997; Liker, 2004; Suzuki, 2004
Poke Yoke (PYOKE)	Melton, 2005; Dennis, 2007
Andon (AND)	Kasul and Motwani, 1997
Standardized Work (STANDW)	Höök and Stehn, 2008; Dennis, 2007; Detty and Yingling, 2000; Melton, 2005; Whitmore, 2008; Liker, 2004
5 S system (FIVES)	Dennis, 2007; Liker, 2004; Veech. 2001; Melton, 2005; Kilpatrick, 2003
Total Productive Maintenance (TPM)	Dennis, 2007; Liker, 2004; Kilpatrick, 2003; Shah and Ward, 2007
Visual Management (VISM)	Hogan, 2009; Dennis, 2007; Adler et al., 1997; Kasul and Motwani, 1997; Parry and Turnerz, 2006; Melton, 2005; Kilpatrick, 2003
Kaizen (Continuous Improvement; KAIZ)	Alukal, 2007; Bernett and Nentl, 2010; Adler et al., 1997; Boyer, 1996; Sanchez and Perez, 2001; Brunet and New, 2003; Detty and Yingling, 2000; Haak, 2006; Harari, 1997
Teams (TEAM)	Sanchez and Perez, 2001; Karlsson and Ahlstrom, 1996; Detty and Yingling, 2000; Haak, 2006; Dennis, 2007; Liker, 2004
Workers Involvement (WINV)	Bodek, 2010; Fullerton and Wempe, 2008; Alukal, 2007; Dibia and Onuh, 2010; Adler et al., 1997; Boyer, 1996; Dennis, 2007

Value Stream Mapping (VSM)	Dennis, 2007; Hettler, 2008; Jovag, 2011; Hettler, 2008; Pepper and Spedding, 2010; Serrano et al., 2008; Sethy and Gupta, 2005
Muda (MUDA)	Dennis, 2007; Liker, 2004, Womack and Jones, 1996
Operational Performance (OPPERF)	Venkatrama and Ramanujam, 1986
Satisfaction with the lean program (SATISF)	Legris et al., 2003; Bailey and Pearson, 1983

Q-sort pilot testing. In addition to identifying ambiguous survey items, Q-sort pilot testing was recommended for assessing content validity and convergent validity (Moore & Benbasat, 1991). Moreover, the Q-sort pilot testing was used to assess the survey items' readability. Professionals with experience in the fields under study served as judges in the Q-sort pilot testing. Each judge was asked to sort the various survey items into the appropriate construct categories (Moore & Benbasat, 1991). Two judges were needed for each round. Different pairs of judges were used in the different sorting rounds.

Agreement between judges was measured through calculating Cohen's Kappa (Blackman & Koval 2000) and making an assessment over the level of agreement across the pairs of judges: inter-judges raw agreement and placement ratio (Moore & Benbasat, 1991). High inter-judge agreement and "correct" placement ratio assured a high degree of construct validity (Moore & Benbasat, 1991).

According to Blackman and Koval (2000, p. 723), "Cohen's Kappa statistic is a very well known measure of agreement between two raters with respect to a dichotomous outcome." A Cohen's Kappa greater than 0.65 is an acceptable score (Todd & Benbasat, 1989; Moore & Benbasat, 1991). According to Landis and Koch (1977), perfect agreement is achieved if Cohen's Kappa score is between 0.81 and 1.00.

For the purpose of this study, four lean professionals were selected and invited to participate as judges in the Q-sort pilot test. The lean knowledge of the professionals was confirmed by their lean experience, lean certificates, and lean consulting experience. Structured interviews were conducted with the first two judges, and a Cohen's Kappa was calculated. The agreement between judges had Cohen's Kappa score less than 0.81; consequently, the survey items were reduced and clarified as suggested. The second round of the Q sort testing was conducted with the second set of judges. Reviewing and refining the survey items continued until the agreement between judges had a Cohen's Kappa score of at least 0.81.

Validity. Validity testing was the third step suggested by Davis (1996). Validity is the extent to which "the instrument measure what it is supposed to measure" (Leedy & Ormrod, 2005, p. 28). For the purpose of this study, content validity, convergent validity, and discriminant validity were tested.

Content validity is the extent to which congruence exists between the survey items operationalizing the concept and the conceptual definitions (Davis, 1996). "Content validity refers to how much a measure covers the range of meanings included within a concept" (Babbie, 2007, p. 147). Content validity can be assessed through a comprehensive literature review (Davis, 1996) and Q-sort pilot testing (Moore & Banbasat, 1991). Based on the comprehensive literature review, conceptual definitions of the constructs were defined and, in congruence with them, the survey items were developed (Davis, 1996).

This study adjusted from the empirically validated measurement instruments for measuring the companies' lean implementations proposed by Shah and Ward (2007), operational items for *Just in Time* (JIT), *Continuous Flow* (CONTFL), *Total Productive Maintenance* (TPM), *Workers Involvement* (WINV), and *Quick Set Up* (QSETUP). According Shah and Ward

(2007), the tested empirically operational measure is "reliable and meets established criteria for assessing validity" (p. 28). In addition, one operational item from the instrument developed by Fullerton and McWatters (2002) was modified: *Just in Time* (JIT).

This study developed a new measurement scale for *Heijunka* (HEIJ), *Jidoka* (JID), *Poke-Yoke* (PYOKE), *Andon* (AND), *Standardized work* (STANDW), *5S* (FIVES), *Visual Management* (VISM), *Kaizen* (KAIZ), *Teams* (TEAM), *Value Stream Mapping* (VSM), *Muda Elimination* (MUDA), perceived Operational performance (OPPERF), and Satisfaction with the lean program (SATISF). In order to assess content validity, this study employed a comprehensive literature review (Davis, 1996) and Q-sort pilot testing (Moore & Banbasat, 1991).

Convergent validity is the extent to which two measures of the same construct are correlated (Cunningham et al., 2001; Hair et al., 2009). "Convergent validity assesses the extent to which the measurement items in one construct come together to form a single common dimension" (Dobrzykowski, 2010, p. 148). If the correlation among the items is high, the intended scale is measuring the concept (Hair et al., 2009).

Confirmatory factor analysis (CFA) is an acceptable method for evaluating convergent validity (Cunningham et al., 2001). Bagossi (1982) recommended assessing convergent validity with at least two measures from two different procedures. Besides the confirmatory factor analysis, Q-sort pilot testing is another method for measuring convergent validity (Moore & Benbasat, 1991). Consequently, the convergent validity of the proposed instrument was assessed through two methods: confirmatory factor analysis using the SmartPLS software and Q-sort pilot testing.

Discriminant validity is defined as the extent to which two conceptually similar concepts are distinct (Hair et al., 2009). In order to ensure that one construct is different from the other related constructs, discriminant validity of the investigated constructs was evaluated (Lucas et al., 1996). One of the suggested methods for assessing discriminant validity is through extracting average variance (AVE; Fornell & Larcker, 1981). Next, the AVE of each construct is compared with the estimated correlation between constructs (Segars, 1997). There is evidence of discriminant validity if the AVE for each construct is greater than the squared correlation between constructs (Segars, 1997). In order to assess the discriminant validity, SmartPLS software was employed to calculate the AVE of each construct, which was compared with the squared correlation between constructs.

Reliability. Reliability testing was the fourth step suggested by Davis (1996). Reliability is the extent to which the measuring instrument yields the same consistent results independent of the testing circumstances (Leedy & Ormrod, 2005, p. 29). Test-retest, Cronbach alpha, or other tools have been used to estimate the reliability of an instrument (Leedy & Ormrod, 2005). Hair et al. (2009) suggested using the Cronbach alpha coefficient for assessing the consistency of the entire scale. A perfect relationship is indicated by a Cronbach alpha of 1.00, while small alpha indicates that the performance of one item is not predictable on the performance of other items (Davis, 1996). Hair et al. (2009) suggested that the lower limit for Cronbach alpha is 0.60. For the purpose of this study, Cronbach alpha was calculated to assess reliability of each construct.

Human Subjects Approval

Health and human service (HHS) policy for the protection of human research subject applies to all research involving human subjects (USDHHS, 2009). According to the EMU Dissertation Manual (2008, p. 13), “If the doctoral students plan to use human subjects as a part of their research, the first step is to submit a *Request for Approval of Research Involving Human Subjects* along with their dissertation proposal to the university human subjects review committee (UHSRC) at the graduate school." The first page of the research survey was the informed consent: The participants were made aware of the research procedure and that they could change their mind regarding their participation. Request for human subject approval was submitted to the human subjects review committee, and approval was obtained (Appendix D).

Data Collection

A survey questionnaire was used for data collection. "Survey research involves acquiring information about one or more groups of people by asking those questions and tabulating their answers" (Leedy & Ormrod, 2005, p. 183). Selm and Jankowski (2006) suggested using online surveys for non-probability sampling. Survey Monkey was used for the creation and electronic distribution of the survey. The survey was anonymous; the participant names were not associated with their responses. According to Sheehan (2001), the survey response rate is higher when a single email contains both an introductory letter and a hyperactive link to the survey. A follow-up email is another method for increasing the response rate (Sheehan & Hoy, 1999). An introductory email and a hyperlink to the web-based survey were posted in the Lean Enterprise Institute (LEI) manufacturing forum and were emailed to 700 members of the Continuous Improvement, Six Sigma, and Lean Group in LinkedIn.

Data Analysis

In most research, the data analysis involves three major steps: data preparation, descriptive statistics, and inferential statistics (Trochim, 2006). Data preparation refers to checking the data for accuracy and transforming the data (Trochim, 2006). Use of descriptive statistics identifies the characteristics of the observed phenomena (Leedy & Ormrod, 2005).

Univariate analysis involves the examination of one variable at a time, looking at the distribution, the central tendency, and the dispersion (Trochim, 2006; Babbie, 2007). Consequently, in this study the distribution of the data was determined. Next, a central tendency as mean, median, and mode of the data distribution was estimated. Standard deviation is the most accurate estimate of dispersion (Trochim, 2006; Babbie, 2007). Finally, the standard deviation of the data was calculated. Inferential statistics is useful for reaching conclusions beyond the data (Trochim, 2006). As recommended by Trochim (2006), inferential tools were used for hypotheses testing in this study.

> H1 (Null): There will be no significant difference between the degrees of utilization of each lean tool when the companies are grouped by the three manufacturing settings: job shop, batch shop, and assembly line.

In order to test H1, the companies were grouped based on the three manufacturing categories: job shop, batch shop, and assembly line. This study did not include the continuous flow manufacturing setting. Because of the limited number of companies in the continuous flow manufacturing setting, researchers did not expect to collect the number of survey responses needed for data analysis. In situations in which the total sample can be divided in groups based on categorical variables, most appropriate is using cluster or discriminate analysis (Hair et al., 2009). Therefore, a discriminant analysis was performed to distinguish the differences between the levels of utilization of the 16 identified lean tools to the three types of manufacturing categories. Moreover, for better visualization, the results of the analysis were plotted in radar/spider plot.

As an example, based on the literature review and logic, a matrix with predicted results was generated (See Table 6).

Table 6

Expected Level of Application of the Lean Tools

Lean Tools/ Manufacturing Processes	Job Shop	Batch Shop	Assembly Line
Just in Time (JIT)	L	M	H
Continuous Flow (CONTFL)	L	M	H
Heijunka (HEIJ)	L	M	H
Poke –Yoke (PYOKE)	L	M	H
Andon (AND)	n/a	M	H
Quick Set Up (QSETUP)	H	M	L
Jidoka (JID)	L	M	H
Standardized Work (STANDW)	L	M	H
5S(FIVES)	H	H	H
Total Productive Maintenance (TPM)	H	H	H
Visual Management (VISM)	H	H	H
Kaizen(KAIZ)	H	H	H
Teams (TEAM)	H	H	H
Workers Involvement (WINV)	H	M	L
Value Stream Mapping (VSM)	L	M	H
Muda Elimination (MUDA)	L	M	H

Just in Time (JIT) implementation was expected to be low in job shop environment and higher in batch shop and assembly line environment. One of the job shop characteristics is large amounts of in process inventory (Hayes and Wheelwright, 1984). Moreover, JIT is very difficult to apply to a high-level mass customization environment (Stump & Badurdeen, 2009).

Continuous flow (CONTFL) implementation was expected to be low in job shop environment and gradually to increase in batch shop and assembly line. Continuous flow is achieved through implementation of manufacturing cells, which are not applicable in small batch and one of a kind manufacturing facility (Zijm, 1995). In a job shop, dominant flow pattern cannot be distinguished (Montreuil et al., 1999).

Heijunka (HEIJ) implementation was expected to be low in job shop environment and gradually to increase in batch shop and assembly line. In high variety production, implementation of Heijunka is very challenging (Huttmeir et al., 2009) because it is very difficult to balance the flow (Cooney, 2002).

Quick Set Up (QSETUP) implementation was expected to be high in job shop and gradually to decrease in batch shop and assembly line. According Hayes and Wheelwright (1984), the set-ups in job shop environment are frequent, in batch shop are some, while in assembly line are few.

Jidoka (JID) implementation was expected to be low in job shop, medium in batch shop and high in assembly line. Job shops have many different products (high variety, low volume), so designing error-proofing devises for a product that will run only one time is not justified.

Standardized Work (STANDW) implementation was expected to be low in a job shop environment because of the high variety products (each job is different and production approaches cannot be standardized [Pepper & Spedding, 2010]), moderate in batch shops, and high in assembly line.

5S (FIVES) implementation was expected to be high in the three different processes: job shop, batch shop, and assembly line. 5S is the first implemented tool when the lean transformation starts (Dennis, 2007).

Total Productive Maintenance (TPM) implementation was expected to be equally high in the three production processes: job shop, batch shop, and assembly line. TPM refers to preventive maintenance work involving everyone working on the shop floor (Dennis, 2007) in order to achieve reliable equipment with longer life (Kilpatrick, 2003).

Visual Management (VISM) implementation was expected to be equally high in the three production processes: job shop, batch shop, and assembly line. Visual management is creating a self-directing, self-explaining and self-improving workplace (Hogan 2009).

Kaizen (KAIZ) implementation was expected to be equally high in the three production processes: job shop, batch shop, and assembly line. Kaizen refers to employees contributing to the company development with *Muda* eliminating suggestions (Boyer 1996).

Teams (TEAM) implementation was expected to be equally high in the three production processes: job shop, batch shop, and assembly line. Teams are essential for successful lean manufacturing, resulting in improved quality, shorter cycle time, and lower costs (Jina et al. 1997).

Workers Involvement (WINV) implementation was expected to be high in job shop because of the higher workers skills compared to moderate in batch shop and low in assembly line workers skills (Hayes & Wheelwright, 1984).

Value Stream Mapping (VSM) implementation was expected to be implemented at low level in job shop, moderate in batch shop and high in assembly line processes. Because of the high variety of products in the job shop environment, use of VSM is not justified.

Muda Elimination (MUDA) implementation was expected to be high in assembly line, medium in batch shop and low in job shop. Some of the eight identified types of *Muda* are characteristics of the job shop and batch shop processes. Parts in typical batch system are queued up at workstations (Susman & Chase, 1986). Work-in-process inventory is large in job shop, moderate in batch shop, and small in assembly line (Hayes & Wheelwright, 1984). Moreover, job shops do not have finished goods inventory; in batch shop it varies; and in assembly line it is high (Hayes & Wheelwright, 1984).

A spider plot was generated when employing the predicted values of use of the lean tools in Statgraphics software (See Figure 5). It was expected that testing of Hypothesis 1 would result in similar Spider Plot.

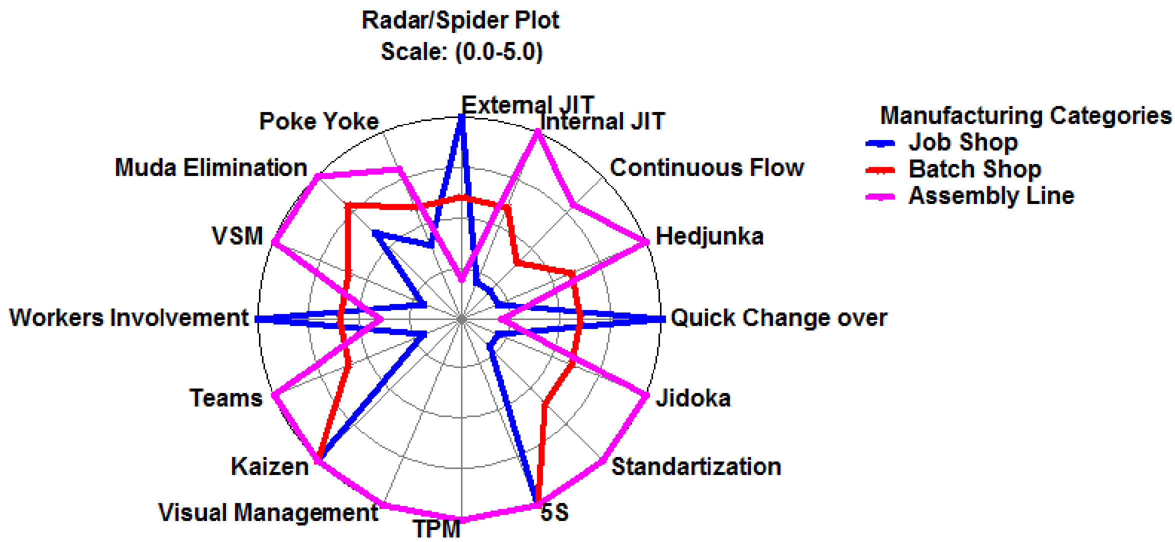

Figure 5. Radar/Spider Plot

Second, to test Hypotheses 2 and 3, SmartPLS was used to investigate whether the type of manufacturing setting has a moderating effect on the relationships between the lean tools and perceived operational performance and between the lean tools and satisfaction with the lean program.

Baron and Kenny (1986) defined moderator as "qualitative or quantitative variable that affects the direction or the strength of the relation between an independent (predictor) variable and a dependent (criterion) variable" (p. 1174). The fit between the independent variable and the moderator is determining the dependent variable, mathematically represented by "Y = *f (X,* Z, X • Z) where *Y* — performance, *X* = strategy and Z = the contextual variable that fits with strategy for performance improvement; here *X* • Z reflects the joint effect of *X* and Z" (Venkatraman, 1989, p. 425). For the purposes of this research, the dependent variables were (a) perceived operational performance and (b) satisfaction with the lean program. The independent variables are the levels of implementation of the sixteen lean tools to the three types of manufacturing categories. Moderator is the type of manufacturing category for job shop, batch shop, and assembly line. The alignment between the manufacturing category (Z) and the appropriate lean tools (X) will be determining the dependent variables: satisfaction with lean program or perceived operational performance (Y). A confirmatory factor analysis using Smart PLS was performed to investigate whether the perceived operational performance and satisfaction with a lean program are related to the alignment of appropriate lean tools with the right manufacturing category.

Summary

This chapter described the research design and methods that were used for this study and explained the steps used for instrument development. Moreover, the testing of instrument validity and reliability, data collection, and data analysis were described.

Chapter 4: Results

This chapter reports the Q-sort results, response rate, characteristics of the survey respondents, validity and reliability estimates of the survey instrument, and the results of hypothesis testing. The data were collected from professionals possessing knowledge of the lean approach who worked in the manufacturing industry during July, August, and September of 2012. The survey was administered via Survey Monkey web link.

Q-Sort Results

Q-Sort pilot testing was used for assessing content validity and convergent validity, which produced favorable results. In addition, the number of items was significantly reduced and readability improved. All sixteen constructs were tested in two rounds. Seventy-four items entered the first Q-sort round. The inter-judge raw agreement score was 79.72% (59/74), the placement ratio was 79.05% (117/148), and the Cohen Kappa was 38.8% (See Appendix B). Based on the first Q-sort round, 23 items on which the first two judges did not agree were deleted from the survey instrument. In addition, some of the questions were rewritten as suggested.

The revised instrument was tested in the second Q-sort round. The inter-judge raw agreement was 96.08% (49/51), the placement ratio was 91.18 percent (93/102), and the Cohen Kappa was 87.80% (See Appendix B). The Cohen Kappa score indicated one almost perfect agreement between the judges. The placement ratio of 91.18 indicated that the items were placed where intended (Moore & Benbasat, 1991; See Table 7). The final 51 items were used for the large-scale survey. The final survey instrument is located in Appendix C.

Table 7

Inter-judges' Agreement

	Round 1	Round 2
Inter-judge raw agreement	79.72%	96.08 %
Placement ratio	79.05%	91.18%
Cohen Kappa	38.8%	87.80%

Response Rate

Surveys were distributed to two groups of professionals with knowledge of lean practices: the members of Lean Enterprise Institute and 700 members of Continuous Improvement, Six Sigma, and Lean Group in LinkedIn. The response rate for the Lean Enterprise Institute (LEI) sample was calculated by dividing the number of completed surveys by the number of LEI members who have seen the introductory letter containing the link to the survey. The response rate for the Lean Enterprise Institute (LEI) was low because of lack of interaction with the potential respondents. The response rate for Continuous Improvement, Six Sigma, and Lean Group was calculated by the number of completed surveys divided by the number of surveys e-mailed through LinkedIn to the lean professionals working in manufacturing fields and members of the group. The response rate for the LinkedIn group was high because each of the potential respondents was contacted individually. The survey response rate is summarized in Table 8.

Table 8

Response Rate Summary

	Surveys	Surveys Completed	Response Rate in Percent
Lean Enterprise Institute	300	59	**19.7**
Continuous Improvement, Six Sigma Group	700	241	**37.9**
Total	1000	300	**33.3**

After reviewing the 300 completed surveys, 38 of them were deleted from the database due to excessive missing values. Another 32 were excluded because their respondents were based in companies outside of the US, and those do not belong to the defined population in the study. Twenty-seven more survey responses were taken out of the study because the respondents reported that their manufacturing setting was not categorized as a job shop, a batch shop, or an assembly line. In addition, fourteen responses were removed from the study because the survey respondents reported that their company had not started the lean transformation yet. Overall, 189 survey responses were used for the data analysis (See Table 9).

Table 9

Usable Surveys

	Completed Surveys	Respondents located in USA	Respondents in JS, BS, and AL	Company Implementing *Lean*	**Overall Usable surveys**
Lean Enterprise Institute	47/59(80%)	35/47 (74%)	27/35 (77%)	23/27 (85%)	**23/59 (39%)**
Continuous Improv., Six Sigma Group	215/241 (89%)	195/215 (91%)	176/195 (90%)	166/176 (94%)	**166/241 (69%)**
Total	262/300 (87%)	230/262 (88%)	203/230 (88%)	189/203(93%)	**189/300 (63%)**

Results of Demographic

Job titles of the individual respondents are displayed in Table 10. A large group of the respondents, 40%, were company executives: 2 CEOs, 2 Global Continuous Improvement directors, 2 Corporate lean managers, 2 VP of Operations, and 1 VP of Continuous Improvement. The next largest group of respondents had job titles as Lean Project Manager

(21%) and Quality Manager (19%). Thirteen percent of the survey respondents had the job title of engineer, and 5% had other job titles.

Table 10

Job Titles of Respondents

Job titles	**Respondents**	**Percentage**
Director	41	21.70%
Lean Project Manager	40	21.20%
Quality Manager	36	19%
Engineer	24	12.70%
Plant Manager	21	11.10%
Other	9	4.80%
Production Manager	5	2.70%
Operations Manager	4	2.10%
CEO	2	1%
Global CI Director	2	1%
Corporate Lean Manager	2	1%
VP of Operations	2	1%
VP of Continuous Improvement	1	0.50%

The lean expertise of the individual respondents is displayed in Table 11. The largest group of respondents (53%) holds Six Sigma Black Belts or Six Sigma Master Black Belts. The Lean Certificate holders account for 13.8% of the population, and Six Sigma Green Belts holders make up 21.7%. Survey respondents with lean experience or lean training account for 11.2%.

Table 11

Lean Expertise of Respondents

Lean Expertise	**Respondents**	**Percentage**
Lean Certificate	26	13.8%
Lean Experience	6	3.2%
Lean Training	15	8%
Six Sigma Green Belt	41	21.7%
Six Sigma Black Belt	69	36.5%
Six Sigma Master Black Belt	32	17%

The size of the plants in which the respondents worked is displayed in Table 12. Sixty-seven percent of the respondents reported working in plants which had fewer than 500 employees, 17.7% of the respondents reported working in plants which had between 501 and 1000 employees, 10.8% of the respondents reported working in plants which had between 1001 and 5000 employees, and only 3.4% of the respondents reported working in plants which had more than 5001 employees.

