ASSESSING LEAN WAREHOUSING:DEVELOPMENT AND VALIDATION OF ALEAN ASSESSMENT TOOL

A DOCTORAL DISSERTATION

By

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DISSERTATION ABSTRACT

This research was undertaken to fill a gap in the academic literature and in practice by developing a comprehensive lean implementation assessment tool for warehousing operations implementing lean manufacturing principles and techniques. The lean implementation assessment tool developed provides specific, actionable items that can be used in practice to further implement lean production and provide useful information to monitor the initiative's progress and make better resource decisions. Furthermore, the results from the application of the lean implementation assessment tool are analyzed to better understand the practical implementation and underlying factors of lean warehousing. Consequently, the research outcomes are two-fold, both filling the gap in the development of a comprehensive warehousing lean implementation assessment tool and providing insight into the actual implementation of lean warehousing.

The academic literature provides the historical context, evolution, fundamental constructs, and corresponding practices associated with lean manufacturing and lean warehousing. The specific lean constructs identified from the lean manufacturing literature that are measured in the lean implementation assessment tool developed in this research are visual management, standardized processes, continuous and leveled flow, pull systems, workplace organization, empowered employees, quality assurance, and continuous improvement.

The lean constructs were operationally defined with respect to the associated lean practices to measure implementation and utilization on various evaluations points comprising the

various warehousing processes in a facility. Each of the key constructs was assessed for all the major functional areas applicable within each warehouse.

The lean constructs identified were further developed working within multiple warehousing facilities, each in various stages of lean implementation with unique characteristics and industries to enhance the generalizability of the lean implementation assessment tool developed in this research. The lean constructs are refined and operationally defined through onsite analysis and multiple assessor use to ensure cross-facility applicability and multiple assessor perspectives.

The operationally defined and scored evaluation items were aggregated to determine scores at the facility level, individual function level, and individual construct level to provide usable feedback and analysis. The data collection process identified specific areas of improvement and provided feedback with regard to the implementation and utilization of lean warehousing principles.

Finally, to validate the assessment tool, twenty-eight lean implementation assessments were performed at twenty-five facilities ensuring that measurement outcomes meet expectations at multiple warehouses across industries and across geographical regions, ensuring equity among comparisons, and identifying future improvements and research opportunities. The data analysis conducted uses various multivariate statistical techniques to identify interrelated lean constructs and practices, any potential effects of inter-rater agreement or non-agreement, and a potentially reduced and simplified lean implementation assessment tool structure. Furthermore, the implications of the underlying factors and structure of assessment, implementation, and practice are examined based on the findings from the application of the lean implementation assessment tool.

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CHAPTER I
INTRODUCTION

Introduction

Over the last twenty-five years, there has been an increasing focus in many organizations in the United States on implementing various organizational improvement paradigms to reduce costs and subsequently increase profitability. Cost containment and cost reduction strategies have become a primary focus for companies to sustain and increase profits due to increases in global competition, transportation costs, free trade, technological advances, and other market changes in today's business environment. There have been numerous organizational improvement strategies that have arisen in the last several decades and become popular in the business press, namely Total Quality Management, Six Sigma, Lean Manufacturing, and Reengineering, among many others. These strategies focus on various aspects of quality improvement, elimination of variation, waste reduction, organizational restructuring, problem solving, cost cutting and the like, all in various combinations and permutations of different principles, tools, and techniques.

Lean manufacturing or lean production has become the common name for the manufacturing strategy developed by the Toyota Motor Corporation beginning primarily in the 1940s and 1950s. *The Machine That Changed the World* by Womack, Jones, & Roos (1990) outlines the development and practices associated with lean manufacturing observed during their five year, five million dollar study of the Toyota Production System conducted at MIT during the late 1980s. According to Womack et al. (1990), lean manufacturing is the improvement paradigm that provides for systematic identification and elimination of waste throughout the production system from the customer's perspective of value-added processes. Lean manufacturing is the paradigm that will be examined in this analysis, in particular lean warehousing operations.

Purpose

The objective of this dissertation research was to develop a lean implementation assessment tool that identifies, operationally defines, and measures the fundamental principles and corresponding practices of lean manufacturing, as it relates to the shop-floor in warehousing operations. Therefore, the focus of this research was to take a comprehensive approach to understanding the principles, tools, and techniques of lean manufacturing and develop a lean implementation assessment tool as it relates to lean logistics, specifically lean warehousing operations. There have been numerous lean assessment tools developed to measure lean principles at the enterprise level (MIT, 2001) or generally for manufacturing operations (Virginia Tech CHPM, 2005). These tools help provide general organizational direction at the enterprise and manufacturing operations level as it relates to lean manufacturing principles and practices, but do not provide specific detail and actionable items for improvement at the shop-floor level, specifically the warehouse-floor level.

There are some detailed shop-floor level lean assessment tools that have been developed to provide insight into various aspects of lean principles and practices, but are not directly related to warehousing operations or truly comprehensive in nature. The existing lean assessment tools only capture some of the fundamental principles and corresponding practices associated with lean warehousing at the shop-floor level of an organization, as evidenced in Taj (2005). The assessment tools identified in the literature do not provide a comprehensive assessment of lean manufacturing principles at the shop-floor level, relate to warehousing operations, or provide comprehensive and specific actionable items for further development and use in those operations.

Thus, this research fills a gap in the academic literature and in practice for a comprehensive lean implementation assessment tool for warehousing operations that provides specific, actionable items to be used in practice. Furthermore, the lean implementation assessment tool developed in this analysis was applied at numerous warehouses where the corresponding results were analyzed to better understand the practical implementation and underlying factors of lean warehousing. Consequently, the research outcomes are two-fold, both filling the gap in the development of a comprehensive warehousing lean implementation assessment tool in the academic literature while providing insight into the actual implementation of lean warehousing in use in the warehousing industry today.

Research Overview

The lean implementation assessment tool developed in this research was completed by conducting an extensive search of the academic literature, lean literature, and print articles. First, the fundamental principles of lean manufacturing as proposed by the developers and key authors related to the Toyota Production System, lean manufacturing, lean production, lean logistics, and lean warehousing were identified and examined from the literature and compared comprehensively. The various lean practices identified throughout the literature were associated with the corresponding lean principles developed in this analysis and expanded into a comprehensive lean implementation assessment tool structure for lean warehousing. The structure of principles and practices identified in the literature were then operationalized into multiple evaluation points for measurement during the data collection process.

The tool was piloted in three warehousing operations where feedback was gathered from a lean expert panel, practicing lean professionals, and warehouse associates to determine the robustness, usefulness, and depth of measurement developed during the assessment process. Then, the lean implementation assessment tool was further refined to increase the cross-facility applicability from the feedback in the pilot process across industries and various types of warehouses. The refined tool was then applied in twenty-five additional warehouses, for a total of twenty-eight times during the course of calendar year 2007 to assess lean implementation in those warehouses and provide additional data for analysis and understanding. The warehouses assessed were across the United States, Canada, the Netherlands, and Germany where lean warehousing implementation was underway with varying degrees of success. Finally, various multivariate statistical techniques were used to identify the underlying factors associated with lean implementation and the validity of the lean implementation assessment tool for measuring lean warehousing operations.

A pared down list of the lean warehousing principles and practices was determined based on the statistical analysis performed from the observed assessment data in practice. The lean implementation assessment tool output was analyzed and compared to expert panel observation, inter-rater agreement, and the number of evaluation points required for determining the tool's efficacy, ease of use, and direction provided.

Research Questions

This analysis answers the following fundamental research questions:

- What are the underlying factors or lean principles sufficient for assessing lean manufacturing implementation and usage in warehousing environments?
- What are the corresponding lean practices associated with the underlying factors required for assessing lean manufacturing implementation and usage in warehousing environments?
- What are the implications of the identified underlying lean principles and lean practices on implementing the paradigm in warehousing operations?

1. The fundamental research questions were first addressed by developing a comprehensive lean implementation assessment tool that operationalized the principles and practices associated with lean manufacturing identified from the literature, practice, and existing assessment tools.
2. The lean implementation assessment tool was then applied twenty-eight times in twenty-five warehouses to gather data for multivariate statistical analysis to identify the significant underlying and interrelated factors measured in warehouses implementing lean principles and practices.
3. The comprehensive list of lean principles and corresponding practices identified from the literature were then pared down based on multivariate statistical analysis and the resultant list compared to the comprehensive list.
4. Data analysis was conducted to address differences in means between assessors and any impact on potentially subjectivity of evaluation points and validity of the overall assessment of facility lean implementation and usage.

The subsequent feedback, analysis, assessment, and identification of opportunities for improvement will help facility personnel, management, and employees to better identify where additional resources, support, and focus may be needed for further implementation. This information will help managers to prioritize improvement activities, track performance over time, and identify potential sources of slippage. Finally, this information will help organizations identify high performers and best practices, and facilitate organizational learning within facilities and across facilities. This research provides insight into the implementation of lean warehousing in practice and a methodology for comparing and analyzing the results.

Assumptions

This analysis contains the following assumptions:

1. Lean is the improvement methodology that was leveraged to achieve increased organizational performance in this analysis and that implementing lean principles and practices improves warehouse operations, service levels, and outputs.
2. Implementing lean principles within an organization or facility will result in improvements over the current practices. Furthermore, the author personally believes that the lean principles of people engagement, reduction of waste, continuous improvement, and the other lean practices will benefit any company or warehouse and will drive continuous improvement.
3. The development of a consistent, shop-floor level lean assessment tool and measurement criteria for the implementation and usage of lean manufacturing principles and practices will provide better results versus the current practice of ad hoc, subjective assessment.

4. The enhanced knowledge gathered from the lean implementation assessment will lead to increased understanding of where improvement opportunities exist and provide better information about resource allocation and prioritization for further implementation in organizations.
5. The organization must be willing to provide the added resources and support to implement lean in its facilities and the time to observe work practices and practical implementation of lean warehousing principles.

Definitions

The following definitions are provided to clarify the terminology and stratification of the framework used in this research. The literature and business press do not provide a common description or verbiage of lean principles, concepts, and practices; consequently, a common and consistent verbiage and stratification of lean constructs and practices is presented.

- Lean Principle – Lean principles are the various general theoretical concepts and fundamental ideas described in the academic literature related to lean manufacturing.
- Lean Construct – Lean constructs are the fundamental principles and concepts outlined in the literature related to lean manufacturing, but synthesized and stratified into specific ideas with associated practices.
- Lean Practice – The lean practices identified are the specific actions used at the shop-floor level and are subsequently associated with the fundamental lean constructs developed.

Why Assessment?

The proposed lean implementation assessment tool allows for better internal and external organizational performance measurement, comparison, and tracking with respect to the implementation levels and usage of lean warehousing principles in various facilities across industries. The lean implementation assessment tool developed provides a common performance measurement device to help identify facilities that have made measurable progress, help recognize implementation leaders, and help determine facilities, functions, and lean principles in need of added support.

Furthermore, the lean implementation assessment tool developed identifies specific actionable opportunities for improvement and best practices, while promoting organizational learning to existing facilities and providing a specific roadmap for facilities beginning lean implementation. Internal and external benchmarking of business processes can be developed from comparison of the results from the assessments to help identify the current state-of-the-art in practice in industry across warehouses in various business sectors. The opportunities for improvement identified from assessments conducted help provide additional direction and prioritization of specific action items that support continuous improvement and growth within the facilities and across organizations. The assessment results identify gaps in specific principles or practices that require additional training or sharing of lessons learned between facilities identified with strengths or opportunities. This information and analysis fosters organizational learning, sharing of best practices, and better decision making for resource allocation and further implementation.

Motivation for the Study

Lean principles have been successfully applied in numerous warehousing environments, originally in Toyota's parts distribution centers, but have had little exposure in the literature (Liker 2004). Trebilcock (2004) identifies the burgeoning concept of lean warehousing, which after fifty years of lean manufacturing has now come to the forefront in service and warehousing operations as much of the waste has been eliminated from the more traditional manufacturing operations. Womack (2006) states that many of the U.S. automotive manufacturers are now able to compete with Toyota on productivity and quality measures in many of their manufacturing operations, but still trail in other business sectors. Consequently, it stands to reason that to further drive down costs and eliminate wastes throughout the entire supply chain, the focus will move to less traditional areas of the organizations. Furthermore, as the United States moves further from a manufacturing based economy to a service based economy, warehousing and distribution of goods will become a primary source of competitive advantage for many companies. In particular, as transportation costs have risen in recent years, the cost structure of manufacturing, inventory, and warehousing has shifted, making the importance of lean logistics, lean warehousing, and supply chain optimization increasingly important.

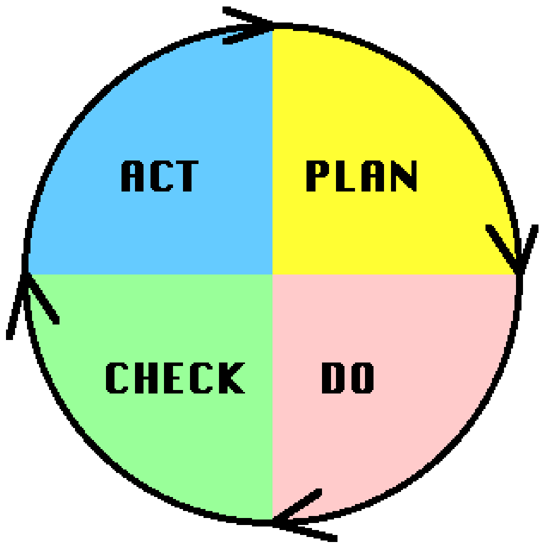
Significance of the Study

Organizations undertaking improvement initiatives are commonly met with limited success or even failure, while incurring great expense when undertaking any new change paradigm or initiative. There are consultants, training, travel, equipment, and myriad other expenses that the organization must incur to implement the desired results of the change initiative. Chadderdon (1999) estimates that the management consulting business alone exceeds seventy billion dollars annually in the United States. The time, resources, and enormity of training people on the corresponding principles, practices, and tools make success and a return on investment extremely important to the stakeholders of the organization implementing the paradigm. Consequently, an assessment tool that consistently and accurately measures the success and opportunities of implementation of the initiative would be extremely important.

Both Miller (2002) and Senge (1999) estimate that only about thirty percent of change initiatives actually succeed in achieving the desired results. Subsequently, there are probably as many reasons for failure as there are observed failures with these organizational change initiatives. According to Kotter (2005), some of the reasons for failure are lack of urgency, not leading by example, declaring victory too soon, and a resistance to change. Most organizational improvement paradigms provide similar simple step-by-step procedures with a one-size-fits-all, silver-bullet approach to implementation promising unprecedented success for all organizations. These strategies and planning appear sound, but the prescriptive characteristics do not address the complex, unique issues that arise in all organizations that can lead to failure during the implementation process. Consequently, developing an assessment tool that provides actionable feedback to implementers will provide useful feedback during the implementation process while measuring and benchmarking successes and opportunities for prioritization of resources, additional training, and implementation opportunities.

Even within a single organization there are varying degrees of successful implementation and utilization for a given improvement initiative, even with virtually the same physical circumstances and levels of organizational support. The development of the lean implementation assessment tool for warehouses in this research will help organizations to better measure, analyze, and determine which facilities are performing as expected, which facilities and functions have opportunities for improvement, and where additional resources and training are required. Collins (2001) identifies accurate measurement systems as one of the traits common in successful organizations undergoing transformation in his book *Good to Great*. Accurately assessing the current situation in warehouses will provide better information of where and when resources and assistance are required to increase the likelihood of successful implementation. Furthermore, the specific practices associated with lean warehousing were identified and measured by the lean implementation assessment tool rather than prescriptive generalizations or vague recommendations provided by other means.

The Deming (1994) Plan-Do-Check-Act Cycle (Figure 1) provides the general process steps associated with continuous improvement within organizations. This analysis started from the assumption that an organization has already made the decision to implement lean manufacturing principles (Plan) and has begun the process of implementing those lean practices (Do). The lean implementation assessment tool developed in this research provides a consistent method for measurement (Check), aiding management in future decisions to be made (Act), thereby completing the Deming (1994) Plan-Do-Check-Act cycle. In essence, the lean implementation assessment tool completes the Deming (1994) Plan-Do-Check-Act cycle at the organizational level for lean warehouse implementation and provides consistent, periodic feedback to management from the shop floor about the success or failure of implementation. Further, an accurate lean implementation assessment tool provides the feedback mechanism for more accurately "checking" the current situation to aid in decisions about resource application, manpower allocation, support services, and performance measurement.



Graphic from http://www.balancedscorecard.org/bkgd/pdca.html

Figure 1: Arveson (1998) Deming's Plan-Do-Check-Act Cycle

Conclusion

This research fills a gap in the academic literature and in industry by developing a comprehensive lean implementation assessment tool for warehousing operations implementing lean manufacturing principles and techniques. The lean implementation assessment tool developed provides specific, actionable items that can be used in practice to further implement lean warehousing and provide useful information to management to monitor the initiatives' progress and make resources decisions. Furthermore, the results from the application of the lean implementation assessment tool were analyzed to better understand the practical implementation and underlying factors and corresponding practices of lean warehousing. Consequently, the research outcomes are two-fold, both filling the gap in the development of a comprehensive warehousing lean implementation assessment tool and providing insight into the actual implementation of lean warehousing.

CHAPTER II
LITERATURE REVIEW

Introduction

The literature was searched and examined in detail with regard to general organizational change strategies, lean manufacturing, lean production, just-in-time (JIT), the Toyota Production System, lean warehousing, lean measurement, lean assessment, warehousing measurement systems, and warehousing assessment. Consequently, the following literature review provides a comprehensive analysis for the framework of the development of a lean implementation assessment tool for warehousing operations.

The detailed review of the business press, academic literature, and various lean assessment tools provided the basis for the development of the eight fundamental lean constructs identified in this analysis. All fifty-eight of the common lean practices identified were stratified into the eight lean constructs, which were operationalized to have specific corresponding measures to assess the concepts and practices associated with implementing lean warehousing. The lean practices identified were then compiled into a comprehensive list as the literature was reviewed, analyzed, and subsequently pared down during statistical analysis after the lean implementation assessment tool was developed and data collected from the corresponding twenty-eight lean implementation assessments conducted.

First, the literature review examined the general organizational change strategies, framework, and necessity for assessing organizational improvement and change. Second, numerous influential lean manufacturing and Toyota Production System related books that have been published over the last thirty years were examined in detail. Third, the general lean literature and associated research articles were examined to establish a comprehensive research framework for lean manufacturing. Then, various assessment tools were discussed within the lean principle framework for warehousing and other contexts to determine the existing measures, constructs, and assessment development methodologies. Finally, the common existing research methodologies and practices were examined with regard to validation, reliability, and usefulness for the lean implementation assessment tool development.

The literature review in this research provides a comprehensive framework to identify the principles, practices, and tools used in lean manufacturing and their relation to lean warehousing to develop a robust lean implementation assessment tool. The framework developed in the literature review provides the structure to operationalize the concepts into evaluation items to be measured and used in the lean implementation assessment tool.

Change Initiative Success Rates

This research is important due to the limited success observed in implementing various change initiatives and the corresponding costs associated with implementation. Miller (2002) estimates that "…only three out of four change initiatives give the return on investment that leadership forecast…" and that "…failure is usually in the execution of the initiative." Furthermore, Miller (2002) cites various statistics regarding change efforts and projects, namely, that seven out of ten change initiatives that are critical to long-term organizational success fail, twenty-eight percent are abandoned before completion, forty-six percent are over budget, and that eighty percent are not used in the way they were intended. Similarly, Senge (1990) illustrates that only seventy percent of the Fortune 500 Industrials in existence in 1970 were able to initiate enough successful change and react to market changes to at least survive, in some recognizable form, until 1983. Consequently, thirty percent of those firms were not able to initiate enough successful change initiatives to survive for those thirteen years studied.

Similarly, the Standish Group (1995) estimates that only slightly more than a quarter of projects studied finish with twenty-five percent to forty-nine percent of the original specifications. The Standish Group (1995) also estimates that forty-six percent of all projects studied encounter unexpected challenges resulting in cost overruns or late delivery, which may affect the classification of success or failure depending on the specific definition. Furthermore, working with the Standish Group, Johnson (1999) illustrates similar results in 1994, 1996, and 1998, finding also that the success rates of the projects are inversely proportional to project size and expenditure.

Conversely, according to White (1993), eighty-six percent of organizations who implemented various "Just-In-Time" practices, or lean practices, indicate that an overall net benefit resulted from the implementation. Only approximately five percent report that there was no overall net benefit and about nine percent did not know if a benefit occurred. The lean practices associated with "Just-In-Time" according to White (1993) are quality circles, total quality control, focused factory, total productive maintenance, reduced setup times, group technology, uniform workload, multifunctional employees, kanban, and purchasing techniques.

White, Pearson, & Wilson (1999) surveyed the perceived benefits of implementing various aspects of "Just-In-Time" practices or lean practices in large versus small manufacturers. According to White et al. (1999), large manufacturers are more advanced in the implementation of lean practices than are smaller manufacturers, with the exception of multifunctional employees. Furthermore, both small and large manufacturers show "…significantly improved performance as a result of implementing JIT systems" (White et al., 1999). Due to the nature of survey research, there may be potential biases in findings due to the differences in perceived benefits as reported and actual benefits relating to total system costs. Furthermore, there are some potential issues interpolating the results of the success rates of non-responders versus those who did respond and their respective success rates. According to White et al. (1993), approximately ninety-six percent of manufacturing firms report implementing at least three of the "Just-In-Time" principles, which may indicate potential over-reporting of implementation, usage, or the effects of non-response if organizations had not implemented any of the principles.

The findings in the change success research illustrates the frequency with which time, resources, and money can be lost due to failed change initiatives and the subsequent importance of providing better information to managers regarding the status of implementation and use of the corresponding principles and practices. Consequently, the development of the lean implementation assessment tool in this research may lead to increased success due to increased information when implementing lean warehousing principles and practices.

Linking Manufacturing Strategy to Performance

Wheelwright & Hayes (1985) propose and develop a linkage between manufacturing strategies and increases in performance of those manufacturing firms through a corresponding competitive advantage gained through implementation. Wheelwright & Hayes (1985) develop the theoretical linkage between the level of involvement of manufacturing in strategic planning and decision making. Similarly, the implementation of lean warehousing principles gained could result in gaining a competitive advantage in the market.

According to Wheelwright & Hayes (1985), the four stages of manufacturing's organizational role move from "internally neutral", to "externally neutral", to "internally supportive", and to "externally supportive", where competitive advantages are gained through manufacturing in the final stage. The decisions associated with manufacturing include "capacity, facilities, equipment and process technologies, vertical integration, vendors, new products, human resources, quality, and systems" (Wheelwright & Hayes, 1985). These practices are the very aspects that lean manufacturing and lean warehousing methodologies attempt to improve and subsequently need to be measured in warehouse assessments.

The Wheelwright & Hayes (1985) stages directly correspond to the degree with which lean implementation activities have progressed and were observed in different warehouses. Subsequently, the perceived importance by management of the warehousing operation's role as a competitive advantage leads to additional resources and focus on competing through operations productivity, quality, and profitability. The importance of the warehouse operation's role was directly observed in this research with the amount of time and resources used to implement lean principles and practices at the warehouses studied.

Bates, Amundson, Schroeder, & Morris (1995) examine the relationship between manufacturing strategy and organizational culture along a continuum within the corresponding framework developed by Wheelwright & Hayes (1985). The Bates et al. (1995) manufacturing strategy continuum ranges from "poorly to well-aligned and implemented" and the organizational culture continuum ranges from "hierarchically-oriented to clan-oriented." The corresponding manufacturing practices are "formal strategic planning process, communication of strategy, manufacturing strategy strength, and the competitive role of manufacturing" (Bates et al., 1995).

Similarly, the cultural practices are "individualism/collectivism, power distance, and cultural congruency" (Bates et al., 1995). Surveys were conducted in forty-one plants in three industries, using a mixed scaling methodology where respondents rated the various manufacturing and cultural aspects of their organizations. The Bates et al. (1995) survey results establish that a relationship exists between manufacturing strategy and organizational culture, but the directionality, causality, or dependency of the relationships is not determined. The relation of culture and strategy directly tie to the principles associated with lean manufacturing and lean warehousing and are further examined in the following sections.

Measuring Organizational Culture Aspects

Many of the lean principles and practices identified in the literature relate to various cultural aspects of organizations and the successful implementation of change initiatives. Subsequently, Hofstede, Neuijen, Ohayv, & Sanders (1990) present the fundamental research framework and methodology for measuring those aspects of organizational cultures that pertain to the lean manufacturing principles and practices quantitatively.

The research framework of Hofstede et al. (1990) operationalizes organizational culture into independent practices to be measured and the extent to which measurable characteristics can be attributed to unique features inherent in organizations. The Hofstede et al. (1990) methodology utilizes interviews as a basis to create a survey questionnaire to measure four types of manifestations of culture: symbols, heroes, rituals, and values. The Hofstede et al. (1990) symbols, heroes, and rituals are combined into the common label of practices in the work situation, while the values relate to work goals and general beliefs. The significant Hofstede et al. (1990) individual factors for those practices are process-oriented versus results-oriented, employee-oriented versus job-oriented, parochial versus professional, open systems versus closed systems, loose control versus tight control, and normative versus pragmatic. Hofstede et al. (1990) report the significant individual factors for values to be a need for security, work certainty, and a need for authority. These significant underlying factors and framework from Hofstede et al. (1990) were used to identify and measure various aspects of organizational culture associated with lean manufacturing principles and practices.

Zeitz, Johannesson, & Ritchie (1997) use a similar methodology to Hofstede et al. (1990) for developing and validating an employee survey measuring the practices and supporting organizational culture relating to the organizational improvement paradigm Total Quality Management (TQM). The survey instrument consists of thirteen practices associated with TQM and ten practices associated with organizational culture or climate, with one-hundred-thirteen individual survey questions. Zeitz et al. (1997) conduct a factor analysis to determine that fifty-six of the original items measure only seven of the original TQM practices and five of the culture practices, accounting for the majority of the variance observed. According to Zeitz et al. (1997), the seven significant TQM practices are management support, suggestions, use of data, supplies, supervision, continuous improvement, and customer orientation, while the five significant TQM culture practices are job challenge, communication, trust, innovation, and social cohesion. The relation of TQM and lean manufacturing make these research findings significant for the development of the lean implementation assessment tool developed in this research.

Zeitz et al. (1997) provide the basic research methodology and framework for developing an assessment tool to measure lean manufacturing implementation in warehousing operations used in this research. Further, Zeitz et al. (1997) provide a methodological framework to determine the significant underlying factors associated with various practices related to lean manufacturing through statistical analysis, while potentially accounting for a significant amount of the observed variance in the data. The research framework, culture, principles, and practices identified in this research to measure the implementation of lean warehousing are derived from the supporting literature and the existing tools leverages the research identified by Zeitz et al. (1997) for the total quality management principles.

Lean Concepts and Theoretical Framework

The fundamental lean concepts, principles, constructs, and practices were garnered by examining the literature and the theoretical framework that Ohno (1986), Shingo (1989), Womack, Jones, and Roos (1990), Womack and Jones (1996), and Liker (2004) develop in their respective works. A summary of each author's fundamental lean concepts, framework, and practices are outlined in this section along with Table 1: Summary Table of Lean Constructs and Key Authors following summarizing and synthesizing the lean theoretical framework described into the common nomenclature developed in this research.

Toyota Production System: Beyond Large-Scale Production

Taichi Ohno's book *Toyota Production System: Beyond Large-Scale Production* was originally written in Japanese in 1976 and translated to the current English version in 1986 introduces the fundamental concepts associated with the Toyota Production System. Taichi Ohno was primarily responsible for the development and achievement of the associated production system at the Toyota Motor Corporation and provides a simple and easy to understand insider perspective of the manufacturing methodologies in his book. Furthermore, Ohno (1986) provides the original, straightforward, uninfluenced framework, and perspective of lean manufacturing principles and practices without the current management jargon and buzzwords.

The two pillars associated with the Toyota Production System, according to Ohno (1986), are just-in-time and autonomation, or automation with a human touch, from which all the other concepts associated with lean manufacturing are derived. According to Ohno (1986), the development of the manufacturing system was originally from necessity due to requirements of production flow with near-zero inventory and the constraints of post-WWII Japan. From this context, the practices of just-in-time, pull systems, kanbans, production leveling, supermarkets, fool-proofing, autonomation, andon, teamwork, and flexible workforce are developed with the overarching goal of cost reduction. Consequently, Ohno (1986) states on page 9, "The Toyota Production system, with its two pillars (*just-in-time and autonomation*) advocating the absolute elimination of waste, was born in Japan out of necessity." The fundamental lean principles associated with manufacturing operations of value-added work, non-value-added work, and waste, developed from the resource constraints in post-WWII Japan are discussed and defined in detail in Ohno (1986). The concept of waste derived the seven forms of waste are defined in Ohno (1986) and their effects discussed, namely, overproduction, waiting, transportation, processing, inventory, movement, and defects.

In addition, many of the other fundamental techniques associated with the Toyota Production System and now lean manufacturing are presented in Ohno (1986). The ideas of profit-making industrial engineering, maximizing worker utilization rather than machine utilization, small lot sizes, quick setup, and preventative maintenance are outlined. The five-why method of problem solving and correcting root-causes of problems rather than symptoms are presented and related to organizational culture, empowerment, and employee engagement.

Furthermore, the decentralization of tasks and assigning duties associated with creating standard work sheets to operators is discussed with the concepts of visual controls, cycle time, takt time, work sequence and standard inventory. Ohno (1986) provides the fundamental framework from which the concepts associated with the Toyota Production System are developed and subsequently the framework associated with lean manufacturing.

The principles and practices outlined in Ohno (1986) were incorporated into the development of the lean implementation assessment used in this research. The conceptual framework for lean warehousing is a derivative of those fundamental principles and practices set forth in Ohno (1986).

A Study of the Toyota Production System: From an Industrial Engineering Viewpoint.

Shingo (1989) describes the basic principles of the Toyota Production System as the process of eliminating waste through continuous process improvement. The fundamentals of continuous process improvement discussed by Shingo (1989) are achieved through studying and mapping processes, which is where the principles of value stream mapping are derived. The main form of waste to be eliminated in the Toyota Production System is the waste of overproduction, which is eliminated by utilizing just-in-time delivery of goods to eliminate inventory and work in progress (WIP). According to Shingo (1989), the waste of overproduction can be reduced in manufacturing primarily through set up reduction techniques, namely the Single-Minute-Exchange-of-Dies (SMED) methodology he developed. The ability to quickly change over machines allows for the other common lean practices associated with the Toyota Production System to be achieved: pull systems, supermarket systems, one-piece and small batch flow, reduced buffer sizes, leveled flow, demand stabilization, eliminating batching and queuing, and increasing order frequency.

Further, the separation of workers and machines is achieved through autonomation, or automation with a human touch, according to Shingo (1989). Additionally, worker utilizations are to be maximized rather than machine utilizations; consequently, workers are cross-trained to work across multiple machines at the same time. This concept enables layout improvements to be made and machines collocated into a cellular structure, further allowing the elimination of various other types of wastes according to Shingo (1989).

Other practices associated to the basic principles of waste elimination discussed by Shingo (1989) are fool-proofing, inspection processes, visual controls, Five-Whys, Andon systems, Statistical Process Control, suppler integration, and standardized work. Shingo (1989) provides additional support to the fundamental concepts associated with the Toyota Production System or lean manufacturing, as discussed by Ohno (1986) and used in the development of the structure of the lean implementation assessment tool used in this research.

The Machine That Changed The World: The Story of Lean Production

Womack, Jones, and Roos (1990) conducted a five-year, five-million-dollar study of the Toyota Production System in conjunction with the Massachusetts Institute of Technology International Motor Vehicle Program during the late 1980s. The study examines the development, current conditions, and potential future state of the automotive industry comparing various statistics across automotive components and organizations within North America, Europe, Japan, newly industrializing countries, and the rest of the world. Furthermore, the book "*The Machine That Changed The World: The Story of Lean Production: How Japan's Secret*

Weapon in the Global Auto Wars Will Revolutionize Western Industry" provides the historical perspective of the development of mass production methodologies in the United States automotive manufacturing industry. In addition, the development of lean production in the Japanese automotive manufacturing industry after WWII is described in Womack et al. (1990).

According to Womack et al. (1990), "The truly lean plant has two key organizational features: *It transfers the maximum number of tasks and responsibilities to those workers actually adding value to the car on the line, and it has in place a system for detecting defects that quickly traces every problem, once discovered, to its ultimate cause*" (Womack et al. 1990, p. 99). Interestingly, these are not the same two most important keys as identified by Ohno (1986), but were identified as important lean concepts and are needed in the theoretical framework of the literature examined. According to Womack et al. (1990), Taichi Ohno found that the American mass production system was wrought with effort, material, and time waste adding to overall system costs. This method of production and inventory investment would not be feasible under the initial system constraints in Japan. Consequently, the role of waste elimination and maximizing the percentage of workers conducting value-added processes became a central tenet in lean manufacturing.

Other important practices of lean manufacturing identified by Womack et al. (1990) are quick changeover, just-in-time systems, kanbans, production leveling, small-batch production, and supplier integration. In addition, some of the quality practices Womack et al. (1990) associate with lean production are quality circles, Kaizen, error-proofing, and problem-solving through root-cause analysis (Five Why's). Finally, the practices related to lean production attributable to workers and organizational culture are the organization of employees into teams, utilizing team-leaders instead of supervisors, worker empowerment for decision making and improvement, and the use of andon systems to fix quality problems upon detection.

Womack et al. (1990) further expand upon the current practices utilized at Toyota in the lean manufacturing environment, to describe industry best practices and the potential future developments of globally lean corporations in all aspects of business from the manufacturing shop-floor, to product development and design, to supply chain management, to customer interaction, and general management practices. Womack et al. (1990) provide additional theoretical framework, identifying the important principles and practices used in lean manufacturing that were incorporated into the development of the lean implementation assessment tool used in this research.

Lean Thinking: Banish Waste and Create Wealth in Your Organization

Womack and Jones (1996) provide additional theoretical framework and principles associated with lean manufacturing, using the modern semantics, phrasing, and ideas, fundamental to the Toyota Production System or lean production. The five main concepts of lean thinking presented by Womack and Jones (1996) are value, value-stream, flow, pull, and perfection or continuous improvement.

According to Womack and Jones (1996, p. 16), "The critical starting point for lean thinking is *value*…defined by the ultimate customer…only meaningful when expressed in terms of a specific product…Value is created by the producer." Additionally, Womack and Jones (1996, p. 15) state that "any human activity which absorbs resources but creates no *value*" is waste, or *muda* in Japanese, of which there are two types: avoidable waste and unavoidable waste. The fundamental lean thinking goal is to increase the ratio of value-creating activities to waste by eliminating the seven forms of waste, presented within the original Ohno (1986) framework.