Table 12

Number of Employees

Number of Employees	**Respondents**	**Percentage**
1-100	33	17.5%
101-250	51	27%
251-500	43	22.7%
501-1000	35	17.7%
1001-5000	20	10.8%
5001<	7	3.4%

The manufacturing settings used in the plants are displayed in Table 13. Job shop manufacturing settings were used in 29.1% of the companies; batch shop-manufacturing settings were used in 37% of the companies, and assembly line manufacturing settings were used in 33.8% of the companies.

Table 13

Processes

Process	**Respondents**	**Percentage**
Job shop	55	29.1%
Batch shop	70	37%
Assembly line	64	33.8%

The level of implementation of the lean approach of the companies is displayed in Table 14. Forty percent of the companies have implemented lean in some manufacturing processes, 46% of the companies have implemented lean in many manufacturing processes, and 14% of the companies have fully implemented lean.

Table 14

Level of Lean Implementation of Respondents' Companies

Lean Implementation	**Respondents**	**Percentage**
1. Implemented in some manufacturing processes.	76	40.2%
2. Implemented in many manufacturing processes.	87	46%
3. Fully implemented *lean*	26	13.8%

The number of years of lean implementation is displayed in Table 15. Fifty-six percent of the companies have been involved in a lean transition for more than five years, 20% of the companies for between 2 and 4 years, and 20% of the respondents for less than 2 years.

Table 15

Number of Years of Lean Implementation

Years of lean transition	**Respondents**	**Percentage**
0-2	40	20.2%
2.1-4	39	19.7%
5.1 -6	44	22.2%
6.1-10	42	21.2%
10.1-23	24	12.3%

In summary, 81% of the respondents had job titles as company executive, lean project manager, and quality manager. Fifty-eight percent of the respondents held Six Sigma Black Belts or Six Sigma Master Black Belts, and 36% of the respondents had lean certificates or Six Sigma green belts. All of the respondents' companies had implemented lean in some manufacturing process, in many manufacturing processes, or have fully implemented lean. Fifty-six percent of the companies had been in a lean transition for more than five years.

Instrument Validation

After the data preparation step was complete (Trochim, 2006), the measurement instrument was tested for validity and reliability. First, as recommended by Gaskin (2012), Exploratory Factor Analysis (EFA) was employed to determine the data structure. Second, the PLS-SEM was employed as the best approach to assess the measurement model validity and reliability, in cases when the latent variable's scores are used in subsequent analysis (Hair et al., 2012).

EFA defined sets of highly correlated variables: factors (Hair et al., 2005). The linkage of the items to their underlying factor is described by the Principal Component Analyses (PCA; Di et al., 2009; Dehghan, 2012). As seen in Table 16, the PCA resulted in Kaiser-Meyer-Olkin measure of sampling adequacy of 0.904, which is a marvelous result (Gaskin, 2012). Bartlett's Test of Sphericity proves significant result of .000 (Sig. < 0.001), indicating that the variables relate to each other (Gaskin, 2012).

Table 16

KMO and Bartlett's Test

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		**.904**
Bartlett's Test of Sphericity	Approx. Chi-Square	7277.818
	Df	1275
	Sig.	**.000**

A communality is the total amount of variance, which the original variable shares with other variables in the analysis (Hair, 2005) and the extent to which an item correlates with all other items (Gaskin, 2012). The communalities of the survey's items have values between 0.578 and 0.884, indicating that all survey items are correlated well with each other.

The variance of the data was explained through twelve factors. To identify the variables with the factor, the component matrix was rotated using the Varimax technique. The rotation revealed that two questions were not placed in the right group. Consequently, one question from the Kaizen group— "Our employees participate in rapid improvement events"—and one question from the Five S group—"We have cleaning responsibilities assigned to the team members"—were transferred to the Workers' Involvement group, probably because the concepts behind Kaizen and Workers' involvement are overlapping and the specific Five S question is about the involvement of the employees in the cleaning responsibility.

According to Hair et al. (2005), factor loadings greater than 0.40 are considered significant, while loadings greater than 0.5 are considered very significant. Twenty-one survey items had factor loadings greater than 0.70, twenty-one survey items had factor loadings between 0.50-0.70, and the remaining nine survey items had factor leadings between 0.40 and 0.50 (See Table 17). Consequently, 42 survey items had very significant factor loadings, and nine survey items had significant factor loading. The factor loadings confirmed the construct validity of the survey instrument.

Table 17

Factor Loading

#	Items Cod	**Survey Items**	**Factor Loading**
Factor 1: Involvement of the working in team shop floor employee s	WINV2	Our shop floor employees drive suggestions programs	**.697**
	WINV4	Most of our shop floor employees are working in teams	**.684**
	WINV3	Our shop floor employees lead production improvement effort	**.668**
	WINV1	Our shop floor employees are key to problem solving	**.626**
	WINV5	Our employees work to eliminate waste in an outgoing fashion.	**.557**
	TEAM1	We have cleaning responsibility assigned to the team members	**.540**
	TEAM2	Our shop floor employees are cross trained	**.443**
	TEAM3	Our shop floor employees change tasks within the team.	**.439**
Factor 2: Work place organization and maintenance	TPM2	We maintain all our equipment regularly.	**.734**
	TPM3	We maintain excellent records of all equipment maintenance related activities.	**.687**
	TPM1	We dedicate a portion of everyday to planned equipment maintenance related activities.	**.630**
	FIVES3	We keep our workplace organized	**.518**
	QSETUP1	Our employees achieve setups that save time.	**-.496**
	QSETUP2	We are working to lower setup times in our plant.	**-.446**
	FIVES1	We organize our workplace with labeled positions for each tool.	**.442**
	QSETUP3	We have low setup times of equipment in our plant	**-.432**
Facto r 5: Muda	MUDA3	Everybody participates in eliminating non-value added activities.	**.827**
	MUDA1	Our workers identify non-value added activities.	**.808**
	MUDA2	We are working to minimize non-value added activities.	**.749**
Factor 4: Jidoka	JID2	We detect quality deviations with automated technology.	**.880**
	JID3	Most inspections are done by automated technology.	**.827**
	JID1	We detect process deviations with automated technology.	**.818**
Factor 5: Just In Time	JIT2	We do not produce a product unless the customer has order it.	**.755**
	JIT4	Production at each station is “pulled” by demand from the next station.	**.615**
	JIT6	We produce exactly as many pieces as needed.	**.604**
	JIT3	We link all processes to customer demand through Kanban	**.550**
	JIT1	We use JIT with our suppliers.	**.528**
	JIT5	We use Kanban signals for production control.	**.479**
Factor 6: Process improveme nt	VSM3	We use VSM to improve our production flow.	**.739**
	VSM1	We use VSM to eliminate Muda.	**.679**
	VSM2	We use VSM to improve our business processes.	**.630**
	KAIZ1	Our employees participate in rapid improvement events.	**.461**
	KAIZ2	Our employees suggestions are generally implemented	**.449**
Factor 7: Visual Manage ment	VISM1	We use a visual board to display key information.	**.726**
	VISM2	We use visual indicators, signs, and controllers.	**.705**
	VISM3	We use simple signals to provide immediate understanding of the situation.	**.683**
Facto r 8: Heiju nka	HEDJ2	We do not have picks and valleys in our production schedule.	**.828**
	HEDJ3	Our production mix is distributed evenly over time.	**.797**
	HEDJ1	Our production volume is distributed evenly over time.	**.741**
Factor 9: Stand Work	STANDW2	We use our standards as a basis for improvement.	**-.797**
	STANDW3	We change our work process standards as needed for improvement.	**-.733**
	STANDW1	Our work processes are standardized.	**-.608**

Factor 10: Cont. Flow	CONTFL1	Products are classified into groups with similar processing requirements.	**.749**
	CONTFL2	Equipment is grouped to produce a continuous flow of families of products	**.715**
	CONTFL3	Families of products determine our factory layout	**.628**
Facto r 11: Poke Yoke	PYOKE2	We use simple, inexpensive error-proofing devices.	**.730**
	PYOKE3	Our poke-yoke devices are used 100% of the time.	**.621**
	PYOKE1	We have poke –yoke devices designed for our work place conditions.	**.581**
Factor 12: Andon	AND1	Everyone working on the production floor is able to stop the production line if a defect is detected.	**.804**
	AND3	Our employees stop the production line if a defect is detected.	**.778**
	AND2	We have a device (cord or button) to stop the production line if a defect is detected.	**.643**

Second, by using the PLS-SEM procedure, the confirmatory factor analysis (CFA) was performed to confirm the factor structure that was extracted in the Exploratory Factor Analysis (EFA; Gaskin, 2012). In addition, the PLS-SEM is the best approach for assessment of the measurement model if the latent variable's scores are used in subsequent analysis (Hair et al., 2011)

In the PLS-SEM, the relationships between unobserved latent variables and their related observed variables are specified by the outer measurement model (Henseler et al., 2009). The path relationships between the unobserved latent variables and their related observed variables are described by a reflective or a formative model (Henseler et al., 2009). When using PLS-SEM, specification of the measurement model is the first step (Hair et al., 2011). "Measurement model misspecification is an often observed phenomenon" (Henseler et al., 2009, p. 290). In the formative measurement model, the direction of causality is from measure to the construct, while in reflective measurement model the direction of causality is form the construct to measure (Hoeck et al., 2010). The measurement model in this study is reflective, because the direction of casualty is from the construct to measure. The coefficients in the PLS-SEM associated with the reflective measurement model are called outer loadings (Hair et al., 2011). The significance of the outer loading coefficients confirmed the results from the EFA.

Table 18

Outer Loading Coefficient

Indicator relationship	**Outer Loading Path Coefficient**	**T-stat**
Andon (AND)		
AND1	0.877223***	30.636782
AND2	0.783636***	17.692996
AND3	0.844223***	22.731347
Continuous Flow (CONTFL)		
CONTFL1	0.827008***	29.522150
CONTFL2	0.906083***	45.020181
CONTFL3	0.782387***	16.488419
Five S (FIVES)		
FIVES1	0.906193***	46.179011
FIVES2	0.913703***	57.626450
Heijunka (HEIJ)		
HEIJ1	0.893855***	43.800073
HEIJ2	0.865183***	23.409770
HEIJ3	0.878318***	25.639323
Jidoka (JID)		
JID1	0.944465***	95.269737
JID2	0.955204***	104.825624
JID3	0.846036***	21.816611
Just in Time (JIT)		
JIT1	0.700581***	13.759591
JIT2	0.697774***	8.562793
JIT3	0.808582***	23.468050
JIT4	0.815826***	32.317061
JIT5	0.828956***	31.052155
JIT6	0.707018***	12.571980
Kaizen (KAIZ)		
KAIZ1	0.887688***	36.833133
KAIZ2	0.911967***	57.656742
Muda Elimination (MUDA)		
MUDA	0.965380***	122.527795
MUDA	0.958078***	97.898385
MUDA	0.966899***	115.901186
Poke Yoke (PYOKE)		
PYOKE1	0.903696***	51.209612
PYOKE2	0.852261***	29.944044
PYOKE3	0.815502***	25.322729
Quick Set Up (QSETUP)		
QSETUP1	0.882749***	50.341729
QSETUP2	0.767795***	15.594564
QSETUP3	0.782283***	17.472421
Standardized Work (STANDW)		
STANDW1	0.837218***	25.946189
STANDW2	0.873734***	21.163717
STANDW2	0.876902***	36.497927
Teams (TEAM)		

TEAM1	0.774833***	18.101564
TEAM2	0.911343***	63.907891
TEAM3	0.895112***	47.261526
Total Productive Maintenance (TPM)		
TPM1	0.874114***	42.874565
TPM2	0.925897***	73.274066
TPM3	0.849836***	33.315466
Visual Management (VISM)		
VISM1	0.905449***	43.800303
VISM2	0.938092***	83.683513
VISM3	0.901830***	60.658748
Value Stream Mapping (VSM)		
VSM1	0.826169***	23.397614
VSM2	0.879980***	64.174106
VSM3	0.927273***	53.755007
Workers Involvement (WINV)		
WINV1	0.813123***	21.658996
WINV2	0.885455***	51.089020
WINV3	0.862399***	43.164181
WINV4	0.702961***	12.441757
WINV5	0.839164***	38.447851

***Significant at $p<0.001$

According to Hair et al. (2011), the next step of the PLS-SEM measurement assessment was to examine the measures and to confirm that they represent the construct of interest through assessing their reliability and validity. A composite reliability greater than 0.70 confirmed the internal consistency reliability (Hair et al., 2011; See Table 18). The indicator reliability was confirmed by indicator outer loadings greater than 0.70 (See Table 18).

Convergent validity was established by composite reliability (CR) greater than the average variance extracted (AVE; Gaskin, 2012). In addition, a sufficient degree of convergent validity was an AVE value greater than 0.50, "meaning that the latent variable explains more than half of the indicators variances" (Hair et al., 2011, p. 145). Convergent validity was established in three ways: (a) CR values greater than the AVE values, (b) all AVE values are greater than 0.5 (see Table 19), and (c) as recommended by Moore and Benbasat (1991). Q-sort pilot testing was performed for assessing convergent validity.

Table 19

Convergent Validity

Lean Tools	AVE	Composite Reliability
Andon (AND)	0.6988	0.8741
Continuous Flow (CONTFL)	0.7056	0.8775
5S's (FIVES)	0.828	0.9059
Heijunka (HEIJ)	0.773	0.9108
Jidoka (JID)	0.8401	0.9402
Just in Time (JIT)	0.5487	0.8777
Kaizen (KAIZ)	0.8098	0.8949
Muda Elimination (MUDA)	0.9282	0.9749
Poke- Yoke (PYOKE)	0.81	0.9275
Quick Set Up (QSETUP)	0.7361	0.8931
Standardized Work (STANDW)	0.6602	0.8531
Teams (TEAM)	0.8003	0.9231
Total Productive Maintenance (TPM)	0.7444	0.8973
Visual Management (VISM)	0.744	0.8967
Value Stream Management (VSM)	0.7812	0.9145
Workers Involvement (WINV)	0.8377	0.9393
Andon (AND)	0.7723	0.9103
Continuous Flow (CONTFL)	0.6711	0.9101

Discriminant Validity

Discriminant validity determines whether each latent variable shares more variances with its own manifest items than with other constructs (Fornell & Bookstein, 1982; Chin, 1998). In the PLS path modeling, the discriminant validity is measured through the Fornell-Larcker criterion and the cross-loading (Henseler et al., 2009, p. 299). In the Fornell-Larcker criterion, the discriminant validity is established by the square root of a construct's AVE greater than the correlations between constructs (Koufteros, 1999; Koufteros et al., 2001). Found on the diagonal of Table 20 is the bolded square root of the AVE for each construct, greater than the value of the correlations in its corresponding row and column, which is evidence of discriminant validity. In addition, the discriminant validity was confirmed through cross-loadings coefficients, indicating that there is no higher correlation with another latent variable than with its respective latent variable (Henseler et al., 2009; See Appendix D).

Table 20

Discriminant Validity

	AND	CONTF	FIVES	HEDJ	JID	JIT	KAIZ	MUDA	POKEY	QSETUP	STANDW	TEAMS	TPM	VISMAN	VSM	WINV
AND	**0.836**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CONTFL	0.337	**0.84**	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FIVES	0.316	0.420	**0.910**	0	0	0	0	0	0	0	0	0	0	0	0	0
HEDJ	0.38	0.440	0.314	**0.880**	0	0	0	0	0	0	0	0	0	0	0	0
JID	0.359	0.345	0.305	0.402	**0.917**	0	0	0	0	0	0	0	0	0	0	0
JIT	0.412	0.445	0.521	0.557	0.38	**0.741**	0	0	0	0	0	0	0	0	0	0
KAIZ	0.370	0.36	0.537	0.247	0.337	0.423	**0.900**	0	0	0	0	0	0	0	0	0
MUDA	0.245	0.452	0.494	0.24	0.290	0.439	0.565	**0.963**	0	0	0	0	0	0	0	0
POKEY	0.410	0.413	0.455	0.441	0.499	0.527	0.466	0.329	**0.858**	0	0	0	0	0	0	0
QSETUP	-0.374	-0.496	-0.575	-0.379	-0.366	-0.556	-0.459	-0.381	-0.523	**0.813**	0	0	0	0	0	0
STANDW	-0.343	-0.415	-0.521	-0.397	-0.437	-0.520	-0.399	-0.385	-0.492	0.517	**0.863**	0	0	0	0	0
TEAMS	0.455	0.441	0.697	0.407	0.394	0.581	0.485	0.48	0.540	-0.632	-0.609	**0.863**	0	0	0	0
TPM	0.411	0.486	0.589	0.398	0.355	0.536	0.541	0.489	0.437	-0.618	-0.504	0.648	**0.8839**	0	0	0
VISMAN	0.439	0.438	0.571	0.345	0.391	0.52	0.541	0.493	0.587	-0.510	-0.513	0.530	0.5417	**0.9153**	0	0
VSM	0.316	0.431	0.472	0.274	0.331	0.489	0.631	0.570	0.397	-0.488	-0.456	0.556	0.5302	0.5258	**0.879**	0
WINV	0.431	0.381	0.590	0.310	0.355	0.529	0.687	0.599	0.476	-0.542	-0.530	0.697	0.5584	0.5007	0.6	**0.819**

* Square Root of each variables AVE is on the diagonal.

Cronbach alpha is the coefficient assessing consistency of the entire scale (Hair et al., 2009). A Cronbach alpha of 1.00 indicates perfect relationship, while a small alpha indicates that the performance of one item is not predictable on the performance of other items (Davis, 1996). The acceptable lower limit for Cronbach alpha is 0.60 (Hair et al., 2009). The reliability of the survey instrument used for data collection in this study was confirmed by two methods: The Cronbach alpha coefficient is greater than 0.74, and the composite reliability is greater than 0.85 (Gaskin, 2012; See Table 21).

Table 21

Cronbach Alfa Coefficient and Composite Reliability

Constructs	Cronbach Alpha	Composite Reliability
Andon (AND)	0.783	0.8741
Continuous Flow (CONTFL)	0.7906	0.8775
5S's (FIVES)	0.7924	0.9059
Heijunka (HEIJ)	0.8568	0.9108
Jidoka (JID)	0.9059	0.9402
Just in Time (JIT)	0.8337	0.8777
Kaizen (KAIZ)	0.7659	0.8949
Muda Elimination (MUDA)	0.9614	0.9749
Poke- Yoke (PYOKE)	0.8206	0.8931
Quick Set Up (QSETUP)	0.7402	0.8531
Standardized Work (STANDW)	0.8287	0.8973
Teams (TEAM)	0.8254	0.8967
Total Productive Maintenance (TPM)	0.8593	0.9145
Visual Management (VISM)	0.903	0.9393
Value Stream Management (VSM)	0.8523	0.9103
Workers Involvement (WINV)	0.8755	0.9101

In summary, the survey instrument in this study revealed adequate reliability and validity with respect to content validity, convergent validity, and discriminant validity. A reliable and valid measurement of latent variables should have a composite reliability higher than 0.6, an indicator loadings higher than 0.7, AVE higher than 0.5, and discriminant validity (Henseler et al., 2009).

1. Reliability was established by Cronbach alpha coefficients greater than 0.74 (Davis, 1996) and composite reliability coefficients greater than 0.85 (Gaskin, 2012).
2. Content validity was assessed through a comprehensive literature review (Davis, 1996) and Q-sort pilot testing (Moore & Banbasat, 1991).
3. Internal consistency reliability was confirmed through a Composite reliability greater than 0.70 (Hair et al. 2011; See Table 19).
4. Indicator reliability was confirmed by indicator outer loadings greater than 0.70 (Hair et al. 2011; See Table 18).
5. Convergent validity was established by CR values greater than the AVE values, AVE values greater than 0.5 (Hair et al., 2011) and Q-sort pilot testing (Moore & Benbasat, 1991).
6. Discriminant validity was established through Fornell-Larcker criterion by the square root of a construct's AVE, greater than the correlations between constructs (Koufteros, 1999; Koufteros et al., 2001, Hair et al., 2011), and by cross-loading indicating higher correlation with its latent variable than with other latent variables (Henseler et al., 2009; Hair et al., 2011; See Appendix D).

Descriptive Statistics

Descriptive statistics identify the characteristics of the observed phenomena (Leedy & Ormrod, 2005). Univariate analysis involves the examination of one variable at time, looking at the distribution, the central tendency, and the dispersion (Trochim, 2006; Babbie, 2007). As recommended by Trochim (2006) and Babbie (2007), the distribution of the data was examined using the MatTab software's function for distribution fitting, and the result was no perfect normally distributed data, which is common when using Likert scale (Norman, 2010). The data distribution is positively or negatively skewed, as seen in Table 21, because the "Likert ratings are ordinal which in turn means that the distributions are highly skewed" (Norman, 2010, p. 4). On the other hand, Schwab (n/a) suggested that for data analysis, accepted normality is defined by skewness and kurtosis between -1 and 1. As seen from Table 21, all of the independent variables have skewness between -1 and 1, and almost all of the independent variables have kurtosis between -1 and 1. Only *Quick Set Up* (QSETUP), *Standardized Work* (STANDW), and Kaizen (KAIZ) had kurtosis greater than 1.

Next, a central tendency as the mean, median, and mode of the data was estimated using SPSS. The central tendency of all latent variables, which were calculated by the average of their construct variables, is listed in Table 22. The mean, the median, the mode, the standard deviation, and the variances were calculated for the 189 valid cases. The means of four latent variables—*Heijunka* (HEIJ), *Quick Set Up* (QSETUP), *Jidoka* (JID) and *Standardized Work* (STANDW)—were below 3, while their mode was 2, indicating that the lean tools represented by the four latent variables are not used in a job shop, a batch shop, and in assembly line manufacturing settings, while the rest of them—*Just in Time* (JIT), *Continuous Flow* (CONTFL), *Poke Yoke* (PYOKE), *Andon* (AND), *5 S's* (FIVES), *Total Productive Maintenance* (TPM), *Visual Management* (VISM), *Kaizen* (KAIZ), *Teams* (TEAM), *Workers Involvement* (WINV), *Value Stream Mapping* (VSM) and *Muda Elimination* (MUDA)—are used in all three manufacturing settings. In addition, *Just in Time* (JIT) had mode of 3.83, *Poke-Yoke* (PYOKE) had mode of 3.67, and the rest of the lean tools had mode of 4. Standard deviation is the most accurate estimate of dispersion (Trochim, 2006; Babbie, 2007). Most of the latent variables have a standard deviation between 0.77 and 0.98, while only two variables have a standard deviation greater than 1: *Jidoka* (JID) and *Muda Elimination* (MUDA).

Table 22

Central Tendency of the Utilization of the Lean Tools

	N						Skewness (Std. Error=0177)	Kurtosis (Std Error=0352)
	Valid	Missing	Mean	Median	Mode	Std. Deviation		
JIT	189	0	3.2063	3.1667	3.83	.87013	-.034	-.472
CONTFL	189	0	3.7019	4.0000	4.00	.86017	-.529	-.195
HEDJ	189	0	2.6631	2.6667	2.00	.98270	.274	-.674
QSETUP	189	0	2.4356	2.3333	2.00	.77498	.790	1.025
JID	189	0	2.7425	3.0000	2.00	1.08428	.019	-.706
PYOKE	189	0	3.2857	3.3333	3.67	.88764	-.354	.103
ANDON	189	0	3.3527	3.3333	4.00	.99358	-.471	-.062
STANDW	189	0	2.1834	2.0000	2.00	.76599	.965	1.546
FIVES	189	0	3.8704	4.0000	4.00	.79082	-.715	.679
TPM	189	0	3.5573	3.6667	4.00	.91406	-.532	-.122
VISM	189	0	3.8871	4.0000	4.00	.78035	-.817	.994
KAIZ	189	0	3.7460	4.0000	4.00	.83095	-.822	1.076
TEAM	189	0	3.7407	4.0000	4.00	.79101	-.825	.925
WINV	189	0	3.5926	3.8000	4.00	.83421	-.455	-.190
VSM	189	0	3.7072	3.6667	4.00	.87052	-.460	-.190
MUDA	189	0	3.5802	4.0000	4.00	1.11095	-.694	-.244

Testing Hypotheses 1

Inferential statistics are useful for reaching conclusions beyond the data (Trochim, 2006). As recommended by Trochim (2006), inferential statistics were used for hypotheses testing in this study.