"The *value-stream* is the set of all the specific actions required to bring a specific product…through the three critical management tasks of any business: the *problem-solving task*…, the *information management task*…, and the *physical transformation task*…" (Womack & Jones, 1996, p. 19). Consequently, the value-stream extends beyond individual businesses to upstream and downstream enterprises, which are to work cooperatively, as a system across organizations, to maximize value and eliminate wastes throughout the supply chain.

After the supply chain has been evaluated in terms of value the next step in creating a lean enterprise is to create product flow because "…things work better when you focus on the product and its needs, rather than the organization or the equipment, so that all the activities needed to design, order, and provide a product occur in continuous flow" (Womack & Jones, 1996, p. 22). Many of the lean concepts corresponding to lot sizing and material flow are derived from the lean product flow principle, from just-in-time, one-piece and small-lot flow, quick changeover, standardized work, takt time, employee empowerment, standard operating procedures, visual control, Andon, demand leveling, total productive maintenance, and mistake-proofing.

Furthermore, according to Womack and Jones (1996), product flow is managed by customer demand, just-in-time, since upstream production is only initiated when end customers purchase products downstream, triggering the pulling of products from producers through suppliers. Pull-systems are achievable mainly through the lean manufacturing inventory management concept of kanbans/production signaling, and by co-locating functions into cellular structures to minimize travel, waiting, and inventory requirements. In addition, trailer arrival, loading, and unloading processes are standardized to facilitate frequent, just-in-time deliveries.

Womack and Jones (1996) specifically address the lean concepts associated with product flow and their importance in warehousing and distribution operations in parts distribution centers. The Womack and Jones (1996) lean warehousing and distribution concepts are commodity delineation, routing and travel paths, velocity and slotting, layout and zones, travel distance, process control boards, Kaizen, and order frequency. Womack and Jones (1996) provide a specific example of process control boards a tool used in lean warehousing.

The fifth and final principle of lean manufacturing according to Womack and Jones (1996, pg 350) is perfection, which is "The complete elimination of *muda* so that all activities along a *value-stream* create *value*." The lean concepts associated with perfection are continuous improvement, radical improvement, change agents, and leadership direction and roles. Leadership direction and roles relates to organizational culture and the importance exhibited by senior management on implementing lean manufacturing principles and practices as was demonstrated in Hayes and Wheelwright (1984).

Additional lean concepts described by Womack and Jones (1996) used for developing measures on the lean implementation assessment tool are product team productivity, on-time deliveries, inventory turns, and quality. Furthermore, Womack and Jones (1996) advocate the use of a lean scoreboard to measure lean implementation. Additionally, Womack and Jones (1996) discuss the lean concepts of order frequency, supplier development, employee and management involvement, value-stream mapping, autonomation, and scrap, rework, and lead-time tracking. Furthermore, Womack and Jones (1996) encourage linking compensation to profits to encourage cross-functional cooperation, enhance overall system efficiency, and support urgency and engagement in the lean initiative. All of these lean principles and practices were identified in the analysis for the development of the lean implementation assessment tool.

The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer

Liker (2004) provides a comprehensive and detailed description of the lean principles of management, business control processes, and management structure used by various lean manufacturing firms. The Toyota Motor Corporation and the Toyota Production System are the most widely described manufacturing systems and methodologies in Liker (2004). The historical development of the business control procedures are discussed in relation to the development of the lean principles and processes used, from the original Toyota product (the loom), to post-WWII vehicle production, to the development of the luxury brand Lexus, and the modern development of the Prius hybrid vehicle. Liker (2004) describes the lean principles not only related to manufacturing, but also in vehicle development, engineering, and corporate strategy.

Liker (2004) outlines the differences between traditional automotive firms and Toyota, the performance differences between the firms, and the underlying principles of problem solving, people and partners, processes, and corporate philosophy. Liker (2004) describes the heart of the Toyota Production System as eliminating waste and the corresponding eight forms of waste, including underutilized people, one more than Ohno (1986).

The Fourteen Lean Principles identified by Liker (2004, pg v - vi) are as follows:

"**Principle 1**: Base your management decisions on a long-term philosophy, even at the expense of short-term goals."

"**Principle 2**: Create continuous process flow to bring problems to the surface."

- The discussion of process flow relates to eliminating waste, value-added work, mass-production thinking, one-piece-flow, production, and creating improvements in various manufacturing, engineering, and office functions.

"**Principle 3**: Use 'Pull' Systems to avoid overproduction."

- The usage of kanbans is discussed in traditional and non-traditional functions.

"**Principle 4**: Level out the workload."

- Balancing work flow and standardized work and tasks is discussed.

"**Principle 5**: Build a culture of stopping to fix problems, to get quality right the first time."

- Andon systems are discussed.

"**Principle 6**: Standardized tasks are the foundation for continuous improvement and employee empowerment."

- The relation of business control processes, decentralization of management, and the corresponding bureaucracy, structure, and employee empowerment involving decision making, creating job standards, and improvement are detailed.

"**Principle 7**: Use visual control so no problems are hidden."

- One-page reports, the Deming's, Plan-Do-Check-Act Cycle, and organizational learning is discussed.

"**Principle 8**: Use only reliable, thoroughly tested technology that serves your people and processes."

- The discussion of implementing technology that truly reduces cost, autonomation versus automation that developed in the 1980s, and the role of IT at Toyota are discussed.

"**Principle 9**: Grow leaders who thoroughly understand the work, live the philosophy, and teach it to others."

“**Principle 10**: Develop exceptional people and teams who follow your company’s philosophy.”

”**Principle 11**: Respect your extended network of partners and suppliers by challenging them and helping them improve.”

- Concurrent engineering, supplier development, and supplier involvement are discussed.

“**Principle 12**: Go and see for yourself to thoroughly understand the situation.”

- Even at the manufacturing plants, managers spend 85% of their time on the floor, solving problems, eliminating waste, and adding value to the operations.

“**Principle 13**: Make decisions slowly by consensus, thoroughly considering all options; implement decisions rapidly.”

- The problem solving approach of developing numerous alternative solutions, collocating problem solving teams, and gaining consensus from all the various functions impacted by solutions to minimize potential implementation issues before decisions are made is discussed.

“**Principle 14**: Become a learning organization through relentless reflection and continuous improvement.”

- Documentation processes, problem solving methodologies, and one-page reports are outlined in detail.

Liker (2004) provides a comprehensive summary of the current management principles and practices associated with lean manufacturing and their historical development as presented in the previous literature. Furthermore, various examples are provided illustrating usage of the various lean manufacturing management principles and practices. Liker (2004) provides additional detailed theoretical and practical framework for determining the lean principles, practices, and subsequent measures for the operationalization of assessing lean implementation.

Analyzing the theoretical framework developed by Ohno (1986), Shingo (1989), Womack et al. (1990), Womack and Jones (1996), and Liker (2004) produced Table 1: Summary Table of Lean Constructs and Key Authors.

Table 1: Summary Table of Lean Constructs and Key Authors

Author / Constructs	Ohno (1986)	Shingo (1989)	Womack et al. (1990)	Womack & Jones (1996)	Liker (2004)	Summary
Standardized Processes	X	X	-	X	X	X
People	X	-	X	X	X	X
Quality Assurance	X	X	X	X	X	X
Visual Management	X	X	-	X	X	X
Workplace Organization	-	-	-	X	X	X
Lot Sizing	X	X	X	X	X	X
Material Flow	X	X	X	X	X	X
Continuous Improvement	X	X	X	X	X	X

Table 1 illustrates that all of the lean principles directly identified by the developers of lean manufacturing are captured in the constructs identified in this research. The lean constructs identified are used to stratify the lean practices in the subsequent literature review and then operationalized to develop the lean implementation assessment tool used in this research.

Lean Trends

Since the initial descriptions of the Toyota Production System, there have been numerous accounts and reports of lean manufacturing, lean production, just-in-time, and the like in the business press, academic literature, and general media. Some of the lean trends, progress, examples, studies, and other research are examined in detail in the following section along with the corresponding relation to the basic lean principles and lean practices. Further, the methodology used in the development of the lean implementation assessment tool required identifying a comprehensive list of the principles and practices associated with lean manufacturing discussed in the literature. This includes the identification of specific tools and organizational culture elements associated with implementing lean manufacturing.

Womack (2006) describes the current state of the automotive industry in America comparing General Motors and Ford to Toyota. The five weaknesses identified by Womack (2006) are design, supplier integration, management culture, brand identity, and customer relations, not the factories, pensions, and unions. According to Womack (2006), GM and Ford factories actually now compete with Toyota in terms of productivity and quality. This illustrates the success that can be achieved in traditional manufacturing operations in quality and productivity through the long-term commitment of creating a lean enterprise. According to Womack (2006), the U.S. automotive focus will have to shift from internal manufacturing operations to other internal functions and external functions to achieve a truly lean enterprise and continue to close the performance gap with Toyota.

Quinn (2005) conducts an interview with the lean manufacturing expert James P. Womack where he describes the implementation process as a slow five or ten year process, which many Western managers have difficulty dealing with and managing. Additionally, the

Quinn (2005) interview describes the key components of lean as the process of creating value from the customer perspective, mapping the process, improving material flow, eliminating waste, pull systems, and customer demand, similar to the key constructs identified.

Balle (2005) describes the improvement paradigm as more than a set of tools, but rather as a system, and successful implementation requires an "attitude" by managers. Balle (2005) states that "…the lean projects started in earnest with the area's manager experiencing an 'aha!' moment…of sudden and profound insight." Furthermore, Balle (2005) describes the importance of managers implementing lean spending time on the shop-floor, obsessively pursuing continuous improvement, and having willingness to experiment with operations and learn. The organizational cultural characteristics Balle (2005) describes are leadership direction, the level of commitment to the initiative, and the overall understanding of the operations by management, supervisors, and employees. These cultural characteristics and traits were incorporated into the development process of the lean implementation assessment tool for this research.

Rooney and Rooney (2005) create a glossary of terms and buzzwords associated with lean manufacturing discussing everything from Andon to waste. Rooney and Rooney (2005) outline a five phase lean approach to systematically implement lean manufacturing as creating process stability, continuous flow to reduce work in process (WIP), synchronous production, a pull system for replenishment, and level production demands. Other important lean practices Rooney & Rooney (2005) identify and define are Andon, autonomation, reducing batch and queue, cellular manufacturing, quick changeover, cycle time, error proofing, FIFO, 5S, flow, leveled production, inventory, JIT, Kaizen, kanban, one-piece flow, Plan-Do-Check-Act (PDCA), process control board, shadow board, standard work, standard operating procedures (SOPs), supermarkets, total productive maintenance, value added, value-stream mapping, visual controls, waste, and WIP. These definitions were important and utilized when determining specific ways to operationalize and subsequently measure the usage and implementation of the lean warehousing principles and practices in the lean implementation assessment tool.

Similarly, Hunter (2004) identifies a ten-step approach to creating lean production for reengineering a manufacturing system. The corresponding practices Hunter (2004) outlines are reducing setup times, integrating quality control, integrating preventative maintenance, leveling and balancing the system, integrating a pull system, utilizing inventory control, integrating suppliers, applying autonomation/fool-proofing, and implementing computer integrated manufacturing.

Hancock and Zayko (1998) describe top management, union management, staff personnel, workers, and process engineers, which is just about everyone, as being the important personnel for implementing lean production. Furthermore, Hancock and Zayko (1998) identify manufacturing equipment reliability, machine setup times, quality detection and resolution methodologies, WIP inventory, leveled production requirements, finished goods inventory, cross-trained employees, and shift communication as the important factors that can enhance or limit lean implementation success.

Chapman (2005) describes the 5S system of workplace organization as sort, set in order, shine, standardize, and sustain which has become a foundational principle associated with lean manufacturing in practice. Furthermore, Chapman (2005) states the cliché “there is a place for everything and everything is in its place” philosophy of the 5S system. The first step is to sort out what material, equipment, machines, and supplies are needed in the workplace to perform the work and which are not. The second step is to set in order, organize, and visually represent the essential material, equipment, machines, and supplies to minimize travel, motion, and searching movements. The third step is to shine, clean, and inspect all the work areas, equipment, and machines. The fourth step is to standardize the workplace organization initiative and maintain the improvements daily by allocating time, creating checklists, and developing schedules for maintenance. Finally, the fifth step is to sustain the initiative by making it a part of everyday business by auditing, providing feedback, and managers, supervisors, and employees verifying compliance to the initiative. The 5S system of workplace organization eliminates many of the forms of waste, creates and enhances visual management, and can reduce potential for errors. 5S is of even greater importance in organizations implementing lean where cross-training is taking place or turnover is high to reduce the amount of time associated with learning a new task.

Worley and Doolen (2006) examine the role of communication and management support in a lean manufacturing implementation case study using a qualitative methodology. Worley and Doolen (2006) find that management support plays a role in driving lean implementation and that communication was positively affected by lean implementation. The tools and practices Worley and Doolen (2006) identify as lean manufacturing are 5S, Kaizen, kanban, pull systems, quick changeover, and value-stream mapping. Worley and Doolen (2006) develop a balanced scorecard measurement approach to assess the effects of lean manufacturing implementation on the following categories: customer needs, customer satisfaction, employee attitude, employee skills, processes streamlined / wastes removed, and lean concepts adopted.

Mehta and Shah (2005) describe the characteristics of a work organization and develop a causal loop diagram for the theoretical directionality of the variables of the conceptual framework associated with each of the practices, characteristics, and contingencies. The lean practices Mehta and Shah (2005) describe are workflow integration, formalization and standardization, and team interdependence, which can be measured using WIP, number of SOPs and regulations, and the percent of employees involved in teams, respectively. The work design characteristics Mehta and Shah (2005) identify are skill variety, task identity, task significance, autonomy, and feedback from the job, which can be measured using survey instruments. The cultural and organizational contingencies identified by Mehta and Shah (2005) are the degree of technical uncertainty and the degree of coercion, and the employee outcomes identified are job satisfaction and job related strain, all measurable using Likert scaling and employee surveys. Finally, Mehta and Shah (2005) determine the organizational outcomes to be productivity and performance, which can be measured using the Economic Value-Added Operating Profit-Taxes-Cost of Capital calculations developed by Brown (1996).

Treville and Antonakis (2006) examine organizational culture and the intrinsically motivating nature of lean production job design and the theoretical relationship between job enrichment and intrinsic motivation as it relates to lean manufacturing. Treville and Antonakis (2006) define lean manufacturing practices regarding reducing inventory and increasing capacity utilization as WIP control and kanbans, pull systems, and setup reduction. Also, Treville and Antonakis (2006) define variability reduction as a lean production practice with regard to standardization, documentation, SOPs, statistical process control, fool-proofing, andon systems, visual management, inspection processes, supplier integration, and workplace organization. The final lean manufacturing practice Treville and Antonakis (2006) outline relates to organizational culture with respect for workers regarding cellular structure, cross-trained employees, and worker empowerment.

Kojima and Kaplinsky (2004) devise three poles of change related to the development of a lean manufacturing index with regard to flexibility, quality, and continuous improvement. The flexibility index comprises seven elements of WIP and finished goods inventory, setup time reduction efforts, cross-trained employees, kanbans, just-in-time, cellular layout, and teamwork and team leaders. The quality index developed measures achievement of quality accreditation and external quality performance arising from customer returns. The continuous improvement index developed measures improvement in flexibility through setup reduction, external quality performance, and suggestion usage rates over a five year period. Kojima and Kaplinsky (2004) provide a framework for which to operationalize and measure some of the principles and practices associated with lean manufacturing.

Martinez-Sanchez and Perez-Perez (2001) develop a framework of six lean indicators and associated practices for each. The first indicator, elimination of zero-value activities, is characterized by the percentage of common parts in company products, value of work in progress in relation to sales, inventory rotation, number of times and distance parts are transported, and percentage of preventative maintenance over total maintenance.

The second Martinez-Sanchez and Perez-Perez (2001) indicator is continuous improvement constituted by the number of suggestions per employee per year, percentage of implemented suggestions, savings and/or benefits from suggestions, percentage of defective parts adjusted by production line workers, percentage of time machines are standing due to malfunction, value of scrap and rework in relation to sales, and the number of people dedicated primarily to quality control.

The third Martinez-Sanchez and Perez-Perez (2001) indicator is multifunctional teams comprised of percentage of employees working in teams, number and percentage of tasks performed by the teams, average frequency of task rotation, and the percentage of team leaders that have been elected by their own team co-workers.

The fourth Martinez-Sanchez and Perez-Perez (2001) indicator is JIT production and delivery consisting of lead time of customers' orders, percentage of parts delivered just-in-time by suppliers, level of integration between supplier's delivery and the company's production information system, percentage of parts delivered just-in-time between sections in the production line, and production and delivery lot sizes.

The fifth Martinez-Sanchez and Perez-Perez (2001) indicator is the integration of suppliers including percentage of parts co-designed with suppliers, number of suggestions made to suppliers, the frequency with which suppliers' technicians visit the company, the frequency with which company's suppliers are visited by technicians, percentage of documents interchanged with suppliers through EDI or intranets, the average length contract with the most important suppliers, and the average number of suppliers in the most important parts.

The final Martinez-Sanchez and Perez-Perez (2001) indicator is flexible information systems defined by the frequency with which information is given to employees, number of informative top management meetings with employees, percentage of written procedures in the company, percentage of production equipment that is computer integrated, and the number of decisions employees may accomplish without supervisory control. Table 2 summarizes the Martinez-Sanchez and Perez-Perez (2001) framework.

Furthermore, Martinez-Sanchez and Perez-Perez (2001) collected data using survey techniques gathering a total of forty-one useful questionnaires. Many of the indicators had varying degrees of use with the largest being setup time, percentage of production procedures documented, and defective part value with relation to total sales. The important Martinez-Sanchez and Perez-Perez (2001) practices related to lean warehousing are inventory rotation, customer order lead time, and percentage of production procedures documented with eighteen variables significant in a stepwise logistics regression procedure predicting factory age, number of employees, cost, quality, flexibility, and lead time. A similar framework as developed by Martinez-Sanchez and Perez-Perez (2001) was used in the development of the lean implementation assessment tool framework and operationalized into the specific scaling of evaluation items used in this research.

Table 2: Summary of Martinez-Sanchez and Perez-Perez (2001) Six Lean Indicators and Associated Practices

Indicator	Practice	Practice	Practice	Practice	Practice	Practice	Practice
Elimination of Zero-Value Activities	% common parts in products	Value of WIP versus sales	Inventory rotation	Frequency /distance parts are transported	% of TPM versus total maintenance		
Continuous Improvement	Suggestions per employee per year	% implemented suggestions	Savings /benefits from suggestions	% defective parts	% idle machines due to malfunction	Scrap /rework versus sales	Number quality control people
Multifunctional Teams	% employees working in teams	Number and % tasks performed by teams	Average frequency of task rotation	% team leaders elected by co-workers			
JIT Production and Delivery	Lead time of customer orders	% parts delivered JIT by suppliers	Supplier information integration with IS	% JIT parts delivered	Production and delivery lot sizes		
Integration of Suppliers	% parts co-designed with suppliers	Number of suggestions made to suppliers,	Frequency supplier technicians visit company	Frequency company technicians visit suppliers	% documents interchanged with suppliers	Average length of contract with key suppliers	Average number suppliers for key parts
Flexible Information Systems	Frequency information given to employees	Number of informative employee /management meetings	% written procedures in company	% computer integrated production equipment	Number of independent decisions made by employees		

Rasch (1998) identifies eight fundamental management practices associated with lean manufacturing: built-in quality, preventative maintenance, just-in-time delivery system, equipment standardization, pull system, leveled production, balanced line capacity, and standardized work. The additional core elements of lean manufacturing according to Rasch

(1998) are team-based work organization, empowered employees, cross-trained employees, Kaizen activities, small batches, error-proofing, root-cause problem-solving, and supplier integration. For comparison, Rasch (1998) operationalizes various human organization, production technology and methods, and quality system performance measures to predict overall company-wide performance.

The Rasch (1998) practices related to organizational culture and structure are unionization, shop floor management layers, formal teams, relaxed work rules, production worker involvement and suggestions, production worker authority, production worker training, production worker cross-training, and pay incentives. These practices directly relate to the cultural aspects of lean manufacturing identified in the literature.

The Rasch (1998) practices of production technology and methods are automated machine control, automated bar code tracking system, business system automation, just-in-time inventory methods, shop scheduling, preventative maintenance, and housekeeping. The quality system practices identified were the use of statistical process control, formalized quality programs and procedures, quality measurement efforts, and product inspection. The Rasch (1998) practices are related to various interim performance measures of shop floor efficiency, product quality, employee grievances, and unscheduled downtime and the significance of their effects estimated in predicting each using regression analysis.

Lean Warehousing

The specific relation between lean manufacturing and lean warehousing principles and practices are examined to determine if there are any additional aspects not identified in the previous literature examined. Further, the limited extent to which lean warehousing has been studied in the academic literature must be outlined to illustrate the importance of this research. The initial work relating to lean logistics and lean warehousing is detailed in Jones, Hines, and Rich (1997).

Jones et al. (1997) describe factory activities as five percent value-added, thirty-five percent necessary non-value-added, and sixty percent waste. Furthermore, Jones et al. (1997) identify the key elements of Toyota's methodology as leveled demand, reduced setup, one-piece flow, pull systems, standardized work, developed SOPs, reduced WIP, error-proofing, visual management, root-cause problem-solving, and kanbans. The additional Jones et al. (1997) distribution specific practices are delivery frequency, lot sizing, order frequency, service rates, value-stream mapping, Five Whys, and quality analysis. The Jones et al. (1997) warehousing specific practices are bin size reduction, commodity storage, velocity stocking, standardized routing, standardized work, facility/department/function synchronization, manpower planning, staggered routing, and root cause problem-solving procedures.

Similarly, Bradley (2006) describes the basic lean manufacturing concepts with regard to warehousing and distribution and a success story regarding lean warehousing. The main concepts discussed with regard to lean warehousing are cultural buy in, Kaizen events, order accuracy, and on-time shipments.

All of the above research and the framework described in the previous sections were synthesized and stratified into the fundamental lean constructs with corresponding lean practices. The lean practices identified from the literature operationalize the fundamental lean constructs by creating a comprehensive list of associated shop-floor lean activities to be measured. The lean practices were subsequently operationalized into specific measureable evaluation items to create the lean implementation assessment tool for measurement, comparison, and data analysis. The resulting summary outlining the corresponding lean principles and practices identified from the literature for lean warehousing can be seen in Table 3. The associated lean constructs and lean practices are proposed from the synthesis of the comprehensive literature review and utilized for development of the lean implementation assessment tool. The structure provided is leveraged to operationalize the lean warehousing concepts into the lean constructs and corresponding lean practices to be measured to understand lean implementation within warehousing for this research and subsequent analysis.

Table 3: Sobanski Lean Implementation Assessment Tool Constructs and Practices

Construct	Lean Practice								
1. Standardized Processes	SOPs	Standardized Work/Planning	Commodity Grouping	Common Processes & Best Practices	Trailer Loading & Unloading	Routing & Travel Paths	-	-	-
2. People	Safety & Ergonomics	Leadership Direction/Roles	Management Style	Cross-Training	Teamwork & Empowerment	Power Distance & Daily Involvement	Recognition & Compensation	Communication Strategy	Absenteeism & Turnover
3. Quality Assurance	5 Whys, Root Cause & Pareto	Inspection & Autonomation	Error Proofing Methodology	Inventory Integrity	Product & Process Quality	Quality Metrics	-	-	-
4. Visual Management	Value Stream Mapping	Process Control Boards	Metrics & KPI Boards	Lean Tracking	Visual Controls	Andon Systems	(A3) One Page Reports	-	-
5. Workplace Organization	5S	Signage & Shadow Boards	Cleanliness	Supply & Material MGMT	Point of Use Storage	ID Problem Parts Areas	-	-	-
6. Lot Sizing	Batch Sizes	WIP	Kanban Systems	Quick Changeover	Lead Time Tracking	Inventory Turns	Order Frequency	-	-
7. Material Flow	Pull Systems	Leveled Flow & Work	FIFO	Layout & Zones	Velocity & Slotting	Travel Distance	Cellular Structure	Demand Stabilization	Cross-Docking
8. Continuous Improvement	PDCA	Kaizen Events	Employee Suggestions	Understand Systems View	Preventative Maintenance	Supplier Integration	SPC	Technology & Equipment	-

Measurement and Assessment Discussion

Numerous analyses, applications, and discussions of various measurement and assessment tools, devices, and techniques are discussed in this section along with their relation to the lean principles identified and the corresponding lean practices measured. Consequently, the methodologies, scoring, and practices used provided a detailed framework with regard to the construction of the lean implementation assessment tool developed for this research.

Taj (2005) uses the Strategos Inc. lean assessment tool to analyze twenty selected plants in the Chinese hi-tech industry. The assessment tool utilizes nine lean manufacturing practices in which facility managers self-report facility performance regarding inventory, team approach, processes, maintenance, layout/handling, suppliers, setups, quality, and scheduling/control. The results are fairly consistent across the various sections from a low of forty-five points in the inventory practice to a high of seventy-one points in the maintenance practice out of the possible one-hundred points. The lower scored items are inventory, suppliers, and processes, which are generally aspects of the business that tend to be out of the control of plant management. Conversely, the higher scored items are maintenance, layout, and scheduling, which are generally within the control of plant management. The Taj (2005) results may have to do with the perceived risk of reporting potential weaknesses to outsiders, a bias when using self-reporting tools, or the specific assessment tool used when scoring these various aspects of lean.

The data collection strategy and methodology used by Taj (2005) is a little vague, but the ninety-one students enrolled in the author's operations management class taught in China were asked to contact "manufacturing executives" to determine if they would be willing to participate in the research project. A "manufacturing executive" is not defined, other than plant management, potentially encompassing a wide array of roles and responsibilities depending on the industry, size, and structure of organizations from directors to managers to supervisors. The individual responses on the forty item questionnaire are coded from zero to four and totaled for each of the nine response areas. Furthermore, the individual questions are scored from zero to four based on the response levels of the individual questions with an assumption of equidistance, although many response possibilities are not equidistant from zero to four. Consequently, any conclusions drawn from the research must be made with this response structure in mind.

Doolen and Hacker (2005) review numerous lean assessment tools developed by and lean practices used in organizations associated with manufacturing strategy, as outlined by Hayes and Wheelwright (1984). Doolen and Hacker (2005) summarize the lean assessment tools and the lean aspects addressed by each tool with regard to topics, practices, and techniques. Many of the specific tools are examined individually in detail in the following section of the literature review, Assessment Tools. Doolen and Hacker (2005) note that despite the numerous tools and research conducted in this area that a universal set of lean practices has not been identified in the literature. Doolen and Hacker (2005) identify six impact areas (manufacturing equipment and processes, shop floor management, new product development, supplier relationships, customer relationships, and workforce management) for twenty-nine various lean manufacturing principles and practices. Doolen and Hacker (2005) develop a survey instrument that asks respondents to rate each of the twenty-nine items, if used, in each impact area, on a Likert scale from always, most of the time, some of the time, rarely, or never. Doolen and Hacker (2005) survey twenty seven companies, finding that most of the lean practices are reportedly being used by nearly every company, while only a few are used less frequently.

Kiefer (1999) develops an empirical analysis of warehouse measurement systems with respect to measuring supply chain performance. The Kiefer (1999) measures are divided into five categories: order fulfillment, storage, receiving, customer satisfaction, and cost/earnings. Each category is further broken down into various measures relating to productivity, performance, utilization, etc. for labor, equipment, and overall. The Kiefer (1999) survey respondents, with a thirty percent response rate, identify measures they use, determine primary units of measurement, rank their perceived level of supply chain management implementation, and provide demographic data. Some of the important measures Kiefer (1999) identifies are picking productivity, utilization, performance relative to standards, on-time shipment, damage, incorrect orders, receiving productivity, inventory accuracy, cycle counting, inventory turns, order fill rates, and costs. The operationalization of the lean principles and practices developed in the lean implementation assessment tool followed the same methodology described by Kiefer (1999).

Shah and Ward (2003) identify twenty-one lean practices and their corresponding appearance in key references relating to bottlenecks, cellular manufacturing, continuous improvement, pull systems, etc. Furthermore, Shah and Ward (2003) explore the relationships of implementation of lean practices on a three-point scale from no implementation, to some implementation, to extensive implementation versus plant unionization, age, and size. Shah and Ward (2003) find four significant factors using factor analysis for the lean practices relating to just-in-time practices, total productive maintenance practices, total quality management practices, and human resource management practices. Furthermore, unionization and age are found to have significant negative relationships with numerous lean practices, while size is found to be significantly positively related to most of the lean practices.

Fullerton, McWatters, and Fawson (2003) identify various practices associated with just-in-time (JIT) and examine the relationship of practice implementation and financial performance.

The work practices are related using surveys associated to the JIT implementation factors and control variables. Using factor analysis, Fullerton et al. (2003) relate the practices with JIT manufacturing (focused factory, group technology, reduced setup times, productive maintenance, multi-function employees, and uniform workload), JIT quality (product quality improvement and process quality improvement), and JIT unique (kanban system and JIT purchasing).

Soriano-Meier and Forrester (2002) develop a model for evaluating levels of "leanness" in manufacturing firms. Soriano-Meier and Forrester (2002) identify nine variables associated with leanness as elimination of waste, continuous improvement, zero defects, JIT deliveries, pull of materials, multifunctional teams, decentralization, integration of functions, and vertical information systems. Surveys supplemented with short, structured interviews are used for data collection across thirty-three firms. Soriano-Meier and Forrester (2002) determine there is a strong relationship between managerial commitment to JIT and infrastructure investment. In addition, they determine there is a correlation between firms who make lean changes and claim adoption of lean principles and the investment in lean changes and performance.

Rowbotham and Barnes (2004) utilize the Hayes and Wheelwright (1985) four-stage concept to develop a questionnaire that identifies the roles which manufacturing plays in organizations along with resulting qualitative research data. Rowbotham and Barnes (2004) operationalize the four stages into a thirty question self-report survey using five-point Likert scales administered to one-hundred-ninety-seven employees in three small manufacturing companies. The classification of manufacturing strategy stages relate to management expectations of the strategy process, the status of the current manufacturing strategy, time management with regard to the strategy process, and final manufacturing plans produced as a result of the strategy process. The three companies were then classified according to the Hayes and Wheelwright (1985) framework into their respective stages based on their responses. A similar framework was utilized to develop the evaluation points and scaling for many of the lean implementation assessment tool evaluation items to operationalize the lean principles and dimensions identified into specific measures.

Holt (2002) addresses readiness for change in organizations by developing a scale for determining organizational change readiness. Holt (2002) identifies three stages associated with the process of implementing change: readiness of the environment, structure, and attitudes of organizational members, adoption of attitudes and behaviors to change expectations, and institutionalization of behaviors. The methodology for development of the change readiness scale begins with an initial inductive identification of individual change readiness themes; next, an empirical identification of the most influential change readiness themes; then, an item development and content validity assessment; and finally, questionnaire administration and refinement. The general methodology utilized by Holt (2002) was used in this research to develop and administer the lean implementation assessment tool.

Holt (2002) identifies five significant factors relating to change readiness: management support, personal confidence, personal benefit, organizational benefit, and a need for change. Furthermore, Holt (2002) sets an important foundation and framework for understanding the potential benefits of implementing a change paradigm like lean manufacturing in an organization.

Lusk (1996) identifies and quantifiably measures organization-wide factors that determine the extent to which lean practices are used in organizations. Furthermore, Lusk (1996) identifies the features and basic principles associated with the Toyota Production System, just-in-time production, and lean production in an extensive review of the lean literature. The Lusk

(1996) data, from eighteen organizations, consists of their scores on the various elements from the fifty-two question SAE J4001 survey. Lusk (1996) measures organizational culture aspects of management and trust, people, and information, in addition to supplier and organizational issues, customers, products, and process flow.

Karlin (2004) describes the principles of lean logistics and the corresponding practices as reducing lead times, eliminating wastes, and achieving high quality in logistics systems. The Karlin (2004) model for lean logistics is the Toyota Production System and Toyota's just-in-time approach to North American logistics operations. Karlin (2004) describes the lean logistic system foundation as being operational stability with continuous improvement, first in-first out processing, standardized work, robust processes, no overburden, and supplier involvement.

The other practices supporting lean logistics according to Karlin (2004) are just-in-time, built-in-quality, and culture, with flexible, highly motivated people, the use of "milk-run" systems, and cross-docking operations for frequent delivery, pickup, and consolidation of materials moving throughout the system. Another important practice Karlin (2004) identifies is the use of visual systems of control that track performance of individual operations against plans in a simple easy to understand manner. Finally, the important metrics Karlin (2004) identifies related to lean logistics are productivity, customer service, and work-life quality.

Assessment Tools

There were numerous measurement and assessment tools identified, analyzed, compiled, and eventually compared to the lean implementation assessment tool developed in this research. The major tools identified and examined are discussed in detail below, along with numerous comparison and summary tables that cross reference the lean constructs identified in this research and the explicit measures used in the various tools in Table 4 through Table 12.

The MIT Assessment Tool (2001) or Lean Enterprise Self-Assessment Tool was developed by the Lean Aerospace Initiative at the Massachusetts Institute of Technology in conjunction with Warwick University, the United States Air Force, and other related government organizations. The MIT Assessment Tool (2001) provides a higher level organizational assessment to examine the alignment of overall business practices with the lean manufacturing philosophy. The tool is intended to assess organizations at the enterprise level and to highlight key integrative functions with regard to the fundamental lean principles of standardized processes, health and safety, leadership and empowerment, training programs, built-in-quality, quality processes, value-stream mapping, supply chain management practices, just-in-time practices, balanced flow, and continuous improvement. According to MIT (2001), the assessment process is part of the lean transition process roadmap to be developed. The MIT tool helps organizations to align business processes at the enterprise level, but it does not provide detailed lower level facility and shop floor feedback or direction, which is an outcome of this research.

Conversely, the Gatlin Educational Services, the Industrial Solutions, Inc., and Strategos Consultants assessment tools all provide a similar basic framework utilizing six, four, and nine fundamental lean principles measured across various numbers of lean practices, respectively. All three assessment tool frameworks can be extrapolated to correspond to the eight lean constructs developed in this analysis. Furthermore, the scaling methodologies used to delineate the traditional practices from the lean practices are somewhat similarly being measured from one to ten on the Gatlin Educational Services tool, zero to five on the Industrial Solutions tool, Inc., and various levels from one to five on the Strategos Consultants tool. The tools provide similar frameworks for assessing general facility lean practices without providing detail to individual functions, specific actionable items, or detailed lean practices, an intended outcome of this research.