H1 (Null): There will be no significant difference between the degrees of utilization of each lean tool when the companies are grouped by the three manufacturing settings: job shop, batch shop, and assembly line.

Discriminant analysis was performed to understand if there is a difference between the degrees of utilization of the sixteen lean tools when the companies are grouped by the three manufacturing settings: a job shop, a batch shop, and an assembly line. According to Hair et al. (2009), discriminant analysis is useful if the dependent variable is categorical and the independent variable is metric. “Discriminant analysis is the appropriate statistical technique for testing the hypothesis that the group means of a set of independent variables for two or more groups are equal” (Hair et al., 2009, p. 236). Using the SPSS software, discriminant analysis was performed to establish whether means of the level of implementation of the lean tools for three types of manufacturing settings are equal. When performing discriminant analysis, Hair et al. (2009) recommended following a few steps.

Step 1: Evaluate group differences on a multivariate profile. First the means of the level of utilization of the sixteen lean tools were calculated for the different groups and were plotted in a spider diagram.

Table 23

Means of Utilization of Sixteen Lean Tools in JS, BS, and AL

	Job Shop, N=55		Batch Shop, N=70		Assembly Line, N=64		Total, N=189	
	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation
JIT	3.0697	.83622	2.9786	.77133	3.5729	.89328	3.2063	.87013
CONTFL	3.5212	.87668	3.7095	.82809	3.8490	.86461	3.7019	.86017
HEDJ	2.2667	.78672	2.5190	.93876	3.1615	.98667	2.6631	.98270
QSETUP	2.6000	.84230	2.4238	.70178	2.3073	.77733	2.4356	.77498
JID	2.3333	1.01227	2.6000	.99532	3.2500	1.05576	2.7425	1.08428
PYOKE	2.9030	.95511	3.1714	.76084	3.7396	.76398	3.2857	.88764
ANDON	3.0970	1.02374	3.2190	.91311	3.7187	.95990	3.3527	.99358
STANDW	2.4182	.87540	2.2619	.76538	1.8958	.55990	2.1834	.76599
FIVES	3.6636	.87694	3.9071	.73373	4.0078	.74797	3.8704	.79082
TPM	3.4727	.98275	3.5429	.89761	3.6458	.87665	3.5573	.91406
VISM	3.6909	.89086	3.8000	.74730	4.1510	.64222	3.8871	.78035
KAIZ	3.4909	.97890	3.7500	.72106	3.9609	.75227	3.7460	.83095
TEAM	3.5818	.90089	3.6905	.73408	3.9323	.72052	3.7407	.79101
WINV	3.5055	.91640	3.5171	.77384	3.7500	.81416	3.5926	.83421
VSM	3.5879	1.03829	3.6714	.75607	3.8490	.82280	3.7072	.87052
MUDA	3.3515	1.28527	3.6286	1.03333	3.7240	1.01411	3.5802	1.11095

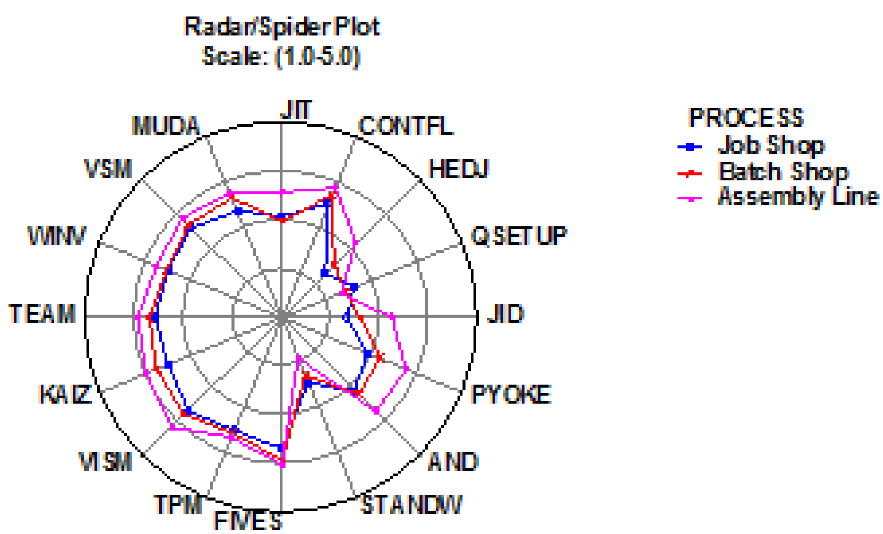

Figure 6. Means of utilization of sixteen lean tools in JS, BS, and AL.

As seen in Figure 6, there was a visible difference between the degree of utilization of the sixteen lean tools in a job shop, a batch shop, and assembly line manufacturing settings.

Just in Time (JIT) was not used in the job shop and batch shop ($\mu \approx 3$) but is used in the assembly line ($\mu=3.6$). *Continuous Flow* (CONTFL) was used in all three manufacturing settings: job shop ($\mu=3.52$), batch shop ($\mu= 3.71$) and assembly line ($\mu=3.85$). *Heijunka* (HEIJ) is not used in job shop and batch shop ($\mu<3$) but is used in assembly line ($\mu=3.16$). *Quick Set Up* (QSETUP) is not used in all three manufacturing settings ($\mu<3$). *Jidoka* (JID) is not used in job shop and batch shop ($\mu<3$) but is used in assembly line ($\mu=3.25$). *Poke-Yoke* (PYOKE) is not used in job shop ($\mu<3$) but is used in batch shop ($\mu=3.17$) and assembly line ($\mu=3.74$). *Andon* (AND) is used in all three manufacturing categories: job shop ($\mu=3.10$), batch shop ($\mu=3.22$) and assembly line ($\mu=3.72$). *Standardized Work* (STANDW) is not used in all three: job shop, batch shop, and assembly line ($\mu<3$). 5S's (FIVES), *Total Productive Maintenance* (TPM), *Visual Management* (VISM), *Kaizen* (KAIZ), *Teams* (TEAM), *Workers Involvement* (WINV), *Value Stream Mapping* (VSM), and *Muda Elimination* (MUDA; $\mu>3$) are used in all three manufacturing settings (See Table 23).

Second, tests of the Equality of Group Means were perfumed in order to understand if there is a significant difference between the three groups.

Table 24

Tests of Equality of Group Means

	Wilks' Lambda	F	df1	df2	Sig.
JIT	.907	9.552	2	186	.000
CONTFL	.977	2.179	2	186	.116
HEDJ	.857	15.539	2	186	.000
QSETUP	.977	2.149	2	186	.120
JID	.877	13.003	2	186	.000
PYOKE	.850	16.354	2	186	.000
ANDON	.928	7.250	2	186	.001
STANDW	.921	8.018	2	186	.000
FIVES	.969	2.983	2	186	.053
TPM	.994	.542	2	186	.583
VISM	.938	6.155	2	186	.003
KAIZ	.950	4.931	2	186	.008
TEAM	.967	3.201	2	186	.043
WINV	.982	1.739	2	186	.178
VSM	.985	1.431	2	186	.242
MUDA	.981	1.782	2	186	.171

As seen in Table 24, there is a statistically significant difference between the means of the level of utilization of *Just in Time* (JIT; p=0.000), *Heijunka* (HEIJ; p= 0.000), *Jidoka* (JID; p=0.000), *Poke-Yoke* (PYOKE; p=0.000), *Andon* (AND; p= 0.001), *Standardized Work* (STANDW; p=0.000), *Visual Management* (VISM; p=0.003), *Kaizen* (KAIZ; p= 0.008), and *Teams* (TEAM; p= 0.043) lean tools from one manufacturing setting to another. On the other hand, there is not a statistically significant difference between the means of the level of utilization of *Continuous Flow* (CONTFL), *Quick Set Up* (QSETUP), *Total Productive Maintenance* (TPM), *Workers Involvement* (WINV), *Value Stream Mapping* (VSM), and *Muda Elimination* (MUDA) from one manufacturing setting to another, while the *5S's* (FIVES) (p=0.053) was very close to being significant. The significance states that there is a high probability that the difference in means is not due to chance (Creswell, 2012).

Third, a multiple range test was performed to determine if there is a statistically significant difference between the means of utilization of the lean tools in the different groups when paired two by two: job shop and batch shop, job shop and assembly line, and batch shop and assembly line manufacturing settings.

Table 25

Differences in Means Between Job Shop, Batch Shop, and Assembly Line (Multiple Range Test)

	N	**Job shop-Batch Shop**	**Batch shop-Assembly line**	**Job shop-Assembly line**
Andon (AND)	189	0.0907403	-0.594411***	-0.50367**
Continuous Flow (CONTFL)	189	-0.188156	-0.140103	-0.328259*
5S's (FIVES)	189	-0.252779	-0.642576***	-0.895355***
Heijunka (HEIJ)	189	0.175818	0.117125	0.292943
Jidoka (JID)	189	-0.266325	-0.649857***	-0.916182***
Just in Time (JIT)	189	-0.268117	-0.568429***	-0.836545***
Kaizen (KAIZ)	189	-0.121662	-0.500179**	-0.621841**
Muda Elimination (MUDA)	189	0.156468	0.365933**	0.52240***1
Poke- Yoke (PYOKE)	189	-0.243506	-0.10067	-0.344176*
Quick Set Up (QSETUP)	189	-0.0702727	-0.103562	-0.173835
Standardized Work (STANDW)	189	-0.109442	-0.350536**	-0.459977**
Teams (TEAM)	189	-0.259091	-0.210938	-0.470028**
Total Productive Maintenance (TPM)	189	-0.109	-0.241188	-0.350187*
Visual Management (VISM)	189	-0.0116883	-0.232857	-0.244545
Value Stream Management (VSM)	189	-0.0845455	-0.177219	-0.261764
Workers Involvement (WINV)	189	-0.277364	-0.09475	-0.372114

***p< 0.000, **p< 0.01, *p< 0.05

There is no statistically significant difference between the means of the level of utilization of the lean tools in job shop-batch shop groups. There is a statistically significant difference between the means of the level of utilization of *Just in Time* (JIT; p< 0.000), *Heijunka*

(HEIJ; $p< 0.000$), *Jidoka* (JID; $p< 0.000$), *Poke-Yoke* (PYOKE; $p< 0.000$), *Andon* (AND; $p< 0.01$), *Standardized Work* (STANDW; $p< 0.01$), and *Visual Management* (VISM; $p< 0.01$) lean tools in the batch shop-assembly line groups. There is a statistically significant difference between the means of the level of utilization of JIT ($p< 0.01$), *Continuous Flow* (CONTFL; $p< 0.05$), *Heijunka* (HEIJ; $p< 0.000$), *Jidoka* (JID; $p< 0.000$), *Poke-Yoke* (PYOKE; $p< 0.000$), *Andon* (AND; $p< 0.01$), *Standardized Work* (STANDW; $p< 0.000$), *5S's* (FIVES; $p< 0.05$), *Visual Management* (VISM; $p< 0.01$), *Kaizen* (KAIZ; $p< 0.01$), and *Teams* (TEAM; $p< 0.05$) lean tools in the batch shop-assembly line groups (See Table 25). Consequently, based on the three types of analysis, there are proven group differences on a multivariate profile.

Step 2: Research design and sample size. Three groups discriminant analysis was performed. The three types of manufacturing settings—job shop, batch shop, and assembly line—were used as a categorical dependent variable. "The most appropriate independent variables are those that differ across at least two of the groups of the dependent variable" (Hair et al. 2009, p. 249). The independent variables that significantly differed across the groups were *Just in Time* (JIT), *Heijunka* (HEIJ), *Jidoka* (JID), *Poke-Yoke* (PYOKE), *Andon* (AND), *Standardized Work* (STANDW), *Visual Management* (VISM), *Kaizen* (KAIZ), and *Teams* (TEAM).

Hair et al. (2009) recommend using a ratio of the sample size to the number of predictor variables, with value of 20. The sample size in this study is 189 observations. The independent variables that differ across at least two of the groups are nine. The ratio of observations to predictors variables is 189/9=21, which is larger than the suggested ratio value of 20. In addition, the discriminant analysis requires the sample size of each group to be at least 20 observations

(Hair et al., 2009). The number of cases in the smallest group (job shop), is 55 cases, which is larger than the suggested number of 20 cases.

Step 3: Assumptions of discriminant analysis. The first assumption is normality of independent variables (Hair et al., 2009). *Standardized Work* (STANDW) had kurtosis of 1.546; consequently, the variable was transformed to acceptable normality with a logarithmic transformation. In addition, *Kaizen* (KAIZ) had kurtosis of 1.076, but neither transformation transformed the variable to acceptable normality. A caution should be added to the findings (Schwab, n/a).

The second assumption is "unknown, but equal dispersion and covariance structure for the groups as defined by the dependent variable" (Hair et al. 2009, p. 251). The equal dispersion is tested with Box's M test. The non-significant probability level indicates that differences between the group covariance matrices do not exist (Hair et al. 2009). The Box's M test resulted in Box's M of 18.812, F of 1.529, and significance of 0.106, which is greater than 0.05, indicating that the dispersion and population covariance matrices are equal.

Step 4: Estimation of the discriminant model, assessing overall fit and interpretation of the results. First, the classification accuracy was calculated before removing the outliers. The result was 49.2% of cross-validated grouped cases, correctly classified. As recommended by Schwab (n/a), the critical value for Mahalanobis D^2 was calculated. Five cases with Mahalanobis D^2 larger than the critical value of 23.1 were removed from the analysis. The new classification accuracy was 53% of cross-validated grouped cases correctly classified.

"Stepwise method is useful when the researcher wants to consider a relatively large number of independent variables for inclusion in the function" (Hair et al., 2009, p. 254). Nine independent variables, significantly different across the three groups, were identified in this study, so stepwise method was performed as the most appropriate. In the stepwise method, at each step, the variable that maximizes the Mahalanobis distance between the two closest groups is entered (SPSS, 2012). The two closest groups with no significant difference between them are job shop and batch shop groups.

Table 26

Variables Entered/Removed

Variables Entered/Removed[a,b,c,d]

		Min. D Squared					
				Exact F			
Step	Entered	Statistic	Between Groups	Statistic	df1	df2	Sig.
1	KAIZ	.093	1 and 2	2.715	1	180.000	.101
2	JIT	.157	1 and 2	2.279	2	179.000	.105
3	HEDJ	.247	1 and 2	2.379	3	178.000	.071

At each step, the variable that maximizes the Mahalanobis distance between the two closest groups is entered.

a. Maximum number of steps is 18.

b. Maximum significance of F to enter is .05.

c. Minimum significance of F to remove is .10.

d. F level, tolerance, or VIN insufficient for further computation.

As shown in Table 26: Variables Entered/Removed, *Heijunka* (HEIJ; D^2=0.247) is the best predictor, followed by *Just in Time* (JIT; D^2=0.157) and *Kaizen* (KAIZ; D^2=0.0.93). Those three variables are included in the model to get the best possible prediction. Those three variables describe the differences between job shop and batch shop manufacturing settings.

Table 27

Wilks' Lambda

Wilks' Lambda									
	Number of					Exact F			
Step	Variables	Lambda	df1	df2	df3	Statistic	df1	df2	Sig.
1	1	.945	1	2	180	5.264	2	180.000	.006
2	2	.867	2	2	180	6.608	4	358.000	.000
3	3	.810	3	2	180	6.613	6	356.000	.000

The model is the best fit of data with just one predictor, two predictors, or with all three predictors. The Wilks' Lambda is statistically significant for all three options, which means that all three predictors add predictive power to the discriminant function (Table 27). Discriminant analysis estimated one less discriminant function than there are groups (Hair et al., 2009; See Table 28).

Table 28

Eigenvalues of Functions 1 and 2

Eigenvalues				
Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	.193[a]	84.6	84.6	.402
2	.035[a]	15.4	100.0	.185

a. First 2 canonical discriminant functions were used in the analysis.

Table 29

Wilks' Lambda of Functions 1 and 2

Wilks' Lambda				
Test of Function(s)	Wilks' Lambda	Chi-square	Df	Sig.
1 through 2	.810	37.827	6	.000
2	.966	6.206	2	.045

The stepwise analysis identified two statistically significant discriminant functions. The Wilks' lambda statistics for the test of function 1 through 2 (chi-square=37.827) had a significant probability of 0.000. The Wilks' lambda statistics for the test of function 2 (chi-square= 6.206) had a significant probability of 0.045 (See Table 29).

The squared canonical correlation's value suggests the percent of the variation in the grouping variable, which the model explains (Agresti, 1996). "Wilks' lambda also shows the proportion of the total variance in the discriminant scores not explained by differences among the groups" (Leles et al., 2009, p. 911). Values of Wilks' lambda close to one indicate small differences between the dispersions (Lopez & Sanchez, 2009). The result is not surprising due to their being no significant difference between the level of utilization of the lean tools in job shop and batch shop manufacturing categories.

Table 30

Discriminant Function Coefficients

Standardized Canonical Discriminant Function Coefficients		
	Function	
	1	2
JIT	.284	-1.079
HEDJ	.706	.459
KAIZ	.312	.751

The predictive equations for both functions are (See Table 30):

DF1=0.284*JIT+0.706*HEDJ+0.312*KAIZ

DF2= -1.079 *JIT+0.459*HEDJ +0.751*KAIZ (Cook, 2010)

Table 31

Functions at Group Centroids

Functions at Group Centroids		
	Function	
PROCESS	1	2
Job Shop	-.422	-.244
Batch Shop	-.232	.215
Assembly Line	.592	-.045

Unstandardized canonical discriminant functions evaluated at group means

Function 1 separates the assembly line (the positive value of .592) from job shop (negative value of -0.422) and batch shop (negative value of -0.232) settings. Function 2 separates batch shop (the positive value of .215) from job shop (negative value of -0.244) and assembly line (negative value of -0.145) settings (See Table 31).

Table 32

Prior Probabilities for Groups

Prior Probabilities for Groups			
		Cases Used in Analysis	
PROCESS	Prior	Unweighted	Weighted
1	.273	50	50.000
2	.383	70	70.000
3	.344	63	63.000
Total	1.000	183	183.000

If the cross-validated classification accuracy rate is significantly higher than the accuracy attainable by chance alone, means that the independent variables are useful predictor of membership in the groups defined by the dependent variables (Schwab, n/a). Schwab (n/a) suggested calculating the proportional by chance accuracy rate by squaring and summing the proportion of cases in each group from the table of prior probabilities for groups: (0.273^2+0.383^2+0.344^2 =0.3395; See Table 32).

Table 33

Classification Results

Classification Results[b,c]

		PROCESS	Predicted Group Membership 1	2	3	Total
Original	Count	1	19	20	11	50
		2	9	40	21	70
		3	3	21	39	63
	%	1	38.0	40.0	22.0	100.0
		2	12.9	57.1	30.0	100.0
		3	4.8	33.3	61.9	100.0
Cross-validated[a]	Count	1	18	21	11	50
		2	9	40	21	70
		3	3	21	39	63
	%	1	36.0	42.0	22.0	100.0
		2	12.9	57.1	30.0	100.0
		3	4.8	33.3	61.9	100.0

a. Cross validation is done only for those cases in the analysis. In cross validation, each case is classified by the functions derived from all cases other than that case.

b. 53.6% of original grouped cases correctly classified.

c. 53.0% of cross-validated grouped cases correctly classified.

An acceptable cross-validated classification accuracy rate should be 25% or more, higher than the proportional by chance accuracy rate (Schwab, n/a). The cross-validated accuracy rate computed by SPSS was 53.0 percent, which was greater than the proportional by chance accuracy criteria of 42.44% (1.25 x 33.95 = 43.7%; See Table 33). The criterion for classification accuracy is satisfied.

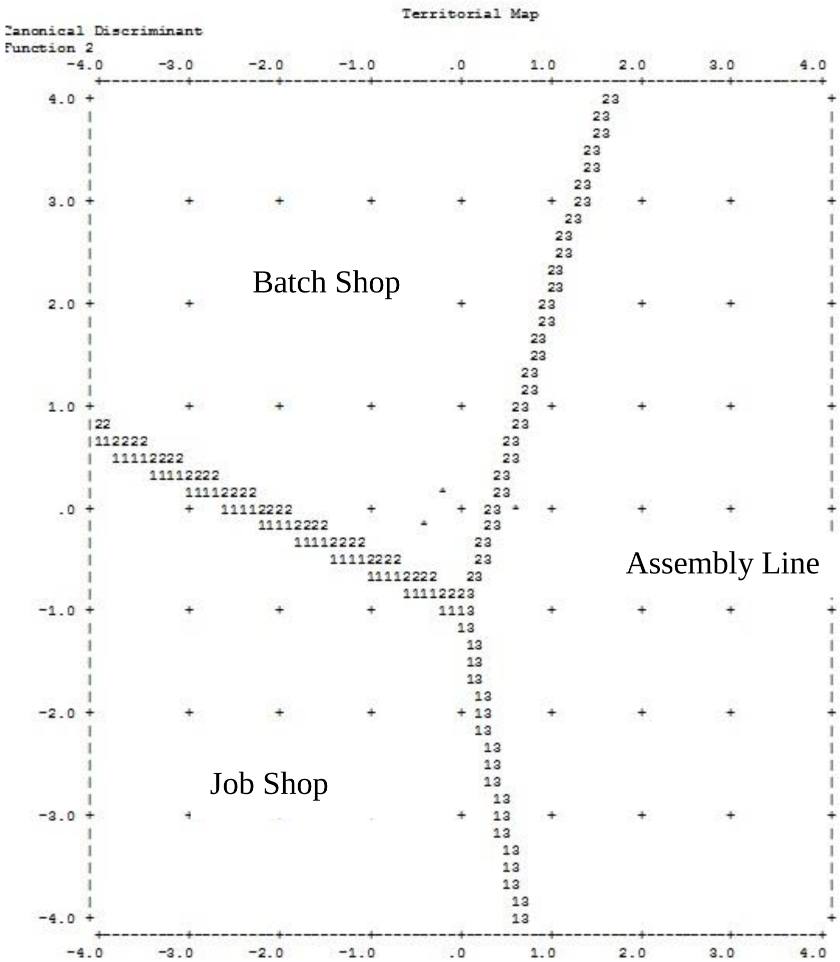

Figure 7. Territorial Map

Consequently, the H1 (Null) "There will be no significant difference between the degrees of utilization of each lean tool when the companies are grouped by the three manufacturing settings: Job shop, Batch shop and Assembly line" is rejected for *Just in Time* (JIT), *Heijunka* (HEIJ), *Jidoka* (JID), *Poke-Yoke* (PYOKE), *Andon* (AND), *Standardized Work* (STANDW), *Visual Management* (VISM), *Kaizen* (KAIZ) and *Teams* (TEAM), which are with significantly different means of utilization in the three groups. Moreover, taken into account that there is no statistically significant difference between the means of utilization of the lean tool in the job shop-batch shop group, the discriminant analysis identified two discriminant functions between the three groups under investigation (Figure 7). The discriminant functions revealed significant relationship between the three groups—a job shop, a batch shop, and an assembly line—and the lean tools contributing most to the group separation: *Heijunka* (HEIJ), *Just in Time* (JIT), and *Kaizen* (KAIZ).

Testing Hypothesis Two and Three

When the research objectives are theory development or prediction, the preferred analysis method is PLS (Hair et al., 2011). A PLS method was used for testing Hypothesis 2, asking if the type of manufacturing setting has a significant moderating effect on the relationship between the lean tools and the operational performance as perceived by the respondents. A PLS method was also used for testing Hypothesis 3, which asks if the type of manufacturing setting has a significant moderating effect on the relationship between the lean tools and the managers' satisfaction with the lean program as perceived by the respondents. Validity and reliability of the measurement model were assessed (Hair et al., 2011) and reported in the instrument validation section of Chapter 4. The next step is calculating the inner path model (Hair et al. 2011). The inner path model specifies the relationships between unobserved variables (Hensler, 2010) and refers to "the number of path relationships directed at a particular construct" (Hair et al., 2012, p. 420).

PLS and moderating effect. Baron and Kenny (1986) defined moderator as a "qualitative or quantitative variable that affects the direction or the strength of the relation between an independent (predictor) variable and a dependent (criterion) variable" (p. 1174). The causes of moderating effects are called "moderator variables" or just "moderators" (Henseler & Fassott, 2010). Partial least squares (PLS) path modeling is suitable for testing moderating effects (Dijkstra & Henseler, 2011). "When the moderator variable is categorical (as, e. g., sex, race, class) it can be used as a grouping variable without further refinement" (Henseler & Fassott, 2010, p. 720). The moderator variable in this study is categorical (manufacturing category: a job shop, a batch shop, and an assembly line) and is used as grouping variable. As recommended by Henseler and Fassott (2010), multiple group analysis was performed. First, a model with the direct effects was estimated for the main model without the moderating effect. Second, after the observations were grouped by the manufacturing category—job shop, batch shop, and assembly line—the model with the direct effects was estimated separately for each group of observations. "Differences in the model parameters between the different data groups are interpreted as moderating effects" (Henseler & Fassott, 2010; p. 720). Analyzing the moderating effect required two steps: (a) testing "whether the path coefficient capturing the moderating effect differs significantly from zero" and (b) assessing the strength of the identified moderating effect (Henseler & Fassott, 2010).

Step 1: Determine the significance of moderating effects. As recommended by Chain (2010), a T-test based on the estimates and standard errors generated by bootstrapping was executed (Yi & Gong, 2010). T-test was the primary approach for group comparison (Keil et al., 2000). "In the case of group comparisons, the researcher is interested in whether certain path coefficients differ across groups" (Henseler & Fassott, 2010, p. 730). Bootstrap resampling analysis was conducted in order to obtain the significance of the differences between the path coefficients in the different groups. The number of cases were set to be equal to the number of observations in the original sample (Hair et al., 2011). The critical t values for a two-tailed test are 1.65 for significance levels that equal 10%, 1.96 for significance levels that equal 5%, and 2.58 for significance levels that equal 1% (Hair et al., 2011).

Table 34

Perceived Operational Performance, Path Coefficient, and T-Statistic

	OPPERF All Path coefficient	T Statistics All	OPPERF Job shop Path coefficient	T Statistics Job shop	OPPERF Batch Shop Path coefficient	T Statistics Batch shop	OPPERF Assembly Line Path coefficient	T Statistics Assembly Line
AND	-0.068155	1.126116	-0.034245	0.404212	-0.054981	0.468839	0.110906	0.670141
CONTFL	-0.013460	0.238095	-0.010606	0.123620	0.018096	0.135708	-0.044770	0.393405
FIVES	0.034659	0.471431	-0.112160	0.934603	-0.044910	0.301841	0.336747	1.638077
HEDJ	0.069313	1.395758	0.108583	1.611218	0.097016	0.571843	0.095864	0.718843
JID	0.004586	0.097762	-0.025258	0.300346	-0.090058	0.877738	0.103077	0.894746
JIT	0.011999	0.168822	0.070653	0.690563	-0.146609	1.160259	0.164352	1.002056
KAIZ	0.004845	0.064102	-0.062136	0.486912	0.030675	0.232004	0.117436	0.728235
MUDA	**0.258483*** **	**3.621143**	**0.236774** **	**2.173435**	**0.304932** **	**2.120111**	0.189797	1.481658
PYOKE	-0.070640	1.164158	-0.055809	0.582526	-0.138707	1.062338	-0.031848	0.301452
QSETUP	-0.048820	0.695072	**-0.238181***	**1.902134**	0.197955	1.466122	-0.065078	0.349129
STANDW	-0.025434	0.347686	0.072864	0.701521	**-0.397256*** **	**2.667475**	**0.319406** **	**2.465131**
TEAM	-0.051764	0.641822	-0.064244	0.471210	-0.017878	0.118232	-0.267945	1.127320
TPM	0.097675	1.289909	0.026824	0.200703	0.142351	1.162062	0.046393	0.324893
VISM	**0.117006***	**1.713482**	0.105979	0.958570	0.031291	0.200680	-0.007115	0.054290
VSM	**0.142564** **	**2.189890**	0.196648	1.581094	0.152615	1.120590	**0.226371***	**1.821356**
WINV	**0.414434*** **	**4.423209**	**0.522829*** **	**3.496109**	**0.434641*** **	**2.582732**	0.286799	1.544459

*Significant at p ≤0.1
**Significant at p ≤0.05
*** Significant at p ≤0.01

First, the direct effect path coefficient for the main model without the moderating effect was estimated, and the significance of the path coefficients was examined by performing a bootstrapping analysis. Statistically significant is the coefficient for the path from MUDA to OPPERF (β=0.258483***, t=3.621143or p=0.01), from VISM to OPPERF (β=0.117006*, t=1.713482 or p=0.10), from VSM to OPPERF (β=0.142564**, t=2.189890 or p=0.05), and from WINV to OPPERF (β=0.414434***, t=2.189890 or p=0.05; See Table 34).

Second, the direct effect path coefficient was estimated only for the job shop model. The significance of the path coefficients was examined by performing a bootstrapping analysis.

Statistically significant is the coefficient for the path from MUDA to OPPERF (β=0.236774, t=2.173435 or p=0.05), from WINV to OPPERF (β=0.522829, t= 3.496 or p=0.01), and QSETUP (β=-0.238181, t= 1.902134 or p=0.10), while the results for the path from HEDJ to OPPERF (β= 0.108583, t= 1.611218) and from VSM to OPPERF (β= 0.196648, t= 1.581094) are very close to significant.

Third, the direct effect path coefficient was estimated only for the batch shop model. The significance of the path coefficients was examined by performing a bootstrapping analysis. Statistically significant is the coefficient for the path from MUDA to OPPERF (β=0.236774, t=2.120111or p=0.05), STANDW to OPPERF (β=0.397256***, t=2.667475 or p=0.01), and WINV to OPPERF (β=0.434641***, t= 2.582732or p=0.01), while the results for the path from QSETUP to OPPERF (β= 0.197955, t= 1.466122) are very close to significant.

Fourth, the direct effect path coefficient was estimated only for the assembly line model. The significance of the path coefficients was examined by performing a bootstrapping analysis. Statistically significant is the coefficient for the path from STANDW to OPPERF (β=0.0.319406**, t=2.465131or p=0.05) and from VSM to OPPERF(β=0.226371*, t= 1.821356 or p=0.10), while the results for the path from FIVES to OPPERF (β= 0.336747, t= 1.638077), from MUDA to OPPERF (β= 0.189797, t= 1.481658), and from WINV to OPPERF (β= 0.286799, t= 1.544459) are very close to significant.

Table 35

Satisfaction with the Lean Program, Path Coefficient, and T-Statistic

	SATISF All Path coefficient	T Statistics All	SATISF Job Shop Path coefficient	T Statistics Job Shop	SATISF Batch Shop Path coefficient	T Statistics Batch Shop	SATISF Assembly Line Path coefficient	T Statistics Assembly Line
AND	-0.01714	0.25461	-0.12388	0.828221	-0.00124	0.010292	0.106164	0.638687
CONTFL	0.129047	1.49186	0.004565	0.029998	**-0.22157***	**1.748651**	**0.385634****	**2.423373**
FIVES	-0.02389	0.281138	-0.14099	0.626949	0.032057	0.180606	0.061629	0.351637
HEDJ	0.03164	0.489685	**0.2293***	**1.757913**	0.013638	0.118586	-0.17618	0.972079
JID	-0.02737	0.467527	-0.11814	0.831186	0.131883	1.212365	-0.05532	0.416998
JIT	0.068911	0.9002	0.041305	0.247616	0.107736	0.882324	0.297097	1.315472
KAIZ	0.051176	0.516525	0.292192	1.285892	-0.13348	0.828779	0.106431	0.484066
MUDA	0.03973	0.508552	0.16382	0.80512	0.151184	1.108891	-0.11803	0.775903
PYOKE	-0.01421	0.185345	-0.07644	0.529373	0.129553	0.990006	-0.14426	0.814672
QSETUP	-0.06881	0.779541	-0.2607	1.27001	-0.08737	0.658403	-0.10185	0.454726
STANDW	0.012809	0.149423	-0.11437	0.478825	-0.12359	0.846612	0.094812	0.528993
TEAM	0.157453	1.415461	0.231816	0.915596	-0.12074	0.72583	0.290601	1.080544
TPM	0.047079	0.607119	-0.04121	0.182376	0.136204	0.936075	0.035803	0.188153
VISM	**0.259103*****	**2.578752**	0.120196	0.575314	0.245837	1.389948	0.096473	0.540956
VSM	0.096786	1.191904	0.165677	0.715301	0.081616	0.488922	0.014255	0.089012
WINV	0.128218	1.152364	-0.10847	0.354536	**0.357362***	**1.880079**	-0.04327	0.154435

*Significant at $p \leq 0.1$
**Significant at $p \leq 0.05$
*** Significant at $p \leq 0.01$

First, the direct effect path coefficient was estimated for the main model without the moderating effect, and the significance of the path coefficients was examined by performing a bootstrapping analysis. Statistically significant is the coefficient for the path from VISM to SATISF (β=0.259103***, t=2.578752, p=0.01; See Table 35).

Second, the direct effect path coefficient was estimated only for the job shop model. The significance of the path coefficients was examined by performing a bootstrapping analysis.

Statistically significant is the coefficient for the path from HEDJ to SATISF (β=0.2293*, t=1.757913, p=0.10).

Third, the direct effect path coefficient was estimated only for the batch shop model. The significance of the path coefficients was examined by performing a bootstrapping analysis. Statistically significant is the coefficient for the path from CONTFL to SATISF (β=0.22157*, t=1.748651, p=0.10) and from WINV to SATISF (β=0.357362*, t= 1.880079, p=0.1).

Fourth, the direct effect path coefficient was estimated only for the assembly line model. The significance of the path coefficients was examined by performing a bootstrapping analysis. Statistically significant is the coefficient for the path from CONTFL to SATISF (β=0.385634**, t=2.423373 or p=0.05), while the results for the path from JIT to SATISF (β= 0.297097, t= 1.315472) are very close to significant.

Step 2: Determining the strength of moderating effects. "Differences in the model parameters between the different data groups are interpreted as moderating effects" (Henseler & Fassott, 2010: p. 720). Hair et al. (2011) described exogenous variables as latent constructs without structural path relationships, while the endogenous variables are the target constructs, explained through the structural model relationships. In Figure 8, the influence of the exogenous variable on the endogenous variable, without moderating effect, is described by the coefficient *b*. The path coefficient *d* indicates the extent to which the exogenous variable's influence on the endogenous variable changes because of the moderating effect (Henseler & Fassott, 2010; Henseler et al., 2009).

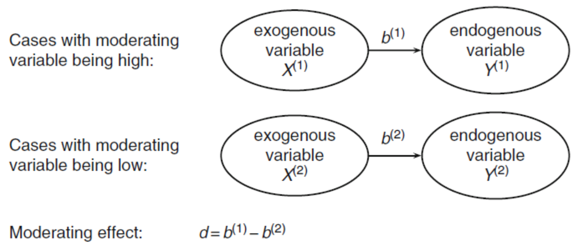

Figure 8. Detecting a moderating effect (d) through group comparisons. Source: Henseler and Fassott, 2010, p. 721.

As recommended by Henseler and Fassott (2010), the moderating effect *d* was detected through group comparison of the path coefficients for the different manufacturing categories and calculated by $d = b^{(1)} - b^{(2)}$. The moderating effect *d* of the different manufacturing categories on the perceived operational performance was calculated (See Table 36).

Table 36

Moderating Effect d, for Perceived Operational Performance

	OPPERF All Path coefficient (b1)	**OPPERF JS Path coefficient (b2)**	**Job Shop D=b2-b1**	**OPPERF BS Path coefficient (b3)**	**Batch Shop D=b3-b1**	**OPPERF AL Path coefficient (b4)**	**Assembly Line D=b4-b1**
AND	-0.068155	-0.034245	**0.03391**	-0.054981	**0.013174**	0.110906	**0.179061**
CONTFL	-0.013460	-0.010606	**0.002854**	0.018096	**0.031556**	-0.044770	-0.03131
FIVES	0.034659	-0.112160	-0.14682	-0.044910	-0.07957	0.336747	**0.302088**
HEDJ	0.069313	0.108583	**0.03927**	0.097016	**0.027703**	0.095864	**0.026551**
JID	0.004586	-0.025258	-0.02984	-0.090058	-0.09464	0.103077	**0.098491**
JIT	0.011999	0.070653	**0.058654**	-0.146609	-0.15861	0.164352	**0.152353**
KAIZ	0.004845	-0.062136	-0.06698	0.030675	**0.02583**	0.117436	**0.112591**
MUDA	**0.258483*** **	**0.236774** **	-0.02171	**0.304932** **	**0.046449**	0.189797	-0.06869
PYOKE	-0.070640	-0.055809	**0.014831**	-0.138707	-0.06807	-0.031848	**0.038792**
QSETUP	-0.048820	**-0.238181** **	-0.18936	0.197955	**0.246775**	-0.065078	-0.01626
STANDW	-0.025434	0.072864	**0.098298**	**-0.397256*** **	-0.37182	**0.319406** **	**0.34484**
TEAM	-0.051764	-0.064244	-0.01248	-0.017878	**0.033886**	-0.267945	-0.21618
TPM	0.097675	0.026824	-0.07085	0.142351	**0.044676**	0.046393	-0.05128
VISM	**0.117006***	0.105979	-0.01103	0.031291	-0.08572	-0.007115	-0.12412
VSM	**0.142564** **	0.196648	**0.054084**	0.152615	**0.010051**	**0.226371***	**0.083807**
WINV	**0.414434*** **	**0.522829*** **	**0.108395**	**0.434641*** **	**0.020207**	0.286799	-0.12764

*Significant at p ≤0.1
**Significant at p ≤0.05
*** Significant at p ≤0.01

The path coefficients between the lean tools and OPPERF All described the effect of different lean tools on the perceived operational performance when the moderator variable is zero. The path coefficients between the lean tools and OPPERF job shop described the effect of the lean tools on the perceived operational performance for a job shop manufacturing settings. The path coefficient *d* was calculated as a difference between the path coefficients without moderator and the job shop's path coefficients. The positive path coefficient *d* indicated positive moderating effect, while the negative path coefficient *d* indicated negative moderating effect. The job shop has a positive moderating effect on the interaction between the lean tools and perceived operational performance for *Andon* (AND), *Continuous Flow* (CONTFL), *Heijunka* (HEIJ), *Just in Time* (JIT), *Poke-Yoke* (PYOKE), *Standardized Work* (STANDW), *Value Stream Mapping* (VSM), and *Workers Involvement* (WINV).

Path coefficients between the lean tools and perceived operational performance in batch shop setting described the effect of the lean tools on the perceived operational performance for batch shop manufacturing settings. The path coefficient *d* was calculated as a difference between the path coefficients without moderator and the batch shop's path coefficients. The batch shop manufacturing setting had a positive moderating effect on the interaction between the lean tools and perceived operational performance for *Andon* (AND), *Continuous Flow* (CONTFL), *Heijunka* (HEIJ), *Kaizen* (KAIZ), *Muda Elimination* (MUDA), *Quick Set Up* (QSETUP), *Teams* (TEAM), *Total Productive Maintenance* (TPM), *Value Stream Mapping* (VSM), and *Workers Involvement* (WINV).

The path coefficients between the lean tools and perceived operational performance in the assembly line settings described the effect of the lean tools on the perceived operational performance for assembly line manufacturing settings. The path coefficient *d* was calculated as a difference between the path coefficients without moderator and the assembly line path coefficients. The assembly line manufacturing setting had a positive moderating effect on the interaction between the lean tools and perceived operational performance for *Andon* (AND), *5S's* (FIVES), *Heijunka* (HEIJ), *Jidoka* (JID), *Just in Time* (JIT), *Kaizen* (KAIZ), *Poke-Yoke* (PYOKE), *Standardized Work* (STANDW), and *Value Stream Mapping* (VSM).

Table 37

Moderating Effect, Satisfaction with the Lean Program

	SATISF All Path coefficient (b1)	**SATISF JS Path coefficient (b2)**	**Job Shop D=b2-b1**	**SATISF BS Path coefficient (b3)**	**Batch Shop D=b3-b1**	**SATISF AL Path coefficient (b4)**	**Assembly Line D=b4-b1**
AND	-0.017138	-0.12388	-0.106742	-0.00124	**0.015898**	0.106164	**0.123302**
CONTFL	0.129047	0.004565	-0.124482	**-0.22157***	-0.350618	**0.385634****	**0.256587**
FIVES	-0.023894	-0.140987	-0.117093	0.032057	**0.055951**	0.061629	**0.085523**
HEDJ	0.03164	**0.2293***	**0.19766**	0.013638	-0.018002	-0.17618	-0.20782
JID	-0.027368	-0.118142	-0.090774	0.131883	**0.159251**	-0.05532	-0.027949
JIT	0.068911	0.041305	-0.027606	0.107736	**0.038825**	0.297097	**0.228186**
KAIZ	0.051176	0.292192	**0.241016**	-0.133477	-0.184653	0.106431	**0.055255**
MUDA	0.03973	0.16382	**0.12409**	0.151184	**0.111454**	-0.11803	-0.157762
PYOKE	-0.014205	-0.076441	-0.062236	0.129553	**0.143758**	-0.14426	-0.13005
QSETUP	-0.068809	-0.260698	-0.191889	-0.087367	-0.018558	-0.10185	-0.03304
STANDW	0.012809	-0.11437	-0.127179	-0.123588	-0.136397	0.094812	**0.082003**
TEAM	0.157453	0.231816	**0.074363**	-0.120737	-0.27819	0.290601	**0.133148**
TPM	0.047079	-0.041214	-0.088293	0.136204	**0.089125**	0.035803	-0.011276
VISM	**0.259103*****	0.120196	-0.138907	0.245837	-0.013266	0.096473	-0.16263
VSM	0.096786	0.165677	**0.068891**	0.081616	-0.01517	0.014255	-0.082531
WINV	0.128218	-0.108469	-0.236687	**0.357362***	**0.229144**	-0.04327	-0.171491

*Significant at p ≤0.1
**Significant at p ≤0.05
*** Significant at p ≤0.01

The path coefficients between the lean tools and managers' satisfaction with the lean program for all described the effect of different lean tools on the satisfaction with the lean program when the moderator variable is zero. The path coefficients between the lean tools and managers' satisfaction with the lean program for job shop setting described the effect of the lean tools on the satisfaction with the lean program for job shop manufacturing settings. The path coefficient *d* was calculated as a difference between the path coefficients without moderator and the job shop's path coefficients. The job shop has a positive moderating effect on the interaction between the lean tools and the satisfaction with the lean program for HEIJ (d= 0.19766), MUDA (d=0.12409), KAIZ (d=0.241016), TEAM (d= 0.074363), and VSM (d=0.068891; See Table 37).

The path coefficients between the lean tools and managers' satisfaction with the lean program in the batch shop setting described the effect of the lean tools on the satisfaction with the lean program for batch shop manufacturing settings. The path coefficient *d* was calculated as a difference between the path coefficients without moderator and the batch shop's path coefficients. The batch shop had a positive moderating effect on the interaction between the lean tools and the satisfaction with the lean program for *Andon* (AND), *5S's* (FIVES), *Jidoka* (JID), *Just in Time* (JIT), *Muda Elimination* (MUDA), *Poke-Yoke* (PYOKE), *Total Productive Maintenance* (TPM) and *Workers Involvement* (WINV).

The path coefficients between the lean tools and managers' satisfaction with the lean program in the assembly line setting described the effect of the lean tools on the satisfaction with the lean program for the assembly line manufacturing settings. The path coefficient *d* was calculated as a difference between the path coefficients without moderator and the path coefficients for assembly line manufacturing setting. The assembly line manufacturing setting had a positive moderating effect on the interaction between the lean tools and the satisfaction with the lean program for *Andon* (AND), *Continuous Flow* (CONTFL), *5S's* (FIVES), *Just in Time* (JIT), *Kaizen* (KAIZ), *Standardized Work* (STANDW), and *Teams* (TEAM).

Moreover, the moderating effect was assessed by "comparing the proportion of variance explained (as expressed by the determination coefficient R^2) of the main effect model (i. e. the model without moderating effect) with the R^2 of the full model (i. e. the model including the moderating effect"; Henseler & Fassott, 2010, p. 732; See Table 38). "R^2 values of 0.75, 0.50, or

0.25 for endogenous latent variables in the structural model can, as a rule of thumb, be described as substantial, moderate, or weak, respectively" (Hair et al., 2011, p. 145). In addition, as Henseler and Fassott (2010) recommended, the effect size f^2 was calculated with the formula f= (R^2 [model with moderator] - R^2 [model without moderator])/ (1- R^2 [model with moderator]). "Moderating effects with effect sizes f^2 of 0.02 may be regarded as weak, effect sizes from 0.15 as moderate, and effect sizes above 0.35 as strong" (Henseler et al., 2009).

Table 38

Moderating Effect of Manufacturing Category on Perceived Operational Performance

	R Square	f^2	Moderating effect
OPPERF All	0.714686*		
OPPERF Job shop	**0.904364****	**1.98**	**Very strong**
OPPERF Batch Shop	0.697727*	-0.056	Negative
OPPERF Assembly Line	**0.775719****	**0.272**	**Moderate**

R square: *moderate, ** substantial

In the main model describing the relationship between the lean tools and the perceived operational performance, R^2 equals 0.71 (moderate), which means that the lean tools explain 71% of the variance in the perceived operations performance. On the other hand, after examining the relationships between the lean tools and the perceived operational performance in the different manufacturing categories, R^2 increased to 0.90 (substantial) for a job shop, indicating positive moderating effect; decreased to 0.69 (moderate) for a batch shop, indicating a negative moderating effect; and increased to 0.78 (substantial) for an assembly line, indicating a positive moderating effect. In addition, as recommended by as Henseler and Fassott (2010), the effect size f^2 was calculated, resulting in 1.98 (very strong moderating effect) for job shop, -0.056 (negative moderating effect) for batch shop, and 0.272 (moderate moderating effect) for an assembly line.

There is a moderating effect of the different manufacturing settings on the relationship between the lean tools and perceived operational performance. The perceived operational performance depends on different lean tools for a job shop, batch shop, and an assembly line. R^2 for the job shop is 0.90 (substantial), which means that 90% of the variance in the operational performance is explained by the job shop lean tools. R^2 for the batch shop is 0.70 (moderate), which means that 70% of the variance in the perceived operational performance is explained by the batch shop lean tools. R^2 for the assembly line is 0.78 (substantial), which means that 78% of the variance in the perceived operational performance is explained by the assembly line lean tools.

Table 39

Moderating Effect of Manufacturing Category on Satisfaction with the Lean Program

	R Square	F^2	Moderating effect
SATISF All	0.575291*		
SATISF Job shop	0.695129*	**0.393**	**Strong**
SATISF Batch Shop	0.659987*	**0.249**	**Moderate**
SATISF Assembly Line	0.638079*	**0.173**	**Moderate**

R square: * moderate

In the main model of the relationship of lean tools and satisfaction with the lean program, R^2 equals 0.58 (moderate), which means that the lean tools explain 58% of the variance in the satisfaction with the lean program (See Table 39). On the other hand, after examining the relationships between the lean tools and the satisfaction with the lean program in the different manufacturing settings, R^2 increased from 0.58 to 0.70 (moderate) for a job shop, indicating positive moderating effect; increased from 0.58 to 0.66 (moderate) for a batch shop; and increased from 0.58 to 0.64 (moderate) for an assembly line, indicating a positive moderating effect. In addition, as recommended by Henseler and Fassott (2010), the effect size f^2 was calculated, resulting in 0.39 (strong moderating effect) for a job shop, 0.25 (moderate moderating effect) for a batch shop, and 0.272 (moderate moderating effect) for an assembly line.