Additionally, the Kremer (2004) assessment tool outlines three specific lean principles: operational excellence, just-in-time, and people. The operational excellence principle is comprised of 5S, quality process, work cell/areas as profit centers, visual controls, standard work, and total productive maintenance. The Kremer (2004) just-in-time principle contains continuous flow, pull systems, leveling, and quick changeover, while the people principle includes continuous improvement, training, and supplier/customer alliances. Kremer (2004) provides a lean assessment handbook for lean implementers to determine scoring, evaluation, planning, and execution of lean implementation activities. The general structure of the tool follows the basic lean constructs developed in this analysis, but the specifics could not be examined in detail since they were not included in the published work.

The ThroughPut Solutions (2005) assessment tool provides a very general and quick assessment structure that only outlines a few of the basic lean constructs with regard to people, quality assurance, and the lean practice machine changeovers. The ThroughPut Solutions (2005) tool seems to be developed as more of a questionnaire for ThroughPut Solutions to gather background information for potential consulting services rather than provide meaningful feedback to individuals regarding lean implementation or assessment.

The Virginia Tech Center for High Performance Manufacturing (CHPM) (2005) and the Montana Manufacturing Center-Virginia's A.L. Philpott Manufacturing Extension Partnership (VPMEP) (2006) assessment tools provide fairly detailed assessments of some of the basic lean constructs. The Virginia Tech CHPM (2005) tool provides detailed response options for assessment questions with various scaling techniques, descriptions, and types. The response options for the forty-six questions on the Virginia Tech CHPM (2005) assessment tool are extremely diverse and range from simple yes/no possibilities, to three, four, five, and six potential options depending on the specific practices being examined. While the Montana Manufacturing Center-VPMEP (2006) assessment tool has twenty questions all with five response options that are consistently equidistant with various Likert-type scales, percentages, and other various numerical figures corresponding to people, dollars, etc. The overall structure of the two tools and the response option scaling methodologies provide a similar, although less comprehensive framework, than developed in this research.

Various other practical industry lean assessment documents were examined from two organizations implementing lean warehousing principles and practices. The internal tools and documents were compared to the framework developed. Both organizational documents capture various aspects of the fundamental lean constructs as developed in this analysis, but do not consistently capture all of the corresponding lean practices associated with each of the lean constructs. Furthermore, the scaling and scoring methodologies developed in both sets of documents are fairly subjective and potentially somewhat assessor specific.

The potential impacts of assessor bias, response option subjectivity, and rating subjectivity are inherent in most of the tools examined in the literature. The evaluation points for the lean implementation assessment tool developed in this analysis aims to create equidistant, consistent, and concrete response options to reduce the amount of assessor bias and rating subjectivity to increase the likelihood that assessment results would be valid, reliable, and have inter-rater agreement.

Detailed Comparison of Assessment Tools

The framework developed from the literature for this research analysis was summarized previously in Table 3, illustrating the eight fundamental lean constructs identified and the fifty-eight corresponding lean practices associated with each of the lean constructs. The other assessment tools are compared side-by-side in Table 4 with regard to the lean constructs developed in this research. Furthermore, Table 5 through Table 12 compare the individual lean practices associated with each of the assessment tools examined in the literature review side-by-side to the lean construct framework developed in this research.

Finally, Table 13 provides a summary of all observed practices addressed in each of the lean assessment tools compared to the comprehensive framework developed in this analysis. There were two practices identified in the literature review that were not addressed in any of the tools analyzed. Cross-docking and trailer loading and unloading are both unique measurements to the lean implementation assessment tool developed in this research. Additionally, there were numerous other practices identified that were only measured in one or two of the various tools examined, which are all included in the development of the lean implementation assessment tool in this research.

Table 4: Lean Constructs Addressed in Various Lean Assessment Tools

Sobanski (2008)	MIT (2001)	Gatlin Educational Services	Industrial Solutions, Inc.	Kremer (2004)	Strategos Consultants	ThroughPut Solutions (2005)	Virginia Tech CHPM (2005)	Montana Mfg. Center-VPMEP (2006)	Internal Company Tool #1	Internal Company Tool #2
Standardized Processes	Standardized Processes	Standard Work	Standard Work	Standard Work	Processes	-	-	SOPs	Processes	Standardize & Stabilize
People	Health & Safety	Team Approach	Operator Flexibility	Training	Team Approach	Employee Safety	Leadership & Empowerment	Cross-Training	Leadership & Empowerment	Training & Development
	Leadership & Empowerment	Leadership & Empowerment	Leadership & Empowerment		Leadership & Empowerment	Layoffs & Turnover	Workplace Environment	Empowered Teams		Lean Culture
	Training	Health & Safety	Communication		Layoffs & Turnover	Leadership Direction	Training	Employee Safety		Leadership & Empowerment
Quality Assurance	Built-In-Quality	Built-In-Quality	Built-In-Quality	Quality Process	Quality Metrics	Quality Metrics	Autonomation	Quality Metrics	Built-In-Quality	Quality Metrics
	Quality Processes	Mistake Proofing	Mistake Proofing			Mistake Proofing		Inspection	Mistake Proofing	Mistake Proofing
Visual Management	Value Stream Mapping	Visual Management	Visual Management	Visual Controls	Visual Controls	-	Value Stream Management	Visual Controls	Visual Management	Visual Management
							Metrics	Value Stream Mapping	Visual Planning	Visual Metrics
Workplace Organization	-	Workplace Organization	Workplace Organization	Workplace Organization	Workplace Organization	-	Workplace Organization	Workplace Organization	Workplace Organization	Workplace Organization
Lot Sizing	Supply Chain Management Practices	Kanban & WIP	Quick Changeover	Quick Changeover	Setups	Setups & Changeover	Lead Time Tracking	Inventory	Batches & WIP	Kanban
		Changeover		Work Cells	Inventory			WIP	Inventory	Inventory
Material Flow	Just-In-Time Practices	Just-In-Time Practices	Just-In-Time Practices	Just-In-Time Practices	Just-In-Time Practices	-	-	-	Just-In-Time Practices	Just-In-Time Practices
	Balanced Flow	Balanced Flow	Balanced Flow	Balanced Flow	Balanced Flow				Balanced Flow	Balanced Flow
Continuous Improvement	Continuous Improvement	Continuous Improvement	Continuous Improvement	Continuous Improvement	TPM	-	-	Continuous Improvement	Continuous Improvement	Continuous Improvement
		TPM	TPM	TPM				TPM		

Table 5: Lean Practices Addressed in Various Lean Assessment Tools: Standardized Processes

Standardized Processes	MIT (2001)	Gatlin Educational Services	Industrial Solutions, Inc.	Strategos Consultants	ThroughPut Solutions (2005)	Virginia Tech CHPM (2005)	Montana Mfg. Center VPMEP (2006)	Internal Company Tool #1	Internal Company Tool #2	Summary
SOPs	X		X				X	X	X	5
Standardized Work/Planning		X						X	X	3
Commodity Grouping								X	X	2
Common Processes & Best Practices	X			X						2
Trailer Loading & Unloading										0
Routing & Travel Paths								X	X	2

Table 6: Lean Practices Addressed in Various Lean Assessment Tools: People

People	MIT (2001)	Gatlin Educational Services	Industrial Solutions, Inc.	Strategos Consultants	ThroughPut Solutions (2005)	Virginia Tech CHPM (2005)	Montana Mfg. Center VPMEP (2006)	Internal Company Tool #1	Internal Company Tool #2	Summary
Safety & Ergonomics	X	X			X	X	X			5
Leadership Direction/Roles	X	X	X	X	X	X		X	X	8
Management Style	X	X		X	X					4
Cross-Training	X		X	X		X	X		X	6
Teamwork & Empowerment	X	X	X	X		X	X	X	X	8
Power Distance & Daily Involvement	X			X		X		X	X	5
Recognition & Compensation	X			X					X	3
Communication Strategy	X		X			X				3
Absenteeism & Turnover				X	X	X				3

Table 7: Lean Practices Addressed in Various Lean Assessment Tools: Quality Assurance

Quality Assurance	MIT (2001)	Gatlin Educational Services	Industrial Solutions, Inc.	Strategos Consultants	ThroughPut Solutions (2005)	Virginia Tech CHPM (2005)	Montana Mfg. Center VPMEP (2006)	Internal Company Tool #1	Internal Company Tool #2	Summary
5 Whys, Root Cause & Pareto		X	X					X		3
Inspection & Autonomation		X	X			X	X	X		5
Error Proofing Methodology	X	X			X			X	X	5
Inventory Integrity								X		1
Product & Process Quality	X							X		2
Quality Metrics		X	X	X	X		X	X		6

Table 8: Lean Practices Addressed in Various Lean Assessment Tools: Visual Management

Visual Management	MIT (2001)	Gatlin Educational Services	Industrial Solutions, Inc.	Strategos Consultants	ThroughPut Solutions (2005)	Virginia Tech CHPM (2005)	Montana Mfg. Center VPMEP (2006)	Internal Company Tool #1	Internal Company Tool #2	Summary
Value Stream Mapping	X		X			X	X		X	5
Process Control Boards			X						X	2
Metrics & KPI Boards	X	X	X			X		X	X	6
Lean Tracking	X		X			X			X	4
Visual Controls				X			X	X	X	4
Andon Systems		X	X			X				3
(A3) One Page Reports	X								X	2

Table 9: Lean Practices Addressed in Various Lean Assessment Tools: Workplace Organization

Workplace Organization	MIT (2001)	Gatlin Educational Services	Industrial Solutions, Inc.	Strategos Consultants	ThroughPut Solutions (2005)	Virginia Tech CHPM (2005)	Montana Mfg. Center VPMEP (2006)	Internal Company Tool #1	Internal Company Tool #2	Summary
5S			X			X	X	X	X	5
Signage & Shadow Boards		X		X		X	X		X	5
Cleanliness		X	X	X		X		X	X	6
Supply & Material MGMT				X					X	2
Point of Use Storage				X						1
ID Problem Parts Areas								X	X	2

Table 10: Lean Practices Addressed in Various Lean Assessment Tools: Lot Sizing

Lot Sizing	MIT (2001)	Gatlin Educational Services	Industrial Solutions, Inc.	Strategos Consultants	ThroughPut Solutions (2005)	Virginia Tech CHPM (2005)	Montana Mfg. Center VPMEP (2006)	Internal Company Tool #1	Internal Company Tool #2	Summary
Batch Sizes				X				X		2
WIP	X	X		X			X	X		5
Kanban Systems		X		X					X	3
Quick Changeover		X	X	X	X					4
Lead Time Tracking					X	X	X	X		4
Inventory Turns				X			X	X		3
Order Frequency				X					X	2

Table 11: Lean Practices Addressed in Various Lean Assessment Tools: Material Flow

Material Flow	MIT (2001)	Gatlin Educational Services	Industrial Solutions, Inc.	Strategos Consultants	ThroughPut Solutions (2005)	Virginia Tech CHPM (2005)	Montana Mfg. Center VPMEP (2006)	Internal Company Tool #1	Internal Company Tool #2	Summary
Pull Systems	X	X		X						3
Leveled Flow & Work	X	X	X	X				X	X	5
FIFO		X						X		2
Layout & Zones			X	X				X	X	4
Velocity & Slotting								X	X	2
Travel Distance			X						X	2
Cellular Structure			X							1
Demand Stabilization									X	1
Cross-Docking										0

Table 12: Lean Practices Addressed in Various Lean Assessment Tools: Continuous Improvement

Continuous Improvement	MIT (2001)	Gatlin Educational Services	Industrial Solutions, Inc.	Strategos Consultants	ThroughPut Solutions (2005)	Virginia Tech CHPM (2005)	Montana Mfg. Center VPMEP (2006)	Internal Company Tool #1	Internal Company Tool #2	Summary
PDCA	X							X	X	3
Kaizen Events		X	X				X	X	X	5
Employee Suggestions			X			X	X	X	X	5
Understand Systems View			X	X				X		3
Preventative Maintenance		X		X			X			3
Supplier Integration	X			X					X	3
SPC		X		X						2
Technology & Equipment				X						1

Table 13: Summary of Lean Practices and Number Addressed for Each Construct in Various Lean Assessment Tools

Standardized Processes	#	People	#	Quality Assurance	#	Visual Management	#	Workplace Organization	#	Lot Sizing	#	Material Flow	#	Continuous Improvement	#
SOPs	**5**	Safety & Ergonomics	**5**	5 Whys, Root Cause & Pareto	**3**	Value Stream Mapping	**5**	5S	**5**	Batch Sizes	**2**	Pull Systems	**3**	PDCA	**3**
Standardized Work/Planning	**3**	Leadership Direction/Roles	**8**	Inspection & Autonomation	**5**	Process Control Boards	**2**	Signage & Shadow Boards	**5**	WIP	**5**	Leveled Flow & Work	**5**	Kaizen Events	**5**
Commodity Grouping	**2**	Management Style	**4**	Error Proofing Methodology	**5**	Metrics & KPI Boards	**6**	Cleanliness	**6**	Kanban Systems	**3**	FIFO	**2**	Employee Suggestions	**5**
Common Processes & Best Practices	**2**	Cross-Training	**6**	Inventory Integrity	**1**	Lean Tracking	**4**	Supply & Material MGMT	**2**	Quick Changeover	**4**	Layout & Zones	**4**	Understand Systems View	**3**
Trailer Loading & Unloading	**0**	Teamwork & Empowerment	**8**	Product & Process Quality	**2**	Visual Controls	**4**	Point of Use Storage	**1**	Lead Time Tracking	**4**	Velocity & Slotting	**2**	Preventative Maintenance	**3**
Routing & Travel Paths	**2**	Power Distance & Daily Involvement	**5**	Quality Metrics	**6**	Andon Systems	**3**	ID Problem Parts Areas	**2**	Inventory Turns	**3**	Travel Distance	**2**	Supplier Integration	**3**
-	-	Recognition & Compensation	**3**	-	-	(A3) One Page Reports	**2**	-	-	Order Frequency	**2**	Cellular Structure	**1**	SPC	**2**
-	-	Communication Strategy	**3**	-	-	-	-	-	-	-	-	Demand Stabilization	**1**	Technology & Equipment	**1**
-	-	Absenteeism & Turnover	**3**	-	-	-	-	-	-	-	-	Cross-Docking	**0**	-	-

Validation

Validation and usefulness are two key elements of research methodology that help to answer the fundamental questions inherent in research regarding measurement accuracy and applicability. Babbie (2004) in *The Practice of Social Research* outlines four different types of validity: face, criterion, construct, and content as criteria for measurement quality. According to Babbie (2004), face validity is the degree to which a measure seems reasonable that it captures the variable. Criterion-related or predictive validity "is the degree to which a measure relates to some external criterion" (Babbie, 2004, p. 144). Construct validity "is the degree to which a measure relates to other variables as expected within a system of theoretical relationships" (Babbie, 2004, p. 144). Content validity "is the degree to which a measure covers the range of meanings included within a concept" (Babbie, 2004, p. 145). Consequently, each type of validity was addressed during the development phases of the lean implementation assessment tool from theoretical development to shop floor development to the piloting process. The feedback from the three development phases provided validation that the tool is *actually* measuring the *intended* concepts.

Pederson, Emblesvag, Allen, and Mistree (2000) present the "validation square" as an alternative approach for validating research design methods where 'formal, rigorous, and quantifiable' validation may be inherently problematic. The Pedersen et al. (2000) "validation square", in Figure 2, directly addresses theoretical structural validity, theoretical performance validity, empirical structural validity, and empirical performance validity. Additionally, Pedersen et al. (2000) argue that validation can only be addressed through procedural validity and not by the validity of method effects or method verification through the use of results.

Consequently, all the steps of the procedure must be valid, rational, self-consistent, and supported by axioms for the entire method to be valid.

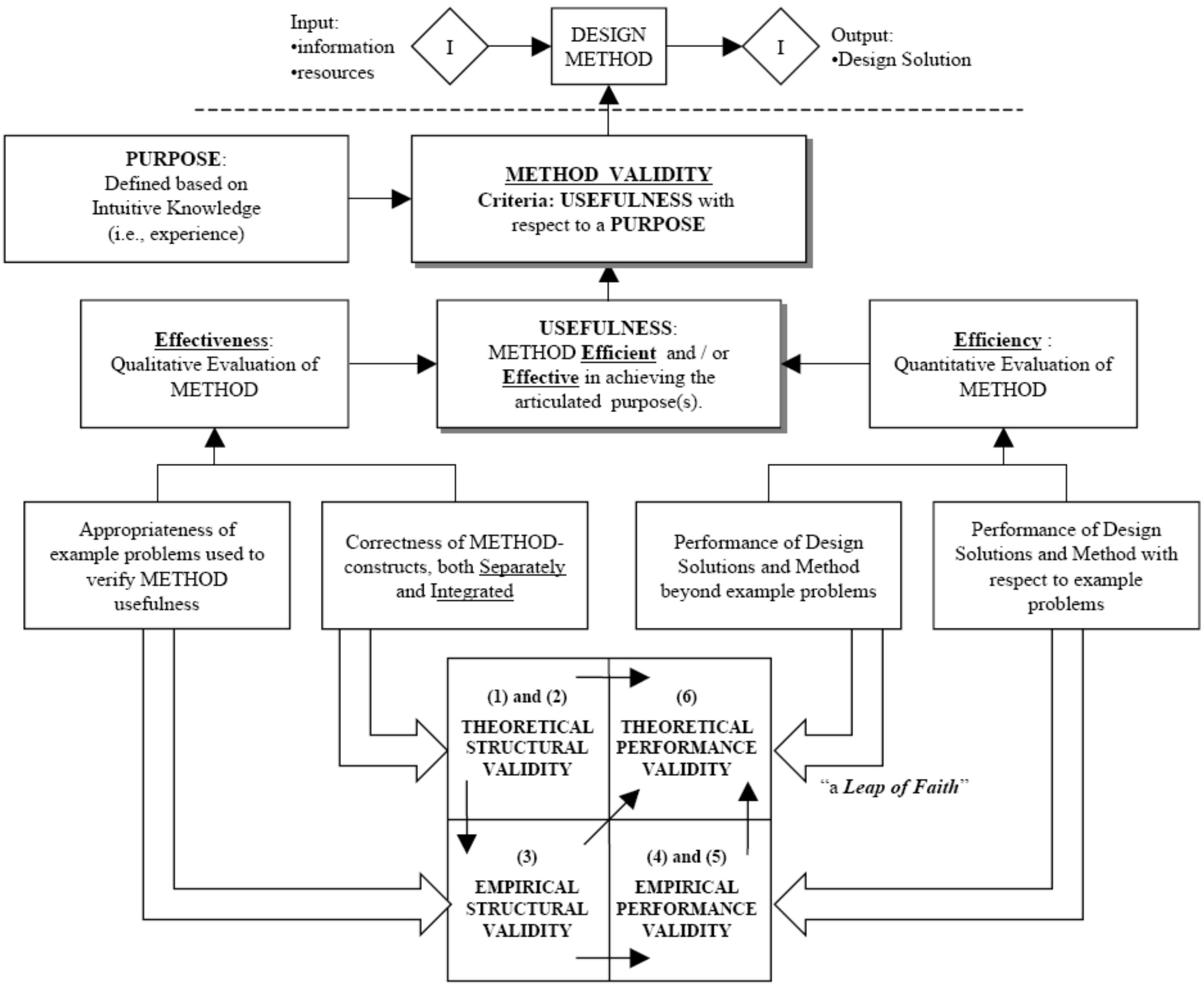


Figure 2: Design Method Validation from Pedersen et al. (2000, p. 7)

The subsequent rationale provided by Pedersen et al. (2000) for method effectiveness requires accepting individual constructs comprising the method, accepting the internal consistency of the construct construction, and accepting the sample chosen for verification of method performance. Furthermore, Pedersen et al. (2000) provide a framework of efficiency implying acceptance of the outcome being useful with respect to the initial purpose, the acceptance that the usefulness is linked to method application, and that the method will be important outside of the case study application.

Thus, the framework set forth by Pederson et al. (2000) for achieving research method validity begins with theoretical structural validity, addressed from existing academic literature, analysis and other sources. Next, empirical structural validity is addressed through the development of example problems, trials, and pilots for method testing. Third, empirical performance validity is addressed by the relevant and accepted evidence seen from analysis of example problem data versus theoretical expectations. Finally, theoretical performance validity is addressed by accepting the method usefulness beyond the example problem or the evidence of generalizability. The Pedersen et al. (2000) method for validation was the general process followed in this research analysis through the theoretical development (construct and practice development), empirical development (onsite development), empirical performance (pilot process and feedback), and theoretical performance (additional application and analysis).

Yauch and Steudel (2003) identify some strengths and weaknesses associated with quantitative and qualitative methods of cultural assessment. The strengths identified with qualitative approaches are the ability to uncover underlying values and beliefs and the malleability in questioning allowing participants to raise issues important to them. The weaknesses identified with qualitative approaches are the amount of time required and the potential for overlooking important issues due to the relatively interpretive results of subjects and the participant control of the interviewing processes. Conversely, according to Yauch and Steudel (2003), the strengths associated with quantitative approaches are the ability to rapidly collect and analyze data and the ease with which comparisons can be made. The corresponding weaknesses with quantitative approaches were with respondent understanding and interpretation of questions, overlooking important issues not evident in preconceived data collection devices, and assumptions made regarding sample appropriateness. Consequently, a mixed method approach can be used to limit the potential weaknesses and enhance the potential benefits inherent in the methodologies. The approach used in the development of this research followed a mixed approach using predevelopment and onsite development at numerous facilities to enhance applicability and generalizability of the tool.

Zeis, Johannesson, Ritchie, and Edgar (2001) examine goodness-of-fit tests for rating scale data on a five point Likert scale from 484 variables from nine management and marketing surveys fit to various statistical distributions. With Likert scale data, there is disagreement with the applicability of ordinal and interval statistical measures due to the continuous, equidistance, and normality assumptions required in many of the subsequent statistical techniques. Consequently, Zeis et al. (2001) examine fitting normal, uniform, lognormal, beta, gamma, exponential, and Weibull distributions to potential survey responses ranging from strongly agree, agree, neutral, disagree, and strongly disagree coded as 1, 2, 3, 4, and 5, respectively. Zeis et al. (2001) find that forty-nine percent of the variables had a "not unreasonable" fit to one of the distributions potentially creating errors in statistical conclusions. This research illustrates that the response values for questions need to be carefully determined to ensure equidistance and that care needs to be taken when applying certain statistical techniques to data for making accurate inferences.

Participatory Action Research

Participatory action research is defined as "an approach to for conducting research across diverse areas of inquiry and social change… (involving) quantitative, qualitative, or combined data methods, depending on the issue under investigation" (Khanlou & Peter, 2005, p. 2333). The data collection process utilized in this research analysis follows this classification and combines various types of methodologies, classifying it as participatory action research as defined by Khanlou and Peter (2005).

Khanlou and Peter (2005) examine validity in participatory action research outlining its origins with action research in conjunction with participatory research. According to Khanlou and Peter (2005), the basic cycle of action research involves a cycle of planning, action, and evaluation, which is similar to the Deming Plan-Do-Check-Act Cycle (1994), and an intended outcome of this research is to provide better information to managers. Additionally, the very nature of participatory action research involves researcher interaction and involvement with research participants and subjects. The nature of this research project is to enhance organizational awareness through involvement with facility personnel by providing better information to enhance organizational change efforts. Khanlou and Peter (2005) identify fair subject selection, favorable risk-benefit ratio, independent review, informed consent, and respect for potential and enrolled participants as the important factors for assessing participatory action research validity. Furthermore, during the lean implementation assessment process and data collection, the interaction of the assessor with the participants was intended to give specific, actionable feedback to identify additional lean implementation opportunities and feedback.

Conclusions

There were eight fundamental constructs and fifty-eight lean practices identified from the literature review associated with lean manufacturing and subsequently lean warehousing, but there is not a common theoretical framework, terminology, or description of the corresponding practices. This research clarifies the fundamental constructs associated with lean warehousing and reviews the associated practices corresponding to each of constructs from the literature and assessment tools that have been developed. Furthermore, the comprehensive lean implementation assessment tool developed measures the implementation and utilization of those lean constructs and practices at the shop-floor level. Additionally, the lean implementation assessment tool developed in this research provides increased information to organizations implementing lean manufacturing principles in warehousing environments and a methodology for making resource allocation decisions, benchmarking, and organizational learning. Finally, this research fills the void that currently exists, while providing a methodology to systematically assess the principles, practices, and functions of lean in warehousing operations.

CHAPTER III
METHODOLOGY

Introduction

The academic literature provides the historical context, evolution, fundamental constructs, and corresponding practices associated with lean manufacturing and lean warehousing. The lean principles that relate to warehousing are of particular interest. The lean constructs identified from the lean manufacturing literature that are measured in the lean implementation assessment tool developed in this research are visual management, standardized processes, continuous and leveled flow, pull systems, workplace organization, empowered employees, quality assurance, and continuous improvement.

The lean constructs were operationally defined with respect to the associated lean practices to measure implementation and utilization on various evaluations points comprising the various warehousing processes in a facility. Each of the key constructs was assessed for all the major functional areas applicable within each warehouse, namely inbound operations, outbound operations, inventory control, material returns, general facility operations, and warehouse office functions.

The lean constructs identified were further developed by working within multiple warehousing facilities, each in various stages of lean implementation with unique characteristics and industries to enhance the generalizability of the lean implementation assessment tool developed in this research. The lean constructs were refined and operationally defined through onsite analysis and multiple assessor use to ensure cross-facility applicability and multiple assessor perspectives.

The lean implementation assessment tool developed utilizes and aggregates a combination of nominal, ordinal, and interval evaluation items, scaled to measure the varying levels of implementation for each of the lean constructs and practices in various warehouses and functions. The operationally defined and scored evaluation items were aggregated to determine scores at the facility level, individual function level, and individual construct level to provide usable feedback and analysis. The data collection process identified specific areas of improvement and provided feedback with regard to the implementation and utilization of lean warehousing principles. Figure 3 illustrates the lean warehousing construct and practice operationalization for the lean implementation assessment tool developed in this research.

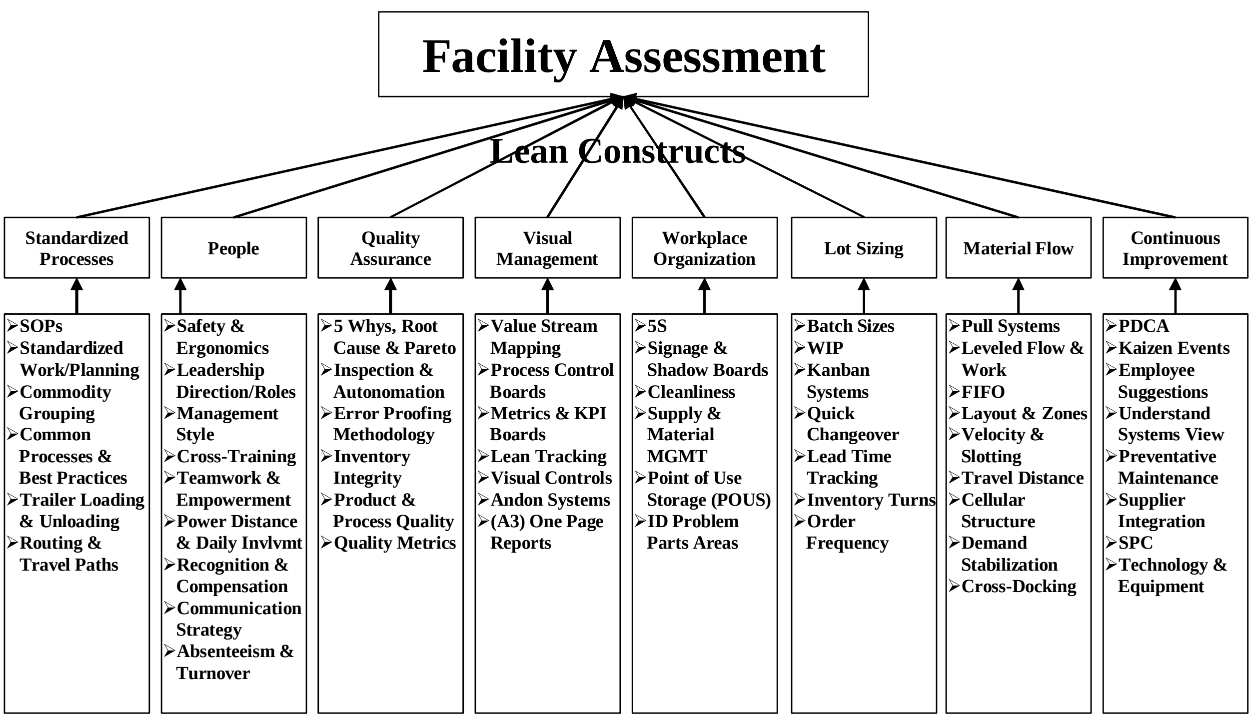


Figure 3: Lean Implementation Assessment Tool Conceptual Model

Finally, to validate the assessment tool, twenty-eight lean implementation assessments were performed at twenty-five facilities ensuring measurement outcomes meet expectations at multiple warehouses across industries and across geographical regions, and ensuring equity among comparisons, while identifying future improvements and research opportunities. The corresponding outcome data analysis was conducted using various multivariate statistical techniques to identify interrelated lean constructs and practices, any potential effects of inter-rater agreement, and a potentially reduced and simplified lean implementation assessment tool structure. The project timeline can be seen in the APPENDIX C. The entire lean implementation assessment tool and evaluation points developed can be seen in APPENDIX A. Furthermore, the corresponding graphs and other aspects of the lean implementation assessment tool developed outlining feedback can be seen in APPENDIX B.

Population/Participants

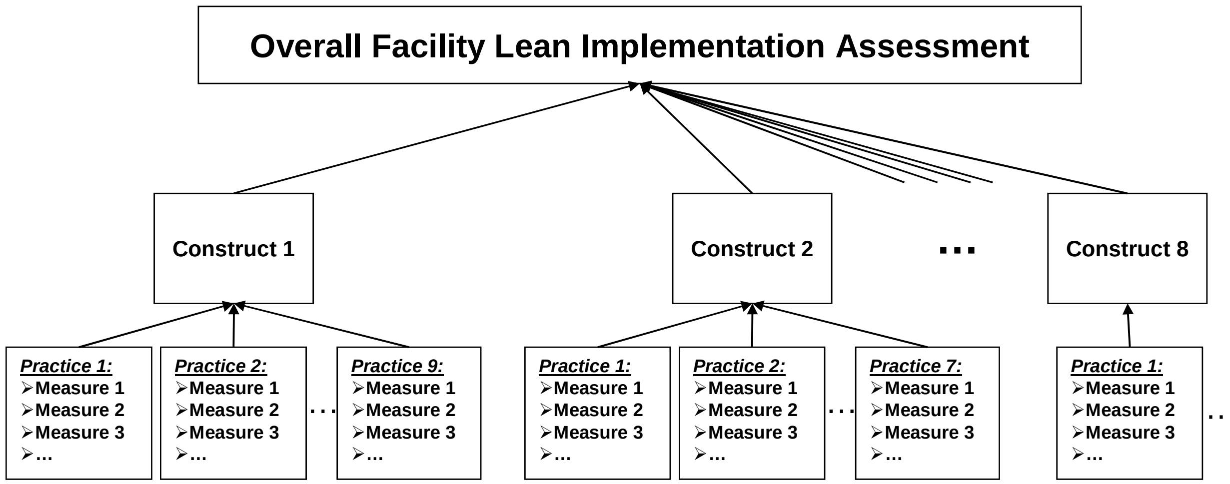
The population of interest for this analysis was organizations in the process of implementing lean manufacturing in their warehousing operations. The participants for this research are within an organization where the author has worked, Menlo Worldwide, a third party logistics company, which allowed open access and funding to assess the various levels of lean implementation and usage. There were twenty-five warehouses assessed and twenty-eight assessments completed throughout the calendar year 2007 by four different individual assessors and four collaborative assessments with two or more assessors. The warehouses assessed were located in the United States, Canada, the Netherlands, and Germany from the automotive, high-tech, and consumer/industrial goods industries.

Instrumentation

The lean implementation assessment tool comprehensively measures the implementation of the lean constructs and corresponding lean practices identified for implementing lean warehousing. The constructs of lean warehousing that were identified and measured in this research are visual management, standardized processes, continuous and leveled flow, pull systems, workplace organization, empowered employees, quality assurance, and continuous improvement. The eight lean constructs and corresponding fifty-eight lean practices were operationally defined into two-hundred-eight evaluation items that measure the degree of implementation of lean warehousing principles, which can be seen fully in APPENDIX A.

Each of the lean constructs and lean practices were assessed for all the major functional areas identified within a warehouse, namely inbound operations, outbound operations, inventory control, material returns, general facility operations, and warehouse office functions. The lean implementation assessment tool evaluation items developed required the use of a combination of nominal, ordinal, and interval measurement items, scaled to identify specific levels of implementation of the various lean constructs within the different facility functions.

The operationally defined and scored evaluation items were compiled using a weighted average technique based on the number of employees in the various functions and the overall facility. The weighted average methodology scores assumed areas with more employees have more activity and would be a higher priority when implementing lean warehousing. The lean implementation assessment tool results comprehensively measure the implementation level of lean warehousing principles. The conceptual model for the structure of the lean implementation assessment tool shown in Figure 4 illustrates the framework for which the lean implementation assessment tool was developed by identifying the lean constructs, identifying the associated lean practices, and then developing multiple evaluation points to measure each.



- **Each Measure is scored for each of the facility functional areas.**
  - **Inbound, Processing, Outbound, Inventory Control, Material Returns, and the Office.**
- **Weighted by the number of employees in each area for overall facility score on each measure.**
- **Measures combined to determine overall Dimension score.**
- **Dimensions combined to determine overall Construct score.**
- **Constructs combined to determine overall Facility score.**

Figure 4: Operationalization Conceptual Model of Tool Development

Functional Tool Framework

The major functional areas within warehousing operations are inbound operations, outbound operations, inventory control, material returns, value-added service operations, and office functions. Inbound operations are material receiving, sorting, checking, stocking, and put-away processes for inventory purposes. Outbound operations are picking, packing, loading, and shipping processes for material moving from inventory to the customer. Inventory control operations are inventory accuracy related for quantity verification, maintenance of stock locations, slotting, and overall facility inventory integrity. Material returns are the processes involved with accepting, rejecting, and restocking material returned from customers. Value-added service operations are the various tasks performed within warehousing operations such as kitting, packaging, light assembly, and various other tasks performed to ensure customers receive products according to specifications. Office functions relate to managing employees, invoicing, records, human resources, and various office requirements necessary for facility operation. Figure 5 illustrates the conceptual model of the lean assessment tool with the functional framework and how each lean construct and practice will be measured for each functional area within the warehouse.