There is a moderating effect of the different manufacturing settings on the relationship between the lean tools and the satisfaction with the lean program. The satisfaction with the lean program depends on different lean tools for a job shop, a batch shop, and an assembly line. R^2 for the job shop is 0.70 (moderate), which means that 70% of the variance in the satisfaction with the lean program is explained the job shop lean tools. R^2 for the batch shop is 0.66 (moderate), which means that 66% of the variance in the satisfaction with the lean program is explained by the batch shop lean tools. R^2 for the assembly line is 0.64 (moderate), which means that 64% of the variance in the satisfaction with the lean program is explained by the assembly line lean tools.

The moderating effect of the manufacturing category on the relationship of lean tools – perceived operational performance suggests that the lean performance depends on different lean tools for a job shop, a batch shop, and an assembly line.

H2(Null): The type of manufacturing setting will not have significant moderating effect on the relationship between the lean tools and the operational performance as perceived by the respondents.

The job shop manufacturing setting is a very strong moderator (f^2= 1.92) on the relationship: lean tools – perceived operational performance. The R^2 for the job shop is 0.90, which means that 90% of the variance in the perceived operational performance depends on the job shop lean tools. The statistical analysis provided support for rejecting the null Hypothesis 2 for job shop manufacturing settings. The lean tools affecting the perceived operational performance of the firm in job shop manufacturing settings are (a) *Workers Involvement*

(WINV), (b) *Muda Elimination* (MUDA), (c) Negative *Quick Set Up* (QSETUP), (d) *Heijunka* (HEIJ) and (e) *Value Stream Mapping* (VSM).

Batch shop manufacturing setting is a negative moderator (f2= -0.056) on the relationship: lean tools – perceived operational performance. R^2 for the batch shop is 0.70, which means that 70% of the variance in the perceived operational performance depends on the batch shop lean tools. The statistical analysis provides support for accepting Hypothesis 2 for batch shop manufacturing settings. The lean tools affecting the perceived operational performance in a Batch shop-manufacturing setting are (a) *Workers Involvement*, (b) *Muda Elimination* (MUDA), (c) Negative *Standardized Work* (STANDW), and (d) *Quick Set Up* (QSETUP).

Assembly line manufacturing category is a moderate moderator (f^2= 0.27) on the relationship: lean tools – perceived operational performance. R^2 for the assembly line is 0.78, which means that 78% of the variance in the perceived operational performance is explained by the assembly line lean tools. The statistical analysis provides support for rejecting Hypothesis 2c for assembly line manufacturing settings. The lean tools affecting the perceived operational performance in assembly line-manufacturing settings are (a) *Standardized Work* (STANDW), (b) *Value Stream Mapping* (VSM), (c) *5S's* (FIVES), (d) *Muda Elimination* (MUDA) and (e) *Workers Involvement* (WINV).

> H3(Null): The type of manufacturing setting will not have significant moderating effect on the relationship between the lean tools and managers' satisfaction with the lean program, as perceived by the respondents.

The job shop is a strong moderator (f=0.39) on the relationship with lean tools – satisfaction with the lean program. The R^2 for the job shop is 0.70 (moderate), which means that

70% of the variance in the satisfaction with the lean program is explained by the job shop lean tools. The statistical analysis provides support for rejecting Hypothesis 3 for job shop manufacturing settings. The only lean tool affecting the satisfaction with lean program in job shop manufacturing settings is *Heijunka* (HEIJ). This suggests for example, that if job shops are concerned with the satisfaction with the lean program, the most important lean tool is *Heijunka* (HEIJ).

The batch shop is a moderate moderator (f=0.25) on the relationship lean tools – satisfaction with the lean program. The R^2 for the batch shop is 0.66 (moderate), which means that 66% of the variance in the satisfaction with the lean program is explained by the batch shop lean tools. The statistical analysis provides support for rejecting Hypothesis 3 for batch shop manufacturing settings. The lean tool affecting the satisfaction with lean program in batch shop-manufacturing settings is *Workers Involvement* (WINV), while *Continuous Flow* (CONTFL) is negatively affecting the satisfaction. This suggests for example, that if batch shops are concerned with the satisfaction with the lean program, the most important lean tools are *Workers Involvement* (WINV) and negative *Continuous Flow* (CONTFL).

The assembly line is a moderate moderator (f= 0.17) on the relationship lean tools – satisfaction with the lean program. The R^2 for the assembly line-manufacturing setting is 0.64 (moderate), which means that 64% of the variance in the satisfaction with the lean program is explained by the assembly line lean tools. The statistical analysis provides support for rejecting Hypothesis 3 for assembly line manufacturing settings. The only lean tool significantly affecting the satisfaction with lean program in the assembly line manufacturing settings is *Continuous Flow* (CONTFL). This suggests for example, that if assembly lines are concerned with the satisfaction with the lean program, the most important lean tool is *Continuous Flow* (CONTFL).

Chapter Summary

This chapter reported the response rate for both groups of lean professionals: the Lean Enterprise Institute and the Continuous Improvement, Six Sigma, and Lean Group. In addition, this chapter provided the demographic characteristics of the survey respondents. Validity of the measurement instrument was estimated through exploratory factor analysis, which defines sets of highly correlated factors. The variance of the data was explained through twelve factors. In addition, the convergent and discriminant validity were estimated through confirmatory factor analysis. Reliability was established by calculating a Cronbach alpha coefficients and composite reliability coefficients. Discriminant analysis was used to test Hypothesis 1 resulting in rejecting the null hypothesis for *Just in Time* (JIT), *Heijunka* (HEIJ), *Jidoka* (JID), *Poke-Yoke* (PYOKE), *Andon* (AND), *Standardized Work* (STANDW), *Visual Management* (VISM), *Kaizen* (KAIZ), and *Teams* (TEAM). In addition, two discriminate functions were identified. A PLS method was used for testing Hypotheses 2 and 3. Hypothesis 2 was rejected for job shop and assembly line settings, while it was accepted for batch shop settings. Hypothesis 3 was rejected for job shop, batch shop, and assembly line settings. The findings and implications will be discussed in the next chapter.

Chapter 5: Discussion, Conclusions, and Implications

Based on the results reported earlier, this chapter presents the findings, discusses their applications in the real world settings, and proposes conclusions relevant to the overall effort. The final section identifies the study limitations and provides suggestions for future research.

The previous chapter provided evidence that job shop, batch shop, and assembly line settings have different levels of utilization for each of the sixteen lean tools. In addition, the perceived operational performance of firms with job shop, batch shop, and assembly line settings is associated with different lean tools for the three manufacturing settings. Furthermore, the managers' satisfaction with the lean program is related to different lean tools for job shop, batch shop, and assembly line settings. This study revealed that the type of manufacturing setting moderates the relationships between the lean tools and the perceived operational performance of the firms as well as the relationships between the lean tools and the managers' satisfaction with the lean program. A summary of the findings is provided under each of the following headings.

Discussion of Findings and Conclusions

Research Question 1, "Are the sixteen lean tools perceived by respondents to be equally utilized in job shop, batch shop, and assembly line manufacturing settings?" was addressed by testing Hypothesis 1.

The null Hypothesis 1 was rejected for each of the following lean tools: *Just in Time* (JIT), *Heijunka* (HEIJ), *Jidoka* (JID), *Poke Yoke* (PYOKE), *Andon* (AND), *Standardized Work* (STANDW), *Visual Management* (VISM), *Kaizen* (KAIZ), and *Teams* (TEAM), which have significantly different means of utilization in the three manufacturing settings. When examined more closely, the results revealed that there was no significant difference between two of the manufacturing settings groups, the job shop and batch shop groups, which is not surprising because Hayes and Wheelwright (1984) described the batch shop as a standardized job shop with a stable line of products. To explore the differences in the level of utilization of each lean tool in all three manufacturing settings, a discriminant analysis procedure was used. The discriminant analysis identified two statistically significant discriminant functions with acceptable cross-validated classification accuracy rates. Both functions were calculated based on the utilization ratings for *Heijunka* (HEIJ), *Just in Time* (JIT), and *Kaizen* (KAIZ). The discriminant analysis was based on Mahalanobis D^2, which is the minimum squared distance. Both functions discriminated between all three groups: job shop, batch shop, and assembly line. The discriminant functions revealed that a significant relationship exists among the three groups. The lean tools that produced the greatest differences among the settings are *Heijunka* (HEIJ), *Just in Time* (JIT), and *Kaizen* (KAIZ).

Since the *Five S's* (FIVES) is typically the first tool implemented when the lean transformation begins (Dennis, 2007), it was expected that the level of utilization of the *Five S's* (FIVES) would be the same in the three manufacturing settings. In addition, it was expected that the level of utilization of *Visual Management* (VISM) would be the same in the three manufacturing settings, because *Visual Management* (VISM) refers to creating a self-directing, self-explaining, and self-improving workplace (Hogan 2009). Since *Kaizen* (KAIZ) is defined as the employees' contribution to the company development by providing Muda-eliminating suggestions (Boyer 1996), it was expected that the level of utilization of *Kaizen* (KAIZ) would be the same in all three manufacturing settings.

This study revealed that there was a statistically significant difference in the levels of utilization of *Visual Management* (VISM) in a batch shop-assembly line group and in a job shop-assembly line group. In addition, there was a statistically significant difference in the level of utilization of the *Five S's* (FIVES) and *Kaizen* (KAIZ) in the job shop-assembly line group. This result is of particular interest, because based on the concepts behind these three lean tools, they would appear to be equally applicable to all three manufacturing settings.

Another interesting finding was that the *Quick Set Up* (QSETUP) and *Standardized Work* (STANDW) tools are not used at all in the three manufacturing settings ($M < 3$, $\mu < 3$). The use of *Standardized Work* (STANDW) was expected to be low in a job shop environment because of the high variety products (each job is different, and production approaches cannot be standardized; Pepper and Spedding, 2010), moderate in a batch shop, and high in an assembly line environment. It was surprising that the assembly line manufacturing setting used *Standardized Work* (STANDW) even less than the job shop and batch shop settings, because very good performance is achieved through implementing lean in high volume/low variety situations (Jina et al., 1997) such as an assembly line setting. *Standardized Work* (STANDW) is the foundation of lean manufacturing (Whitmore, 2008) and provides a base for improvement (Dennis, 2007). If *Standardized Work* (STANDW) was not being used, what then would be the basis for process improvements, which the companies must continue to pursue? The level of utilization of *Quick Set Up* (QSETUP) was expected to be high in a job shop and lower in a batch shop and an assembly line. According to Hayes and Wheelwright (1984), the set-ups in a job shop environment are frequent, in a batch shop less frequent, and in an assembly line far less frequent. The use of *Quick Set Up* (QSETUP) in a job shop manufacturing settings should be investigated further.

The data analysis revealed that *Total Productive Maintenance* (TPM), *Workers Involvement* (WINV), *Value Stream Mapping* (VSM), and *Muda Elimination* (MUDA) are almost equally utilized in all three manufacturing settings. It was expected that *Total Productive Maintenance* (TPM) and *Workers Involvement* (WINV) would be equally utilized. *Total Productive Maintenance* (TPM) refers to preventive maintenance work involving everyone working on the shop floor (Dennis, 2007) in order to achieve reliable equipment with longer life (Kilpatrick, 2003), while the *Workers Involvement* (WINV) is the extent to which employees are motivated to participate in continuous improvement and problem-solving activities (Bodek, 2010; Fullerton and Wempe, 2008). On the other hand, it was expected that *Value Stream Mapping* (VSM) would be implemented at a low level in a job shop setting, moderate in a batch shop setting, and high in an assembly line setting. With the high variety of products in a job shop environment, the use of *Value Stream Mapping* (VSM) would not be justified. *Muda Elimination* (MUDA) was expected to be used at a high level in an assembly line, medium in a batch shop, and low in a job shop. Some of the eight identified types of *Muda* are characteristics of the job shop and batch shop processes (Susman and Chase, 1986). The use of VSM and MUDA in all three manufacturing settings should be investigated further.

Research Question 2, "Is there a relationship between the operational performance of the firm as perceived by the respondents and the perceived alignment of the lean tools with the type of manufacturing setting?" was addressed by testing Hypotheses 2.

The results suggested that the perceived operational performance of the job shops is predicted by the implementation of *Muda Elimination* (MUDA), *Workers Involvement* (WINV), and negative *Quick Set Up* (QSETUP). The *Quick Set Up* (QSETUP) is the only lean tool with a significant negative path coefficient. Why the path coefficient of *Quick Set Up* (QSETUP)-perceived operational performance of the firm is negative, when, according Hayes and

Wheelwright (1984), the set ups in a job shop environment are frequent, appears to need further investigation.

Heijunka (HEDJ) and *Value Stream Mapping* (VSM) must be taken into account because their T-scores are very close to the .05 level of significance. Based on a positive path coefficient and T-scores, a ranking of the lean tools on which the perceived operational performance of job shop firm depends is displayed in Table 40.

Table 40

Job Shop Perceived Operational Performance

	Operational Performance Job shop path coefficient	**T Statistics**	**Ranking**
Workers Involvement (WINV)	**0.522829*** **	**3.496109**	1
Muda Elimination (MUDA)	**0.236774** **	**2.173435**	2
Quick Set Up (QSETUP)	**-0.238181***	**1.902134**	3
Heijunka (HEDJ)	0.108583	1.611218	4
Value Stream Management (VSM)	0.196648	1.581094	5
Visual Management (VISM)	0.105979	0.95857	6
Standardized Work (STANDW)	0.072864	0.701521	7
Just in Time (JIT)	0.070653	0.690563	8
Total Productive Maintenance (TPM)	0.026824	0.200703	9

*Significant at p ≤0.1
**Significant at p ≤0.05
*** Significant at p ≤0.01

The results obtained from this study suggest that the perceived operational performance of the batch shop is impacted most strongly by the implementation of *Muda Elimination* (MUDA), and *Workers' Involvement* (WINV) and negatively correlated with *Standardized Work* (STANDW). In addition, *Quick Set Up* (QSETUP) must be considered as a lean tool for improving the operational performance of the firm, because the result is only slightly outside the .05 level selected for significance. Based on a positive path coefficient and T-statistics, a ranking of the lean tools on which the perceived operational performance of a batch shop is impacted is displayed in Table 41. The *Standardized Work* (STANDW) was the only lean tool with a statistically significant negative path coefficient. The negative path coefficient of *Standardized Work* (STANDW)-perceived operational performance of the Batch shop firms needs to be investigated further.

Table 41

Batch Shop Perceived Operational Performance

	OPPERF Batch Shop path coefficient	**T Statistics**	**Ranking**
Standardized Work (STANDW)	**-0.397256*** **	**2.667475**	1
Workers Involvement (WINV)	**0.434641*** **	**2.582732**	2
Muda Elimination (MUDA)	**0.304932** **	**2.120111**	3
Quick Set Up (QSETUP)	0.197955	1.466122	4
Total Productive Maintenance (TPM)	0.142351	1.162062	5
Value Stream Mapping (VSM)	0.152615	1.12059	6
Heijunka (HEIJ)	0.097016	0.571843	7
Kaizen (KAIZ)	0.030675	0.232004	8
Visual Management (VISM)	0.031291	0.20068	9
Continuous Flow (CONTFL)	0.018096	0.135708	10

*Significant at $p \leq 0.1$
**Significant at $p \leq 0.05$
*** Significant at $p \leq 0.01$

The results suggest that the perceived operational performance of the firms using the assembly line manufacturing setting depended on the implementation of *Standardized Work* (STANDW) and *Value Stream Mapping* (VSM). In addition*, Five S's* (FIVES), *Muda Elimination* (MUDA) and *Workers' Involvement* (WINV) must be considered because their path coefficients are very close to the .05 level of significance. Based on a positive path coefficient and T-statistics, a ranking of the lean tools on which the perceived operational performance of a firm employing an assembly line setting is displayed in Table 42. Despite a result that suggests that the assembly line firms do not use *Standardized Work* (STANDW), it is the most important lean tool on which the perceived operational performance of firms depends. The primary purpose of standardization is to provide a base for improvement; this is based on the belief that there is no one best way to do the work, and the employees doing the work are able to create the best work design (Dennis, 2007). Moreover, standardization is constantly changing because of the implementation of process improvements being made to address *Muda* elimination (Dennis, 2007).

Table 42

Assembly Line Perceived Operational Performance

	OPPERF Assembly Line Path Coefficient	**T Statistics**	**Ranking**
Standardized Work (STANDW)	**0.319406****	**2.465131**	1
Value Stream Mapping (VSM)	**0.226371***	**1.821356**	2
Five S's (FIVES)	0.336747	1.638077	3
Workers Involvement (WINV)	0.286799	1.544459	4
Muda Elimination(MUDA)	0.189797	1.481658	5
Just in Time (JIT)	0.164352	1.002056	6
Jidoka (JID)	0.103077	0.894746	7
Kaizen (KAIZ)	0.117436	0.728235	8
Heijunka (HEIJ)	0.095864	0.718843	9
Andon (AND)	0.110906	0.670141	10
Total Productive Maintenance (TPM)	0.046393	0.324893	11

*Significant at $p \leq 0.1$
**Significant at $p \leq 0.05$
*** Significant at $p \leq 0.01$

Based on the perceptions of the respondents, there was a significant relationship between the perceived operational performance of the firm and the utilization of the lean tools within each manufacturing setting. The operational performance of firms depends on the use of different lean tools in the three different manufacturing settings.

Research Question 3 ("Is there a relationship between the reported managers' satisfaction with the *lean* program and the perceived alignment of the *lean* tools with the type of manufacturing setting?") was addressed by testing Hypothesis 3. The results of the statistical analysis in Chapter 4 provided support for rejecting the null Hypothesis 3 for job shop, batch shop, and assembly line settings. The only lean tool significantly affecting the managers' satisfaction with the lean program in a Job shop manufacturing setting is *Heijunka* (HEIJ). Based on a positive path coefficient and T-statistics, the ranking of the lean tools on which the managers' satisfaction with the lean program in a job shop setting depends is displayed in Table 43.

Table 43

Job Shop Managers' Satisfaction with the Lean Program

	SATISF	**T Statistics Job Shop**	**Ranking**
Heijunka (HEDJ)	**0.2293***	**1.757913**	1
Kaizen (KAIZ)	0.292192	1.285892	2
Teams (TEAM)	0.231816	0.915596	3
Muda Elimination (MUDA)	0.16382	0.80512	4
Value Stream Mapping (VSM)	0.165677	0.715301	5
Visual Management (VISM)	0.120196	0.575314	6
Just in Time (JIT)	0.041305	0.247616	7
Continuous Flow (CONTFL)	0.004565	0.029998	8

*Significant at p ≤0.1
**Significant at p ≤0.05
*** Significant at p ≤0.01

The lean tools affecting the managers' satisfaction with the overall lean program in a batch shop-manufacturing setting are *Workers Involvement* (WINV) and *Continuous Flow* (CONTFL); it is interesting why the latter is negatively related to the managers' satisfaction with the lean program. Based on a positive path coefficient and T-statistics, ranking of the lean tools on which managers' satisfaction with the lean program in a batch shop setting depends is displayed in Table 44.

Table 44

Batch Shop Managers' Satisfaction with the Lean Program

	SATISF	**T Statistics Batch Shop**	**Ranking**
Workers' Involvement (WINV)	**0.357362***	**1.880079**	1
Continuous Flow (CONTFL)	**-0.22157***	**1.748651**	2
Visual Management (VISM)	0.245837	1.389948	3
Judoka (JID)	0.131883	1.212365	4
Muda Elimination (MUDA)	0.151184	1.108891	5
Poke Yoke (PYOKE)	0.129553	0.990006	6
Total Productive Maintenance (TPM)	0.136204	0.936075	7
Just in Time (JIT)	0.107736	0.882324	8
Value Stream Mapping (VSM)	0.081616	0.488922	9
Five S's (FIVES)	0.032057	0.180606	10
Heijunka (HEIJ)	0.013638	0.118586	11

*Significant at $p \leq 0.1$
**Significant at $p \leq 0.05$
*** Significant at $p \leq 0.01$

The only lean tool significantly affecting the managers' satisfaction with a lean program in an assembly line manufacturing settings was *Continuous Flow* (CONTFL). Based on a positive path coefficient and significance, the ranking for the lean tools on which the managers' satisfaction with the lean program in an assembly line setting depends is displayed in Table 45.

Table 45

Assembly Line Managers' Satisfaction with the Lean Program

	SATISF	T Statistics Assembly Line	Ranking
Continuous Flow (CONTFL)	**0.385634****	**2.423373**	1
Just in Time (JIT)	0.297097	1.315472	2
Teams (TEAM)	0.290601	1.080544	3
Andon (AND)	0.106164	0.638687	4
Visual Management (VISM)	0.096473	0.540956	5
Standardized Work (STANDW)	0.094812	0.528993	6
Kaizen (KAIZ)	0.106431	0.484066	7
Five S's (FIVES)	0.061629	0.351637	8
Total Productive Maintenance (TPM)	0.035803	0.188153	9
Value Stream Mapping (VSM)	0.014255	0.089012	10

*Significant at $p \leq 0.1$
**Significant at $p \leq 0.05$
*** Significant at $p \leq 0.01$

Consequently, there was a statistically significant relationship between the managers' satisfaction with the lean program as perceived by the respondents and the perceived alignment of the lean tools with the type of manufacturing setting. The level of the managers' satisfaction with the lean program was affected by different lean tools for the three manufacturing settings.

Implications

No study comparing the level of application of the sixteen lean tools to the three manufacturing settings—a job shop, a batch shop, and an assembly line—could be found. Moreover, no previous research could be found which explored whether the lean tools affect the operational performance of firms that employ these settings and the managers' satisfaction with the lean program for the three manufacturing settings. The first contribution of this study was to confirm that the lean success trajectory is a difficult path because of the uniqueness of each lean implementation (Lewis, 2000).

The second contribution of this study was in testing the moderating effect of the three types of manufacturing settings on the relationship between the levels of utilization of the sixteen lean tools and the performance of the firm based on the perceptions of the respondents. This study provided empirical evidence that the perceived operational performance of the firm depends on the use of different lean tools in each of the three manufacturing settings. In addition, this study identified the lean tools on which the perceived operational performance of a job shop, a batch shop, or an assembly line was most likely impacted.

The third contribution of this study is testing the moderating effect of the three types of manufacturing settings on the relationship between the levels of use of the sixteen lean tools and the managers' satisfaction with the lean program. Based on the results, the perception of the respondents' satisfaction with the lean program is correlated to different lean tools in job shop, batch shop, and assembly line manufacturing settings. Furthermore, this research identified the lean tools on which the managers' satisfaction with the lean program in a job shop, a batch shop, or an assembly line firm depends.

The fourth contribution of this study was the development of 11 scales measuring the level of implementation of *Heijunka* (HEIJ), *Jidoka* (JID), *Poke- Yoke* (PYOKE), *Andon* (AND), *Standardized Work* (STANDW), *5S* (FIVES), *Visual Management* (VISM), *Kaizen* (KAIZ), *Teams* (TEAM), Value Stream Mapping (VSM), and *Muda Elimination* (MUDA) lean tools. The scales were tested through a Q-sort pilot test and empirical data analysis, which provided strong evidence of construct validity.

This study provided many valuable insights that, when considered, could likely help practitioners successfully implement lean manufacturing principles in their job shop, batch shop, or assembly line manufacturing operations. This study confirmed that the level of utilization of the different lean tools within the different categories of manufacturing settings is crucial for a successful lean implementation (Corbett, 2007).

The findings revealed that the perceived operational performance in a job shop setting would likely depend on the implementation of *Workers Involvement* (WINV), *Muda Elimination* (MUDA), *Heijunka* (HEIJ), and *Value Stream Mapping* (VSM) lean tools. The results suggest that those job shops looking to improve the operational performance of the firm need to emphasize the implementation of these four lean tools. In addition, the data analysis revealed that the managers' satisfaction with the lean program as perceived by the respondents depends on the implementation of *Heijunka* (HEIJ) in the job shop firms. Consequently, job shops concerned with the managers' satisfaction with the lean program need to emphasize the implementation of the *Heijunka* (HEIJ) lean tool.

The findings revealed, as well, that the perceived operational performance of batch shop firms depend on the implementation of *Workers Involvement* (WINV), *Muda Elimination* (MUDA), *Quick Set Up* (QSETUP), and *Total Productive Maintenance* (TPM) lean tools. The results suggested that batch shop firms looking to improve their operational performance need to emphasize the implementation of these four lean tools. In addition, the analysis revealed that the managers' satisfaction with the lean program depends on the implementation of *Workers Involvement* (WINV), *Visual Management* (WINV), *Jidoka* (JID), and *Muda Elimination* (MUDA) lean tools in batch shop firms. Consequently, batch shops firms concerned with the managers' satisfaction with the lean program need to emphasize the implementation of *Workers Involvement* (WINV), *Visual Management* (WINV), *Jidoka* (JID), and *Muda Elimination* (MUDA) lean tools.

Third, the findings revealed that the perceived operational performance of the firms using an assembly line setting depends on the implementation of *Standardized Work* (STANDW), *Value Stream Mapping* (VSM), *Five S's* (FIVES), *Workers Involvement* (WINV), and *Muda Elimination* (MUDA). The results suggested that in order to improve their operational performance, firms with assembly line settings need to emphasize the implementation of these five lean tools. In addition, the data analysis revealed that the managers' satisfaction with the lean program depends on the implementation of *Continuous Flow* (CONTFL) and *Just in Time* (JIT) lean tools in an Assembly line setting.

Fourth, the managers should know that the *Workers Involvement* (WINV) tool is a key factor on which the operational performance in all three manufacturing settings depends. This study highlighted the importance of *Workers Involvement* (WINV) confirming that the root of the Toyota way is encouraging people continuously to improve the process they work on, saying "It's the people who bring the system to life: working, communicating, resolving issues, and growing together" (Liker 2004, p. 36).

Limitations and Future Research

There are several limitations in this research study. The first limitation involves the sample; the population of this study included lean managers in U.S. companies, and the results may differ if the population were not limited to the US. There is a need to replicate this study with an extended sample including manufacturing managers from other countries.

The second limitation is that this study examined the level of utilization of the lean tools based on the perception of the respondents. An extension of this study could be to measure the level of utilization of the lean tools based on actual events and observations. The third limitation of this survey research is that it captures a fleeting moment in time and relies on self-reported data (Leedy & Ormrod, 2005). Moreover, the personal biases of the respondents cannot be controlled. In addition, when using an online survey, there is a possibility of sampling bias issues (Selm & Jankowski, 2006).

The results of the analysis revealed that the *Standardized Work* (STANDW) lean tool is not used at all in job shop, batch shop, and assembly line manufacturing settings. *Standardized Work* (STANDW) is the foundation of lean manufacturing (Whitmore, 2008). Further research should investigate which are the lean tools that manufacturers may use as a basis for improvement during the Kaizen events.

Future research should examine the reason why *Value Stream Mapping* (VSM) and *Muda Elimination* (MUDA) are almost equally implemented in all three manufacturing settings. In addition, an extension of this study would determine if the perceived operational performance of the firm was a mediator of the relationships between the job shop lean tools and the managers' satisfaction with the lean program. A future study should examine why *Visual Management* (VISM), *Five S's* (FIVES), and *Kaizen* (KAIZ) are implemented at different levels within job shop and assembly line settings, when these concepts seem to be equally applicable to both types of settings.

References

Achanga, P., Shehab, E., Roy, R., & Nelder, G. (2006). Critical success factors for lean implementation within SMEs. *Journal of Manufacturing Technology Management, 17*(4), 460.

Adler, P., Goldoftas, B., & Levine, D. (1997). Stability and change at NUMMI. Working paper, Oxford University Press.

Advanced Productivity, Innovations and Competitive Success (APICS), Chapter Detroit. (2012). Retrieved December 2010 from http://apicsdetroit.org/

Agresti, A. (1996). *An Introduction to Categorical Data Analysis*. New York. John Wiley & Sons, Inc.

Aladwania, A. M., & Palvia, P. C. (2002). Developing and validating an instrument for measuring user-perceived Web quality. *Information and Management*, 39 (6), 467–476.

Alfnes, E., & Strandhagen, J. (2000). Enterprise design for mass customization, the control model methodology. *Working paper.* Department of Production and Quality Engineering. Norwegian University of Science and Technology

Allen, J. H. (2000). Make lean manufacturing work for you. *Manufacturing Engineering, 124*(6), 54.

Art of Lean, (n.d.) *Toyota production system, basic handbook*. Art of Lean, Inc.

Atkinson, P. (2010). “Lean” is a Cultural Issue. *Management Services, 54*(2), 35-41.

Babbie, E. (2007). *The practice of social research*. CA, Belmont. Thomson Learning, Inc.

Bagozzi, R. P., and Phillips, L. W. (1982). Representing and testing organizational theories: a holistic construct. *Administrative Science Quarterly*, 27, 459-489.

Bailey, J. E., & Pearson, S. W. (1983). Development of a tool for measuring and analyzing computer user satisfaction. *Management Science, 29*(5), 530-545.

Ballard, G., & Howell, G. (1998). Shielding Production: Essential Step in Production Control. *J. Constr. Engrg. and Mgmt*., 124 (1) 11 - 17.

Baron, R., & Kenny, D. (1986). The moderator-mediator variable distinction in social psychological research: conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology, 51(6), 1173-1182.*

Beard, L., & Butler, S. A. (2000). Introducing JIT manufacturing: It's easier than you think. *Business Horizons, 43*(5), 61-64.

Becker, R. (1998). Lean manufacturing and the Toyota production system. *Encyclopedia of World Biography*, MI, Detroit, Gale Inc.

Bernett, R., & Nentl, N. (2010).Opinions and expectations about continuous improvement programs. *The Journal for Quality and Participation, 32*(4), 35.

Bhasin, S., & Burcher, P. (2004). Lean viewed as a philosophy. *Journal of Manufacturing Technology Management*. 17(1), 56-72. Retrieved June 17, 2008, from www.emeraldinsight.com/1741-038X.htm.

Billesbach, T. J., & Hayen, R. (1994). Long-term impact of just-in-time on inventory performance measures. *Production and Inventory Management Journal, 35*(1), 62.

Black, J. (2007). Design rules for implementing the Toyota Production System. *International Journal of Production Research, 45(16), 3639-3664.*

Blackman, N. J., & Koval, J. J. (2000). Interval estimation for Cohen’s kappa as a measure of agreement. *Statistics in Medicine, 19*(5), 723-741.

Bodek, N. (2008). Leadership is critical to lean. *Manufacturing Engineering, 140*(3), 145.

Bodek, N. (2010). A new way to become lean. *Manufacturing Engineering, 145*(2), 17.

Boyer, K. K. (1996). An assessment of managerial commitment to lean production. *International Journal of Operations & Production Management, 16*(9), 48.

Brown, K. A., & Mitchell, T. R. (1991). A comparison of just-in-time and batch manufacturing: The role of performance obstacles. *Academy of Management Journal, 34*(4), 906.

Browning, T. R., & Heath, R. D. (2009). Reconceptualizing the effects of lean on production costs with evidence from the F-22 program. *Journal of Operations Management, 27*(1), 23-44.

Brunet, A., & New, S. (2003). Kaizen in Japan: an empirical study. *International Journal of Operations & Production Management, 23 (12), 1426 - 1446*

Burack, E. H. (1967). Industrial management in advanced production systems: Some theoretical concepts and preliminary findings. *Administrative Science Quarterly, 12*(3), 479-500.

Burg, J. (2009). LEAN PRINCIPLES: Don't exclude automation. *Manufacturing Engineering, 143*(1), 63.

Chase, R. B., and Aquilano, N. J. (1995). *Production and Operations Management: A Life Cycle Approach*, 7th Ed., Irwin, Homewood, IL.

Chen, J., Li, Y., & Shady, B. (2010). From value stream mapping toward a lean/sigma continuous improvement process: an industrial case study. *International Journal of Production Research, 48 (4), 1069-1086.*

Cheney, H., Mann, R., & Amoroso, D. (1986). Organizational factors affecting the success of end-user computing. *Journal of Management Information Systems III (1), 65– 80.*

Chin, W. W. (1998b). The partial least squares approach for structural equation modeling. In

G. A. Marcoulides (Ed.), *Modern methods for business research* (pp. 295–336). Hillsdale, NJ: Lawrence Erlbaum Associates.

Chong, A., Ooi, K., Lin, B., & Tang, S. (2009). Influence of inter-organizational relationships on SMEs' e-business adoption. *Internet Research, 19*(3), 313- 331.

Cohen, A. (1996). On the discriminant validity of the Meyer and Allen measure of organizational commitment: How does it fit with the work commitment construct? *Educational and Psychological Measurement*, *56*(3), 494-503.

Coleman, J., and Vaghefi, R. (1994).Heijunka (?): A key to the Toyota production system. *Production and Inventory Management Journal*. *35*(4), 31-36.

Comm, C. L., & Mathaisel, D. F. X. (2000).A paradigm for benchmarking lean initiatives for quality improvement. *Benchmarking, 7*(2), 118.

Cook, P. (2010). Discriminant Function Analysis in SPSS. University of Colorado Denver, Center for Nursing Research.

Cooney, R. (2002). Is "lean" a universal production system? Batch production in the automotive industry. *International Journal of Operations & Production Management*, *22*(9/10), 1130.

Corbett, S. (2007). "Beyond manufacturing: the evolution of lean production." The McKinsey Quarterly, August.

Creswell, J. (2009). *Research design: qualitative, quantitative, and mixed methods approach.* CA, Thousand Oaks. Sage Publications, Inc.

Creswell, J. (2012). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research (4th.).* Upper Saddle River, NJ: Pearson Education, Inc.

Crute, V., Ward, Y., Brown, S., & Graves, A. (2003). Implementing lean in aerospace—

challenging the assumptions and understanding the challenges. *Technovation, 23*(12), 917-928.

Cua, K. O., McKone, K. E., & Schroeder, R. G. (2001). Relationships between implementation of TQM, JIT, and TPM and manufacturing performance. *Journal of Operations Management, 19*(6), 675-694.

Cudney, E. (2010). Implementing lean manufacturing. *Manufacturing Engineering, 144*(3), 83.

Cunningham, A., Preacher, K. & Banaji, M. (2001). Implicit attitude measures: consistency, stability, and convergent validity. *Psychological Science. 12(2), 163-170.*

Davis, A. (1996). Instrument development: getting started. *Journal of Neuroscience Nursing. 28(3), 204.*

De Araujo, L., & De Queiroz, A. (2010). A conceptual model for production leveling (heijunka) implementation in batch production systems. *IFIP (International Federation for Information Processing) AICT 338, 81–88.*

Dehghan, A. (2012). Student Loyalty Assessment with Online Master's Programs. Dissertation. *Masters Theses and Doctoral Dissertations.* Paper 431.

Dehghan, A., & Shahin, A. (2011). Customer Loyalty Assessment—A Case Study in MADDIRAN, the Distributor of LG electronics in Iran. *Business Management and Strategy*. 2(1)

Dehghan, A., & Trafalis, T. (2012). Examining Churn and Loyalty Using Support Vector Machine. *Business and Management Research.* 1(4)

Deif, A. (2011). Dynamic analysis of a lean cell under uncertainty. *International Journal of Production Research, 1*(13).

Dennis, P. (2007). *Lean production simplified (2nd ed.)*. University Park, IL: Productivity

Press.

Detty, R., & Yingling, J. (2000). Quantifying benefits of conversion to lean manufacturing with discrete event simulation: A case study. *International Journal of Production Research, 38*(2), 429-445.

Di, C.-Z., Crainiceanu, C. M., Caffo, B. S., and Punjabi, N. M. (2009). Multilevel functional\ principal component analysis. *Annals of Applied Statistics 3*, 458

Dibia, I., & Onuh, S. (2010). Lean Revolution and the Human Resource Aspects. *Proceedings of the World Congress on Engineering 2010 Vol IIIWCE 2010, June 30 - July 2, 2010, London, U.K.*

Dickson, E. W., Anguelov, Z., Vetterick, D., Eller, A., & Singh, S. (2009). Use of lean in the emergency department: A case series of 4 hospitals. *Annals of Emergency Medicine, 54*(4), 504-510.

Dijkstra, T., & Henseler, J. (2011). Linear indices in nonlinear structural equation models: best fitting proper indices and other composites. *Quality Quant* 45, 1505–1518.

Dlott, J. (2011). Sustainability: getting down to business. *American Vegetable Grower 59*(6), 32.

Dobrzykowski, D. (2010). Linking antecedents and consequences of value density in the healthcare delivery supply chain. Doctoral Dissertation, University of Toledo, OH.

Doll, W. J., & Torkzadeh, G. (1988).The measurement of end-user computing satisfaction. *MIS Quarterly*, *12*(2), 259-274.

Drazin, R., & Ven, A. H. (1985). Alternative forms of fit in contingency theory. *Administrative Science Quarterly, 30*(4), 514-539.

Eastern Michigan University (EMU). (2008). Dissertation Manual.Graduate School.

Emiliani, M. L., & Stec, D. J. (2005). Leaders lost in transformation. *Leadership & Organization*

Development Journal, *26*(5/6), 370.

Emiliani, M. L. (1998). Lean behaviors. *Management Decision*, *36*(9), 615.

Eswaramoorthi, M., Kathiresan, G., Jayasudhan, T., Prasad, P. & Mohanram, P. (2011). Flow Index based line balancing: a tool to improve the leanness of assembly line design. *International Journal of Production Research*, *1*(14).

Faizul, H., & Lamb, W. B. (1996). Impact of short-term variations in demand on opportunity costs in a just-in-time.

Fang, S., & Kleiner, B. (2003). Excellence at Toyota motor manufacturing in the United States. *Management Research News, 26 (2/3/4), 116 – 122.*

Fiedler, F. E. (1972). The effects of leadership training and experience: A contingency model interpretation. *Administrative Science Quarterly, 17*(4), 453-470.

Fiedler, F. E. (n.d.). Contingency Theory-Fiedler. Value Based Management. Net. Retrieved September 2011 from http://www.valuebasedmanagement.net/methods_contingency_theory.html

Fine, C., & Hax, A., (1985). Manufacturing Strategy: A Methodology and an Illustration. *Interfaces, 15*(6), 28-46

Flinchbaugh, J. (2005). Lean can combat off shoring. *Manufacturing Engineering*, *134*(6), 144.

Flinchbaugh, J. (2006). Learning is a key to lean. *Manufacturing Engineering*, *136*(4), 18.

Fornell, C., & Larcker, D. (1981). Evaluating Structural Equations Models with Unobservable Variables and Measurement Error. *Journal of Marketing Research, 18,* 39-50.

Fornell, C. and Bookstein, F. (1982) Two Structural Equation Models: LISREL and PLS Applied to Consumer Exit-Voice Theory. *Journal of Marketing Research*, 19 (4), 440-452

Forza, C. (1996). Work organization in lean production and traditional plants what are the differences? *International Journal of Operations & Production Management, 16*(2), 42.

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

Fullerton, R. R., & McWatters, C. S. (2002). The role of performance measures and incentive systems in relation to the degree of JIT implementation. *Accounting, Organizations and Society*, *27* (8) (2002), 711–735

Fullerton, R. R., McWatters, C. S., & Fawson, C. (2003). An examination of the relationships between JIT and financial performance. *Journal of Operations Management, 21*(4), 383-404.

Fullerton, R. R., & Wempe, W. F. (2009). Lean manufacturing, non-financial performance measures, and financial performance. *International Journal of Operations & Production Management*, *29*(3), 214.

Furmans, K. (2005). Models of heijunka-leveled kanban-systems. Working paper. IFL, \ University of Karlsruhe (TH).

Gaskin, J. (2012). "Name of section," Gaskination's StatWiki. http://statwiki.kolobkreations.com

George, M. (2002). *Lean Six Sigma: Combining Six Sigma quality with Lean speed*. New York: McGraw-Hill.

Graves, S. C. (1986). A tactical planning model for a job shop. *Operations Research, 34*(4), 522-533.

Green, J., Lee, J., & Kozman, T. (2010). Managing lean manufacturing in material handling operations, *International Journal of Production Research, 48*(10), 2975-2993.

Gupta, M., Holladay, H., & Mahoney, M. (2000).The human factor in JIT implementation: A case study of Ambrake Corporation. *Production and Inventory Management Journal, 41*(4) 29.

Ha, S. (2007). Continuous processes can be lean. *Manufacturing Engineering, 138*(6), 103.

Haak, R. (2006). Implementing Process Innovation – The Case of the Toyota Production System. Working paper.

Haaster, R., Hoogenboom, P., Ingen, J., Knoben, V., Overkamp, P., Romijn, K., & Vermeij, R. (2010). Lean for jet support. University of Applied Sciences Amsterdam.

Hair, J., Black, W., Babin, B., Anderson, R., & Tatham, R. (2005). *Multivariate Data Analysis*, 6th ed. Prentice-Hall: Englewood Cliffs, NJ.

Hair, J., Black, W., Babin, B., Anderson, R., and Tatham, R. (2009). *Multivariate Data Analysis, Seventh edition.* Pearson Prentice Hall: Upper Saddle River, NJ.

Hair, J. F., Ringle, C. M., & Sarstedt, M. (2011). PLS-SEM: indeed a silver bullet. *Journal of Marketing Theory and Practice*, *19*(2), 139–151.

Hair, J., Sarstedt, M., Ringle, C., & Mena, J. (2012). An assessment of the use of partial least squares structural equation modeling in marketing research. *J Acad Market Sci* (forthcoming).

Hampson, I. (1999). Lean Production and the Toyota Production System Or, the Case of the Forgotten Production Concepts. *Economic and Industrial Democracy.* 20, 369.

Han, S. (1997). A conceptual framework of the impact of technology on customer-supplier relationships. *The Journal of Business & Industrial Marketing, 12*(1), 22.

Harari, O. (1997). Kaizen is not enough. *Management Review, 86*(8), 25.

Hayes, R., & Wheelwright, S. (1984). *Restoring our Competitive Edge: Competing Through*

Manufacturing. New York. John Wiley & Sons, Inc.

Hayes, R., and Wheelwright, S. (1979). Linking manufacturing process and product life cycles. *Harvard Business Review 57*(1), 133-140.

Henseler, J. (2010). On the convergence of the partial least squares path-modeling algorithm. *Computational Statistics*, *25*(1), 107–120.

Henseler, J., & Fassott, G. (2010). Testing moderating effects in PLS path models: An illustration of available procedures. In V. E. Vinzi, W. W. Chin, J. Henseler, & H. Wang (Eds.), Handbook of partial least squares: Concepts, methods and applications in marketing and related fields (pp. 713–735). Berlin: Springer.

Henseler, J., Ringle, C. M., & Sinkovics, R. R. (2009). The use of partial least squares path modeling in international marketing. Advances in international marketing, 20, 277–319.

Hettler, N. (2008). Lean means business. *Manufacturing Engineering*, *140*(1), 103.

Hinckley, C. (2007). Combining mistake-proofing and Jidoka to achieve world class quality in clinical chemistry. *Accred. Qual. Assur. 12*, 223–230.

Hines, P. (1996). Purchasing for lean production: the new strategic agenda. *International Journal of Purchasing and Materials Management. 32*(1), 2-10.

Hines, P., Holwe, M., & Rich, N. (2004). Learning to evolve: A review of contemporary lean thinking. *International Journal of Operations & Production Management*, *24*(9/10), 994.

Hogan, B. (2009). Sustaining a lean culture. *Manufacturing Engineering*, *143*(5), 71.

Hogan, B. J. (2005). Is there a new manufacturing paradigm? *Manufacturing Engineering, 135*(5), 10.

Holweg, M. (2007). The genealogy of lean production. *Journal of Operations Management*, *25*(2), 420-437.

Hong, P., Dobrzykowski, D., & Vonderembse, M. (2010). Integration of supply chain IT and lean practices for mass customization: benchmarking of product and service focused manufacturers. *Benchmarking: An International Journal, 17*(4), 561-592.

Höök, M., & Stehn, L. (2008). Applicability of lean principles and practices in industrialized housing production. *Construction Management and Economics, 26*(10), 1091-1100.

Howard, M., & Newman, R. (1993). From job shop to just-in-time. A successful conversion. *Production and Inventory Management Journal, 34*(3), 70.

Hüttmeir, A., de Treville, S., van Ackere, A., Monnier, L., & Prenninger, J. (2009). Trading off between heijunka and just-in-sequence. *International Journal of Production Economics, 118*(2), 501-507.

Imai, M. (1997). *Gemba kaizen: a commonsense, low cost approach to management*. NY. New York, McGraw Hill, Inc.

Ives, B., Olson, M., & Baroudi, S. (1983). The measurement of user information satisfaction. *Communications of the ACM, 26*(10), 785-793.

James-Moore, S. M., & Gibbons, A. (1997). Is lean manufacture universally relevant? An investigative methodology. *International Journal of Operations & Production Management, 17*(9), 899.

Jina, J., Bhattacharya, A., & Walton, A. (1997). Applying lean principles for high product variety and low volumes: some issues and propositions. *Logistics Information Management, 10*(1), 5-13.

Jing, Z., & Xuejun, X. (2009). Research on lean production based on organizational change model. Third International Symposium on Intelligent Information Technology Application.

Jones, D. T. (2006). Heijunka: Leveling production. *Manufacturing Engineering, 137*(2), 29.

Jorgensen, F., Mathiessen, R., Nielsen, J., & Johansen, J. (2007). Lean Maturity, Lean Sustainability. IFIP International Federation for Information Processing, 246, Advances in Production Management Systems, eds. Olhager, J., Persson, F., (Boston: Springer), 249. 371.

Jovag, L. (2011). Connect process flows to become lean. *Manufacturing Engineering, 146*(5), 97.

Karlsson, C., & Ahlstrom, P. (1996). Assessing changes towards lean production. *International Journal of Operations & Production Management, 16*(2), 24.

Kasul, R., & Motwani, J. (1997). Successful implementation of TPS in a manufacturing setting: a case study. *Industrial Management & Data Systems, 97*(7), 274–279.

Katayama, H., & Bennett, D. (1996). Lean production in a changing competitive world: A Japanese perspective. *International Journal of Operations & Production Management, 16*(2), 8.

Keil, M., Tan, B. C., Wei, K.-K., Saarinen, T., Tuunainen, V., & Wassenaar, A. (2000). A cross-cultural study on escalation of commitment behavior in software projects. *Management Information Systems Quarterly, 24*(2), 299–325.

Kilpatrick, J. (2003). Lean principles. *Utah Manufacturing Extension Partnership* Retrieved December 2010 fromhttp://supplychain.tamu.edu/academics/444/LeanPrinciples.pdf

Kim, C. S., Spahlinger, D. A., Kin, J. M., & Billi, J. E. (2006). Lean health care: What can hospitals learn from a world-class automaker? *Journal of Hospital Medicine, 1*(3), 191–199.

Koenigsaecker, G. (2005). Leadership and the lean transformation. *Manufacturing Engineering, 135*(5), L7.

Koufteros, X., Vonderembse, M. A., & Doll, W. (2001). Concurrent engineering and its consequences. *Journal of Operations Management, 19*, 97–115.

Koufteros, X. (1999). Testing a model of pull production: a paradigm for manufacturing research using structural equation modeling. *Journal of Operations Management, 17,* 467–488.

Kristjuhan, K. (2010). Lean production, its related production management approaches and other contemporaries. *7th International DAAAM Baltic Conference "Industrial Engineering," April 2010, Tallinn, Estonia.*

Lander, E., & Liker, J. (2007). The Toyota Production System and art: making highly customized and creative products the Toyota way. *International Journal of Production Research, 45*(16), 3681-3698.

Landis, J. R., and Koch, G. G. (1977). The measurement of observe agreement for categorical data. *Biometrics*, 33, 159.

Law, K. S., Wong, C. S., and Mobley, W. H. (1998). Toward a taxonomy of multidimensional constructs. *Academy of Management Review, 23*(4), 741-755.

Lee, B., & Jo, H. (2007). The mutation of the Toyota Production System: adapting the TPS at Hyundai Motor Company. *International Journal of Production Research, 45(16), 3665-3679.*

Leedy, P., & Ormrod, J. (2005). *Practical Research: Planning and Design*. Boston, MA: Upper Saddle River.

Legris, P., Ingham, J., & Collerette, P. (2003). Why do people use information technology? A critical review of the technology acceptance model. *Information & Management, 40,* *191–204.*

Leister, A., Borden, D., & Fiedler, F. E. (1977). Validation of contingency model leadership training: Leader match. *The Academy of Management Journal, 20*(3), 464-470.