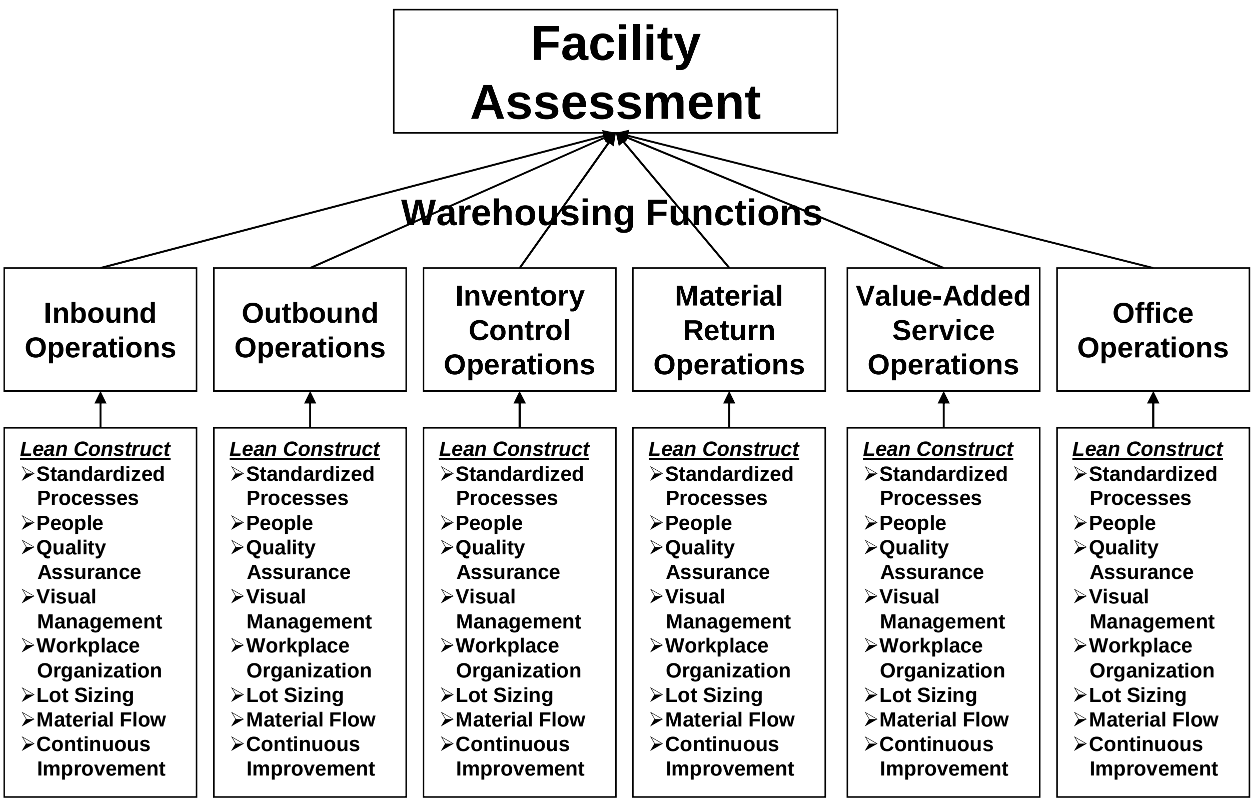


Figure 5: Conceptual Functional Facility Assessment Model

Operationalizing the Lean Constructs and Lean Practices

The key authors and developers of the lean manufacturing philosophy were examined in detail in CHAPTER II to identify the fundamental lean principles into the lean constructs identified in this research. The academic research, existing assessment tools, and other literature were examined in detail to identify the corresponding lean practices associated with the lean construct framework developed. The lean implementation assessment tool development was comprehensive and inclusive in nature outlining fifty-eight lean practices for the eight lean constructs identified.

The inclusive nature for operationalizing the lean constructs and lean practices was done with the intention of developing a pared down lean implementation assessment tool structure from the data collection and subsequent multivariate statistical analysis. The fifty-eight lean practices identified were operationalized into two-hundred-eight individual evaluation points consisting of various combinations of nominal, ordinal, and interval scaled items assessing the various aspects of the lean practices.

The scoring methodology utilizes an equal weighting structure for each lean construct and lean practice cumulatively scoring each evaluation point and weighting the functions by the number of employees for the overall facility scoring methodology. The lean construct and lean practice scoring methodology was scaled from zero through five, with zero being the lowest score possible and five being the highest score possible. The scores were graphed using spider graphs to identify which constructs, practices, and/or functions are excelling and/or deficient requiring additional management attention, training, or resources. The lean implementation assessment tool evaluation points and output graphs developed can be seen in APPENDIX A and APPENDIX B.

Detailed Description of the Eight Lean Constructs and Fifty-Eight Lean Practices

The corresponding eight lean constructs that were determined and the individual practices comprising each construct are detailed in the following section. A brief description and definition of each of the specific lean practices comprising the lean constructs are given as it relates to lean warehousing principles and practices. The two-hundred-eight evaluation points comprising the lean implementation tool were developed using this framework.

Standardized Processes:

The standardized processes lean construct is comprised of the lean practices related to Standard Operating Procedures (SOPs), Standardized Work and Planning, Commodity Grouping, Common Processes and Best Practices, Trailer Loading and Unloading, and Routing and Travel Paths. Standardized processes were explicitly identified as a fundamental principle of lean manufacturing by four of the five authors, Ohno (1986), Shingo (1989), Womack and Jones (1996), and Liker (2004), as seen in Table 1.

- Standard Operating Procedures (SOPs) are the specific, written work instructions and steps that are required to complete a specific job, function, or task.
- Standardized Work and Planning are the amount of work dispatched to workers combining the steps, amount of WIP, and time required to complete the task. Standardized work dispatch information allows for accurate planning and tracking of work.
- Commodity Grouping relates to combining similar types of products, tasks, or work into single dispatches to increase the density of the picking travel path.

- Common Processes and Best Practices are identifying a standard process for determining the best methods for performing work and creating consistent output and the process for sharing that information internally and externally.
- Trailer Loading and Unloading processes relate to the methodology in which trailers are received and shipped to drive standard inbound and outbound processes. Creating standard loading, unloading, and storage principles for trailer's reduces variation, eliminates motion, and drives efficiencies between internal and external customers.
- Routing and Travel Paths are the methodologies for determining the movement within the warehouse during inbound and outbound processes.

People:

The people lean construct is comprised of the lean practices related to Safety and Ergonomics, Leadership Direction and Roles, Management Style, Cross-Training, Teamwork and Empowerment, Power Distance and Daily Involvement, Employee Recognition and Compensation, Communication Strategy, and Absenteeism, Layoffs, and Turnover. People were explicitly identified as a fundamental principle of lean manufacturing by four of the five authors, Ohno (1986), Womack et al. (1990), Womack and Jones (1996), and Liker (2004), as seen in Table 1.

- Safety and Ergonomics are the tools, processes, and incidents related to maintaining a safe work environment for employees.
- Leadership Direction and Roles relate to the sense of urgency, change initiative origin, ownership, and input of employees as it relates to implementing lean warehousing in the facility.

- Management Style is specifically the consensus gathering process for implementing changes which was identified as important in lean warehousing.
- Cross-Training is the amount and documentation process for employees who have been taught how to perform other work tasks than their normal job role both within their function and outside their function.
- Teamwork and Empowerment relate to the organizational work structure utilizing team leads, the authority given to individuals to make changes, and to initiate the continuous improvement process in and of their selves.
- Power Distance and Daily Involvement correlate to the time spent on the shop-floor by both supervisors and managers and their accessibility to employees.
- Employee Recognition and Compensation relates to the process for identifying individual and group outstanding achievements and the reward structure associated with the recognition.
- Communication Strategy is the depth of sharing and understanding of metrics and information and the frequency and timeliness of employee concerns being voiced and resolution determined.
- Absenteeism, Layoffs, and Turnover are the specific performance in each area as it relates to unplanned employee absences, layoffs, and terminations.

Quality Assurance

The quality assurance lean construct is comprised of the lean practices related to Five Whys, Root Cause, and Pareto Inspection and Autonomation, Error Proofing Methodology, Inventory Integrity, Product and Process Quality, and Quality Metrics. Quality Assurance was specifically identified as a fundamental principle of lean manufacturing by all five authors, Ohno (1986), Shingo (1989), Womack et al. (1990), Womack and Jones (1996), and Liker (2004), as seen in Table 1.

- Five Whys, Root Cause and Pareto are some of the problem solving techniques used in lean manufacturing to determine the root causes of problems and stratify defects to determine countermeasures.
- Inspection and Autonomation are the quality inspection processes used during the process and after the process to identify defects.
- Error Proofing Methodology relates to the building in of quality steps to make it extremely difficult to make defects while completing a process.
- Inventory Integrity is the accuracy of the physical inventory located within the warehouse and corresponding cycle counting processes.
- Product and Process Quality relates to the identification of defects and associating them as either input errors or process related errors.
- Quality Metrics are all the specific measurements related to quality and the respective corrective action methodologies in place for each.

Visual Management:

The visual management lean construct is comprised of the lean practices related to Value Stream Mapping, Process Control Boards, Metrics and Key Performance Indicator (KPI) Boards, Lean Tracking, Visual Controls, Andon Systems, and (A3) One-Page Reports. Visual Management was specifically identified as a fundamental principle of lean manufacturing by four of the five authors, Ohno (1986), Shingo (1989), Womack and Jones (1996), and Liker (2004), as seen in Table 1.

- Value Stream Mapping is the lean practice used to identify continuous improvements and the value-added, non-value-added, and wastes inherent in all processes.
- Process Control Boards are the visual management tools used to communicate the actual performance versus planned performance towards goals on a daily, hourly, and continual basis to everyone on the shop floor.
- Metrics and Key Performance Indicator (KPI) Boards are the communication devices used to show function, department, and facility performance on key measurements to all employees.
- Lean Tracking is the process for monitoring the training and implementation activities and the actual performance towards planned performance.
- Visual Controls are the visual communication devices used for managing material flow, staging, and pull systems.
- Andon Systems are the quality communication device systems and their usage.
- (A3) One-Page Reports are the simple single page documents used to communicate the implementation plans and implementation activities that are in process and have been completed telling the story of improvement.

Workplace Organization:

The workplace organization lean construct is comprised of the lean practices related to 5S, Signage and Shadow Boards, Cleanliness, Supply and Material Management (MGMT), Point of Use Storage (POUS), and Identification of Problem Parts Areas. Workplace Organization was specifically identified as a fundamental principle of lean manufacturing by two of the five authors, Womack and Jones (1996), and Liker (2004) as seen in Table 1.

- 5S is the workplace organization methodology and process used by leveraging the five step process of sort, set-in-order, shine, standardize, and sustain to identify a place for everything and have everything in its place.
- Signage and Shadow Boards are the tools used to reduce wastes associated with looking for places, tools, etc.
- Cleanliness is the actual overall, area, and location performance related to workplace organization.
- Supply and Material Management (MGMT) is the physical process for managing key materials, supplies, etc. to complete the work.
- Point of Use Storage (POUS) is the technique used to minimize travel time and locate material, product, and supplies directly where they will be used.
- Identification of Problem Parts Areas is the physical location and identification process for potential defects and problems and the documentation steps.

Lot Sizing:

The lot sizing lean construct is comprised of the lean practices related to Batch Sizes, Work in Process (WIP), Kanban Systems, Quick Changeover, Lead Time Tracking, Inventory Turns, and Order Frequency. Lot Sizing was specifically identified as a fundamental principle of lean manufacturing by all five authors, Ohno (1986), Shingo (1989), Womack et al. (1990), Womack and Jones (1996), and Liker (2004), as seen in Table 1.

- Batch Sizes are the physical quantities of work utilized by functions to move material through each process step.
- Work in Process (WIP) is the actual amount of work and time associated with it in each process both within functions and between functions.
- Kanban Systems are the physical pull mechanisms used to manage work in process in each function.
- Quick Changeover is defined in warehousing operations as the amount of time it takes to shift between functions and operations to balance workload and minimize work in process, versus the traditionally as the time it takes to change a machine from one product to another.
- Lead Time Tracking is the physical process time associated with functions and operations to move the product through from start to finish.
- Inventory Turns is the calculated amount of times annually the physical inventory turns versus sales volume.
- Order Frequency is the general philosophy used for replenishing inventory as it is sold: large lot, small lot, or sell one, make one.

Material Flow

The material flow lean construct is comprised of the lean practices related to Pull Systems, Leveled Flow and Work, First-In-First-Out (FIFO), Layout and Zones, Velocity and Slotting, Travel Distance, Cellular Structure, Demand Stabilization, and Cross-Docking. Material Flow was specifically identified as a fundamental principle of lean manufacturing by all five authors, Ohno (1986), Shingo (1989), Womack et al. (1990), Womack and Jones (1996), and Liker (2004), as seen in Table 1.

- Pull Systems are the triggering of production or material flow based on downstream demand or product movement versus pushing product or material regardless of downstream demand.
- Leveled Flow and Work are the concepts of balancing the material and manpower movement within work functions and between work functions to manage WIP.
- First-In-First-Out (FIFO) is the concept of processing material and having tools to maintain those processes in the same order in which it was planned, prioritized, and required by the customer.
- Layout and Zones refer to the physical layout of product within the warehouse, functions, and operations to reduce people and material movement throughout the process.
- Velocity and Slotting are the inventory management and setup philosophies that place faster movers closer to the locations of use minimizing travel for both inbound and outbound operations.
- Travel Distance is the logic and programming used to minimize travel distance in the physical layout of operations and in the warehouse management system.
- Cellular Structure is the philosophy of collocating multiple functions into a single area to reduce travel and processing time, which can be of particular interest in value-added service functions in warehousing.
- Demand Stabilization is the philosophy of balancing demand, manpower, and equipment to accommodate shifts in customer demand across hours, days, and weeks to operate efficiently.

- Cross-Docking in this warehousing analysis refers to physically moving product directly from inbound to outbound functions where customer demand requires eliminating the steps of placing product into storage and consolidating freight to reduce transportation expenditure.

Continuous Improvement:

The continuous improvement lean construct is comprised of the lean practices related to Plan-Do-Check-Act (PDCA), Kaizen Events, Employee Suggestions, Understand Systems View, Preventative Maintenance, Supplier Integration, Statistical Process Control (SPC), and Technology and Equipment. Continuous Improvement was specifically identified as a fundamental principle of lean manufacturing by all five authors, Ohno (1986), Shingo (1989), Womack et al. (1990), Womack and Jones (1996), and Liker (2004), as seen in Table 1.

- Plan-Do-Check-Act (PDCA) is the Deming (1994) cycle for continuous improvement and refers to the planning and sustainment activities as well as specific continuous improvements in this analysis.
- Kaizen Events are the physical continuous improvement activities and documentation of those activities where employees directly impacted by changes are involved in developing solutions for improvement.
- Employee Suggestions are the processes used to capture employee ideas for improvement, implementation, and recognition.
- Understand Systems View relates to the concept discussed by Deming (1994) where employees, supervisors, and managers understand their individual function, department,

and facility impact on other operations, the supply chain, and organization as a whole and how the pieces fit together.

- Preventative Maintenance is the proactive approach utilized for maintaining equipment, machinery, and tools in order to prevent defects and failures from occurring.
- Supplier Integration incorporates both upstream and downstream entities into improvement activities to ensure both internal and external customers requirements are met more efficiently.
- Statistical Process Control (SPC) is the utilization of statistical analysis tools to identify opportunities for improvement, prioritize improvements, and develop countermeasures.
- Technology and Equipment is leveraging technological solutions to automate repetitive tasks where possible to separate man’s work from machines’ work.

The fifty-eight lean practices defined are stratified into the eight corresponding lean constructs as summarized in Table 14. This structure follows the operationalization of the lean concepts to lean constructs per Babbie (2004) where specific lean practices are identified to be measured for usage and understanding in various warehouse functions for assessment. The systematic operationalization process described was leveraged to develop the lean implementation assessment tool used in this research. The research validation process is described in further detail in the following sections *Validation* and *Verification* and in CHAPTER IV.

Table 14: Sobanski Lean Implementation Assessment Tool Constructs and Practices

Practice / Construct	Lean Practice	Lean Practice	Lean Practice	Lean Practice	Lean Practice	Lean Practice	Lean Practice	Lean Practice	Lean Practice
1. Standardized Processes	SOPs	Standardized Work/Planning	Commodity Grouping	Common Processes & Best Practices	Trailer Loading & Unloading	Routing & Travel Paths	-	-	-
2. People	Safety & Ergonomics	Leadership Direction/Roles	Management Style	Cross-Training	Teamwork & Empowerment	Power Distance & Daily Involvement	Recognition & Compensation	Communication Strategy	Absenteeism & Turnover
3. Quality Assurance	5 Whys, Root Cause & Pareto	Inspection & Autonomation	Error Proofing Methodology	Inventory Integrity	Product & Process Quality	Quality Metrics	-	-	-
4. Visual Management	Value Stream Mapping	Process Control Boards	Metrics & KPI Boards	Lean Tracking	Visual Controls	Andon Systems	(A3) One Page Reports	-	-
5. Workplace Organization	5S	Signage & Shadow Boards	Cleanliness	Supply & Material MGMT	Point of Use Storage	ID Problem Parts Areas	-	-	-
6. Lot Sizing	Batch Sizes	WIP	Kanban Systems	Quick Changeover	Lead Time Tracking	Inventory Turns	Order Frequency	-	-
7. Material Flow	Pull Systems	Leveled Flow & Work	FIFO	Layout & Zones	Velocity & Slotting	Travel Distance	Cellular Structure	Demand Stabilization	Cross-Docking
8. Continuous Improvement	PDCA	Kaizen Events	Employee Suggestions	Understand Systems View	Preventative Maintenance	Supplier Integration	SPC	Technology & Equipment	-

The complete conceptual model for the facility lean implementation assessment tool can be seen in Figure 6. Each practice for each construct will be assessed for each of the functional areas as previously described and defined. The lean implementation assessment tool evaluation points and output graphs developed can be seen in APPENDIX A and APPENDIX B.

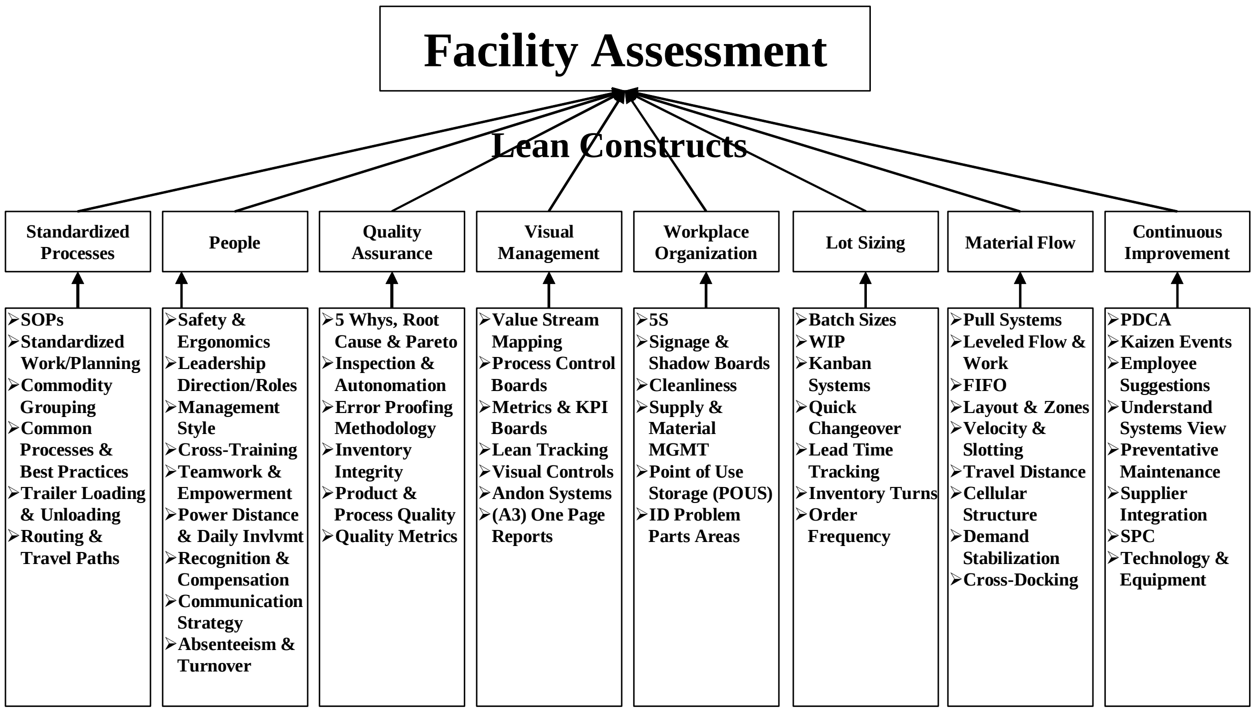


Figure 6: Complete Conceptual Model for Facility Lean Implementation Assessment Tool

Research Design

This research was an exploratory assessment tool development process and analysis of the twenty-eight applications with respect to the implementation level of lean principles as they apply to warehousing strategy and processes. Furthermore, due to the author participation in data collection and providing corresponding feedback to facilities, the research is participatory action research. The validity of the results of the lean implementation assessment tool was examined, and statistical analysis was performed to identify the underlying factors and present a pared-down structure for lean implementation assessment. This research design addresses the specific research questions identified in CHAPTER I and determines the factors that are sufficient for assessing lean manufacturing implementation and usage in warehousing environments.

Pilot Study

Three facilities within an organization were selected for developing the shop-floor operational definitions and evaluation points of the lean constructs and lean practices identified in the literature review for the warehousing environment. The facilities were in various stages of lean implementation and maturity, and had different industry characteristics providing different avenues for piloting the data collection techniques, applicability, and completeness of the lean implementation assessment tool. The pilot approach was used to ensure the generalizability of the lean implementation assessment tool to accurately measure numerous warehouse applications across different industries with different characteristics. Furthermore, feedback was gathered from lean professionals, site managers, supervisors, and associates during this process to ensure the accuracy of measurement and usefulness of feedback provided. The specific timing, practices, and approach for development of the project timeline can be seen in APPENDIX C.

Validation

According to Cronbach (1971), validation is a process of collecting evidence to support any conclusions drawn from test scores. Babbie (2004) outlines four different types of validity: face validity, criterion validity, construct validity, and content validity as criteria for measurement quality. Consequently, validation is the process that determines how well the *intended* concept is *actually* being measured by an instrument. Validation provides feedback from the quantifiable measures to the operationalized theoretical concepts, answering the question: *Does the instrument measure what it is supposed to measure?* A graphical representation of the concept operationalization and validation process can be seen in Figure 7.

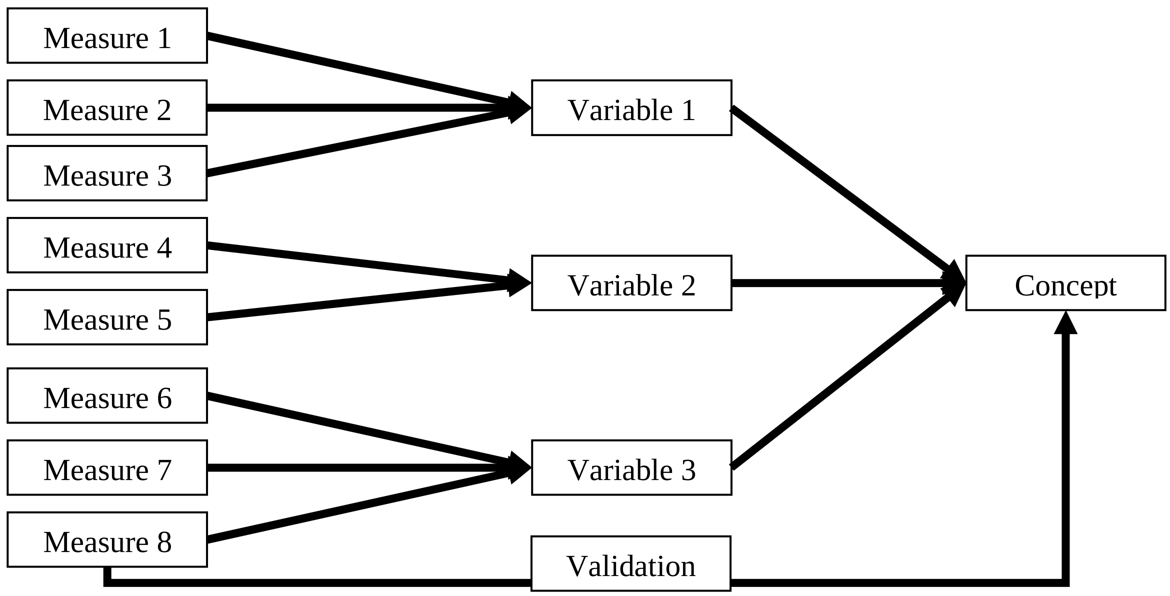


Figure 7: Graphical Representation of Operationalizing Concepts and Validity

Consequently, the lean implementation assessment tool development will consist of three phases: theoretical development, shop-floor development, and the piloting process. The theoretical development phase was completed at the academic level, gathering information from existing literature, tools, experience, and input away from the shop-floor. The key concepts of lean manufacturing were determined, identifying existing and potential measures. This stage of the development addressed the face validity of specific measures ensuring the "reasonableness" of potential measures identified to capture a concept. This process was detailed explicitly in CHAPTER II and the resulting structure in Table 2.

The shop-floor development phase entailed gathering input from workers, supervisors, managers, and lean experts in three different facilities providing insights at the shop-floor level for measurement and feedback. The three facilities provided multiple sources of data for validation and generalizability without being excessively cost- or time-prohibitive and appropriate to the scope of this research project. The content validity was addressed by involving multiple levels of input from the shop-floor to lean practitioners and academics ensuring the lean concepts and practices were measured by the evaluation items. The construct validity was determined by utilizing multiple measures intended to determine the level of agreement and relation between the measures, for the same population across different applications versus expectations.

A graphical representation of content and construct validity and their relation to the operationalization of concepts is illustrated in Figure 8. Furthermore, addressing validity at each stage of development ensures all types of validity are addressed to provide accurate output from the lean implementation assessments for statistical analysis in CHAPTER IV.

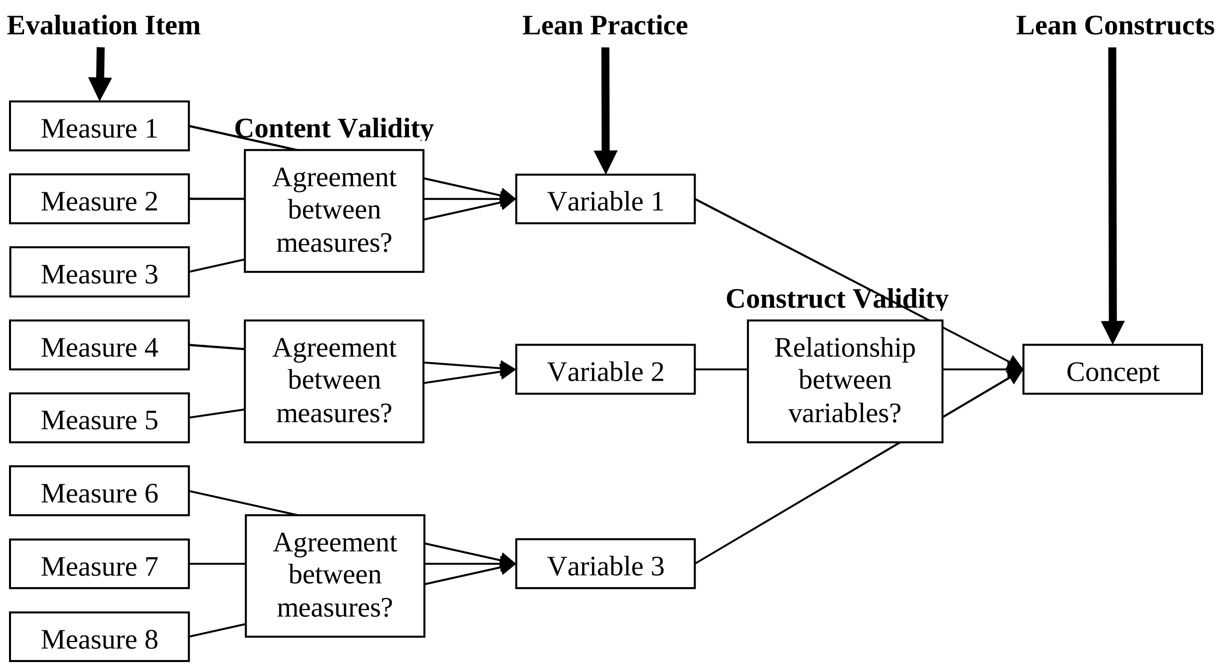


Figure 8: Graphical Relationship of Content and Construct Validity

Thus, during the shop-floor development phase, three warehouses in different industries, with unique operational characteristics, and in different stages of lean implementation were used to operationalize the eight lean constructs and fifty-eight lean practices into specific measures and evaluation items. The two-hundred-eight evaluation items comprising the fifty-eight lean practices were combined to create the variables that make up the various lean practices which make up the lean constructs used to assess lean implementation levels. The lean constructs of standardized processes, people, quality assurance, workplace organization, visual management, lot sizing, material flow, and continuous improvement were measured and aggregated for the different functional areas of each facility to assess the lean implementation levels within and between facilities.

The lean implementation assessment tool was further validated during pilot tests of the evaluation items conducted while onsite during the development phase in each of the three facilities. The pilot process addressed criterion-related validity ensuring the evaluation items actually measured lean implementation levels across various facilities and functions. The feedback from the three development phases provided validation that the tool was *actually* measuring the *intended* concepts. An illustration of the development phases and the validity addressed in each can be seen in Figure 9.

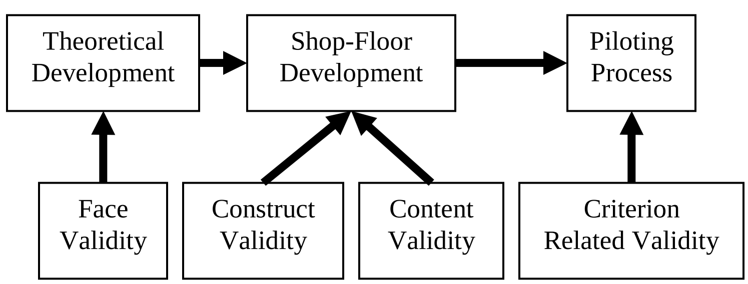


Figure 9: Assessment Tool Development Phases and Validity Addressed

Verification

According to Merriam-Webster.com, verification is "to establish the truth, accuracy, or reality of" a claim. Consequently, the tool verification phase was completed after the tool development process, while performing the twenty-eight actual lean implementation assessments conducted in twenty-five different warehouses. The assessments were performed in twenty-five different facilities providing support for the "correctness" of the assessed level of lean implementation. Furthermore, each of the six different functions identified for warehousing operations within each facility were assessed providing an overall facility lean implementation assessment.

The applicability and "correctness" of the measures were determined through comparison of assessments between the facilities and functions versus lean expert observational expectations. The assessments provided objective results and were in line with the lean expert practitioner expectations as outlined in the CHAPTER IV. Furthermore, three facilities were assessed twice during 2007 to provide additional insight into the results over time, growth, and trends for additional analysis.

The use and application of the lean implementation assessment tool in twenty-two additional facilities during the verification phase reduced any bias of applying the tool in the same environment in which it was piloted and initial feedback garnered. The application of the lean implementation assessment tool in twenty-five different warehouses across various industries ensured the generalizability of the tool and results, and that the feedback provided *actually* met the *intended* research objectives. Moreover, the scope and resources utilized during the development, validation, verification, and data-collection phases provided a comprehensive framework for ensuring a statistically significant number of assessments were performed for data analysis and that inferences could be made about the underlying factors, lean constructs, lean practices, and state of the industry used during lean warehousing implementation.

Validity of Participatory Action Research

Khanlou (2005) identifies fair subject selection, favorable risk-benefit ratio, independent review, informed consent, and respect for potential and enrolled participants as the important factors for assessing participatory action research validity. The warehouse participants were selected fairly through the use of voluntary subjects within Menlo Worldwide where lean implementation activities were in progress and the assessors were involved in lean implementation. The subjects were the twenty eight warehouses, and information was gathered through participation by lean experts, lean practitioners, warehouse managers, and associates involved in implementing lean at each of the warehouses.

The sampling technique was purposive in nature to gather a diverse set of data samples while still capturing a statistically significant number of samples that provide a representative sample of warehousing operations implementing lean principles and practices. A favorable risk-benefit ratio was maintained by providing constructive feedback to the participants with the aim of helping to identify additional opportunities for improvement while helping managers to prioritize improvement activities and resources. The research withstood an independent review by lean practitioners and lean subject matter experts due to the nature of the dissertation project and the intimate involvement of the doctoral research committee.

The participants were informed of the research and consented to participation by volunteering for lean implementation assessment and receiving corresponding feedback with anonymity in publication. Finally, respect of potential and enrolled participants was achieved through maintaining a constructive nature of the feedback provided and facility assessment being the overarching outcome of assessment results. The true subjects of the lean implementation assessments were the warehouses and the processes implemented in each of the six functional areas in the warehouses, rather than the participating employees.

Objectivity

Research objectivity was maintained through the relatively quantitative nature of the evaluation points and subsequent scoring methodology used during the facility lean implementation assessments. Additionally, multiple-assessor lean implementation assessments were performed in five instances by multiple assessors with the participation of the author, and in all twenty-eight assessments the facility manager, facility lean coordinator, and warehouse associates were involved in scoring the evaluation points.

The lean implementation assessment process, assessors, and expert observations are explicitly detailed in CHAPTER IV. The subsequent data analysis, results, and conclusions performed in this research are seen in CHAPTER IV, CHAPTER V and CHAPTER VI. The feedback and participation by all these individuals was instrumental in determining the validity, reliability, and usefulness of the lean implementation assessment tool and understanding lean implementation in practice within facilities and between warehouses.

Generalizability

The generalizability of the lean implementation assessment tool and the results are primarily to organizations with warehousing facilities undergoing some degree of lean implementation or similar organizational improvement strategies. The lean constructs identified were assumed to be generally improved practices for any warehouse where material is received, put away into locations, stored, picked, and shipped. The lean principles of standardized processes, people, quality assurance, workplace organization, visual management, lot sizing, material flow, and continuous improvement have been utilized in numerous organizations with great success over the last fifty years as outlined in CHAPTER II.

Following Toyota's continued success, lean manufacturing or the Toyota Production System has become the improvement paradigm of choice for many organizations throughout the world. The Shingo Prize was created in 1988 to promote the awareness of lean philosophies and recognize organizations in North America who have achieved world-class manufacturing status (Shingo, 2003). The winners of the 2005 Shingo Prize were Autoliv, BAE Systems, Boeing Company, Celestica, Delphi, Boston Scientific Corporation, GDX Automotive, Hearth and Home Technologies, Lockheed Martin, and Takata Seat Belts Inc. (Shingo, 2003). These are only a sampling of the organizations that have implemented lean manufacturing principles with recognized success, and only scratch the surface of the wide array of organizations implementing lean concepts and practices.

Lean manufacturing continues to be applied to other non-traditional additional industries such as warehousing and distribution, as wastes are reduced in traditional manufacturing applications when applying lean concepts (Womack, 2006). Lean warehousing is being applied with great success in numerous organizations such as Toyota, Boeing, General Motors, Menlo Worldwide, Hewlett Packard, Bobcat, and OPW Fueling Components, to name a few. Lean warehousing was even a topic of discussion in an issue of Modern Materials Handling and is a growing field for consulting practices (Modern Materials Handling, 2006). Although, if "lean" was not the paradigm of choice, various applicable aspects of the paradigm and lean implementation assessment tool could still provide specific guidance to shop-floor practices and potential opportunities for improvement for warehousing operations.

Limiting Factors

The level of involvement required by the author and the potential bias stemming from this involvement was a limitation of any subsequent conclusions or inferences made from this research. The lean implementation assessment tool developed in this analysis was intended to be primarily for measuring the level of implementation on the shop-floor of warehousing operations undergoing a lean transformation. Consequently, the generalizability and applicability to other types of facilities or organizations not studied may be a limiting factor. In addition, the lean implementation tool was developed through onsite analysis of only three facilities in different stages of lean implementation and validated at twenty-two other facilities within a single organization. Furthermore, the experience of the author, experts, participants, and research examined are not necessarily indicative of the entire warehousing profession, which could lead to additional limiting factors unknown or not examined. Feedback was gathered from the lean expert panel and participants to identify sources of improvement for future research and use with the implementation assessment tool in addition to the multivariate statistical analysis.

The semantics of the scaling used in the lean implementation tool evaluation items could also be a limiting factor for the research. The individual(s) performing the lean implementation assessment and participants may perceive the scales differently than was intended. For example, when using Likert type scales, semantics such as strongly agree, agree, undecided, disagree, and strongly disagree, without specific term definitions, assessors may interpret the levels of agreement differently. Adding detail for each of the evaluation points by describing the purpose, methodology, and location in the warehouse reduces the potential impact on the results of the assessment along with training on use, intent, and scoring.

In addition, the lean implementation assessment tool was developed through onsite analysis of three facilities at different stages of lean implementation and validated at twenty-two other facilities. If there are unique, unobserved differences in warehousing operations not captured during the development, validation, and verification phases of the research aspects of the lean implementation assessment tool, the results may not be applicable, could be misapplied, or may be inaccurate.

Finally, the motivations of the person performing the assessment could also limit the generalizability. If the assessor has a vested interest in presenting a "good" or "bad" assessment, the objectivity of the lean implementation assessment evaluation items could be skewed and not representative of actual lean implementation. This may be a result of the reward structure associated with the lean implementation assessment, perceptions of the facility, or perceptions of the personal biases of the personnel at the facility.

Enhancing Factors

There are numerous factors that could enhance the generalizability of the lean implementation assessment tool and results. One factor that may enhance the generalizability of the lean implementation tool is the comprehensive range of applicable academic literature that was used in the development of this research to identify the key lean concepts, practices, and the measures derived from those concepts. Furthermore, the utilization of three different facilities during the development of the tool in various warehousing industries increases the likelihood of other facilities being able to use the tool successfully. This enhancing factor was observed in the twenty-eight lean implementation assessments performed during the course of this research.

Finally, the tool developer has a wide range of warehousing experience, having been involved in implementing lean warehousing concepts in multiple organizations and numerous facilities in the industry over ten years increasing the likelihood of applicability to other facilities. Similarly, the participation of other lean experts, the dissertation committee, and the assessment participants provided a wide range of perspectives, backgrounds, and consensus enhancing the likelihood that the research outcomes achieved the desired results.

Conclusion

In conclusion, the detailed development of the lean assessment tool followed the construction and methodology to operationalize the eight lean constructs and fifty-eight corresponding lean practices identified from the literature review. The result was the lean implementation assessment tool's subsequent two-hundred eight specific evaluation points to be assessed for each of the six warehousing functions outlined. The tool development methodology addressed the four types of validity outlined by Babbie (2004) and reduced the impact of the limiting factors outlined to enhance the generalizability of the lean implementation assessment tool and the corresponding results for data analysis.

Furthermore, the participatory action research methodology outlined was followed to ensure that a statistically significant number of samples of data were taken and the data were objectively gathered for verification of the lean assessment tool and results. The specific data collection methodology is described in CHAPTER IV and the entire lean implementation assessment tool constructs, practices, and evaluation points are included in APPENDIX A.

CHAPTER IV
DATA COLLECTION AND ANALYSIS

Introduction

The data collected for this analysis were from twenty-eight assessments conducted at twenty-five warehouses operated by Menlo Worldwide in the United States, Canada, the Netherlands, and Germany. The assessments were completed using the lean implementation assessment tool developed in this research throughout the calendar year of 2007. There were four individual assessors for twenty four assessments and four multiple assessors assessments completed lean implementation assessments for this analysis to gather a statistically significant number of assessments for data analysis. The warehouse industry groups, warehouse management systems, and physical layouts varied greatly between the twenty-five different warehouses assessed in this analysis.

The Sample Data: Menlo Worldwide Warehouses

The data analyzed were gathered from Menlo Worldwide, a third party logistics company, which began implementing lean warehousing principles on a large scale in 2006. The implementation strategy arose from grassroots implementation driven by success within multiple warehouses that had piloted lean principles in 2004 and 2005. In 2006, seven additional warehouses were chosen to begin a systematic, large-scale lean implementation approach, which was expanded company-wide to all eighty warehouses in 2007. According to the Menlo

Worldwide Website, the elements of Menlo's lean logistics culture include reducing inventory, reducing waste, mistake-proofing, and standardizing work.

Menlo Worldwide Logistics serves the automotive, high-tech, retail/consumer, chemical, government, and industrial goods industries in various supply chain service capacities. The supply chain services provided by Menlo Worldwide include transportation management, warehouse management, value-added services, professional services, information technology, truckload brokerage, and intermodal transportation. Menlo Worldwide employs over 6,500 employees in ninety locations in seventeen countries on five continents. The eighty global warehouses total more than sixteen-million square feet of warehouse space which was the focus of data collection for this analysis.

Additionally, the technology solutions utilized in the warehouses vary greatly from warehouse to warehouse depending on the customer specifications, product type, and complexity. Technology solutions range from more manual solutions which require manual input into the warehouse management system to more automated solutions utilizing radio frequency identification, barcode scanners, serialization, and dynamic process tasking. There are internal Menlo Worldwide warehouse management systems in use as well as customer systems providing a wide range of technology solutions used, thus enhancing the general applicability of the lean implementation assessment tool of this analysis.

Menlo Lean Implementation Process

Menlo Worldwide uses a multi-phased approach to implementing lean warehousing principles and techniques in facilities. The initial phase is comprised of general lean principle training to increase understanding and physical implementation milestones of 5S, visual management, standardized work, and value stream mapping over a six-month period culminating in an initial Kaizen event activity. Further, lean leaders are solicited at the warehouse to identify individuals who will be responsible for ensuring the successful completion of implementation milestones. The initial phase follows a template project plan methodology for each warehouse with standard training, implementation milestones, and timing for the initial six-month plan.

The regional lean project manager is intimately involved in all aspects of the initial implementation instructing the team on 5S activities, continuous improvement opportunities, and the development of standardized work and visual management tools. After the successful implementation and training during the initial phase, the lean project manager develops a six-month continuous improvement plan outlining additional training, continuous improvement activities, and other projects in cooperation with the warehouses' customer requirements. The six-month continuous improvement plan is developed through a value stream mapping activity where the warehouse processes are documented and the value-added, non-value-added, and wastes are observed with customer involvement.

Additionally, the lean implementation assessment tool results are used to identify additional opportunities and provide feedback regarding lean implementation. The continuous improvement activities identified are prioritized against customer requirements, metrics, company initiatives, and opportunities identified. The subsequent phases of implementation are developed by leveraging the Deming (1994) Plan-Do-Check-Act Cycle every six months, developing a new continuous improvement plan, and identifying additional opportunities for improvement and training requirements. The lean implementation assessment tool results provide the "check" with regard to lean implementation process at the warehouse.

The implementation status and importance are monitored monthly through regional meetings where the warehouses discuss the progress towards the plan and share opportunities with senior organizational leadership and lean implementation leadership. This process provides an avenue for the sites to share successes, organization learning, and spotlight opportunities where other sites may be able to provide insight on what has worked for them or identify resources to aid in implementation. Furthermore, during leadership site visits, the focus is on the warehouse floor where improvements have been made and opportunities have been identified, which maintains the focus on lean implementation. Menlo Worldwide has made implementing lean warehousing a priority, as demonstrated through strategic initiatives, status updates, and site visits to drive a competitive advantage in the third party logistics industry.

Lean Implementation Assessment Tool Process

The lean implementation assessment tool data collection process leveraged the Menlo Worldwide organizational structure of lean project managers responsible for lean implementation in their corresponding geographical regions. The lean project manager is responsible for training employees in the warehouses on the principles of lean warehousing, developing six-month continuous improvement plans for the warehouse, and identifying opportunities for improvement at their respective warehouses. The lean project manager would generally spend time each month during the initial six-month phase, and then at least quarterly during the subsequent phases, supporting the site depending on specific requirements and circumstances. Consequently, the lean project manager would have a detailed understanding of the warehouse lean implementation and processes in each of the warehousing functions.

The lean implementation assessments were principally conducted by the regional lean project manager and involved the respective warehouse manager and lean coordinator throughout the entire assessment process. Further, the corresponding functional area supervisors, team leads, and employees were engaged as required throughout the entire assessment process. Each lean implementation assessment took approximately a full eight-hour day with the majority of the time being spent on the warehouse shop-floor walking through the functions, demonstrated examples, improvements, and opportunities. The warehouse functions examined during the assessment generally followed the structure from inbound, to outbound, inventory control, value-added services, material returns, and office functions. In total, the eight constructs, fifty-eight dimensions, and two-hundred-eight evaluation points were examined for each of the applicable functional areas for each of the twenty-eight assessments.

The Assessors

For this analysis, four individuals were trained on the lean implementation assessment tool usage, constructs, dimensions, and evaluation points. In total, three other assessors were trained during a week-long training and participation session where the team conducted four multiple assessments together. The training session was used to ensure each assessor understood the spirit and intent of each of the evaluation points and scoring methodology in the lean implementation assessment tool, ensuring each assessor would be evaluating their respective facilities equivalently.

The potential issues that could arise from this approach were with regard to inter-rater agreement, personal bias, and differences in understanding of lean implementation. These concerns were addressed through statistical analysis, training, multiple-assessor assessments, and a detailed expert panel observation and comparisons by the assessors. The expert panel observations versus lean implementation assessment results can be seen in Table 15.

During the training activities and the corresponding multiple-assessor assessments a consensus approach was used to determine the scores for each of the two-hundred-eight evaluation points between the lean project managers, warehouse manager, and lean coordinator. Similarly, during the single-assessor assessments a consensus approach was used to determine the scores for each of the evaluation points between the lean project manager, warehouse manager, and lean coordinator for each of the warehouses being assessed. The assessor, the lean project manager, scored the evaluation points using their expert judgment when consensus was not reached or the behavior was not directly observed. Since many of the warehouses examined were multiple shift operations and not all activities take place on all shifts, there were evaluation points that could not be directly observed in all assessments and the assessor was required to use their expert judgment. Indirect observation and lack of consensus were more the exception than the rule, but are noted for the sake of thoroughness.

Lean Expert Panel Observations

The expert panel approach to validation was discussed by Babbie (2004) where "Ultimately, social researchers should look both to their colleagues and to their subjects as sources of agreement on the most useful meanings and measurements of the concepts they study." For the lean implementation assessment tool, the literature, tools, and techniques were examined to identify measures to assess lean implementation; for the results, both statistical tools and expert observations were used to assess the validity and reliability of the output from the assessments conducted. The intent of the expert panel was to get feedback individually from each of the lean expert practitioners and relate their expectations to the results of the lean implementation assessment tool developed in this analysis. The expert panel provided feedback regarding the actual results of the assessment and the process versus those intended through the development of this research.

The lean implementation assessment tool was examined in detail and utilized by four assessors who are expert lean professionals and two additional lean professionals who participated in lean implementation assessments that were not used in this analysis. The feedback was solicited by individual correspondence to gather insight into the lean implementation assessment tool efficacy of results versus expectations and gather senior leadership perspective of the *intended* and *actual* use of the results. The expert panel observations versus lean implementation assessment results can be seen in Table 15.

Table 15: Lean Expert Panel Observations

Expert / Assessor	Comments / Observations
Anthony Oliverio (Senior Director of Operations Strategy - Menlo Worldwide)	"Lean Assessment Tool – A Strategic Barometer The Lean Assessment is an important tool to evaluate the success of our overall Lean Implementation Strategy for Menlo Worldwide Logistics. The Assessments multi dimensional design and scoring methodology is instrumental in validating that key Lean principles and milestones along the lean Journey are sustained and become institutionalized within our operating culture. The Assessment also serves as a Compass for Continuous Improvement and aligns the organizations expectations on the depth and breadth in which Lean must be applied. Prior to the implementation of the Assessment Tool, validation was ad hoc in nature through a series of Go Look / Go See activities and write ups. Variation of these ad hoc assessments were all over the map and likely to be aligned with the experience level of the assessor and his lean background. Today we are confident that the Assessment outcome and scoring methodology is an accurate depiction of where we are and where we need to focus improvement efforts." (Oliverio, personal communication, September 16, 2008)

Table 15: Lean Expert Panel Observations

Jeff Rivera (Director of Operations - Menlo Worldwide)	"Menlo is taking a 'balanced approach' to understanding current state and building solid plans to achieve future state objectives. The balanced approach is made up of: • VOC - soft feedback and quantitative goals • VOM - culture and financial objectives • Voice of Lean - The lean assessment is the only tool that can quantitatively give us direction on our lean journey and outline key steps that help build a lean foundation. VOC and VOM are operational results. The lean assessment helps us get there using a proven approach that yields long term gains. Too many times at Menlo we swing for the fences, but have no idea how to use a bat or hit a ball. The balanced approach lets us know what distance we should be swinging for. The lean assessments are the tools and techniques that give us an effective swing. It tells us what to focus on during batting practice and how to get ready for a full season in the big leagues. All of Menlo's batting coaches (lean managers) use a standardized and common measuring system to give feedback to hitters (site managers) on how their swing is progressing. In most instances, the swing is getting better, in some instances it gets worse and the batting coach and hitter have to look at the data to determine how to quickly correct. The lean assessment tool is a game changer for Menlo and a huge differentiator for us against our competition." (Rivera, personal communication, August 31, 2008)
Tim Sroka (Regional Lean Project Manager - Menlo Worldwide)	"Prior to conducting Lean Assessments at the various sites utilizing the assessment tool, I had reached a certain level of comfort as I approached each site. Based on the Go Look, Go See (seeing the actuals on the floor) of the facility and spending time with the leadership I was able to conclude a certain level of accomplishment. The Lean Assessment tool was a great validation for me as the tool was in depth covering the various constructs that allowed me to begin looking deeper into all the aspects of the business from the culture to actual material flow. I found the tool to be very consistent as I approached various sites and I was able to baseline the scores while being able to conduct an analysis of the site as well as to develop conclusions and recommendations as we assessed each portion. The tool allowed me to clearly begin to see the total picture rather than just one facet of the business. The conclusions were drawn up because of the tool and allowed me to develop a 'go forward' plan for each site with the focus on the weaknesses/opportunities that began to show up during the assessment as we started looking from the foundation on up. The site managers have been extremely confident both in the tool and the conclusions that will take them to the next levels of Lean.

Table 15: Lean Expert Panel Observations

	The sites that have been assessed have been able to establish the next steps of the lean journey in warehousing while also looking at the administrative and operational aspects as well. The tool has been a leveler in looking at the sites that will be developing through the various Lean stages in the overall Menlo Worldwide lean implementation that have been set for the company. The tool took the 'feeling' out of the equation as it gave us a balanced series of comprehensive questions to ask that would truly show if a site was developing or not." (Sroka, personal communication, August 29, 2008)
Peter Clark (Regional Lean Project Manager - Menlo Worldwide)	"Overall the Lean Implementation Assessment Tool provides output that is relative to how a lean warehouse is actually progressing through its' lean journey. In my opinion, the assessment tools most important function is reducing the subjective nature of observations before, during and after the assessment process. The assessment tool enables the assessor to accurately depict the status of the facility and provide pointed feedback as to the next step the facility should take on their lean journey. During one assessment, I recognized that my subjective observation of where the facility was in relation to the Standardized Processes construct was very different from the lean assessment score. The assessment tool ties more than just the three elements of standard work to Standardized Processes, it ties in all the operational support processes. In my experience, Culture is the most difficult aspect to objectively measure. During my use of the lean assessment tool, the scores in the People construct and associated dimensions have been very close to my subjective observations prior to the lean assessment process occurring. My overall observations regarding Quality Assurance assessment scores is that they are not necessarily linked to the Quality Performance of the facility. Although this construct measures metrics as a dimension, variance in the physical execution of the specific Quality Assurance processes as outlined by the assessment tool forces the assessor to make a subjective observation, therefore facilitating the variance of the score. Visual Management as a construct and associated dimensions have proved to be very accurate against my subjective observations. I have had no experiences during my assessments, where I have second guessed a Visual Management assessment score. I have had the same experience with the Workplace Organization Construct and the associated dimensions. The only exception is the Point of Use Storage dimension (POUS). In my opinion, POUS as a dimension is not comprehensive enough; my recommendation would be to have more response and points options, so that a facility can show progression through this dimension. In my opinion, the most difficult construct for a lean warehouse to achieve

Table 15: Lean Expert Panel Observations

	a high score in is Lot Sizing. My Lot Sizing assessment observations have accurately reflected this obstacle that exists throughout the entire Menlo Worldwide Logistics organization. The most comprehensive construct in the assessment tool is Material Flow. In my experience in operations, lean and as an assessor, this construct clearly defines all the elements of material movement. I have only had one occurrence where my subjective observation was different from the achieved lean assessment score. In this situation, the defining dimension was Pull Systems. Again, the physical execution of the Pull System processes was the cause of the variance. In my experience with the Continuous Improvement construct and associated dimensions, the attained scores have been very close to my subjective observations, but typically higher. It is my opinion that this is due to the documentation elements associated to the Continuous Improvement construct. Since I am de-centralized from the facilities I support, do not always know what is happening at the facility and typically I become fully aware during this part of the assessment process." (Clark, personal communication, August 29, 2008)
Dan Wallace (Regional Lean Project Manager - Menlo Worldwide)	"In my opinion I think the tool is great. For the most part, I think the tool was dead on with regards to the actual score versus lean implementation progression compared to my subjective analysis. As sites progress over time I will have quantitative analysis to compare against providing additional feedback on growth, especially for the sites that have declined and the correlation between certain constructs like the people score. Hopefully future research and analysis will determine if there is a construct, dimension, or question that more accurately predicts the future of the site and sustainability." (Wallace, personal communication, August 29, 2008)
Mike Wilusz (Regional Lean Project Manager - Menlo Worldwide)	"Standardized Processes – Sites making improvements in Storage, Sharing Best Practices, or WMS configuration (routing and travel paths) could move the needle significantly without necessarily demonstrating the three elements of the Standardized Work Principle. Overall the score for Standardized Processes wasn't always indicative of how standardized a site's processes were. People – The tool and points accurately depict the culture of the site. Generally speaking, sites that had high scores in Management Style, Leadership Direction/roles, and Distance & Mgmt Involvement scored high in the other components. This speaks to how impactful good leadership is on a site's overall culture. Quality Assurance – The tool places significant value on results (3 of the 6 elements evaluate metrics), and as a result, a site could achieve a higher

Table 15: Lean Expert Panel Observations

	score without having proper quality assurance (error proofing, autonomation, etc) points built in. Generally speaking, the results were in line with expectations. Visual Management – The tool accurately depicts the state of visual management in the sites. A site can not significantly impact the overall score without placing focus on each element. Because elements thoroughly incorporate our visual management tools and approach, scores are in line with expectations. Workplace Organization – Again, the tool accurately depicts level of workplace organization present in the site. Also, scores from this portion of the assessment generally follow the scores from a detailed 5S assessment. Lot Sizing and Material Flow – I have included these together because they paint a clear picture of Just-In-Time, when combined. At first glance, sites seemed to struggle to increase scores for these two areas, despite making reductions to WIP, implementing Pull Signals, eliminating steps, and standardizing batch sizes. Upon deeper analysis, these improvements were typically offset by a decline in another evaluation element. As a result, the scores are generally in line with expectations. Continuous Improvement – The scores are indicative of expectations. Sites that fail to involve associates in discovering improvement opportunities and implementing change score lower overall. This is a good sign that the tool captures the essence of Lean Continuous Improvement. Overall, sites that took a targeted approach to implementing opportunities revealed through the assessment saw improvements to their scores and noticeable, visual improvements on the floor. Sites that didn't see improvements to their overall score also didn't make much visual improvement to their processes.” (Wilusz, personal communication, August 29, 2008)

The expert panel observations outlined numerous enhancing and limiting factors of the lean implementation assessment tool. The feedback garnered from the expert panel provides insight into the validity of the methodology used to develop the lean implementation assessment tool, the lean constructs, lean practices, and corresponding evaluation items. Additionally, the expert panel confirmed the comprehensive nature of the lean implementation assessment tool and the corresponding output providing a consistent, objective measurement methodology.

All of the expert lean practitioners concluded that the lean implementation assessment tool provided objective results and feedback to the warehouses assessed. Additionally, the expert panel concluded that the overall results, individual lean constructs, and lean practices included in the lean implementation assessment provided a comprehensive, objective evaluation of the lean implementation progress in line with subjective expectations. The expert panel's subjective analysis was intended to be the barometer on which lean implementation was assessed objectively providing a consistent methodology for measuring lean implementation providing better information to management for decision making. Furthermore, the results from the lean implementation assessments can also be analyzed to better understand which tools should be applied and taught based on statistical analysis as discuss by Wallace (personal communication, August 29, 2008).

The opportunities for improvement with regard to the lean implementation assessment tool centered on Standardized Processes, Quality Assurance, and some of the specific lean practices associated with various lean constructs. In particular, Standardized Processes was outlined as inconsistent with expectations by Wilusz (personal communication, August 29, 2008) and that the results did not indicate lean implementation in lean storage practices. This feedback will be incorporated into future research, although the lean practices identified regarding lean storage practices are included specifically in the material flow construct, but not with regard to standardized processes due to the stratification of the lean constructs and lean principles developed in the literature review.

Additionally, the feedback provided by Clark (personal communication, August 29, 2008) regarding the Quality Assurance construct related to measuring both the actual quality outcomes and quality processes. This may be a result of implementation timing and the potential for lags due to the time to implement strong quality processes versus quality outcomes or vice versa. Furthermore, some of the lean practices outlined for enhancement by Clark (personal communication, August 29, 2008) were Point-Of-Use-Storage and Lot Sizing where additional elements will be added to provide additional feedback and identification of opportunities to enhance the lean implementation assessment tool usefulness for facilities implementing lean warehousing.

Another of the struggles noted by both Wilusz (personal communication, August 29, 2008) and Clark (personal communication, August 29, 2008) was with regard to the application of the Lot Sizing lean construct and corresponding lean practices. This information will be useful for management to make decisions regarding training, development, and implementation activities during future lean implementations. Information and feedback about specific concepts, tools, and techniques identifies opportunities for improvement, learning, and benchmarking activities to enhance organizational learning.

The observations from the lean expert panel confirm the four different types of validity outlined by Babbie (2004), face validity, criterion validity, construct validity, and content validity ensuring that the lean implementation assessment tool is actually measuring the lean constructs and practices intended. Furthermore, the observations from the lean expert panel confirm the generalizability of the lean implementation assessment tool to other warehouses with other assessors reducing the limiting factors outlined in CHAPTER III. Most importantly, the observation by Sroka (personal communication, August 31, 2008) that the site managers found the lean implementation assessment tool and output useful for making decisions about further lean implementation validates the *actual* results achieved the *intended* results.

Assessor Agreement

The assessors utilized for this analysis were lean implementation project managers from Menlo Worldwide with diverse industry backgrounds of aerospace, automotive, and consumer goods. Additionally, each assessor had years of experience in lean implementation related activities both within Menlo Worldwide and in other organizations. In all, the four individuals completed twenty-eight assessments with the compiled results in Table 16 illustrating the descriptive statistics for each assessor and assessment. Three of the multiple assessor assessments were completed with two assessors and one was completed with three assessors and the results can be seen in Table 19.

Table 16: Assessor Statistics

Assessor	# Assessments	Minimum	Maximum	Mean	Std. Deviation
ES – 1	8	0	5	2.52	1.41
TS – 2	11	0	5	2.27	1.38
PC – 3	1	0	5	2.17	1.80
DW – 4	4	0	5	2.02	1.42
Multi – 5	4	0	5	2.23	1.43

The difference in assessment scores was found to be significant for the sample set, but not significant between the assessors as seen in Table 17 and Table 18. The difference in means for the sample set was expected due to the inherent differences in the warehouses relative to lean implementation maturity and growth rates rather than differences in assessors.

Table 17: Difference in Means

ANOVA Table					
Mean * Assessor	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Between Groups (Combined)	0.74	4	0.19	1.52	0.23
Within Groups	2.80	23	0.12		
Total	3.54	27			

The lower means seen in the assessments completed by Wallace and Clark correspond to sites in regions that began their lean implementation later versus the higher scores seen in the assessments completed by Sobanski, Sroka, and Multiple Assessors. Additionally, there were not any significant differences found in the means of the assessors seen in Table 18. These statistical outcomes help validate the results for the consistency of output and differences among sample warehouses of the lean implementation assessment tool regardless of assessor.

Table 18: Tukey's Pairwise Comparison

Tukey's Pairwise Comparison				
	1	2	3	4
2	-0.2258			
	0.7331			
3	-0.7443	-0.9813		
	1.4443	1.1740		
4	-0.1343	-0.3586	-1.0060	
	1.1293	0.8463	1.3010	
5	-0.3443	-0.5686	-1.2160	-0.9396
	0.9193	0.6363	1.0910	0.5196

Although the statistical results not finding any pairwise differences in the means by assessor may be due to the relatively low number of samples for some of the assessors, which can impact the results. The differences in assessment scores were found to be significant for the sample set and consequently differences between the warehouses, but not significant for differences between the assessors. In conclusion, the statistical results further confirm the validity and generalizability of the output from the lean implementation assessment tool across assessors, warehouses, and industries.

Data

For this analysis, twenty-eight lean implementation assessments were completed by the four assessors in twenty-five different warehouses in the United States, Canada, Germany, and the Netherlands throughout the calendar year of 2007. Within the United States, warehouses were assessed from various states including California, Georgia, Michigan, New Jersey, Ohio, Oregon, Pennsylvania, Tennessee, Texas, and Virginia. The warehouses assessed were from the automotive, high-tech, and consumer/industrial goods industry groups. Three warehouses were assessed twice, once in early 2007 and again at the end of 2007 to potentially identify any time and growth impact on the lean implementation assessment tool and the results. Given this wide dispersion of industry, region, country, and states, the single company impact should be minimized and the data should be representative of lean warehousing in general.

The eight lean constructs, fifty-eight lean practices, and two-hundred-eight individual evaluation points were examined for each of the applicable six functional areas during every lean implementation assessment. The data collected resulted in 9,744 individual evaluation points, 1,624 compiled lean practice scores, and 224 overall construct scores for the twenty-eight lean implementation assessments completed. The general descriptive statistics for this data are summarized in Table 19.

Table 19: Lean Implementation Assessment Results Descriptive Statistics

Warehouse	Assessor	N	Minimum	Maximum	Mean	Std. Deviation
AUST – TX	PC – 3	58	0	5	2.17	1.80
CAN – NJ	DW – 4	58	0	5	1.54	1.30
DGM48 – MI	ES – 1	58	0	5	2.16	1.56
DGMW – MI	ES – 1	58	0	5	2.09	1.34
EERSEL – ND	ES/PC – 5	58	0	5	2.78	1.40
GMV – MI	ES – 1	58	0	5	2.22	1.42
HAHN – GE	ES/PC – 5	58	0	4.58	1.48	1.25
CORV – CA	TS – 2	58	0	5	2.29	1.44
WOOD – CA	TS – 2	58	0	5	2.03	1.36
WCLLC – CA	TS – 2	58	0	5	2.42	1.33
CANA – CN	TS – 2	58	0	5	2.38	1.44
RICHM – VA	ES – 1	58	0	5	2.32	1.40
MEM714 – TN	ES/DW/PC – 5	58	0	5	2.53	1.62
LARECA – CA	TS – 2	58	0	5	2.55	1.28
CICA – CA	TS – 2	58	0	5	2.12	1.34
SPACA – CA	TS – 2	58	0	5	2.14	1.43
ATL1 – GA	ES – 1	58	0	5	2.60	1.45
ATL2 – GA	ES – 1	58	0.53	5	3.04	1.22
NETCA – CA	TS – 2	58	0	5	2.03	1.59
NITIOR – OR	TS – 2	58	0	5	2.57	1.40
ROTT – ND	ES/PC – 5	58	0	4.67	2.14	1.45
RIPA – PA	DW – 4	58	0	5	2.32	1.45
RICA1 – CA	TS – 2	58	0	5	2.04	1.32
RICA2 – CA	TS – 2	58	0	5	2.36	1.30
RITN1 – TN	ES – 1	58	0	5	2.68	1.44
RITN2 – TN	ES – 1	58	0	5	3.05	1.46
KEPT – PA	DW – 4	58	0	5	2.28	1.47
KPTEDW – OH	DW – 4	58	0	5	1.95	1.47

The 9,744 individual evaluation point pieces of data were averaged for each of the functional areas by weighting the functional areas by the number of employees. The weighted average approach by employees in each functional area was taken to ensure the scores for each dimension were weighted by the amount of activity taking place in each of the functional areas. It was determined by the expert panel during the lean implementation assessment tool development that the number of employees in each area would provide the best indication as to the amount and importance of the work being done in each function. Further, if a particular warehouse did not have a specific function, the weight would be zero, and the subsequent score for that function would not have any weight on the results and not be counted for or against the warehouse during the assessment. If the first evaluation point was not in practice and subsequent evaluation points are used, the first score would be a zero while the other evaluation points would be scored as observed. An example of the calculations can be seen in Table 20.

Table 20: Weighted Average Calculation

Dimension Score Calculation Example					
	Function	**Employees**	**Score**	**Weight**	**Calculation**
Evaluation Point 1 (Scored out of 1)	**Inbound**	10	1	10	30/250 = 0.120
	Value Added Services	6	0	0	12/250 = 0.048
	Outbound	25	1	25	100/250 = 0.400
	Inventory Control	4	1	4	12/250 = 0.048
	Material Returns	3	1	3	6/250 = 0.024
	Office	2	0	2	2/250 = 0.008
	Total	50	Possible = 50	44	44/50 = 0.88*5.0 = **4.400**
Evaluation Point 2 (Scored out of 5)	**Inbound**	10	3	30	30/250 = 0.120
	Value Added Services	6	2	12	12/250 = 0.048
	Outbound	25	4	100	100/250 = 0.400
	Inventory Control	4	3	12	12/250 = 0.048
	Material Returns	3	2	6	6/250 = 0.024
	Office	2	1	2	2/250 = 0.008
	Total	50	Possible = 250	162	162/250 = 0.648*5.0 = **3.240**
Total Dimension	**Total Score**		Possible = 300	206	206/300 = 0.687*5.0 = **3.433**

The weighted average calculation method does not equally weight evaluation points within a dimension, but rather weights them on the number of response criteria for each evaluation point. This scoring methodology was used because the first evaluation point was generally an entry type evaluation point and the subsequent evaluation points are with regard to the depth of implementation. For example, the first evaluation point may be whether or not Standard Operating Procedures exist and the subsequent evaluation points look to the depth with which they have been incorporated into standard work dispatches, workload planning, and cycle lengths. This may be a point for additional research and study to understand the impact on scoring by leveraging this methodology.

Data Collection Methodology Validity Conclusions

The types of validity outlined in Babbie (2004) face, criterion, construct, and content validity were addressed in the identification of the eight lean constructs and fifty-eight lean practices and operationalization into the two-hundred-eight evaluation items. The validity was analyzed by the expert panel and through statistical analysis to ensure the *actual* lean implementation assessment tool output measured the *intended* lean constructs and lean practices.

Furthermore, the output was found to be consistent with subjective analysis by the lean expert panel and the effects of the assessor were not found to be statistically significant. These results confirm the methodology for developing the lean implementation assessment tool, the operationalization of the lean constructs and lean practices, and that the data collection practices measured the intended concepts associated with lean warehousing. The following chapters further analyze the results to better understand the underlying factors, draw conclusions, and develop a pared down lean implementation assessment tool framework.

CHAPTER V
FACTOR ANALYSIS

Introduction

The data collected from the twenty-eight lean implementation assessments conducted were analyzed using statistical analysis and multivariate factor analysis. The statistical analysis examined the Range, Minimum, Maximum, Mean, Standard Deviation, Variance, Skewness, and Kurtosis statistics for each of the lean practices developed and corresponding evaluation points. The data were checked for normality, correlation, and interdependency before conducting factor analysis as described by Johnson (1998). Finally, factor analysis was performed for sixteen factors and seventeen significant factors and the corresponding outputs examined including the Scree Plot, QQ-Plots, Principal Components Analysis, and Rotated Components Matrix. The results from the seventeen factor analysis are discussed in detail in CHAPTER VI.