Leles, C., Martins, R., Silva, E., & Nunes, M. (2009). Discriminant analysis of patients' reasons for choosing or refusing treatments for partial edentulism. *Journal of Oral Rehabilitation 2009. 36,* 909–915.

Lewis, M. A. (2000). Lean production and sustainable competitive advantage. *International Journal of Operations & Production Management, 20*(8), 959.

Liker, J. K. (2004). *The Toyota way: 14 management principles from the world's greatest manufacturer*. New York: McGraw-Hill.

Liker, J., & Rother, M. (n.d.). *Why lean programs fail.* Lean Enterprise Institute. Retrieved December 2010 from www. Lean.org

Lima, P., Lobo, C., & Fumagali, A. (n.d.). Comparison of the implementation of lean assembly cells in different production environments. Taktica, Lean Consulting, Brazil.

LinkedIn (2011). Retrieved December 2011 from http://www.linkedin.com/

Loftus, P. (2006). When lean companies stay fat. *Chief Executive,* (221), 44.

Lopez, L., & Sanchez, J. (2009). Discriminant methods for radar detection of hail. *Atmospheric Research.* 93,358–368.

Lucas, R., Diener, E., & Suh, E. (1996). Discriminant Validity of Weil-Being Measures. *Journal of Personality and Social Psychology, 71*(3), 616-628.

Mackelprang, A. W., & Nair, A. (2010). Relationship between just-in-time manufacturing practices and performance: A meta-analytic investigation. *Journal of Operations Management, 28*(4), 283-302.

Manos, A. (2007). The benefits of kaizen and kaizen events. *Quality Progress, 40*(2), 47.

Marsh, H., Balla, J., & McDonald, R. (1988). Goodness-of-Fit Indexes in Confirmatory Factor Analysis: The Effect of Sample Size. *Psychological Bulletin, 103*(3), 391-400.

Masson, C., Smith, A., & Jacobson, S. (2007). Demand-Driven Manufacturing. AMR Research Report. AMR Research, Inc.

McDonald, T., Ellis, K., Van Aken, E., & Koelling, P. (2009). Development and application of a worker assignment model to evaluate a lean manufacturing cell. *International Journal of Production Research, 47*(9), 2427-2447.

Melton, T. (2005). The benefits of lean manufacturing what lean thinking has to offer the process industries. *Chemical Engineering Research and Design, 83*(A6): 662–673.

Miles, R., & Snow, C. (2003). *Organization Strategy, Structure and Process*. Stanford, CA. Stanford University Press.

Miltenburg, J. (2007). Level schedules for mixed-model JIT production lines: characteristics of the largest instances that can be solved optimally. *International Journal of Production Research, 45*(16), 3555-3577.

Mitchell, T. R., Biglan, A., Oncken, G. R., & Fiedler, F. E. (1970). The contingency model: Criticism and suggestions. *The Academy of Management Journal, 13*(3), 253-267.

Montreuil, B. (1999). Fractal layout organization for job shop environments. *International Journal of Production Research, 37*(3), 501-521.

Moore, G. C., & Benbasat, I. (1991). Development of an instrument to measure the perceptions of adopting an information technology innovation. *Information Systems Research, 2*(3), 192-222.

Morey, B. (2008). Automating LEAN TOOLS. *Manufacturing Engineering, 141*(1), 115.

Morgan, J., & Liker, J. (2006). *The Toyota product development system.* New York: Productivity Press.

Nahm, A. Y., Vonderembse, M. A., & Koufteros, X. A. (2003). The impact of organizational structure on time-based manufacturing and plant performance. *Journal of Operations Management, 21*(3), 281-306.

NetMBA, Business Knowledge Center. (2010). Process Flow Structures. Retrieved February 2010 from http://www.netmba.com/operations/process/structure/

Norman, G. (2010). Likert scales, levels of measurement and the “laws” of statistics. *Adv in Health Sci Educ.* DOI 10.1007/s10459-010-9222-y

Ohno, T. (1988). *Toyota production system: beyond large scale production*. Portland, OR. Productivity, Inc.

Oosterman, B., Land, M., & Gaalman, G. (2000). The influence of shop characteristics on workload control. *International Journal of Production Economics, 68*(1), 107-119.

Paez, O., Dewees, J., Genaidy, A., Tuncel, S., Karwowski, W., & Zurada, J. (2004). The lean manufacturing enterprise: An emerging socio-technological system integration. *Human Factors and Ergonomics in Manufacturing & Service Industries, 14*(3), 285-306.

Palvia, P. C. (1996). A Model and Instrument for Measuring Small Business User Satisfaction with Information Technology. *Information & Management, 31,*151-163.

Parker, S. (2003). Longitudinal effects of lean production on employee outcomes and the mediating role of work characteristics. *Journal of Applied Psychology,* 88 (4), 620.

Parry, G., & Turner, C. (2006). Application of lean visual process management tools. *Production Planning & Control, 17*(1), 77-86.

Pavnaskar, S., Gershenson, J., & Jambekar, A. (2003). Classification scheme for lean manufacturing tools. *International Journal of Production Research, 41(13), 3075-3090.*

Pay, R. (2008). Being taken for a lean ride. Lean Manufacturing.

Pepper, M. P. J., & Spedding, T. A. (2010). The evolution of lean six sigma. *The International Journal of Quality & Reliability Management*, *27*(2), 138.

Pettersen, J. (2009). Defining lean production: Some conceptual and practical issues.*TQM Journal*, *21*(2), 127.

Poppendieck, M. (2002). Principles of Lean Thinking. Working paper. Poppendieck. LLC

Průša, P., & Schacherl, L. (2007). The leveling. Scientific Papers of the University of Pardubice Series B - The Jan Perner Transport Faculty 13.

Raymond, A. (2006). Becoming lean.*FDM.*78 (8), 26

Recht, R., & Wilderom, C. (1998). Kaizen and culture: On the transferability of Japanese suggestion systems. *International Business Review, 7*(1), 7-22.

Reeb, J., & Leavengood, S. (2010). Introduction to lean manufacturing. Extension Service. Oregon State University.

Reeves, T., & Turner, B. A. (1972). A theory of organization and behavior in batch production factories. *Administrative Science Quarterly, 17*(1), pp. 81-98.

Reichhart, A., & Holweg, M. (2007). Lean distribution: concepts, contributions, conflicts. *International Journal of Production Research, 45*(16), 3699-3722.

Ringle, C., Wende, S., & Will, S. (2005). SmartPLS 2.0 (M3) Beta, Hamburg http://www.smartpls.de.

Ruekert, R. W., Walker, O. C., Jr., & Roering, K. J. (1985). The organization of marketing activities: A contingency theory of structure and performance. *The Journal of Marketing*, *49*(1), 13-25.

Safizadeh, M. H., Ritzman, L. P., Sharma, D., & Wood, C. (1996). An empirical analysis of the product-process matrix. *Management Science, 42*(11), 1576.

Sanchez, A. M., & Perez, M. P. (2001). Lean indicators and manufacturing strategies. *International Journal of Operations & Production Management*, *21*(11), 1433.

Sawhney, R., & Chason, S. (2005). Human behavior based exploratory model for successful implementation of lean enterprise in industry. *Performance Improvement Quarterly, 18*(2), 76-96.

Scherrer-Rathje, M., Boyle, T. A., & Deflorin, P. (2009). Lean, take two! Reflections from the second attempt at lean implementation. *Business Horizons, 52*(1), 79-88.

Schwab (n/a). Data Analysis & Computers II Strategy for complete discriminant analysis. The University of Texas at Austin.

Segars, A. H. (1997). Assessing the unidimensionality of measurement: A paradigm and illustration within the context of information systems research. *Omega*, *25*(1), 107-121.

Selm, M., & Jankowski, N. (2006). Conducting online surveys. *Quality & Quantity, 40*, 435–456.

Serrano, I., Ochoa, C., & De Castro, R. (2008). Evaluation of value stream mapping in manufacturing system redesign. *International Journal of Production Research, 46*(16), 4409-4430.

Seth, D., & Gupta, V. (2005). Application of value stream mapping for lean operations and cycle time reduction: an Indian case study. *Production Planning & Control, 16*(1), 44-59.

Shah, R., Goldstein, S., Unger, B., & Henry, T. (2008). Explaining anomalous high performance in a health care supply chain. *Egglestone Decision Sciences, 39*(4), 759-789.

Shah, R., & Ward, P. T. (2003). Lean manufacturing: Context, practice bundles, and performance. *Journal of Operations Management, 21*(2), 129-149.

Shah, R., & Ward, P. T. (2007). Defining and developing measures of lean production. *Journal of Operations Management, 25*(4), 785-805.

Sheehan, K. B. (2001). E-mail survey response rates: A review. *Journal of Computer Mediated Communication, 6*(2).

Sheehan, K. B., & Hoy, M. B. (1999). Using e-mail to survey internet users in the United States: Methodology and assessment. *Journal of Computer Mediated Communication, 4*(3).

Shenhar, A. (2001). One size does not fit all projects: Exploring classical contingency domains. *Management Science, 47*(3), 394-414.

Shinohara, I. (1988). NPS: New Production System, Productivity Press, Cambridge, MA, 153-5.

Shingo, S. (1981). *Study of Toyota production system from industrial engineering viewpoint.* Tokyo: Japan Management Association.

Skinner, W. (1969). Manufacturing – missing link in corporate strategy, *Harvard Business Review*, *47*(3), 136-45.

Smeds, R. (1994). Managing change towards lean enterprises. *International Journal of Operations & Production Management, 14*(3), 66.

Smith, J. (2006). Driving continuous improvement. *Plant Engineering, 60*(12), 42.

Smith , T., & Reece, J. (1998). The relationship of strategy, fit, productivity, and business performance in a services setting. *Journal of Operations Management, 17*, 145–161.

Sohal, A. S. (1996). Developing a lean production organization: An Australian case study. *International Journal of Operations & Production Management, 16*(2), 91.

Sohal, A. S., & Egglestone, A. (1994). Lean production: Experience among Australian organizations. *International Journal of Operations & Production Management, 14*(11), 35.

Spear, S. J. (2004). Learning to lead at Toyota. *Harvard Business Review, 82*(5), 78–86.

Spence, H. (1997). Structure of anxiety symptoms among children: A confirmatory factor-analytic study. *Journal of Abnormal Psychology, 106*(2), 280-297.

Stump, B., & Badurdeen, F. (2009). Integrating lean and other strategies for mass customization manufacturing: a case study. *Journal of Intilligent Manufacturing. 23*(1), 109-124.

Sugimori, Y., Kusunoki, K., Cho, F., & Uchikawa, S. (1977). Toyota production system and Kanban system materialization of just-in-time and respect-for-human system. International. *Journal of Production Research, 15*(6), 553-564.

Susman, I., & Chase, B. (1986). A socio-technical analysis of the integrated factory. *Journal of Applied Behavioral Science, 22,* 257-270.

Suzuki, Y. (2004). Structure of the Japanese Production System: Elusiveness and Reality. *Asian Business & Management, 3, 201–219.*

Swanson, R., & Holton III, E. (2005). *Research in Organizations: Foundations and Methods of Inquiry.* San Francisko, CA. Berrett-Koehler Publishers.

Taninecz, G. (2005). Lean beyond production. Lean Enterprise Institute, Brookline, MA www.lean.org

Todd, P. A., & Benbasat, I. (1989). An Experimental Investigation of the Impact of Computer Based Decision Aids on the Process of Preferential Choice. Working Paper, School of Business, Queen's University, Kingston, Ontario.

Trochim, W. (2006). Research Methods Knowledge Base. Retrieved January, 2012 from http://www.socialresearchmethods.net/kb/analysis.php

U.S. Department of Health & Human Services (2009). Code of Federal Regulations, Title 45: Public Welfare, Part 46: Protection of Human Subjects. Retrieved November, 2010 from http://www.hhs.gov/ohrp/humansubjects/guidance/45cfr46.html

Veech, D. (2001). A person centered approach to sustaining a lean environment-job design for self-efficacy. *Defense Acquisition Review Journal.* 159-171

Venkatraman, N., & Camillus, J. C. (1984). Exploring the concept of "fit" in strategic management. *The Academy of Management Review, 9*(3), 513-525.

Venkatraman, N., & Ramanujam, V. (1986). Measurement of business performance in strategy research: A comparison of approaches. *The Academy of Management Review, 11*(4), 801-814.

Venkatraman, N. (1989). The concept of fit in strategy research: toward verbal and statistical correspondence. *Academy of Management Review, 14*(3), 423-444.

Vinodh, S., & Balaji, S. (2011). Fuzzy logic based leanness assessment and its decision support system. *International Journal of Production Research, 49*(13), 4027-4041.

Vinodh, S., & Chintha, S. (2011). Leanness assessment using multigrade fuzzy approach. *International Journal of Production Research, 49*(2), 431-445.

Wan, H., & Chen, F. (2008). A leanness measure of manufacturing systems for quantifying impacts of lean initiatives. *International Journal of Production Research, 46*(23), 6567-6584.

Weill, P., & Olson, M. (1989). An assessment of the contingency theory of management information systems. *Journal of Management Information Systems, 6*(1), 59-85.

White, R. E., Pearson, J. N., & Wilson, J. R. (1999). JIT Manufacturing: a survey of Implementation in small and large US manufacturers. *Management Science 45*(1), 1–15.

White, R. E., & Prybutok, V. (2001). The relationship between JIT practices and type of production system. *Omega, 29*(2), 113-124.

Whitmore, T. (2008). Standardized WORK. *Manufacturing Engineering, 140*(5), 171.

Womack, J. P., Jones, D. T., Roos, D. (1990). *The Machine That Changed the World*. Harper Perennial, New York.

Womack, J. P., Jones, D. T. (1996). *Lean Thinking: Banish Waste and Create Wealth in Your Corporation*. New York, Simon & Schuster.

Woodward, J. (1965). *Industrial organization: theory and practice*. London, Oxford University Press.

Yi, Y. & Gong, T. (2008). The Electronic Service Quality Model: The Moderating Effect of Customer Self-Efficacy. *Psychology & Marketing, 25*(7), 587–601.

Zijm, W. H. M., & Kals, H. J. J. (1995). The integration of process planning and shop floor scheduling in small batch part manufacturing. *CIRP Annals - Manufacturing Technology, 44*(1), 429-432.

Appendices

Appendix A: Items entering the first round of Q sorting

External JIT
We use **JIT** purchasing.
We do not produce something, unless the customer has **order it.**
We link all processes to customer demand through **Kanban**.
Internal JIT
Production at stations is “**pulled**” by the current demand of the next station.
We use **Kanban** signals for production control.
We produce exactly **as much** pieces **as needed.**
Continuous Flow
Products are classified into **groups** with similar processing requirements.
Products are classified into **groups** with similar routing requirements.
Equipment is **grouped** to produce a continuous flow of families of products.
Families of products determine our factory layout.
Heijunka
Our production volume and mix is distributed **evenly** over time.
We do not have **peaks and valleys** in our production schedule.
We change our **heijunka** model dependent on the demand at least every few days.
We change our **heijunka** model dependent on the demand at least every few weeks.
We change our **heijunka** model dependent on the demand at least every few months.
Quick change over and set up
Our employees practice **setups** to reduce the time required.
We are working to lower **setup** times in our plant.
We have low **setup** times of equipment in our plant.
Jidoka
We detect process deviations with **automated technology**.
We detect quality deviations with **automated technology**.
Most inspections are done by **automated technology**.
Poke-Yoke
We have **poke-yoke** devices designed for our work place conditions.
We use **simple, inexpensive** error-proofing devices.
Our **poke-yoke** devices inspect 100% of the time.

Andon
Everyone working on the production floor is able **to stop the production line** if defect is detected.
We have a device (cord or button) able **to stop the production line** if defect is detected.
Our employees **stop the production line** if defect is detected.

Standardized Work
Our work processes are **standardized.**
Our shop floor employees are responsible for the design of work process **standards.**
We use our **standards** as a base for improvement.
We change our work process **standards** every week.
We change our work process **standards** every month.
We change our work process **standards** every year.

5 S systems
We organize our work place with **marked positions** for each tool.
We have **cleaning responsibility** assigned to the team members.
We have **cleaning schedule** assigned to the team members.
We have standardized approach to measure the **5 s** conditions.
5s is owned by the team members.
Our employees have **5s** training.

TPM
We dedicate a portion of everyday to planned **equipment maintenance** related activities.
We **maintain** all our **equipment** regularly.
We maintain excellent records of all **equipment maintenance** related activities.
We post **equipment maintenance** records on shop floor for active sharing with employees.
Everyone on the shop floor participates in the **TPM** activities with performing basic tasks.

Visual Management
We use **visual board** to display value added information.
We use **visual indicators**, signs and controllers.
We use simple signals providing **immediate understanding of situation**.

Kaizen
Our employees have **numbers of suggestions** per month.
Our employees have **numbers of suggestions** per year.

More than 70 percent of the employees’ **suggestions** are **implemented**.
We have significant savings/benefits from **implemented suggestions**.
We have **Kaizen events**.

Multifunctional Teams

Most of our shop-floor employees are working in **multifunctional teams.**
Our shop-floor employees are **cross-trained**.
Our shop-floor employees **change tasks** within the team every four hours.
Our shop-floor employees **change tasks** within the team every day.
Our shop-floor employees **change tasks** within the team once per week.

Workers involvement

Our shop-floor employees are **key to problem solving**.
Our shop-floor employees **drive suggestion programs**.
Our shop-floor employees **lead product/process improvement** efforts.
Our shop-floor employees **perform supervisory** tasks.
Team **leadership rotates** among the shop-floor employees.

Value Stream Mapping

We use **value stream mapping** to eliminate Muda.
We use **VSM** to improve our business process.
We use **VSM** to improve our production flow.
We use **VSM** to improve our information flow.

Muda

We produce **only what the customer requires**.
We have **minimal work in process inventory**.
The **scrap** is counted and **reported automatically**.
We do not have a **rework area**.
We do **not move** parts between processes.
Our workers **do not wait** for materials or parts to arrive.
Our workers **do not perform** unnecessary motions.
We **implement** most of our workers **suggestions.**

Appendix B: Q-Sort Results

Table 46: Items Placement Ratios: First Q-sort Round

	JIT Internal	JIT External	Cont. Flow	Hedjunka	Quick Set up	Jidoka	Poke Yoke	Andon	Standardized Work	5S	TPM	Workers involvement	Kaizen	Visual Management	Value Stream Map	Muda	Teams	Total	%
JIT Internal	6																	6	100
JIT External		6																6	100
Continuous Flow			6		2													8	75
Hedjunka		2		8														10	80
Quick setup			1		5													6	66
Jidoka						6												6	100
Poke Yoke							6											6	100
Andon								6										6	100
Standardized Work								3	9									12	66
5S										9				3				12	66
TPM											6		4					10	60
Worker Involvement												7	3					10	60
Kaizen											3		7					10	60
Visual Management														6				6	100
VSM															8			8	100
Muda												6				10		16	63
Teams															4		6	10	60

Total Items Placed: 148 Number of Hits: 117 Overall Hit Ratio, 79.05 %

Table 47: Inter-Judge Raw Agreement Scores: First Q-sort Round

	JIT Internal	JIT External	Cont. Flow	Hedjunka	Quick Set up	Jidoka	Poke Yoke	Andon	Standardized Work	5S	TPM	Workers involvment	Kaizen	Visual Management	Value Stream Map	Muda	Teams
JIT Internal	3																
JIT External		3															
Continuous Flow			4														
Hedjunka				5													
Quick setup					2												
Jidoka						3											
Poke Yoke							3										
Andon								3									
Standardized Work									5								
5S										5							
TPM											3						
Worker Involvement												4					
Kaizen													2				
Visual Management														3			
VSM															4		
Muda																4	
Teams																	3
Total Items placed 74					Number Agreements 59							Agreement Ratio 79, 72%					

Table 48: Items Placement Ratios: Second Q-sort Round

	JIT Internal	JIT External	Cont. Flow	Hejuinka	Quick Set up	Jidoka	Poke Yoke	Andon	Standardized Work	5S	TPM	Workers involvement	Kaizen	Visual Management	Value Stream Map	Muda	Teams	Total	%
JIT Internal	6																	6	100
JIT External		6																6	100
Continuous Flow			6															6	100
Hedjunka		2		4														6	100
Quick setup			1		5													6	83
Jidoka						6												6	100
Poke Yoke							6											6	100
Andon								6										6	100
Standardized Work							2		4									6	83
5S										4				2				6	83
TPM											6							6	100
Worker Involvement												6						6	100
Kaizen													6					6	100
Visual Management														6				6	100
VSM															4		2	6	83
Muda																6		6	83
Teams																	6	6	100

Total Items Placed: 102 Number of Hits: 93 Overall Hit Ratio, 91.18%

Table 49: Inter-Judge Raw Agreement Scores: Second Q-sort Round

	JIT Internal	JIT External	Cont. Flow	Hedjunka	Quick Set up	Jidoka	Poke Yoke	Andon	Standardized Work	5S	TPM	Workers involvment	Kaizen	Visual Management	Value Stream Map	Muda	Teams
JIT Internal	3																
JIT External		3															
Continuous Flow			3														
Hedjunka				3													
Quick setup					2												
Jidoka						3											
Poke Yoke							3										
Andon								3									
Standardized Work									2								
5S										3							
TPM											3						
Worker Involvement												3					
Kaizen													3				
Visual Management														3			
VSM															3		
Muda																3	
Teams																	3
Total Items placed 51					Number Agreements 49							Agreement Ratio 96.08%					

Appendix C: Online Survey Instrument Used to Collect Data

Introductory Email:

Based on your extensive experience in manufacturing and your knowledge of lean systems, your help is being solicited in an effort to better understand the utilization of the lean approach within different types of manufacturing organizations. Specifically this study will attempt to identify the best lean practices for job shops, batch shops, an assembly lines, and continuous flow manufacturing settings. Please take up to fifteen minutes to complete the survey instrument that can be accessed by the link below.

https://www.surveymonkey.com/s/KW8KPKT

As an incentive, all survey completers will be entered into a drawing where the winner will receive $200 in cash. In addition, anyone who requests a summary report will be emailed a Word file with a summary of the results of the survey.

If you have any questions, please email me at dtodorov@emich.edu
Thank you very much
Daniela Todorova

Informed Consent

Title: Exploring lean implementation success factors in job shop, batch shop, and assembly line manufacturing settings

Investigator: Daniela Todorova, COT Doctoral Student, Eastern Michigan University

Purpose of the Research: The first purpose of this study is to examine the level of utilization of the sixteen lean tools in three manufacturing settings: job shop, batch shop and assembly line. The second purpose of this study is to determine if the use of certain lean tools in specific manufacturing settings can improve operational performance. Finally this study will attempt to determine if the use of certain lean tools in a specific manufacturing setting is related to improved satisfaction with your lean program.

Procedure: Following this informed consent section, are a number of questions regarding your experience with lean manufacturing. The first few questions ask you to provide the number of employees at the plant location, product mix, lean implementation and the type of manufacturing; the next questions are regarding your experience with the implementation of lean manufacturing. The approximate time to complete the questionnaires should be about 10-15 minutes.

Confidentiality: Only code numbers will be used to identify your completed questionnaire. Your name will never be associated with your responses. All information will be kept in the password protected computer of the investigator

Expected Risks: There are no foreseeable risks to you by completing this survey, as all results will be kept completely confidential.

Expected Benefits: Participation will enable you to share your professional experience and knowledge along with enabling you to receive a copy of the results if requested. In addition, you will receive a chance to win $200.

Voluntary Participation: Participation in this study is voluntary. You may choose not to participate. If you do decide to participate, you can change your mind at any time and withdraw from the study without negative consequences. If you want to withdraw from the study, you can stop answering or not submit the responses. Once the survey has been completed and submitted you can no longer withdraw from the study.

Use of Research Results: Results will be presented in an aggregate form only. No names or indentifying information will be revealed. Results may be presented at research meetings and conferences, and in academic publications.

Future Questions: If you have any questions concerning your participation in this study now or in the future, please contact the principal investigator, Daniela Todorova at 734 239 3770 or via email (dtodorov@emich.edu).