Descriptive Statistics

The descriptive statistics of Range, Minimum, Maximum, Mean, Standard Deviation, Variance, Skewness, and Kurtosis from the assessment data were determined for each of the cumulative fifty-eight lean practices and the cumulative total from the twenty-eight lean implementation assessments performed. The lean practices were scored for each of the corresponding evaluation points and total scores were determined from zero to five as previously described in CHAPTER IV. The cumulative results were determined for the twenty-eight lean implementation assessments conducted by averaging the results of each sample for each of the individual lean practices and totals. A graph of the total scores attained by each of the twenty-eight warehouses can be seen in Figure 10. The descriptive statistics are presented in Table 21. The descriptive statistics for the cumulative totals and cumulative lean practices provide insight into the warehouses sampled and into the corresponding population of warehouses implementing lean warehousing principles and practices.

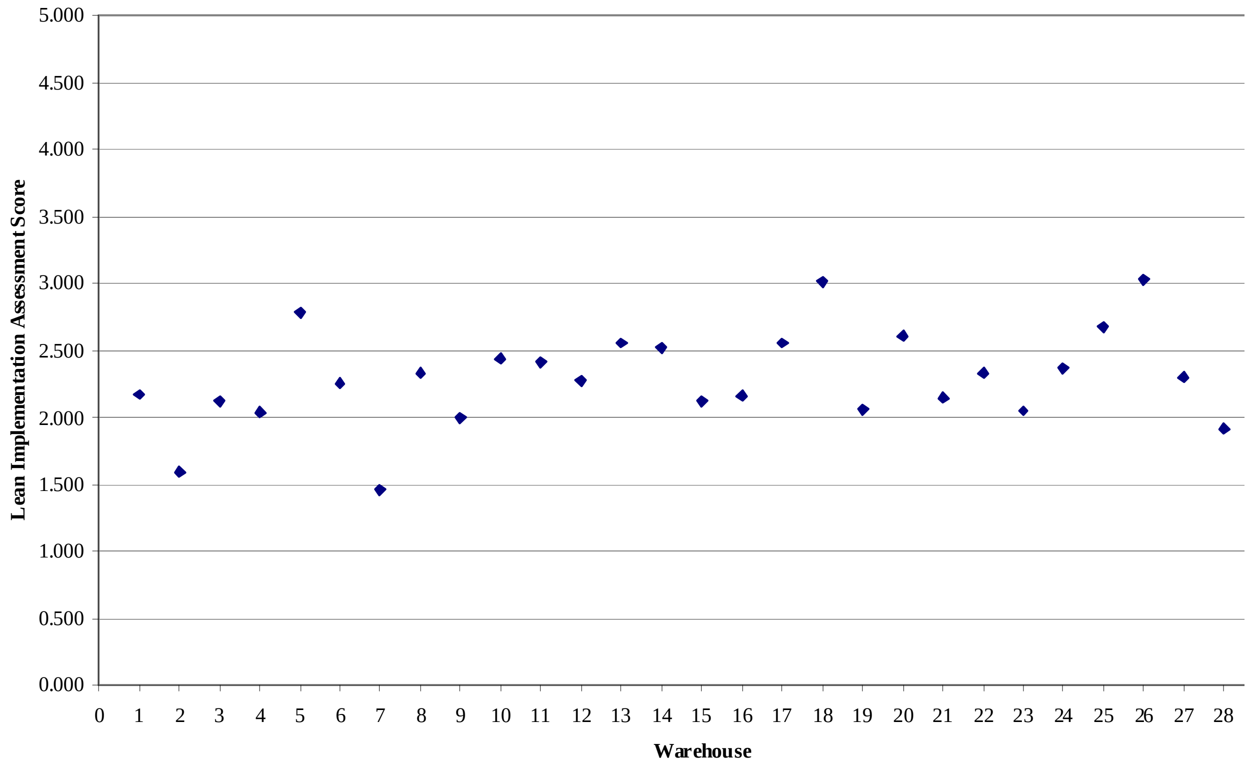


Figure 10: Lean Implementation Assessment Cumulative Totals

Figure 10 illustrates the dispersion of the total scores from 1.5 to 3.0. There were two warehouses that attained total scores of approximately 1.5 and two that attained total scores of approximately 3.0 with the majority of the total scores being between 2.0 and 2.5. The lower total scores attained were in warehouses where lean implementation had either just begun or had limited success. Conversely, the higher scores were in warehouses where lean implementation had begun earlier and had been successful. The normality of the data is revealed in the following section *Normality Tests*.

Table 21: Descriptive Statistics of Lean Practices

Descriptive Statistics										
	Range	**Min**	**Max**	**Mean**	**Std. Deviation**	**Variance**	**Skewness**		**Kurtosis**	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Total	1.567	1.461	3.028	2.298	0.359	0.129	-0.062	0.441	0.606	0.858
SOPs	4.167	0.417	4.583	3.129	1.086	1.179	-0.799	0.441	0.004	0.858
StndWorkDispatches	3.112	0.000	3.112	1.317	0.989	0.978	0.568	0.441	-1.139	0.858
CommodityGroup	5.000	0.000	5.000	2.101	1.633	2.666	0.186	0.441	-0.954	0.858
CommonPrcsBestPractices	4.167	0.000	4.167	1.850	1.325	1.755	0.114	0.441	-1.165	0.858
LoadUnload	3.500	0.000	3.500	1.090	1.062	1.127	0.512	0.441	-0.960	0.858
RoutingTravel	3.750	1.250	5.000	2.548	1.088	1.183	0.429	0.441	-0.530	0.858
SafetyErgonomics	4.688	0.000	4.688	2.962	1.345	1.810	-0.695	0.441	-0.299	0.858
LeadershipRoles	3.045	1.190	4.235	3.159	0.798	0.636	-1.015	0.441	0.612	0.858
MgmtStyle	3.000	1.250	4.250	3.154	0.851	0.724	-0.687	0.441	-0.372	0.858
CrossTraining	4.545	0.000	4.545	2.630	1.118	1.250	-0.974	0.441	0.911	0.858
TeamworkEmpowerment	3.750	0.625	4.375	3.276	0.881	0.777	-1.121	0.441	1.636	0.858
PowerDistance	3.182	1.364	4.545	2.945	0.682	0.466	-0.135	0.441	0.711	0.858
EERecognition	5.000	0.000	5.000	2.871	1.461	2.134	-0.072	0.441	-0.812	0.858
CommunicationStrategy	3.125	1.250	4.375	3.466	0.809	0.654	-1.032	0.441	0.777	0.858
TurnoverLayoff	4.000	0.667	4.667	2.946	1.179	1.390	-0.124	0.441	-1.156	0.858
FiveWhyRootCause	5.000	0.000	5.000	1.810	1.467	2.153	0.587	0.441	-0.656	0.858
InspectionAutonomation	5.000	0.000	5.000	2.972	1.425	2.032	-0.523	0.441	-0.382	0.858
ErrorProofing	4.346	0.000	4.346	1.887	0.953	0.908	0.167	0.441	0.314	0.858
InventoryIntegrity	5.000	0.000	5.000	3.661	1.483	2.198	-1.357	0.441	1.055	0.858
ProductProcessQuality	5.000	0.000	5.000	1.890	1.865	3.479	0.570	0.441	-1.135	0.858
QualityMeasStats	4.529	0.138	4.667	2.597	1.338	1.790	-0.183	0.441	-1.020	0.858
VSM	3.571	0.238	3.810	1.510	0.895	0.801	0.983	0.441	1.171	0.858
ProcessControlBoards	2.630	0.000	2.630	1.287	0.944	0.891	-0.236	0.441	-1.641	0.858
MetricsKPIBoards	3.067	1.099	4.167	2.878	0.887	0.786	-0.418	0.441	-0.990	0.858
LeanTracking	3.036	0.777	3.813	2.144	0.701	0.491	0.092	0.441	0.530	0.858
VisualControls	2.854	0.000	2.854	1.389	1.095	1.198	-0.140	0.441	-1.756	0.858
AndonSys	5.000	0.000	5.000	0.770	1.607	2.581	1.991	0.441	2.487	0.858
A3	4.500	0.500	5.000	2.982	1.302	1.694	-0.677	0.441	-0.794	0.858
FiveS	3.865	0.635	4.500	2.862	0.925	0.856	-0.082	0.441	0.257	0.858
SignageShadowBoards	4.003	0.997	5.000	2.892	1.175	1.381	0.107	0.441	-0.803	0.858
Cleanliness	4.000	1.000	5.000	3.195	1.113	1.238	-0.473	0.441	-0.360	0.858
SupplyMtrlMgmt	5.000	0.000	5.000	2.684	1.637	2.679	-0.349	0.441	-1.164	0.858
POUS	5.000	0.000	5.000	3.733	1.688	2.849	-1.275	0.441	0.459	0.858
IDProblemParts	5.000	0.000	5.000	2.719	1.353	1.830	-0.574	0.441	-0.650	0.858

Table 21: Descriptive Statistics of Lean Practices

Descriptive Statistics										
	Range	**Min**	**Max**	**Mean**	**Std. Deviation**	**Variance**	**Skewness**		**Kurtosis**	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
BatchSizes	2.215	0.000	2.215	1.155	0.620	0.384	-0.332	0.441	-0.509	0.858
WIP	2.330	0.674	3.004	1.702	0.648	0.420	0.461	0.441	-0.900	0.858
KanbanSystems	3.250	0.000	3.250	0.984	1.107	1.225	0.726	0.441	-0.967	0.858
QuickChangeover	5.000	0.000	5.000	2.527	1.082	1.171	0.173	0.441	0.423	0.858
LeadTimeTracking	3.245	0.182	3.427	1.611	0.731	0.534	0.457	0.441	0.387	0.858
InvTurns	4.343	0.657	5.000	2.719	1.201	1.443	0.082	0.441	-0.611	0.858
OrderFreq	4.548	0.000	4.548	2.575	1.051	1.105	-0.147	0.441	0.720	0.858
PullSystems	3.544	0.000	3.544	0.881	1.291	1.668	1.000	0.441	-0.674	0.858
LeveledFlowWork	4.661	0.000	4.661	2.334	1.257	1.580	-0.469	0.441	-0.056	0.858
FIFO	5.000	0.000	5.000	3.083	1.347	1.814	-1.131	0.441	1.034	0.858
LayoutZones	4.375	0.625	5.000	3.037	1.136	1.291	-0.273	0.441	-0.372	0.858
VelocitySlotting	5.000	0.000	5.000	2.377	1.604	2.573	-0.017	0.441	-1.354	0.858
TravelDistance	5.000	0.000	5.000	2.523	1.141	1.302	-0.012	0.441	1.099	0.858
CellStructure	4.000	0.000	4.000	1.060	1.417	2.008	1.065	0.441	-0.392	0.858
DemandStabilization	3.750	0.000	3.750	1.707	1.238	1.533	-0.494	0.441	-1.388	0.858
CrossDocking	5.000	0.000	5.000	1.193	1.555	2.419	1.344	0.441	0.975	0.858
PDCA	4.000	1.000	5.000	3.517	1.301	1.694	-0.326	0.441	-0.996	0.858
KaizenEvents	5.000	0.000	5.000	2.484	1.825	3.332	0.223	0.441	-1.582	0.858
EmployeeSuggestion	3.000	0.000	3.000	1.375	0.873	0.762	0.363	0.441	-0.645	0.858
SystemsView	2.140	2.500	4.640	3.635	0.469	0.220	-0.019	0.441	0.499	0.858
PreventativeMaint	4.000	0.000	4.000	1.786	1.013	1.026	0.119	0.441	-0.567	0.858
SupplierIntegration	4.000	0.000	4.000	1.359	1.170	1.368	0.368	0.441	-0.927	0.858
SPC	1.157	0.000	1.157	0.082	0.284	0.080	3.497	0.441	11.251	0.858
TechEquip	4.167	0.000	4.167	2.405	1.530	2.340	-0.546	0.441	-1.068	0.858

The descriptive statistics for the cumulative total scores of the lean practices show that the average lean implementation assessment score attained was 2.298 with a minimum of 1.461 and maximum of 3.028 providing a range of 1.567. The results from the assessments corresponded to the level of lean implementation attainment and progression foreseen by the Lean Expert Panel with regard to the lean practices examined which was discussed in detail in CHAPTER IV. Furthermore, the warehouses with high mean scores can be leveraged for best practice sharing and the warehouses with lower mean scores to identify opportunities and develop countermeasures to leverage best practices.

The highest means observed were for the lean practices of Point-of-Use-Storage, systems view, PDCA, and inventory integrity. These results are not surprising given the size of warehouses and the importance of reducing travel and the usage of point-of-use-storage techniques. Furthermore, inventory integrity is a key performance measurement in warehousing, and it is not surprising that there was high attainment in the sample warehouses. Additionally, it is not surprising there was a strong understanding of the interdependencies of functions, planning, and the PDCA cycle given the usage of lean practices like value stream mapping and the development of continuous improvement plans for each of the warehouses undergoing lean implementation.

The lowest mean scores seen were for the lean practices related to Statistical Process Control (SPC), pull systems, and Andon systems. This result follows the experiences and approach taken to implementing lean principles where practices related to SPC and pull systems are used later in implementation due to complexity and involvement of other outside parties. The general approach taken was for the warehouses to initially work on internal issues and expand externally with data to drive pull systems. Additionally, the lean practice related to Andon systems was only implemented in a couple of instances. The lowest maximum scores observed in the data were for the lean practice related to SPC, and there were numerous lean practices observed that attained the maximum score of five. Conversely, the highest minimum score for a lean practice related to systems view.

The largest variance observed in the data was for the lean practice of Kaizen events which corresponds to the number completed and sustained during lean implementation. This finding makes sense due to the more advanced sites having more time and completing more Kaizen events and conversely other sites just beginning to conduct Kaizen events. Conversely, the smallest variance was observed for the lean practice related to SPC which follows with the low scores and low dispersion of scores seen.

Factor Analysis Preparation

To properly conduct factor analysis, the data collected from the twenty-eight lean implementation assessments conducted need to be checked for normality, correlation, and interdependence according to Johnson (1998). Factor analysis can be conducted to determine the underlying factors being measured in the lean implementation assessment assuming the data are normally distributed, the variables are correlated, and there is interdependence between the variables.

Each was tested in the following sections with the corresponding detail and implications for each discussed, followed by the factor analysis output, scree plot, principle components analysis, and rotated components matrix. Additionally, Normality Plots and QQ Plots for each of the total scores and lean practices were developed using the statistical software SPSS and Minitab and are included in the following section QQ Plots. The individual QQ Plots can be seen in Figure 13.

Normality Tests

To determine if the data were normally distributed the totals for each of the lean implementation assessments were plotted on a probability plot which can be seen in Figure 11 and Figure 12. Two normality tests of the total scores were conducted; the Anderson-Darling test and the Kolmogorov-Smirnov test to determine if the data were normally distributed. The test values and p-values for each test can be seen in Figure 11 and Figure 12. The normality tests and probability plots were conducted using the statistical software Minitab with p-values of 0.05 to reject the null hypothesis of the data not being normally distributed. Furthermore, Q-Q Plots for each of the lean practices and the totals were developed using the statistical software SPSS and are included in the following section *QQ Plots* and the individual QQ Plots can be seen in Figure 13.

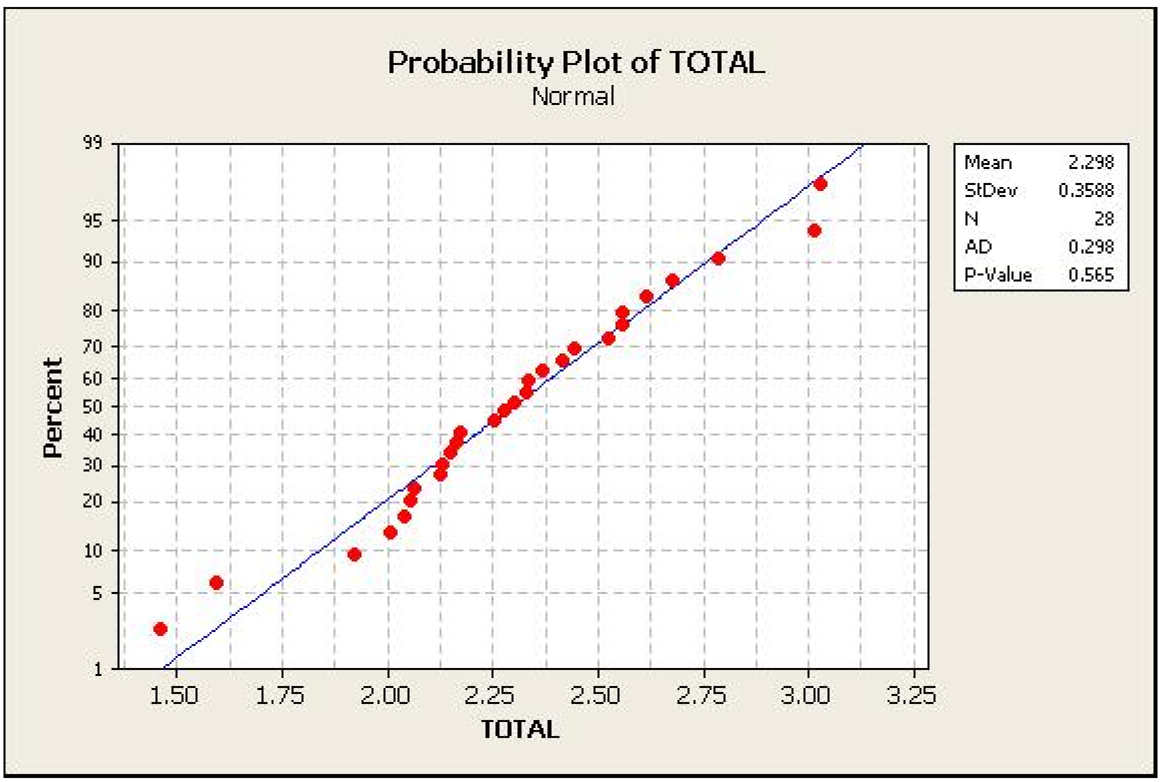


Figure 11: Probability Plot and Anderson-Darling Test of Total Scores

The results from the Anderson-Darling Test and the probability plot from Figure 11 do not reject normality with a p-value of 0.05. Furthermore, the probability plot in Figure 11 shows the totals to be normally distributed as well. This finding was confirmed using the Kolmogorov-Smirnov Test in the following analysis testing normality.

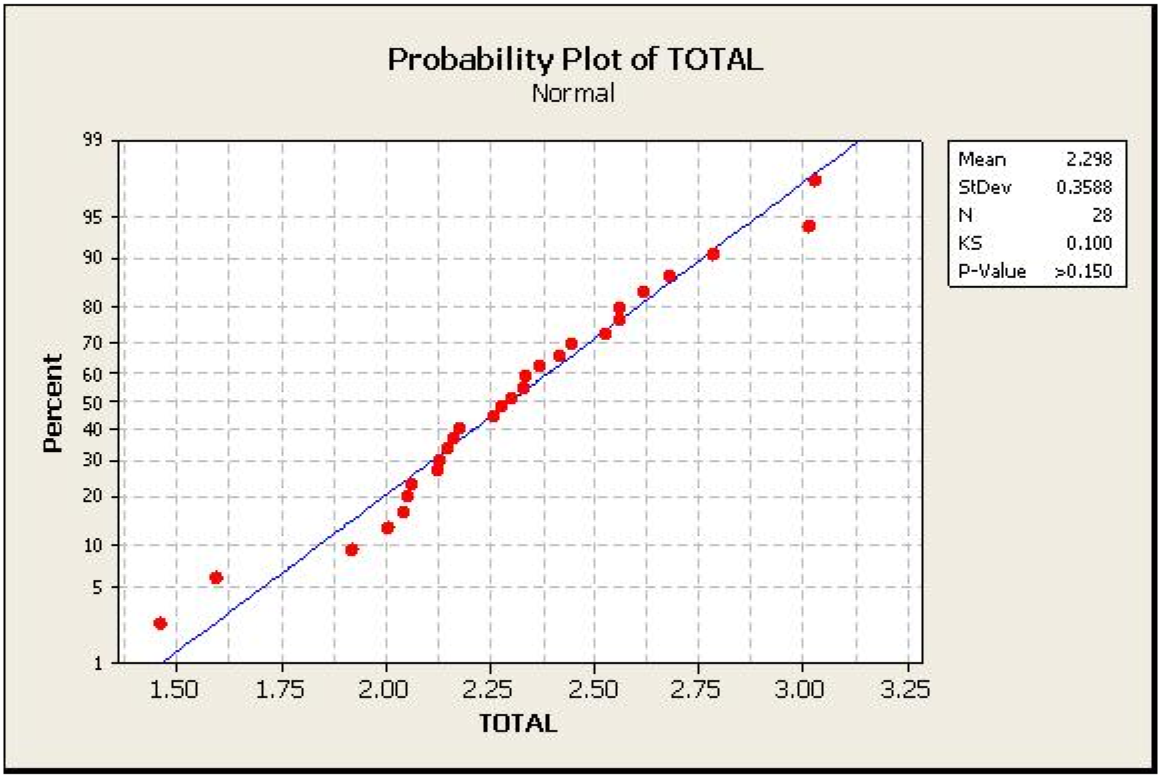


Figure 12: Probability Plot and Kolmogorov-Smirnov Test of Total Scores

The results from the Kolmogorov-Smirnov Test and the probability plot from Figure 12 do not reject normality with a p-value of 0.05. Furthermore, the probability plot in Figure 12 shows the totals to be normally distributed as well. This finding confirms the results found from the Anderson-Darling Test in the previous analysis for normality.

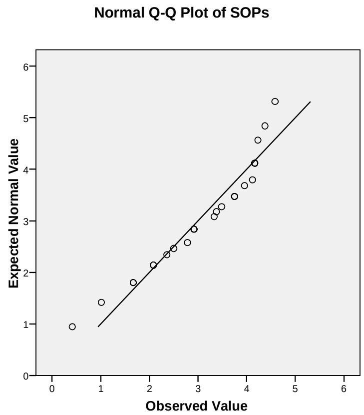
The two tests for normality conducted, Anderson-Darling and Kolmogorov-Smirnov and the probability plots do not reject the null hypothesis that the totals for the lean assessments conducted are normally distributed. Similarly, the QQ-Plots for each of the lean practices measured in the data were normally distributed and are discussed in further detail in the following section. Consequently, with normal data, subsequent statistical analyses can be performed to assess the prudence of conducting factor analysis.

QQ Plots

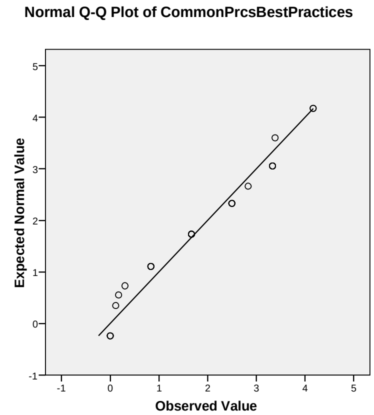
The QQ Plots were used to determine if the individual lean practices were normally distributed and can be seen in Figure 13. The QQ Plots for the lean practices appeared to be fairly normally distributed with the exception of Andon systems, point-of-use-storage (POUS), pull systems, cellular structure, statistical process control (SPC), and Kaizen events. All of these practices had similarities in that they were either generally observed and practiced or not observed in practice. These lean practices had larger groupings around the lower end of the graphs and the higher end of the graphs due to the relative binary observations for these practices. Consequently, the relative scaling of results for these lean practices tended to not follow a normal distribution with a grouping around the mean.

However, the results of the individual normality tests were not enough to impact the relative normality of the results seen for the totals, nor when taken into account on the entire data set enough to skew results. Furthermore, it has been shown that factor analysis and subsequent inferences made from the results of factor analysis are relatively robust for data where normality was not observed according to Johnson (1998). Thus, fifty-two of the lean practices appear to be normally distributed, and the totals for the twenty-eight lean implementation assessment totals appear to be normally distributed, with the possible exception of six of the lean practices. The six lean practices do not have a significant impact on the normality of the whole, and factor analysis will not be precluded because of this result.

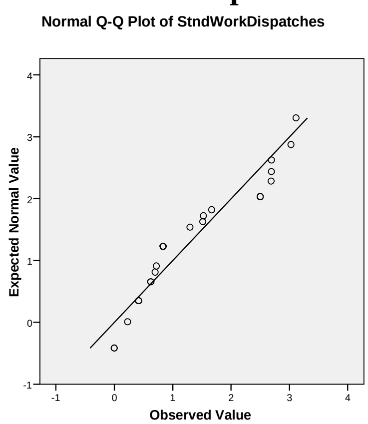
SOPs



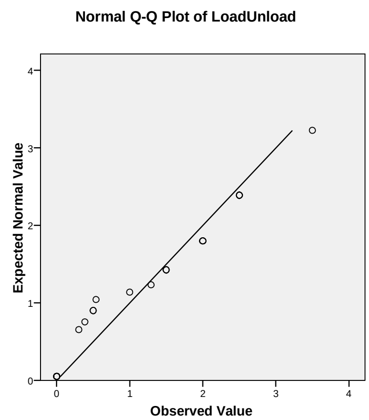
CommonPrcsBestPractices



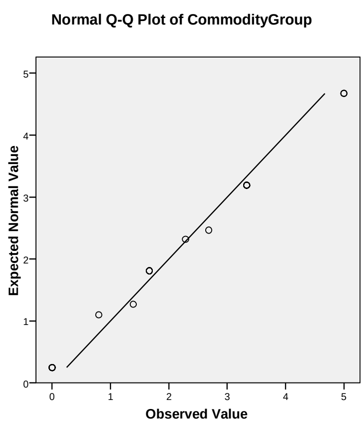
StndWork Dispatches



LoadUnload



CommodityGroup



RoutingTravel

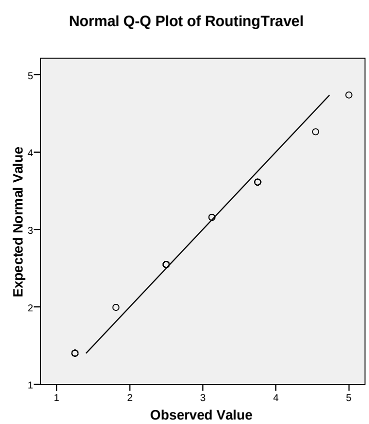
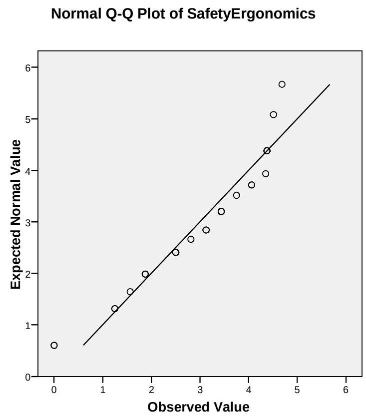
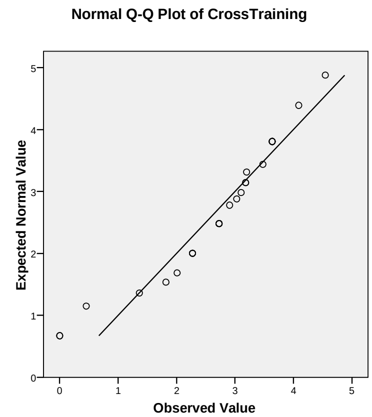


Figure 13: QQ Plots of Lean Dimensions

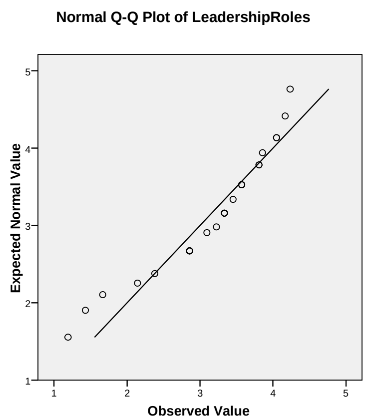
SafetyErgonomics



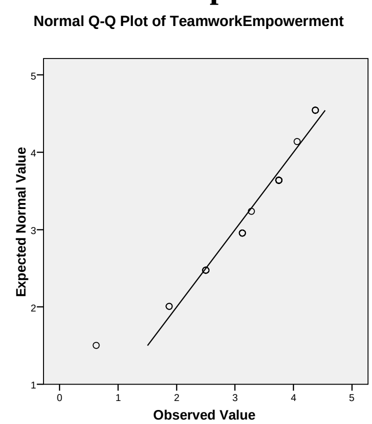
CrossTraining



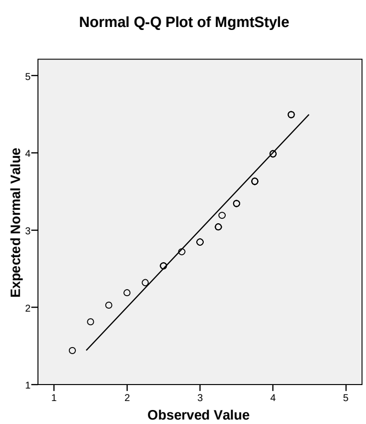
LeadershipRoles



TeamworkEmpowerment



MgmtStyle



PowerDistance

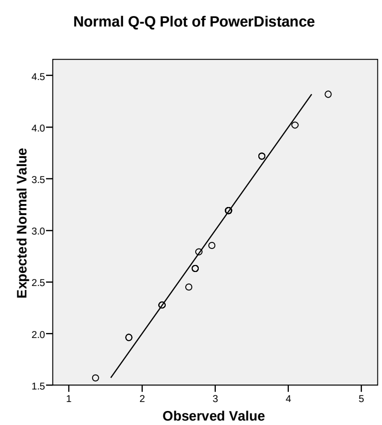


Figure 13: QQ Plots of Lean Dimensions

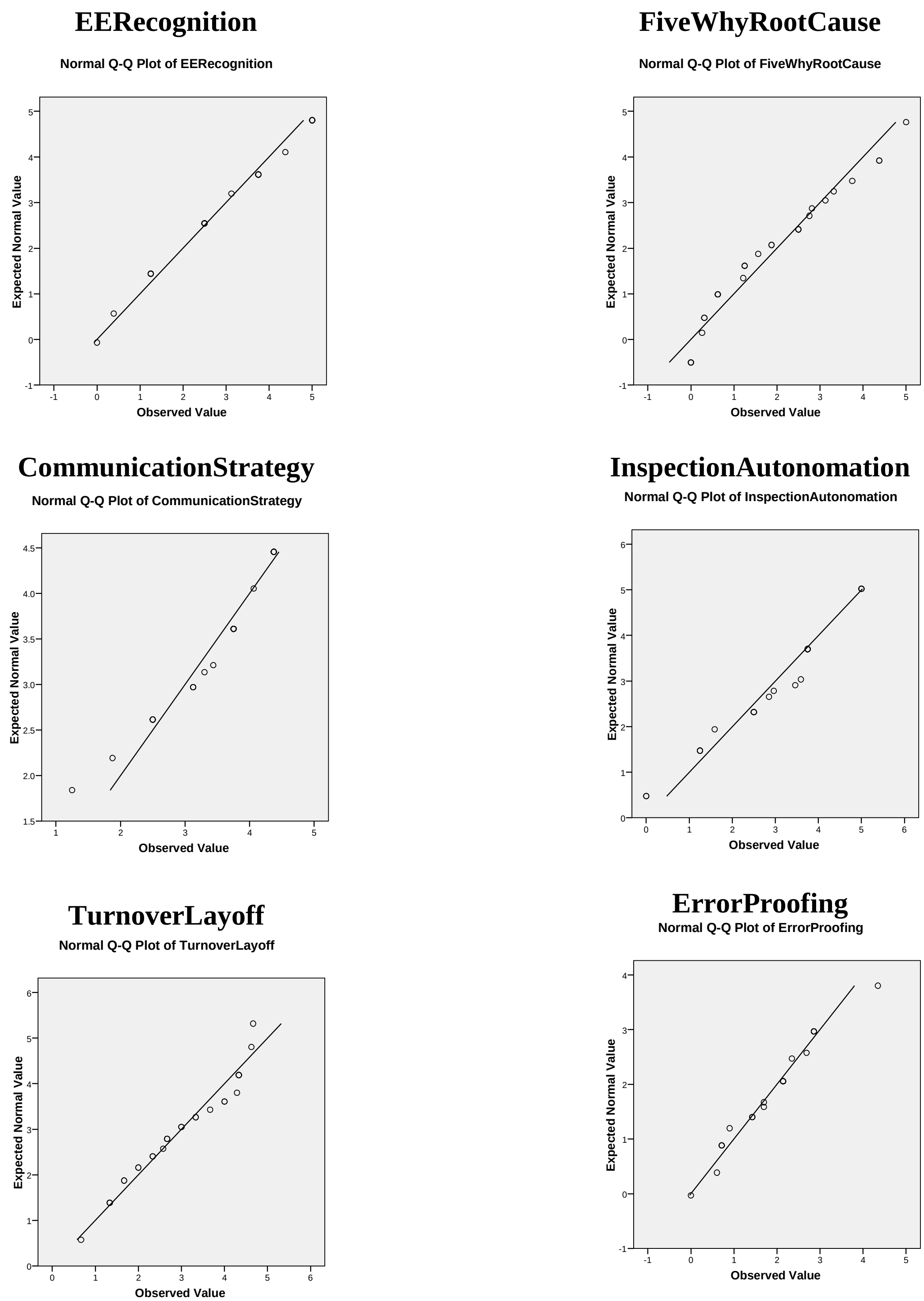
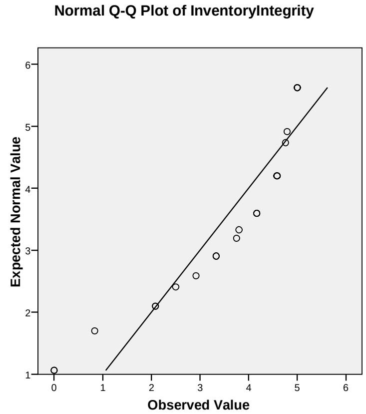
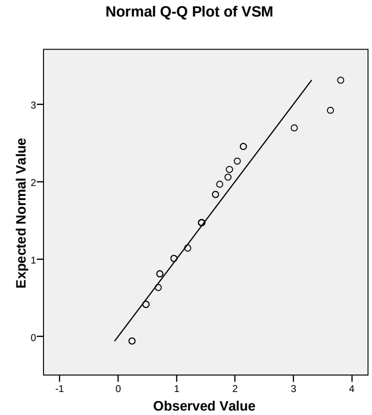