Human Subjects Review Board: This research protocol and informed consent document has been reviewed and approved by the Eastern Michigan University Human Subjects Review Committee. If you have questions about the approval process, please contact Dr. Deb de Laski-Smith (734.487.0042, Interim Dean of the Graduate School and Administrative Co-chair of UHSRC, human.subjects@emich.edu)."

Consent to Participate: I have read or have had read to me all the above information about this research study, including the research procedures, possible risks, side effects, and the likelihood of any benefit to me. The content and meaning of this information has been explained and I understand. All my questions, at this time, have been answered. By proceeding to the next page and taking the survey, I give my consent and I do voluntarily offer to follow the study requirements and take a part in the study.

Questionnaire

Please answer the following questions

*1. Total number of employees at the plant location:

Total number employees (Type in)

*2. Categorize your product mix:

- High volume/high variety
- High volume/ low variety
- Medium volume/medium variety
- Low volume/high variety
- Low volume/low variety

*3. What portion of your plant operations is:

Job shop: high flexibility, many different products, and low volumes, e.g. a machine tool shop, a machining center, a paint shop.

Batch shop: moderate flexibility, several products and moderate volumes. Usually a set up time is required to change from one product to another. e.g. an injection molding.

Assembly line: low flexibility, a few products, and high volumes. e.g. an automobile plant.

Continuous flow: very low flexibility, one product and very high volume. Usually the product is measured byweight or volume. e.g. a petroleum refinery or a sugar refinery

(please make sure that the total is 100%)

	Percent
Job Shop	
Batch Shop	
Assembly Line	
Continuous Flow	

***4. To what extend has your company implemented lean in your manufacturing processes?**

- ◯ Not implemented.
- ◯ Not implemented but planning to start.
- ◯ Implemented in some manufacturing processes.
- ◯ Implemented in many manufacturing processes.
- ◯ Fully implemented lean

5. For how many years has your company used lean?

Years (Please Type in, the closest whole number) ____

***6. Is your company located in the USA?**

- ◯ Yes
- ◯ No

***7. In which country is located your company? (Please type in)**

____

***8. What is the ISIC code that most closely represent your organization?**

***9. What is the SIC code that most closely represent your organization?**

Link to SIC codes: http://www.sec.gov/info/edgar/siccodes.htm

SIC code (Type in) ____

*10. Manufacturing process & products 1

	Highly Customized	Somewhat Customized	Balanced Between Customized and Standardized	Somewhat Standardized	Highly Standardized
Our products are:	◯	◯	◯	◯	◯

*11. Manufacturing process & products 2

	Very Low	Somewhat Low	Neither high, nor low	Somewhat High	Very High
Our product volume is:	◯	◯	◯	◯	◯

*12. Manufacturing process & products 3

	Highly Divergent	Somewhat Divergent	Balance of Divergent and Standardized	Somewhat Standardized	Highly Standardized
Our manufacturing processes are:	◯	◯	◯	◯	◯

*13. External Just in Time

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
We use JIT with our suppliers.	◯	◯	◯	◯	◯
We do not produce a product, unless the customer has order it.	◯	◯	◯	◯	◯
We link all processes to customer demand through Kanban.	◯	◯	◯	◯	◯

*14. Internal Just in Time

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Production at each station is "pulled" by demand from the next station.	◯	◯	◯	◯	◯
We use Kanban signals for production control.	◯	◯	◯	◯	◯
We produce exactly as many pieces as needed.	◯	◯	◯	◯	◯

*15. Continuous Flow

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Products are classified into groups with similar processing requirements.	◯	◯	◯	◯	◯
Equipment is grouped to produce a continuous flow of families of products.	◯	◯	◯	◯	◯
Families of products determine our factory layout.	◯	◯	◯	◯	◯

*16. Heijunka

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Our production volume is distributed evenly over time.	◯	◯	◯	◯	◯
We do not have peaks and valleys in our production schedule.	◯	◯	◯	◯	◯
Our production mix is distributed evenly over time.	◯	◯	◯	◯	◯

*17. Quick setup

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Our employees achieve setups that save time.	◯	◯	◯	◯	◯
We are working to lower setup times in our plant.	◯	◯	◯	◯	◯
We have low setup times of equipment in our plant.	◯	◯	◯	◯	◯

*18. Jidoka

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
We detect process deviations with automated technology.	◯	◯	◯	◯	◯
We detect quality deviations with automated technology.	◯	◯	◯	◯	◯
Most inspections are done by automated technology	◯	◯	◯	◯	◯

*19. Poke-Yoke

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
We have poke-yoke devices designed for our work place conditions.	◯	◯	◯	◯	◯
We use simple, inexpensive error-proofing devices.	◯	◯	◯	◯	◯
Our poke-yoke devices are used 100% of the time	◯	◯	◯	◯	◯

*20. Andon

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Everyone working on the production floor is able to stop the production line if a defect is detected.	◯	◯	◯	◯	◯
We have a device (cord or button) to stop the production line if a defect is detected.	◯	◯	◯	◯	◯
Our employees stop the production line if a defect is detected.	◯	◯	◯	◯	◯

*21. Standardized Work

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Our work processes are standardized.	◯	◯	◯	◯	◯
We use our standards as a basis for improvement.	◯	◯	◯	◯	◯
We change our work process standards as needed for improvement.	◯	◯	◯	◯	◯

*22. 5 S systems

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
We organize our work place with labeled positions for each tool.	◯	◯	◯	◯	◯
We have cleaning responsibilities assigned to the team members.	◯	◯	◯	◯	◯
We keep our workplace organized.	◯	◯	◯	◯	◯

*23. Total Productive/Preventive Maintenance

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
We dedicate a portion of every day to planned equipment maintenance related activities.	◯	◯	◯	◯	◯
We maintain all our equipment regularly.	◯	◯	◯	◯	◯
We maintain excellent records of all equipment maintenance related activities.	◯	◯	◯	◯	◯

*24. Visual Management

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
We use a visual board to display key information.	◯	◯	◯	◯	◯
We use visual indicators, signs and controllers.	◯	◯	◯	◯	◯
We use simple signals to provide immediate understanding of the situation.	◯	◯	◯	◯	◯

*25. Kaizen (Continuous Improvement)

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Our employees participate in rapid improvement events.	◯	◯	◯	◯	◯
Our employees' suggestions are generally implemented.	◯	◯	◯	◯	◯
Our employees work to eliminate waste in an ongoing fashion.	◯	◯	◯	◯	◯

*26. Teams

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Most of our shop-floor employees are working in teams.	◯	◯	◯	◯	◯
Our shop-floor employees are cross-trained.	◯	◯	◯	◯	◯
Our shop-floor employees change tasks within the team	◯	◯	◯	◯	◯

*27. Workers involvement

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Our shop-floor employees are key to problem solving.	◯	◯	◯	◯	◯
Our shop-floor employees drive suggestion programs.	◯	◯	◯	◯	◯
Our shop-floor employees lead product/process improvement efforts.	◯	◯	◯	◯	◯

28. Management Involvement

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Our managers are members of the kaizen teams.	◯	◯	◯	◯	◯
Our managers are fully committed to lean.	◯	◯	◯	◯	◯
Our managers participate in lean activities.	◯	◯	◯	◯	◯

*29. Value Stream Mapping

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
We use value stream mapping to eliminate muda.	◯	◯	◯	◯	◯
We use VSM to improve our business process.	◯	◯	◯	◯	◯
We use VSM to improve our production flow.	◯	◯	◯	◯	◯

*30. Muda

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Our workers identify non value added activities	◯	◯	◯	◯	◯
We are working to minimize non value added activities.	◯	◯	◯	◯	◯
Everybody participates in eliminating non value added activities.	◯	◯	◯	◯	◯

*31. Operational performance since implementing lean.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
We reduced overall production costs.	◯	◯	◯	◯	◯
We improved quality.	◯	◯	◯	◯	◯
We improved delivery on time.	◯	◯	◯	◯	◯

*32. Firm performance since implementing lean.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Our sales have increased	◯	◯	◯	◯	◯
Our market share has increased	◯	◯	◯	◯	◯
Our Return on Investments (ROI) has increased	◯	◯	◯	◯	◯

*33. Satisfaction with the lean program

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
The use of lean has met our expectations.	◯	◯	◯	◯	◯
Our company has achieved lean program goals.	◯	◯	◯	◯	◯
We are pleased with our lean program.	◯	◯	◯	◯	◯

*34. Your job title (Indicate the closest job title that applies)

◯ Plant Manager

◯ Director

◯ Quality Manager

◯ Lean project manager

◯ Engineer

◯ Other

If other, please specify

***35. Your lean knowledge**

- [ ] Lean experience
- [ ] Lean training
- [ ] Lean certificate
- [ ] Six-Sigma/Lean certificate Green Belt
- [ ] Six-Sigma/Lean certificate Black Belt
- [ ] Six-Sigma/Lean certificate Master Black Belt
- [ ] Other

If other, please specify

THANK YOU FOR PARTICIPATING!

If you would like to be entered into the $200 raffle, or if you want a summary report of the survey findings, please send an email to dtodorov@emich.edu

THANK YOU FOR PARTICIPATING!

Daniela Todorova
Doctoral Candidate

Eastern Michigan University
College of Technology
Ypsilanti, MI 48197

Appendix D: Human Subject Approval

EASTERN MICHIGAN UNIVERSITY
Education First

UHSRC

June 8, 2012

INITIAL APPROVAL

To: Ms. Daniela Todorova
School of Engineering Technology

Re: **UHSRC#120509** Category: EXEMPT #2
Approval Date: **June 8, 2012**

Title: Exploring Lean Implementation Success Factors in Job Shop, Batch Shop, and Assembly Line Manufacturing Settings

The Eastern Michigan University Human Subjects Review Committee (UHSRC) has completed their review of your project. I am pleased to advise you that **your research has been deemed** as **exempt** in accordance with federal regulations.

The UHSRC has found that your research project meets the criteria for exempt status and the criteria for the protection of human subjects in exempt research. **Under our exempt policy the Principal Investigator assumes the responsibility for the protection of human subjects** in this project as outlined in the assurance letter and exempt educational material.

Renewals: Exempt protocols do not need to be renewed. If the project is completed, please submit the **Human Subjects Study Completion Form** (found on the UHSRC website).

Revisions: Exempt protocols do not require revisions. However, if changes are made to a protocol that may no longer meet the exempt criteria, a **Human Subjects Minor Modification Form** or new **Human Subjects Approval Request Form** (if major changes) will be required (see UHSRC website for forms).

Problems: If issues should arise during the conduct of the research, such as unanticipated problems, adverse events, or any problem that may increase the risk to human subjects and change the category of review, notify the UHSRC office within 24 hours. Any complaints from participants regarding the risk and benefits of the project must be reported to the UHSRC.

Follow-up: If your exempt project is not completed and closed after three years, the UHSRC office will contact you regarding the status of the project and to verify that no changes have occurred that may affect exempt status.

Please use the UHSRC number listed above on any forms submitted that relate to this project, or on any correspondence with the UHSRC office.

Good luck in your research. If we can be of further assistance, please contact us at 734-487-0042 or via e-mail at human.subjects@emich.edu. Thank you for your cooperation.

Sincerely,

Deb de Laski-Smith, Ph.D.
Interim Dean
Graduate School
Administrative Co-Chair
University Human Subjects Review Committee

University Human Subjects Review Committee · Eastern Michigan University · 200 Boone Hall
Ypsilanti, Michigan 48197
Phone: 734.487.0042 Fax: 734.487.0050
E-mail: human.subjects@emich.edu
www.ord.emich.edu (see Federal Compliance)

The EMU UHSRC complies with the Title 45 Code of Federal Regulations part 46 (45 CFR 46) under FWA00000050.

Appendix E: PLS Cross Loadings

	AND	CONTFL	FIVES	HEDJ	JID	JIT	KAIZ	MUDA
AND1	0.877223	0.306538	0.250120	0.302429	0.247855	0.353425	0.293445	0.236500
AND2	0.783636	0.281219	0.255299	0.368278	0.453693	0.287661	0.355324	0.204141
AND3	0.844223	0.255924	0.288230	0.291998	0.204252	0.389276	0.281870	0.171648
CONTFL1	0.288883	0.827008	0.293852	0.320930	0.276519	0.263117	0.279135	0.347802
CONTFL2	0.294617	0.906083	0.445102	0.397502	0.331487	0.440060	0.325587	0.410926
CONTFL3	0.263944	0.782387	0.312247	0.398557	0.254984	0.432314	0.305513	0.383965
FIVES1	0.246324	0.299225	0.906193	0.287756	0.256149	0.480731	0.461772	0.479482
FIVES3	0.327957	0.462661	0.913703	0.283766	0.298951	0.467167	0.515270	0.420968
HEDJ1	0.348749	0.460112	0.334134	0.893855	0.347834	0.500949	0.257096	0.268690
HEDJ2	0.307411	0.360250	0.233231	0.865183	0.370366	0.479805	0.229944	0.168396
HEDJ3	0.350595	0.310396	0.236651	0.878318	0.348520	0.486835	0.147497	0.171482
JID1	0.342363	0.352584	0.321133	0.387724	0.944465	0.372041	0.351060	0.280824
JID2	0.325616	0.322621	0.293783	0.371677	0.955204	0.343781	0.285415	0.249564
JID3	0.319594	0.256729	0.203339	0.345341	0.846036	0.327027	0.283290	0.271362
JIT1	0.297869	0.261971	0.311140	0.368314	0.320398	0.700581	0.212400	0.172469
JIT2	0.211445	0.084613	0.175192	0.240786	0.085138	0.697774	0.113200	0.153707
JIT3	0.327940	0.377662	0.452887	0.479580	0.409370	0.808582	0.370248	0.340435
JIT4	0.341963	0.396149	0.450690	0.402290	0.254498	0.815826	0.331575	0.389779
JIT5	0.383837	0.418945	0.450137	0.511733	0.377409	0.828956	0.424409	0.475747
JIT6	0.231806	0.333704	0.389725	0.415241	0.168128	0.707018	0.333361	0.311291
KAIZ1	0.292338	0.326946	0.477471	0.229991	0.314820	0.421303	0.887688	0.557881
KAIZ2	0.369957	0.321846	0.489722	0.214996	0.293832	0.345465	0.911967	0.464973
MUDA1	0.240658	0.395839	0.441090	0.197721	0.280334	0.415458	0.540810	0.965380
MUDA2	0.254317	0.471688	0.515670	0.259426	0.271417	0.426503	0.562250	0.958078
MUDA3	0.209714	0.436141	0.468100	0.234350	0.286783	0.427196	0.528011	0.966899
OPPERF1	0.287558	0.333052	0.469014	0.256988	0.289553	0.437423	0.525315	0.607534
OPPERF2	0.258178	0.416059	0.502902	0.310492	0.299705	0.439788	0.549851	0.687546
OPPERF3	0.330621	0.419019	0.571985	0.352296	0.330904	0.533536	0.614221	0.577070
PYOKE1	0.397667	0.383960	0.432820	0.421591	0.521191	0.497200	0.432255	0.311597

PYOKE2	0.301203	0.366411	0.384353	0.321323	0.329606	0.409253	0.441704	0.307808
PYOKE3	0.359602	0.306848	0.347435	0.397382	0.433974	0.450724	0.313354	0.218115
QSETUP1	-0.398820	-0.442519	-0.534295	-0.351043	-0.371070	-0.520358	-0.412262	-0.335400
QSETUP2	-0.256181	-0.325886	-0.433824	-0.228426	-0.202230	-0.348760	-0.356691	-0.244705
QSETUP3	-0.247437	-0.441381	-0.427233	-0.344911	-0.314605	-0.485400	-0.348820	-0.349157
SATISF1	0.348065	0.429487	0.466171	0.390152	0.298404	0.442768	0.450073	0.445653
SATISF2	0.327913	0.458985	0.531214	0.353658	0.348966	0.529081	0.519305	0.472035
SATISF3	0.356863	0.462226	0.452761	0.261947	0.260819	0.481491	0.478233	0.465122
STANDW1	-0.284879	-0.361070	-0.487181	-0.391622	-0.429445	-0.513969	-0.305913	-0.316950
STANDW2	-0.294614	-0.316229	-0.433176	-0.295980	-0.373310	-0.424090	-0.355687	-0.372009
STANDW3	-0.308099	-0.390693	-0.431767	-0.341043	-0.334125	-0.413574	-0.368407	-0.311678
TEAM1	0.326571	0.371772	0.722641	0.271359	0.309290	0.439477	0.376568	0.448735
TEAM2	0.363562	0.413213	0.587652	0.362728	0.339294	0.509300	0.433946	0.391391
TEAM3	0.483962	0.357345	0.511569	0.412659	0.368707	0.550334	0.442308	0.409512
TPM1	0.379432	0.459233	0.499190	0.305069	0.261289	0.481034	0.441947	0.434776
TPM2	0.381879	0.440456	0.519373	0.387121	0.341412	0.517043	0.483418	0.392808
TPM3	0.325221	0.386724	0.544975	0.364606	0.341173	0.419024	0.511801	0.472110
VISM1	0.345598	0.426736	0.499723	0.286188	0.324225	0.450040	0.472791	0.478229
VISM2	0.409720	0.429597	0.518812	0.338521	0.380189	0.526947	0.499133	0.456478
VISM3	0.448448	0.344486	0.550590	0.320847	0.366506	0.446103	0.514567	0.420102
VSM1	0.271157	0.369176	0.369402	0.214367	0.209266	0.368173	0.463870	0.421437
VSM2	0.282864	0.400833	0.491550	0.298829	0.370175	0.493991	0.653193	0.590292
VSM3	0.279058	0.362305	0.368543	0.199527	0.274748	0.413471	0.525890	0.470742
WINV1	0.347919	0.283421	0.378258	0.168194	0.192401	0.374915	0.528762	0.499929
WINV2	0.359844	0.292833	0.516448	0.287932	0.346287	0.460343	0.589540	0.518796
WINV3	0.376732	0.276147	0.469233	0.253095	0.282138	0.456734	0.558311	0.468092
WINV4	0.272783	0.283767	0.417966	0.266189	0.252768	0.345259	0.377512	0.448630
WINV5	0.395880	0.418994	0.613820	0.293440	0.360588	0.508946	0.716103	0.516750

	PYOKE	QSETUP	STANDW	TEAM	TPM	VISM	VSM	WINV
AND1	0.292624	-0.305289	-0.293871	0.379998	0.333250	0.380359	0.299540	0.352147
AND2	0.367095	-0.281568	-0.272422	0.336071	0.306170	0.437257	0.201526	0.348708
AND3	0.371355	-0.351911	-0.294394	0.423760	0.389743	0.284999	0.289018	0.380367
CONTFL1	0.290477	-0.404125	-0.335922	0.352078	0.358036	0.319251	0.336455	0.287742
CONTFL2	0.418905	-0.475199	-0.392637	0.423485	0.493693	0.444117	0.387972	0.388683
CONTFL3	0.329144	-0.363262	-0.311617	0.330952	0.366453	0.333175	0.364586	0.277033
FIVES1	0.360375	-0.474565	-0.456957	0.591166	0.496883	0.495578	0.435217	0.500817
FIVES3	0.465152	-0.570266	-0.491110	0.675550	0.573203	0.543404	0.423914	0.572508
HEDJ1	0.394496	-0.380260	-0.343231	0.427658	0.423253	0.326605	0.291391	0.320707
HEDJ2	0.366013	-0.277384	-0.353154	0.281991	0.282470	0.252121	0.239218	0.224103
HEDJ3	0.402632	-0.324782	-0.357843	0.335639	0.313016	0.321829	0.172718	0.253591
JID1	0.507404	-0.367834	-0.459888	0.401361	0.385712	0.406436	0.323175	0.377987
JID2	0.452360	-0.362217	-0.376269	0.374355	0.315348	0.338259	0.300030	0.309827
JID3	0.395680	-0.258123	-0.348641	0.287593	0.251386	0.317259	0.284728	0.270430
JIT1	0.437205	-0.431339	-0.413236	0.337019	0.407347	0.306680	0.242692	0.275346
JIT2	0.143478	-0.154005	-0.165648	0.247403	0.155535	0.180093	0.266639	0.288625
JIT3	0.405741	-0.447820	-0.408960	0.460562	0.428946	0.434709	0.405690	0.387466
JIT4	0.452497	-0.494093	-0.461092	0.520987	0.421453	0.438820	0.403223	0.456728
JIT5	0.438743	-0.443693	-0.452068	0.509775	0.472889	0.465855	0.438017	0.438146
JIT6	0.393672	-0.428819	-0.338937	0.428898	0.421603	0.397324	0.371778	0.470496
KAIZ1	0.419088	-0.366730	-0.315858	0.389741	0.480938	0.518846	0.592501	0.572596
KAIZ2	0.420783	-0.456474	-0.398044	0.478947	0.492413	0.459672	0.547113	0.660642
MUDA1	0.303110	-0.353069	-0.354947	0.419911	0.447129	0.482576	0.542790	0.556550
MUDA2	0.349588	-0.396110	-0.413986	0.517166	0.505537	0.492467	0.575018	0.622129
MUDA3	0.296126	-0.349059	-0.339289	0.445547	0.457813	0.448641	0.525989	0.547177
PYOKE1	0.903696	-0.498908	-0.484098	0.555434	0.426619	0.558848	0.358435	0.448677
PYOKE2	0.852261	-0.452210	-0.412481	0.423006	0.352449	0.461666	0.359367	0.387255
PYOKE3	0.815502	-0.387120	-0.360492	0.402067	0.340048	0.489758	0.298940	0.389266
QSETUP1	-0.483508	0.882749	0.495763	-0.615604	-0.550003	-0.467103	-0.381388	-0.492697
QSETUP2	-0.314069	0.767795	0.339276	-0.403271	-0.455992	-0.404056	-0.397390	-0.406346
QSETUP3	-0.477036	0.782283	0.418504	-0.513065	-0.498788	-0.367977	-0.415618	-0.419483
STANDW1	-0.492403	0.462436	0.837218	-0.522242	-0.462500	-0.472436	-0.359791	-0.468059
STANDW2	-0.396267	0.382766	0.873734	-0.541028	-0.400754	-0.403112	-0.369347	-0.471119

STANDW3	-0.389904	0.484786	0.876902	-0.515265	-0.440588	-0.451087	-0.443874	-0.436019
TEAM1	0.418295	-0.538236	-0.466603	0.774833	0.528258	0.446099	0.444933	0.587701
TEAM2	0.460735	-0.576378	-0.547214	0.911343	0.575539	0.457010	0.520854	0.603697
TEAM3	0.516745	-0.521448	-0.557404	0.895112	0.572855	0.469381	0.471237	0.615377
TPM1	0.355259	-0.568567	-0.428000	0.575732	0.874114	0.523880	0.449360	0.498340
TPM2	0.406840	-0.587782	-0.438882	0.582510	0.925897	0.469686	0.471253	0.518502
TPM3	0.397155	-0.478566	-0.472470	0.559684	0.849836	0.439562	0.487260	0.462375
VISM1	0.476431	-0.487809	-0.452439	0.471343	0.520703	0.905449	0.506402	0.441681
VISM2	0.557720	-0.466786	-0.458433	0.482844	0.482904	0.938092	0.475321	0.438450
VISM3	0.575922	-0.448277	-0.498948	0.500480	0.485002	0.901830	0.463152	0.496476
VSM1	0.276801	-0.462207	-0.339526	0.413435	0.392034	0.390638	0.826169	0.477126
VSM2	0.411433	-0.437938	-0.454757	0.545860	0.532878	0.514817	0.879980	0.604485
VSM3	0.343854	-0.389026	-0.395872	0.493477	0.457667	0.467868	0.927273	0.486018
WINV1	0.282805	-0.363375	-0.440415	0.523135	0.403049	0.349977	0.474146	0.813123
WINV2	0.402141	-0.484536	-0.464849	0.609785	0.488556	0.413816	0.491415	0.885455
WINV3	0.399753	-0.440779	-0.423358	0.601101	0.456220	0.425566	0.516370	0.862399
WINV4	0.359004	-0.350902	-0.336912	0.519052	0.374933	0.345047	0.381235	0.702961
WINV5	0.495262	-0.554988	-0.486744	0.599271	0.545089	0.502120	0.575701	0.839164