Figure 13: QQ Plots of Lean Dimensions

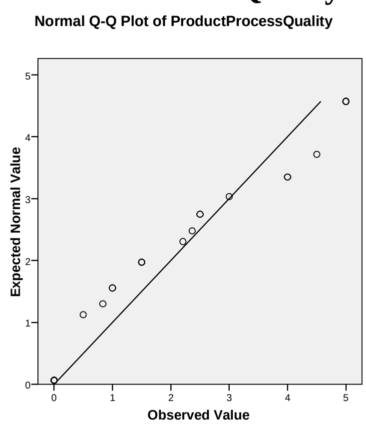
InventoryIntegrity



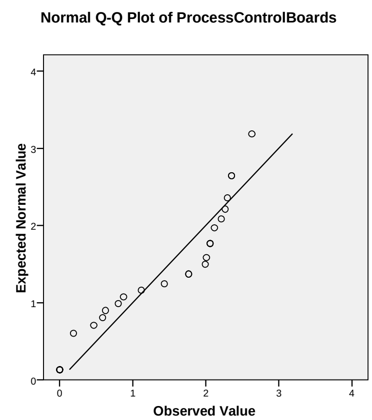
VSM



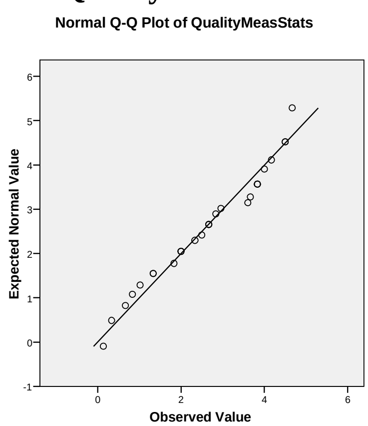
ProductProcessQuality



ProcessControlBoards



QualityMeasStats



MetricsKPIBoards

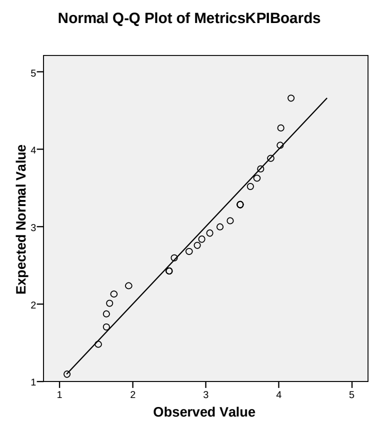
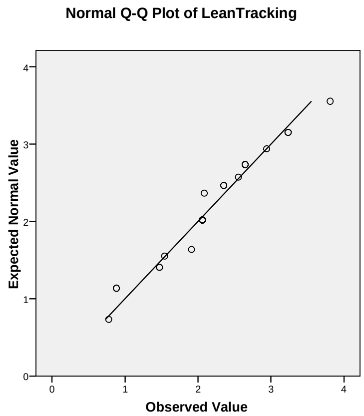
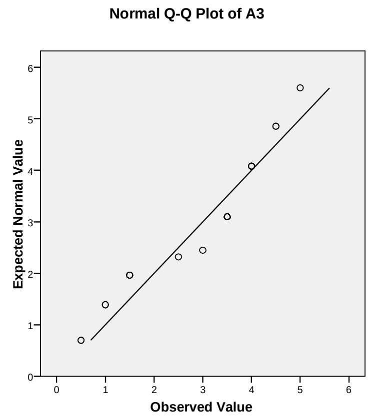


Figure 13: QQ Plots of Lean Dimensions

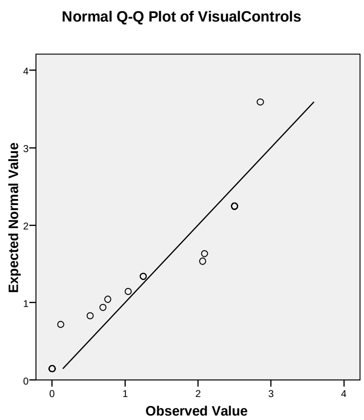
LeanTracking



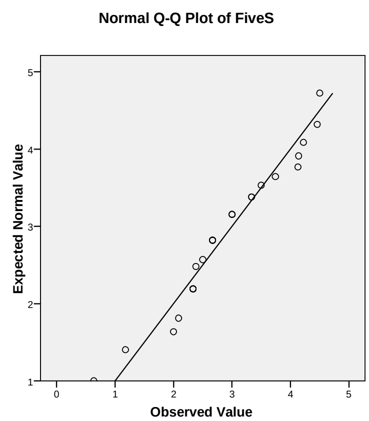
A3



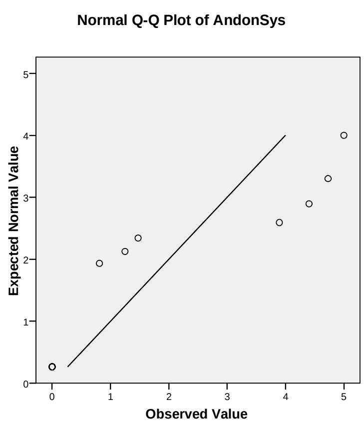
VisualControls



FiveS



AndonSys



SignageShadowBoards

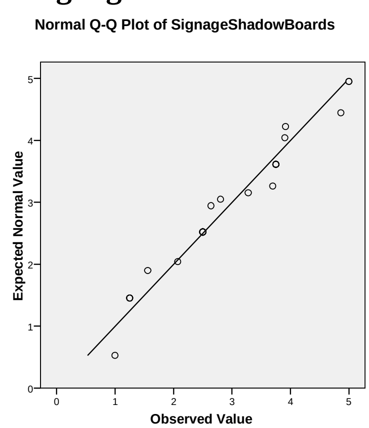
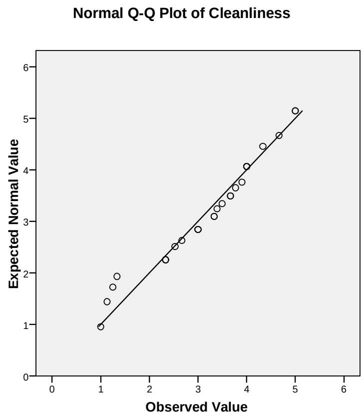
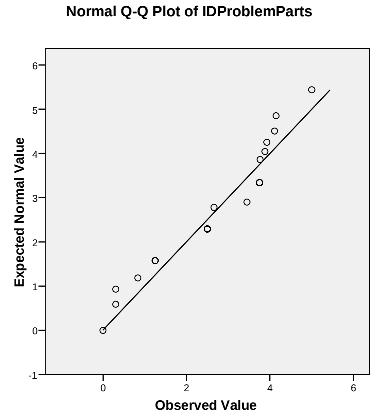


Figure 13: QQ Plots of Lean Dimensions

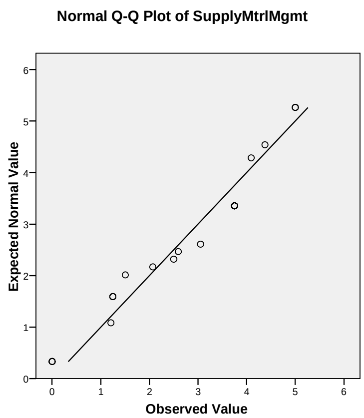
Cleanliness



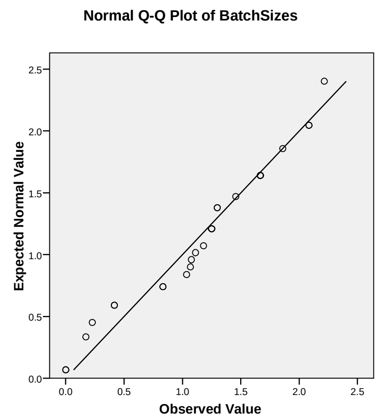
IDProblemParts



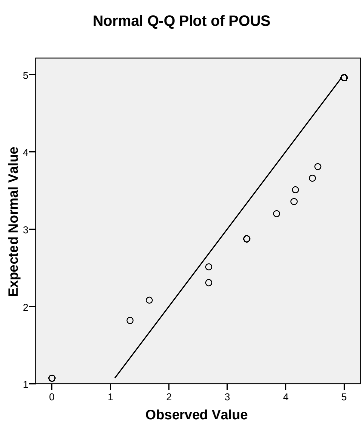
SupplyMtrlMgmt



BatchSizes



POUS



WIP

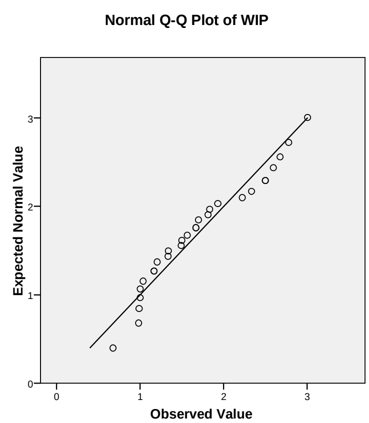


Figure 13: QQ Plots of Lean Dimensions

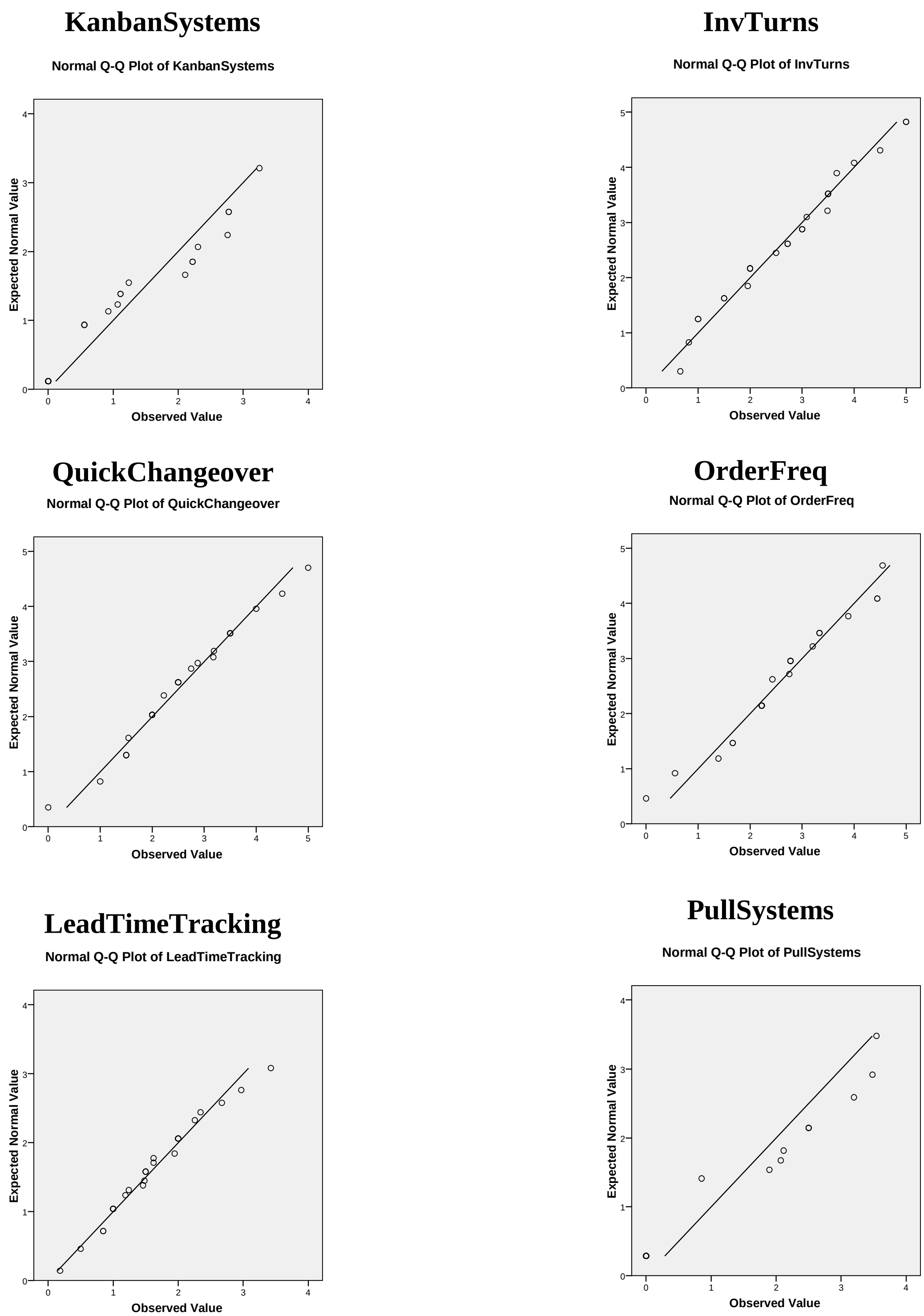
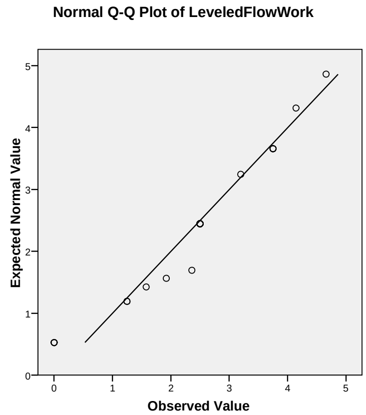
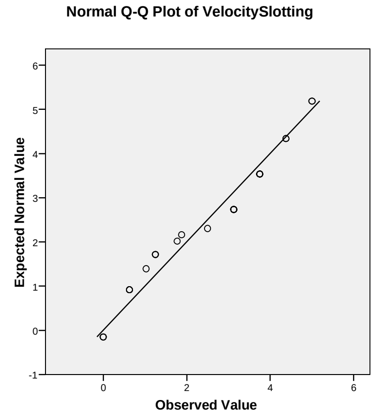


Figure 13: QQ Plots of Lean Dimensions

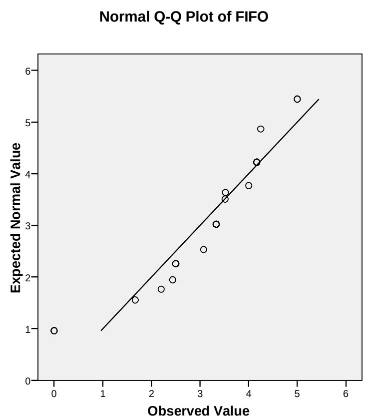
LeveledFlowWork



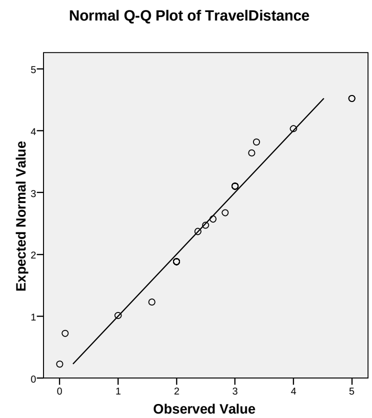
VelocitySlotting



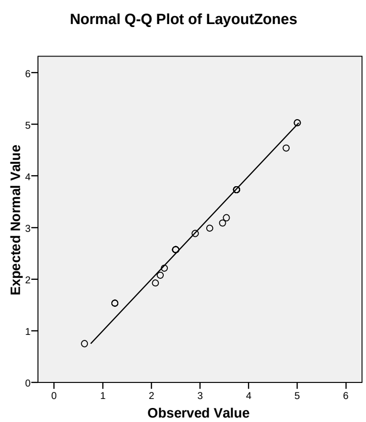
FIFO



TravelDistance



LayoutZones



CellStructure

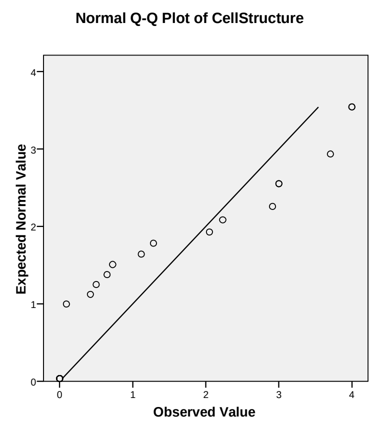
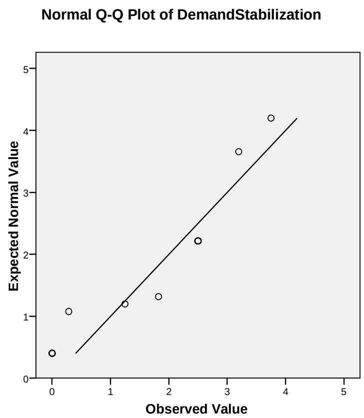
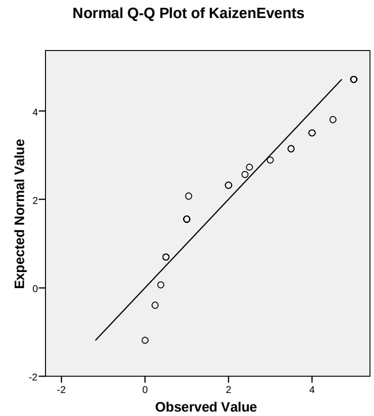


Figure 13: QQ Plots of Lean Dimensions

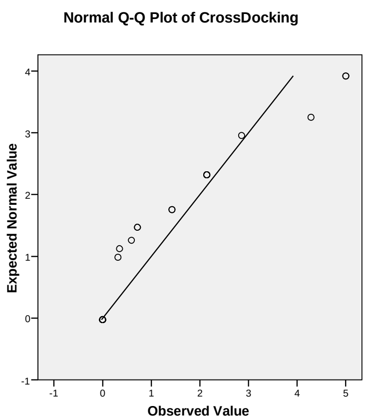
DemandStabilization



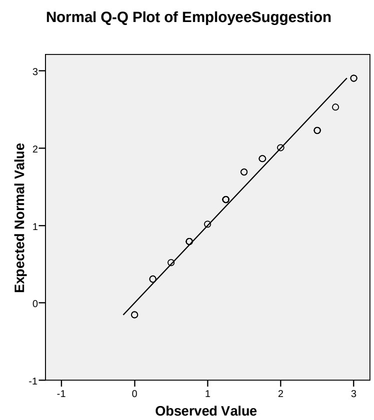
KaizenEvents



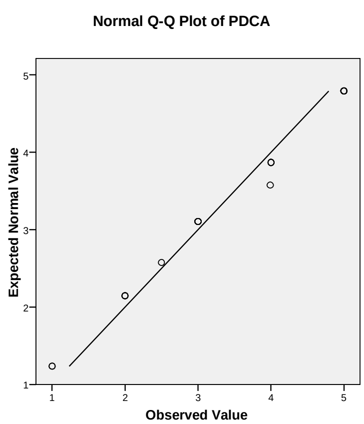
CrossDocking



EmployeeSuggestion



PDCA



SystemsView

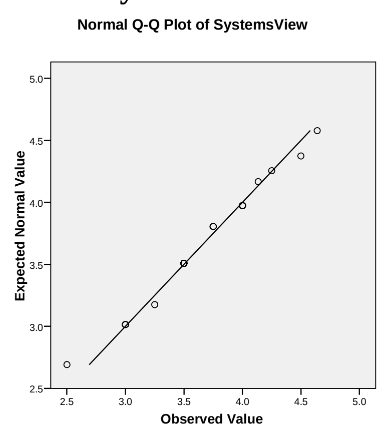


Figure 13: QQ Plots of Lean Dimensions

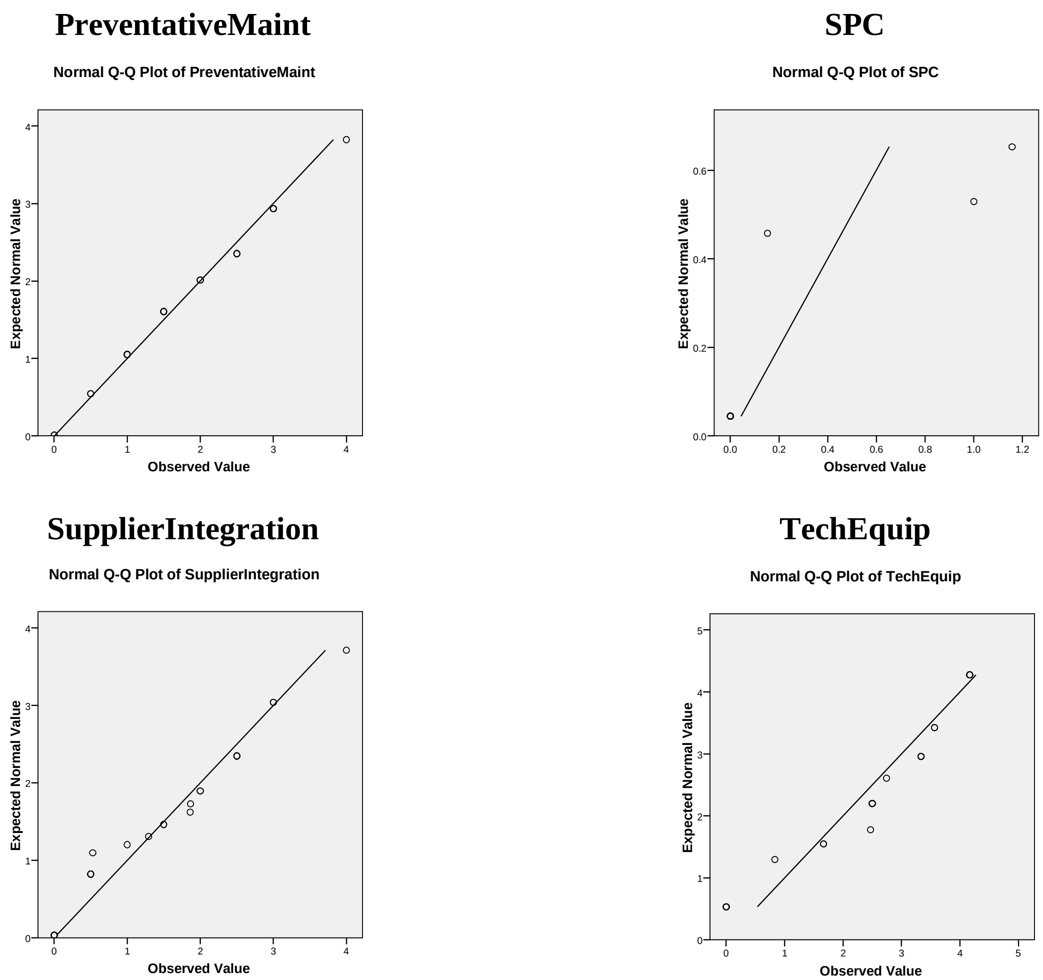


Figure 13: QQ Plots of Lean Dimensions

Correlation Matrix

The correlations among the lean practices were examined and can be seen in Table 22. To illustrate strong positive and negative correlations among the lean practices measured, the correlations above 0.5 and below -0.5 have been highlighted in the Table 22. Correlation among the lean practices intimates that some of the lean practices may be measuring the same underlying factors and that factor analysis would be informational if performed. Correlation among the variables enables factor analysis to be used to better understand the underlying independent variables being measured by the larger data set and the interdependency among the dependent variables.

Strong positive correlations were observed among the lean practices of safety/ergonomics and leadership roles, leadership roles and management style, leadership roles, and teamwork and empowerment. The high correlation among these lean practices follows a logical progression of empowering employees, engaging them in safe work practices, and fostering teamwork which were fundamental principles of lean warehousing described in CHAPTER II and the subsequent lean construct proposed for People and the corresponding lean practices associated with the lean construct of People.

Similarly, there was a strong correlation observed between error proofing, Five-Why, and root cause analysis, which makes logical sense because the Five-Why and root cause methodologies identify underlying problems, and error proofing is the implementation of countermeasures for those corresponding root causes. The root cause analysis and Five-Why methodology enables the identification and implementation of error proofing countermeasures. Furthermore, the root cause methodology communicates the causes of errors to associates allowing the development of processes to identify and eliminate potential sources of errors.

Travel distance and batch sizes were also found to be highly positively correlated which was interesting because on the surface it would logically follow that smaller batch sizes would lead to increased travel distances, where the converse was found to be true. The travel distance becomes more important as batch sizes are reduced, number of waves increased, and trips increased. The balance of travel distance and batch sizes in warehousing is similar to that in manufacturing of quick changeover setup time versus production time, balancing work in process. Consequently, the development of smaller batch sizes may lead to reductions in travel by identifying and implementing zone picking schemes, organizing work into cellular structures, collocating equipment, and other lean practices to ensure that productivity increases and that it does not lead to increased travel. Reduction in batch sizes without changing inventory or picking schemes could result in more trips throughout the warehouse with less dense pick paths and consequently increased travel to perform the same amount of work.

Kanban systems and pull systems, kanban systems and cellular structure, and pull systems and cellular structure were all also found to be highly correlated in the data. This follows because many of these practices are interrelated and implemented simultaneously. Ohno (1978) discusses the original development of pull systems and the management of those systems through the use of kanban cards. Similarly, in warehouses, kanban cards are used for the management of materials, supplies, and equipment with pull systems being maintained through cellular structures and kanbans at the shop-floor level. These lean practices are often implemented simultaneously, with one practice enhancing the other practices.

Additionally, the Plan-Do-Check-Act Cycle (PDCA) and Kaizen events were found to be highly positively correlated. PDCA was identified as an integral part of the Kaizen event process used in lean warehousing and problem solving, so it follows that the two lean practices are highly correlated. The nine-step Kaizen event process observed in practice has the following structure.

- Plan: 1) Project Theme, 2) Boundaries, and 3) Grasp the Situation
- Do: 5) Action Plan and Implementation
- Check: 6) SMART Target Development (Specific, Measureable, Attainable, Relevant, and Trackable) and 7) Lessons Learned
- Act: 8) Parking Lot / Future Concerns and 9) Cost Savings / Calculations.

The development of SMART Targets was an integral part of both PDCA and Kaizen events were appropriate to ensure that the metrics used to measure the results of Kaizen events and ensure that the countermeasures implemented achieve the desired results, or the Check Phase of the PDCA Deming Cycle, and any subsequent actions to adjust the Plan.

Finally, demand stabilization and technology and equipment were found to be highly correlated. This result may be due to demand stabilization requiring the usage of technology and equipment as a methodology to stabilize demand. Often, the lean tools used to achieve these results were standardized work dispatches, heijunka boards, process control boards, and other similar tools. These results can also be achieved by leveraging tools and functionality in the various Warehouse Management Systems used in the warehouses to manage inventory and to ensure the work allocated matches customer demand. One such example was the use of dispatching algorithms in the Warehouse Management System to create standardized work dispatches by zone allocated by outbound delivery schedules.

Table 22: Correlation Matrix of Assessment Dimensions

Correlation Matrix (a,b)	SOPs	Standard Work Dispatches	Commodity Group	Common/ Best Practices	Load Unload	Routing Travel	Safety Ergonomics	Leadership Roles	Mgmt Style	Cross Training	Teamwork Empower-ment	Power Distance	EE Recognition
SOPs	1.000	0.270	0.207	0.119	-0.336	0.048	0.085	0.451	0.245	-0.043	0.268	0.126	0.397
StandardWorkDispatches		1.000	0.254	0.012	0.008	0.082	0.155	0.092	0.068	0.054	0.121	0.010	0.107
CommodityGroup			1.000	0.061	0.071	0.029	-0.185	-0.158	-0.132	-0.092	-0.143	0.178	0.023
Common/BestPractices				1.000	-0.293	-0.010	0.569	0.380	0.346	0.054	0.128	0.208	0.068
LoadUnload					1.000	-0.050	-0.339	-0.541	-0.345	0.281	-0.210	0.037	-0.465
RoutingTravel						1.000	-0.154	-0.105	-0.042	0.270	-0.054	0.058	0.193
SafetyErgonomics							1.000	0.719	0.511	0.141	0.481	0.012	0.209
LeadershipRoles								1.000	0.700	0.082	0.671	0.071	0.490
MgmtStyle									1.000	0.135	0.369	0.169	0.250
CrossTraining										1.000	0.054	0.468	-0.143
TeamworkEmpowerment											1.000	-0.061	0.496
PowerDistance												1.000	0.018
EERecognition													1.000

Table 22: Correlation Matrix of Assessment Dimensions, cont.

Correlation Matrix (a,b)	Communi-cation Strategy	Turnover Layoff	Five-Why RootCause	Inspection Autonoma-tion	Error Proofing	Inventory Integrity	Product Process Quality	Quality MeasStats	VSM	Process Control Boards	Metrics KPIBoards	Lean Tracking	Visual Controls
SOPs	0.313	-0.218	0.339	0.035	0.308	0.015	0.016	0.012	0.209	0.434	0.204	0.405	-0.153
StandardWorkDispatches	0.241	0.049	0.135	0.194	0.077	-0.224	-0.027	-0.139	0.008	0.502	-0.123	0.138	0.116
CommodityGroup	0.066	0.149	0.296	0.078	-0.104	0.298	0.450	0.296	-0.260	0.046	0.528	-0.051	-0.098
Common/BestPractices	0.308	0.360	0.235	0.376	0.119	0.253	-0.221	-0.054	0.410	-0.178	0.192	0.186	-0.443
LoadUnload	-0.145	0.223	-0.142	-0.325	-0.203	-0.234	0.056	-0.076	-0.254	0.070	-0.154	-0.329	0.433
RoutingTravel	-0.156	-0.139	-0.031	-0.090	0.055	0.048	-0.427	-0.216	0.136	-0.061	0.228	0.034	0.004
SafetyErgonomics	0.462	0.296	0.260	0.451	0.130	0.204	-0.110	-0.033	0.163	0.115	-0.004	0.182	-0.392
LeadershipRoles	0.372	0.033	0.226	0.420	0.173	0.345	-0.065	0.014	0.368	0.130	-0.014	0.288	-0.408
MgmtStyle	0.464	0.051	0.222	0.454	0.261	0.086	-0.047	0.047	0.535	0.031	-0.167	0.414	-0.346
CrossTraining	-0.150	0.082	-0.137	0.067	-0.031	0.109	-0.269	-0.049	0.154	0.074	0.262	0.007	0.092
TeamworkEmpowerment	0.441	0.062	0.354	0.392	0.166	0.070	-0.246	-0.111	0.249	-0.007	-0.003	0.056	-0.149
PowerDistance	0.002	0.039	-0.118	-0.017	-0.193	0.114	-0.070	0.145	0.217	0.000	0.384	0.183	-0.083
EERecognition	0.407	-0.034	0.021	0.070	0.017	0.306	-0.036	0.200	0.002	0.061	0.300	0.316	-0.168
CommunicationStrategy	1.000	0.208	0.359	0.349	0.194	-0.037	-0.156	0.053	0.257	0.206	0.037	0.356	-0.319
TurnoverLayoff		1.000	-0.147	-0.104	-0.200	0.023	0.112	-0.290	-0.077	-0.170	0.194	-0.015	-0.213
Five-WhyRootCause			1.000	0.456	0.686	-0.075	-0.156	0.059	0.088	0.266	0.136	0.186	-0.193
InspectionAutonomation				1.000	0.458	0.071	-0.017	0.152	0.301	0.005	-0.007	0.151	-0.123
ErrorProofing					1.000	-0.222	-0.187	-0.145	0.287	0.288	-0.003	0.246	-0.011
InventoryIntegrity						1.000	0.327	0.573	-0.050	-0.034	0.536	-0.090	-0.177
ProductProcessQuality							1.000	0.516	-0.339	0.226	0.201	-0.034	0.214
QualityMeasStats								1.000	-0.371	0.242	0.311	0.245	0.047
VSM									1.000	-0.114	-0.025	0.147	-0.111
ProcessControlBoards										1.000	0.039	0.389	0.124
MetricsKPIBoards											1.000	0.111	-0.108
LeanTracking												1.000	-0.137
VisualControls													1.000

Table 22: Correlation Matrix of Assessment Dimensions, cont.

Correlation Matrix (a,b)	Andon Sys	A3	FiveS
SOPs	-0.180	0.311	0.123
StndWorkDispatches	-0.056	0.317	-0.069
CommodityGroup	-0.270	0.206	-0.165
CommonPrcsBestPractices	0.154	0.287	0.367
LoadUnload	0.182	-0.197	-0.222
RoutingTravel	-0.274	0.034	-0.352
SafetyErgonomics	0.092	0.284	0.404
LeadershipRoles	0.110	0.362	0.378
MgmtStyle	0.040	0.577	0.288
CrossTraining	-0.026	0.012	0.137
TeamworkEmpowerment	0.399	0.161	0.260
PowerDistance	-0.053	0.126	0.242
EERecognition	0.113	0.167	0.439
CommunicationStrategy	0.186	0.513	0.500
TurnoverLayoff	-0.040	-0.208	0.137
FiveWhyRootCause	0.307	0.161	0.002
InspectionAutonomation	0.334	0.386	0.226
ErrorProofing	0.264	-0.069	-0.046
InventoryIntegrity	-0.203	0.097	0.261
ProductProcessQuality	-0.375	-0.068	-0.199
QualityMeasStats	-0.001	0.231	0.227
VSM	-0.010	0.339	0.097
ProcessControlBoards	-0.096	0.066	-0.140
MetricsKPIBoards	-0.333	-0.125	0.180
LeanTracking	0.113	0.445	0.202
VisualControls	0.021	-0.112	-0.307
AndonSys	1.000	0.009	0.343
A3		1.000	0.230
5S			1.000

Table 22: Correlation Matrix of Assessment Dimensions, cont.

Correlation Matrix (a,b)	Signage Shadow Boards	Cleanli-ness	Supply MtrlMgmt	POUS	IDProblem Parts	Batch Sizes	WIP	Kanban Systems	Quick Changeover	LeadTime Tracking	Inv Turns	Order Freq	Pull Systems	Leveled FlowWork
SignageShadowBoards	1.000	0.357	0.310	0.197	-0.137	-0.138	-0.067	-0.108	-0.149	0.067	-0.047	0.075	-0.225	0.201
Cleanliness		1.000	0.160	0.237	-0.047	-0.052	0.169	-0.118	-0.229	-0.339	-0.174	-0.259	-0.210	0.287
SupplyMtrlMgmt			1.000	0.353	-0.102	0.099	0.297	-0.194	-0.126	0.162	0.319	0.190	-0.121	0.169
POUS				1.000	0.158	-0.001	0.464	0.099	-0.412	-0.150	-0.090	-0.234	0.070	0.084
IDProblemParts					1.000	0.127	0.146	0.435	0.024	-0.193	-0.190	-0.367	0.279	-0.011
BatchSizes						1.000	0.238	0.210	0.437	0.091	0.128	0.223	0.241	0.480
WIP							1.000	0.082	-0.100	0.088	0.058	-0.009	0.134	0.309
KanbanSystems								1.000	0.171	-0.196	0.154	0.223	0.795	0.042
QuickChangeover									1.000	0.163	0.131	0.487	0.243	0.294
LeadTimeTracking										1.000	0.488	0.253	-0.295	-0.220
InvTurns											1.000	0.199	0.167	-0.149
OrderFreq												1.000	0.307	0.115
PullSystems													1.000	-0.045
LeveledFlowWork														1.000

Table 22: Correlation Matrix of Assessment Dimensions, cont.

Correlation Matrix (a,b)	FIFO	Layout Zones	Velocity Slotting	Travel Distance	Cell Structure	Demand Stabilization	Cross Docking	PDCA	Kaizen Events	Employee Suggestion	Systems View	Preventative Maint	Supplier Integration
SignageShadowBoards	-0.267	-0.029	0.451	0.051	0.064	-0.076	0.217	-0.074	-0.187	0.178	-0.050	0.150	0.203
Cleanliness	-0.129	-0.044	0.220	0.112	-0.308	-0.064	-0.150	-0.067	-0.188	0.356	-0.201	0.050	-0.030
SupplyMtrlMgmt	-0.131	-0.114	-0.032	0.098	-0.363	0.364	0.055	0.138	0.271	0.162	0.550	0.048	0.174
POUS	-0.113	0.152	0.192	0.081	0.053	-0.275	0.113	-0.109	-0.021	0.151	0.196	0.082	0.389
IDProblemParts	-0.094	-0.100	-0.265	-0.146	0.237	-0.054	0.361	0.044	0.186	0.053	-0.082	0.238	0.082
BatchSizes	0.283	0.228	0.158	0.718	0.040	0.379	0.069	0.337	0.497	-0.224	0.065	-0.006	0.144
WIP	0.178	0.400	0.171	0.482	0.005	0.158	-0.035	0.386	0.415	0.157	0.345	0.119	-0.239
KanbanSystems	0.215	0.329	-0.064	0.165	0.602	0.018	0.195	0.254	0.223	0.270	0.048	0.294	-0.033
QuickChangeover	0.102	-0.086	-0.049	0.169	0.067	0.508	-0.207	0.455	0.308	0.011	0.032	0.088	-0.046
LeadTimeTracking	0.100	-0.193	0.086	0.282	0.008	0.140	0.076	0.227	0.331	-0.246	0.214	0.242	0.110
InvTurns	0.015	-0.069	0.082	0.235	0.069	0.044	0.239	0.286	0.243	0.095	0.302	0.071	0.090
OrderFreq	0.022	0.307	0.156	0.302	0.184	0.470	-0.212	0.475	0.411	0.044	0.180	-0.134	-0.164
PullSystems	0.247	0.412	0.001	0.131	0.680	0.047	0.089	0.352	0.319	0.286	0.172	0.318	-0.038
LeveledFlowWork	0.245	0.034	0.279	0.316	-0.168	0.398	-0.336	0.226	0.166	0.002	0.057	-0.023	-0.130
FIFO	1.000	-0.078	-0.119	0.281	0.067	0.257	-0.265	0.379	0.213	0.062	0.136	0.257	-0.317
LayoutZones		1.000	0.444	0.549	0.333	-0.139	0.017	0.197	0.321	0.015	0.138	-0.128	-0.098
VelocitySlotting			1.000	0.496	0.178	-0.123	-0.139	0.092	0.086	-0.193	-0.149	0.050	0.192
TravelDistance				1.000	0.057	0.162	0.027	0.414	0.555	-0.186	0.049	-0.019	-0.021
CellStructure					1.000	-0.396	0.385	0.139	0.073	0.128	0.040	0.336	0.046
DemandStabilization						1.000	-0.443	0.369	0.319	0.091	0.180	0.105	-0.105
CrossDocking							1.000	-0.107	-0.151	-0.030	-0.090	0.017	0.134
PDCA								1.000	0.613	0.356	0.384	0.284	-0.441
KaizenEvents									1.000	-0.152	0.324	0.103	-0.103
EmployeeSuggestion										1.000	0.297	0.298	-0.177
SystemsView											1.000	0.226	0.031
PreventativeMaint												1.000	0.060
SupplierIntegration													1.000

Table 22: Correlation Matrix of Assessment Dimensions, cont.

Correlation Matrix (a,b)	SPC	TechEquip
SignageShadowBoards	-0.250	-0.178
Cleanliness	0.027	-0.080
SupplyMtrlMgmt	0.110	0.318
POUS	0.187	0.015
IDProblemParts	0.235	-0.124
BatchSizes	0.064	0.233
WIP	0.425	0.088
KanbanSystems	0.363	-0.086
QuickChangeover	0.024	0.275
LeadTimeTracking	-0.285	0.181
InvTurns	0.007	0.099
OrderFreq	-0.057	0.211
PullSystems	0.586	-0.149
LeveledFlowWork	0.084	0.258
FIFO	0.240	0.002
LayoutZones	0.120	-0.092
VelocitySlotting	-0.190	-0.125
TravelDistance	-0.121	0.016
CellStructure	0.167	-0.477
DemandStabilization	0.278	0.671
CrossDocking	-0.146	-0.493
PDCA	0.328	0.009
KaizenEvents	0.157	0.086
EmployeeSuggestion	0.458	0.123
SystemsView	0.291	0.231
PreventativeMaint	0.511	0.038
SupplierIntegration	-0.250	0.111
SPC	1.000	0.214
TechEquip		1.000

The correlation matrix in Table 22 outlines numerous lean practices that were both highly correlated as discussed and many other lean practices that were both moderately positively correlated and moderately negatively correlated. Conversely, there were not any highly negatively correlated lean practices observed in the data, which indicates that none of the lean practices implemented negatively impacted other lean practices. Having no significantly negatively correlated lean practices supports the assumption that lean warehousing practices are generally better than traditional practices by indicating that none of the lean practices negatively correlate to each other. The correlations among the lean practices enhance the likelihood that many of the variables may be measuring the same underlying factors and that factor analysis will provide additional insight into the measurement of lean warehousing.

Additionally, a Spearman Rho test was performed using SPSS to determine the statistical significance of the correlations among the variables in the data and the results are in APPENDIX D. The results of the significance testing of correlations among the lean practices found that each was statistically significantly correlated to at least one other variable, where $\alpha = 0.05$. The only lean practice that was not found to have a statistically significant correlation with another lean practice was Cross-Training. Consequently, there was statistically significant correlation among the variables with the possible exception of Cross-Training, which may be an independent variable, to be tested during subsequent factor analysis.

Interdependence

According to Johnson (1998), the response variables should be tested to ensure that they are independent or uncorrelated before performing factor analysis or principal components analysis, which can be tested by examining the eigenvalues and determining whether or not the result is a diagonal matrix. To ensure that factor analysis will provide meaningful results, there must be significant correlation among the variables, which was tested by conducting the likelihood test for independence of the variables, where H_0: $\mathbf{P} = \mathbf{I}$ and Ha: $\mathbf{P} \neq \mathbf{I}$. The test from Johnson (1998, p 111) rejects H_0 if $-a*\ln\mathbf{V} > \chi^2_{\alpha,p(p-1)/2}$. For this analysis, with the fifty-eight degrees of freedom for this test, the results of this test provide that H_0 was rejected and that there is interdependence among the variables. Subsequently, principal components analysis and factor analysis were performed to provide insight into the underlying factors inherent in the data. Furthermore, the data exhibited interdependence due to the statistically significant correlations among the lean practices as discussed in the previous section.

Additionally, the subsequent principal components analysis illustrates multicollinearity between the variables since there appear to be only seventeen significant principle components for the data explaining 91.34% of the variance with just seventeen variables for the fifty-eight lean practices. Consequently, there was high correlation observed between the fifty-eight variables because the space was over-defined with fifty-eight variables when seventeen explain the vast majority of the variance observed in the data.

Factor Analysis

Factor analysis was performed since all the Johnson (1998) conditions required were met as discussed in the previous sections for normality of the totals, QQ Plots of the variables, correlation among the variables, and interdependence of the variables in the data. Therefore, principal components analysis and factor analysis were performed and are discussed in the following sections with the results discussed in CHAPTER VI.

According to Johnson (1998, p147), the objectives of factor analysis are to "derive, create, or develop a new set of uncorrelated variables, called *underlying factors* or *underlying characteristics*, with the hope that these new variables will give a better understanding of the data being analyzed." Furthermore, according to Johnson (1998) the goals of factor analysis are to determine a smaller set of uncorrelated variables, determine the number of underlying variables, interpret the new variables, and potentially use the new variables in subsequent statistical analyses. Consequently, the scree plot, principal component analysis, variance explained in various models, sixteen-factor analysis, and seventeen-factor analysis were performed and the corresponding results examined in the following sections and in CHAPTER VI.

Scree Plot

The Scree Plot was developed in SPSS to examine the variance explained by each subsequent eigenvalue developed from the principal components analysis and seen in Figure 14. The Scree Plot of the principal components along with the principal components analysis of variance, testing different numbers of factors, and looking at the eigenvalues greater than one helped determine the appropriate number of underlying factors best describing the data observed in this analysis.

Often the Scree Plot will show a clear delineation in the amount of variance explained by each of the principal components and help in determining the appropriate number of underlying factors (Johnson 1998). There was not a clear precipitous delineation in the amount of variance explained except at sixteen or seventeen principal components and after twenty-three principal components seen in Figure 14. This follows after examining the eigenvalues greater than one which include seventeen principal components seen in following section, Principal Components Analysis. The subsequent factor analysis was conducted for both sixteen and seventeen significant factors and discussed in detail in the following sections, Rotated Components Matrix Sixteen Factors and Rotated Components Matrix Seventeen Factors and in CHAPTER VI.

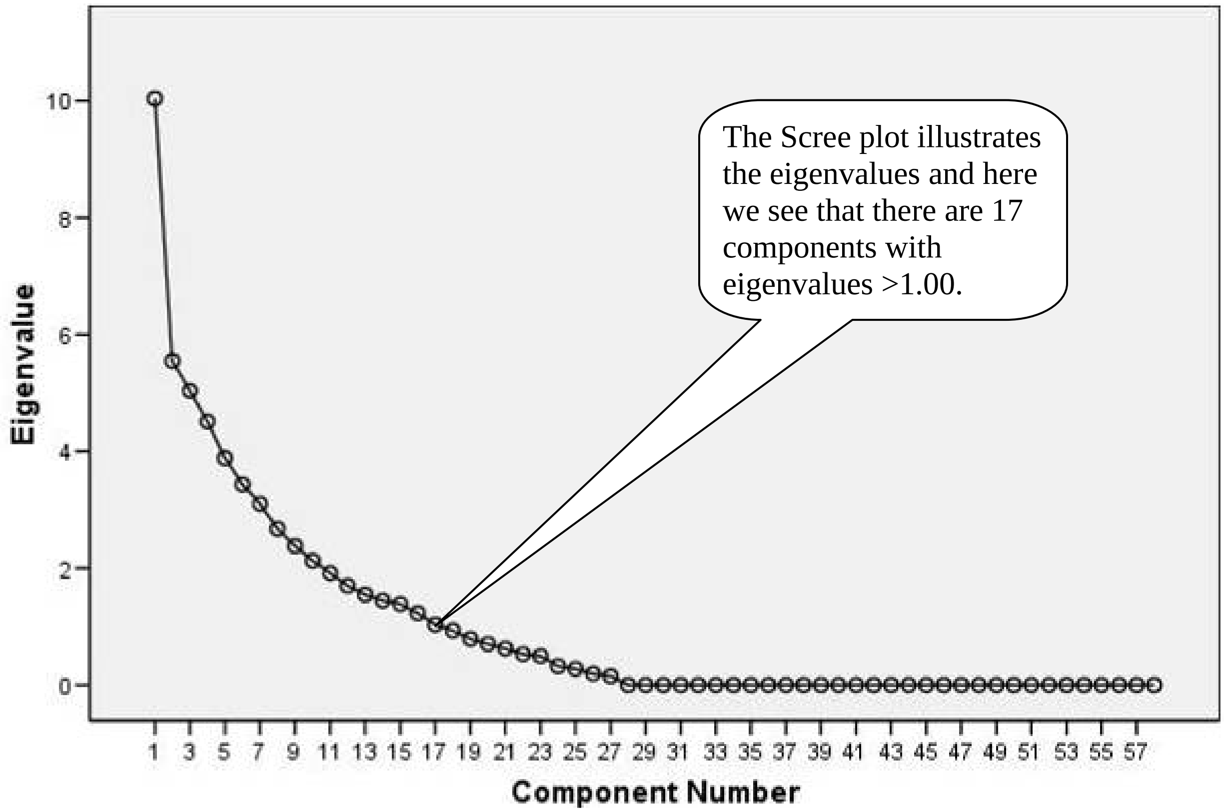


Figure 14: Scree Plot of Principal Components

Principal Components Analysis

Principal components analysis was conducted to develop a new set of uncorrelated variables and to determine the true dimensionality of the data set due to the multicollinearity and interdependence of the fifty-eight lean practices identified and measured in the data. The uncorrelated set of variables was used to determine the number of underlying factors significant in explaining the variance in the data set, predictions about the population without multicollinearity, and other inferences made in subsequent analyses. The details of the principal components analysis and results are included in Table 23.

Table 23: Principal Components Analysis

Total Variance Explained									
	Initial Eigenvalues			Extraction Sums of Sq Loadings			Rotation Sums of Loadings		
Comp	Total	% of Var.	Cumul. %	Total	% of Var.	Cumul. %	Total	% of Var.	Cumul. %
1	10.03779	17.30653	17.30653	10.03779	17.30653	17.30653	4.67424	8.05903	8.05903
2	5.54441	9.55932	26.86585	5.54441	9.55932	26.86585	4.62172	7.96848	16.02751
3	5.03621	8.68313	35.54897	5.03621	8.68313	35.54897	4.19795	7.23784	23.26534
4	4.50814	7.77266	43.32163	4.50814	7.77266	43.32163	4.04043	6.96625	30.23160
5	3.88286	6.69459	50.01622	3.88286	6.69459	50.01622	3.72865	6.42871	36.66030
6	3.43214	5.91749	55.93371	3.43214	5.91749	55.93371	3.70849	6.39395	43.05425
7	3.10182	5.34796	61.28167	3.10182	5.34796	61.28167	3.07410	5.30017	48.35442
8	2.67388	4.61014	65.89181	2.67388	4.61014	65.89181	3.00366	5.17872	53.53314
9	2.38052	4.10434	69.99615	2.38052	4.10434	69.99615	2.77724	4.78834	58.32148
10	2.12647	3.66633	73.66248	2.12647	3.66633	73.66248	2.70251	4.65951	62.98099
11	1.91600	3.30346	76.96594	1.91600	3.30346	76.96594	2.66209	4.58982	67.57081
12	1.69832	2.92813	79.89407	1.69832	2.92813	79.89407	2.63038	4.53514	72.10595
13	1.54778	2.66858	82.56266	1.54778	2.66858	82.56266	2.53557	4.37166	76.47761
14	1.44493	2.49126	85.05392	1.44493	2.49126	85.05392	2.45447	4.23184	80.70945
15	1.38534	2.38851	87.44243	1.38534	2.38851	87.44243	2.35962	4.06831	84.77776
16	1.22875	2.11853	89.56097	1.22875	2.11853	89.56097	2.02006	3.48287	88.26063
17	***1.03511***	***1.78467***	***91.34564***	***1.03511***	***1.78467***	***91.34564***	***1.78931***	***3.08501***	***91.34564***
18	0.93149	1.60601	92.95165						
19	0.79063	1.36315	94.31480						
20	0.70317	1.21236	95.52715						
21	0.62524	1.07800	96.60516						
22	0.52848	0.91117	97.51633						
23	0.49532	0.85400	98.37033						
24	0.32326	0.55734	98.92767						
25	0.27597	0.47582	99.40348						
26	0.19422	0.33486	99.73834						
27	0.15176	0.26166	100.00000						
…	…	…	…						
58	0.00000	0.00000	100.00000						
Extraction Method: Principal Component Analysis.									

From Table 23, one can see that the first principal component has an eigenvalue of 10.03 and explains 17.30% of the variance observed in the data. It follows through the seventeenth principal component which has an eigenvalue of 1.03 and explains 1.78% of the variance in the data set. Beyond the seventeenth principal component, the eigenvalues are less than 1 and explain less than 1.60% of the variance in the data. Cumulatively, 91.34% of the variance observed in the data was explained through the seventeenth principal component. The subsequent factor analyses were conducted for sixteen factors and seventeen factors and discussed in the following two sections. The full SPSS statistical outputs are included in APPENDIX E and APPENDIX F.

Rotated Components Matrix Sixteen Factors

Factor analysis was completed using one less factor, 16, than found statistically significant from the principal components analysis, 17, with initial eigenvalues greater than one. According to Johnson (1998), this methodology provides an initial starting point for analyzing the number of significant factors that best describe the data being examined. SPSS was used to conduct the factor analysis using the Varimax with Kaiser Normalization method for rotating the component matrix to ease the interpretation of the corresponding results. A pared-down table was included in APPENDIX E in Table 24 with correlations of plus or minus 0.50 shows the results of the sixteen factor analysis for additional analysis. The rotated components matrix table was pared down to ease the understanding of the lean practices that were highly correlated and present a concise, interpretable table.

The results for sixteen factors did not explain as much variance nor provide as much clarity on the corresponding independent factors for the rotated components matrix as seen for seventeen factors and discussed in the following section Rotated Components Matrix Seventeen Factors. The sixteen-factor analysis explained 89.289% of the variance observed in the dataset. The full SPSS statistical output for sixteen factors is provided in APPENDIX E. Similarly, other numbers of significant factors were examined with similar results and findings, but it was found that seventeen factors provide the best explanation of the variance and describe the underlying factors with the most clarity.

Rotated Components Matrix Seventeen Factors

Factor analysis was completed using seventeen statistically significant factors and compared to sixteen factors along with analysis of other numbers of significant factors. For all the analyses, SPSS was used to conduct the factor analysis using the Varimax with Kaiser Normalization method for rotating the component matrix to ease the interpretation of the corresponding results along with comparing the amount of variance explained. The full SPSS statistical output for seventeen factors is provided in APPENDIX F.

The rotated components matrix for seventeen factors was included in the Table 24 along with a pared down version in CHAPTER VI in the Table 25 to illustrate the results and significant correlations among the seventeen significant factors. The rotated components matrix makes it easier to understand the correlations among the underlying factors by providing a best fit across the data set to interpret the results. The non-rotated component matrix was also included in APPENDIX F.

Table 24: Rotated Components Matrix Seventeen Factors

Rotated Component Matrix[a]																	
Component	**Factor Number**																
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
SOPs	.217	-.149	-.050	.335	.180	.052	.331	.037	.087	.624	-.015	.125	-.012	.170	-.200	-.278	.022
StndWorkDispatches	.100	.129	.037	.812	-.109	-.276	.107	.030	-.016	.067	.049	.088	.027	.000	.111	-.060	-.020
CommodityGroup	.036	-.027	.043	.314	-.073	.254	-.091	.006	.001	.003	-.057	.882	-.068	.014	.103	-.046	.023
CommonPrcsBestPractices	.270	.396	-.055	-.128	.414	.040	-.126	.171	.024	.035	.051	.089	.100	.347	.436	-.112	.010
LoadUnload	-.165	-.062	.109	-.119	-.781	-.209	-.260	-.048	-.168	.034	.196	.083	.150	.006	.189	.016	-.098
RoutingTravel	-.089	-.201	.200	.118	.230	-.117	.049	.596	-.436	-.089	-.100	.060	.313	-.250	-.082	.014	.130
SafetyErgonomics	.340	.523	-.378	.106	.257	.067	.243	.026	-.007	.113	-.022	-.222	.081	.039	.414	.161	-.035
LeadershipRoles	.461	.280	-.193	.003	.315	.108	.637	-.044	.126	.152	-.129	-.117	.160	.016	.076	-.057	-.167
MgmtStyle	.805	.117	-.090	-.132	.228	-.041	.252	.040	.180	.095	.004	-.060	.180	-.075	.101	.032	.041
CrossTraining	-.011	.078	-.102	.080	-.125	-.022	-.015	.004	-.140	-.006	.087	-.085	.913	.076	.048	.087	.118
TeamworkEmpowerment	.142	.323	-.092	-.084	-.013	-.188	.820	-.068	.007	.084	-.068	-.025	.030	.042	.084	.009	.189
PowerDistance	.142	-.110	-.094	-.077	.054	.246	-.056	.048	-.009	.119	.442	.227	.560	.168	.030	-.181	.133
EERecognition	.046	-.010	.108	.147	.289	.252	.742	.289	-.045	.018	.217	-.013	-.176	.169	-.058	.061	.003
CommunicationStrategy	.493	.197	.113	.156	.012	-.080	.273	.079	-.062	.267	.008	-.033	-.302	.326	.358	.048	.271
TurnoverLayoff	-.095	-.028	-.020	-.067	-.032	.049	.048	-.055	.060	-.088	.041	.061	.033	.006	.931	-.096	.007
FiveWhyRootCause	.116	.403	.050	-.051	.163	-.276	.089	-.046	-.024	.562	-.191	.465	-.105	.005	-.066	.174	.185
InspectionAutonomation	.334	.788	.136	.077	.253	-.035	.064	-.194	.019	-.056	-.075	.098	.049	-.105	-.061	-.030	.218
ErrorProofing	-.026	.452	.139	-.084	.243	-.354	-.008	.185	.205	.545	-.108	.046	-.032	-.160	-.182	.009	.129
InventoryIntegrity	.062	.177	.015	-.093	-.006	.704	.213	.242	-.006	-.150	-.321	.201	.175	.197	.020	.150	-.226
ProductProcessQuality	.045	.007	-.056	.156	-.305	.606	-.106	-.169	.407	-.013	.010	.228	-.236	-.322	.020	-.004	-.191
QualityMeasStats	.146	.120	.140	.010	-.144	.679	-.041	-.093	.095	.061	.046	.169	-.061	.140	-.268	.519	.016
VSM	.463	.120	.127	-.174	.156	-.262	.037	.289	.262	.011	-.183	-.173	.292	.119	-.037	-.486	.179
ProcessControlBoards	.052	.052	.141	.507	-.189	.071	.019	-.016	.052	.679	-.062	-.137	.067	-.162	-.031	.188	-.170
MetricsKPIBoards	-.284	.025	.099	.084	.169	.570	.060	.266	.053	.160	-.070	.392	.290	.172	.137	-.054	.266
LeanTracking	.398	-.126	.414	.177	.374	.105	.074	-.008	.190	.372	.272	-.143	.044	-.017	.033	.263	.175
VisualControls	-.203	.085	.207	.087	-.616	.076	-.064	.033	-.052	-.052	.245	-.166	.016	-.280	-.334	-.171	.209
AndonSys	-.033	.444	.292	-.356	-.032	-.415	.245	-.252	-.093	.012	.328	-.003	-.079	.248	-.064	.216	-.090
A3	.861	.081	.071	.273	.027	.026	.018	.051	-.139	-.066	.023	.088	-.042	.203	-.132	.029	.149
FiveS	.156	.239	.007	-.056	.199	.234	.248	-.147	-.021	.006	.217	-.188	.031	.733	.120	.026	.031
SignageShadowBoards	-.032	-.270	-.123	-.170	-.162	.236	-.079	.311	.125	.104	.069	.164	.318	.618	-.124	.004	-.119
Cleanliness	-.096	-.057	-.187	-.050	.150	.815	-.014	.095	-.256	.013	.240	-.112	.027	.216	.115	.030	-.023
SupplyMtrlMgmt	.309	.134	-.139	.134	-.172	.222	.299	-.230	.360	.104	.347	.095	.348	.166	.040	-.109	-.299
POUS	.071	-.074	.080	.104	-.237	.002	-.033	.104	-.096	-.060	.732	-.118	.181	.201	-.123	.145	-.211
IDProblemParts	.117	-.218	.399	.167	-.092	.047	-.184	-.431	-.160	-.024	.015	-.471	-.216	.178	-.270	.026	-.063
BatchSizes	.089	.050	.117	.897	-.014	.127	-.026	.048	.071	.090	-.097	.102	-.014	-.071	-.223	.003	.117
WIP	.391	.119	.134	.358	.379	.051	-.018	.179	.046	-.019	.462	-.313	.257	.035	.160	.031	-.086
KanbanSystems	.044	-.026	.876	.130	-.015	.013	-.111	-.036	-.039	.031	-.037	.061	-.169	.116	.055	.003	.090
QuickChangeover	.074	.313	.171	.310	.149	.002	-.094	-.035	.084	.078	-.712	.086	.000	.056	-.184	.084	-.136
LeadTimeTracking	.210	.079	-.249	.016	.050	-.104	-.217	.076	.837	.001	-.096	.070	-.026	-.052	-.098	.196	.095
InvTurns	.077	-.153	.145	.118	.079	.006	.376	-.009	.756	.071	-.096	.040	-.123	.018	.215	-.043	-.077

Table 24: Rotated Components Matrix Seventeen Factors

Rotated Component Matrix[a]

Component	Factor Number															
OrderFreq	.177	.381	.283	.029	.153	.020	-.058	.222	.248	.091	-.226	.622	.121	-.068	-.157	-.256	-.195
PullSystems	.115	.029	.932	.069	-.037	-.023	.143	.063	-.083	.107	-.030	.020	-.008	-.144	-.068	.028	.049
LeveledFlowWork	.081	.209	-.040	.553	.192	.166	.164	.136	-.276	-.255	-.103	.130	.159	.520	.038	.104	.007
FIFO	.198	.173	.153	.153	.191	-.103	.096	-.028	-.007	-.015	-.054	.020	.216	-.020	.000	.102	.838
LayoutZones	.245	-.029	.326	.221	.030	-.073	-.070	.613	-.226	.278	.215	.116	-.168	-.199	.212	-.183	-.136
VelocitySlotting	.020	-.085	-.017	.124	-.088	.182	.068	.878	.095	-.083	.072	.012	-.025	.198	-.088	.009	-.040
TravelDistance	.300	-.048	.024	.659	.135	.191	-.166	.477	.196	.102	.083	.114	-.012	-.103	.013	-.094	.195
CellStructure	-.020	-.334	.748	-.107	-.016	-.198	-.243	.253	.088	.003	-.063	.086	.042	-.051	-.075	.226	-.009
DemandStabilization	.159	.672	.009	.313	.055	.189	.184	-.184	.096	.106	-.296	.057	.310	.064	-.109	-.111	.027
CrossDocking	-.207	-.783	.197	.132	-.013	-.100	-.141	-.192	.272	.158	.089	-.079	.092	-.056	-.058	-.079	-.156
PDCA	.520	.079	.262	.167	.554	.075	.116	.039	.138	.294	-.120	.165	.024	.069	-.214	.114	.081
KaizenEvents	.738	.201	.222	.342	.102	.056	-.092	.020	.243	-.032	.029	.023	-.224	-.053	-.169	-.096	.015
EmployeeSuggestion	.029	.046	.302	-.256	.201	.252	.070	-.196	-.142	.582	.091	.054	.211	.301	.238	.194	-.062
SystemsView	.568	.119	.073	.027	-.037	-.170	.330	-.155	.217	.271	.178	.157	.138	.004	.187	.228	-.170
PreventativeMaint	.117	.070	.328	-.126	-.032	.168	.045	.025	.201	.136	-.020	-.243	.094	.064	-.129	.755	.173
SupplierIntegration	-.038	-.143	-.061	.137	-.859	.139	-.036	.038	.139	-.077	.006	.006	.042	.008	-.066	.164	-.187
SPC	.023	.337	.548	.049	.211	.018	.334	-.180	-.137	.162	.307	-.255	.107	-.043	.039	.314	.030
TechEquip	-.118	.785	-.179	.289	-.148	-.027	.135	-.137	.144	.255	-.009	-.003	-.060	.155	.079	.074	-.139

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 33 iterations.

Conclusions

The data collected from the twenty-eight lean implementation assessments conducted were analyzed using statistical analysis and multivariate factor analysis. The descriptive statistics were examined for each of the lean practices and total scores. The data were checked for normality, correlation, and interdependency before conducting factor analysis as described by Johnson (1998). Finally, factor analysis was performed for sixteen factors and seventeen significant factors and the corresponding outputs examined including the Scree Plot, QQ-Plots, Principal Components Analysis, and Rotated Components Matrix. The rotated components matrix shows the correlations among the lean practices for each of the seventeen significant underlying factors determined from the factor analysis. The higher correlations, interpretation of the results, and conclusions are discussed in detail in CHAPTER VI: RESULTS and CHAPTER VII: CONCLUSIONS.

CHAPTER VI
RESULTS

Introduction

The results of the development and application of the lean implementation assessment tool were analyzed using the factor analysis output and rotated matrix with seventeen factors as previously described in CHAPTER V. The factor analysis uncovered seventeen independent variables being measured by the lean implementation assessment tool and are discussed in this chapter.

Significant Factors

From the factor analysis, there were seventeen significant factors observed in the data measuring lean warehousing related to continuous improvement and problem solving, building in quality, pull systems, standardized processes, customer integration, quality assurance, people, inventory management, material flow, information sharing, point of use storage, inventory strategy, employee development, workplace organization, employee retention, quality systems, and first in first out. The underlying factors were found to be significant based on the significant correlation coefficients greater than or less than 0.5 for each of the significant factors or components and are included in Table 25. The significant factors and correlated lean practices were synthesized into the following seventeen independent variables. The seventeen significant underlying factors identified will be discussed in detail in this section along with the implications and conclusions that can be drawn in CHAPTER VII.

Table 25: Pared Down Rotated Components Matrix Seventeen Factors

Component 1	Correlation
A3	0.86106
MgmtStyle	0.80469
KaizenEvents	0.73824
SystemsView	0.56810
PDCA	0.51996

Component 2	Correlation
InspectionAutonomation	0.78818
TechEquip	0.78529
DemandStabilization	0.67205
SafetyErgonomics	0.52284
CrossDocking	-0.78310

Component 3	Correlation
PullSystems	0.93214
KanbanSystems	0.87575
CellStructure	0.74849
SPC	0.54752

Component 4	Correlation
BatchSizes	0.89746
StndWorkDispatches	0.81164
TravelDistance	0.65904
LeveledFlowWork	0.55321
ProcessControlBoards	0.50746

Component 5	Correlation
PDCA	0.55437
VisualControls	-0.61558
LoadUnload	-0.78055
SupplierIntegration	-0.85939

Component 6	Correlation
Cleanliness	0.81528
InventoryIntegrity	0.70427
QualityMeasStats	0.67910
ProductProcessQuality	0.60625
MetricsKPIBoards	0.56966

Component 7	Correlation
TeamworkEmpowerment	0.81959
EERecognition	0.74238
LeadershipRoles	0.63729

Component 8	Correlation
VelocitySlotting	0.87789
LayoutZones	0.61270
RoutingTravel	0.59626

Component 9	Correlation
LeadTimeTracking	0.83744
InvTurns	0.75590

Component 10	Correlation
ProcessControlBoards	0.67944
SOPs	0.62351
EmployeeSuggestion	0.58181
FiveWhyRootCause	0.56179
ErrorProofing	0.54469

Component 11	Correlation
POUS	0.73152
QuickChangeover	-0.71191

Component 12	Correlation
CommodityGroup	0.88185
OrderFreq	0.62208

Component 13	Correlation
CrossTraining	0.91299
PowerDistance	0.55979

Component 14	Correlation
FiveS	0.73251
SignageShadowBoards	0.61785
LeveledFlowWork	0.51993

Component 15	Correlation
TurnoverLayoff	0.93075

Component 16	Correlation
PreventativeMaint	0.75521
QualityMeasStats	0.51863

Component 17	Correlation
FIFO	0.83843

Component One – Continuous Improvement and Problem Solving

The significant correlations for component one consisted of One-Page Reports (A3), Management Style, Kaizen Events, Systems View, and Plan-Do-Check-Act (PDCA). The first component was found to be the most significant and explained 17.3% of the variance observed in the data. This component seems to be primarily measuring an underlying factor related to basic lean principles of problem solving and the problem solving process discussed by Deming (1994) with regard to Plan-Do-Check-Act using a Systems View to solve problems. The management style used in lean warehousing involves engaging employees in goal setting and problem solving and leverages the corresponding tools, Kaizen events and one-page reports (A3s). Consequently, continuous improvement and problem solving was the most significant factor for measuring lean warehousing. This factor relates to the process of problem solving and getting people engaged in lean warehousing rather than to specific tools, which is an important finding.

Component Two – Building in Quality

The significant correlations found for component two were Inspection and Autonomation, Technology and Equipment, Demand Stabilization, Safety and Ergonomics, and negatively Cross-Docking. The second significant component explained 9.6% of the variance observed in the data when measuring lean warehousing. This component seems to be primarily measuring an underlying factor related to basic lean principles of building in quality to processes, people, and technology. Building in quality with regard to processes relates to inspection and autonomation and demand stabilization with relation to people through safety and ergonomics, and technology through technology and equipment. Interestingly, cross-docking was found to be negatively correlated to this component which may be a result of some standard processes being circumvented to move material quickly from one area to another without following the standard process, or of having two processes for material flow. Cross-docking should lead to efficiency gains due to the elimination of process steps, but may require further study to determine the efficacy in lean warehousing or may require additional process stability to reduce the negative correlations found. Consequently, cross-docking needs to be further analyzed and potentially eliminated from further assessment applications. These lean practices are often fundamental in identifying problems and getting people engaged in reducing process variability.

Component Three – Pull Systems

The significant correlations for component three were Pull Systems, Kanban Systems, Cellular Structure, and Statistical Process Control. The third component explained 8.7% of the variance observed in the data. This component seems to be primarily measuring an underlying factor related to the basic lean principle of pull systems. Pull systems are a basic principle of lean discussed by Ohno (1978) utilizing the techniques of kanban systems and cellular structures. Interestingly, statistical process control was found to be highly correlated to this factor which may be a result of the requirement to have a strong quality measurement system to ensure output meets requirements when leveraging pull systems to ensure defects are not passed to the next process and quality is built in.

Component Four – Standardized Processes

The significant correlations for component four were Batch Sizes, Standard Work Dispatches, Travel Distance, Leveled Flow and Work, and Process Control Boards. The fourth component explained 7.8% of the variance observed in the data from the analysis. This component seems to be primarily measuring an underlying factor related to the basic lean principle of standardized processes which was another key principle identified by Ohno (1978). The development of standardized processes involves determining consistent batch sizes and standardized work dispatches to manage work. Subsequently, the development of standardized processes leverages process control boards to communicate the progress towards plan and identify variances to plan. The variances to plan can be root-caused and the problem solving process can occur. These practices enable the leveling of material flow and work, while reducing travel distance, one of the forms of waste, by grouping similar types of work.

Component Five – Customer Integration

The significant correlations for component five were Plan-Do-Check-Act (PDCA) and negatively Visual Controls, Load and Unload Processes, and Supplier Integration. The fifth component explained 6.7% of the variance observed in the data for measuring lean warehousing. This component seems to be primarily measuring an underlying factor related to the basic lean principle of customer integration which was observed in the Plan-Do-Check-Act (PDCA) continuous improvement plan development. Interestingly, PDCA was negatively correlated with visual controls, load and unload processes, and supplier integration. The negative correlations may be explained by the limited customer involvement in driving standard load and unload processes and supplier integration in many of the samples. By incorporating the PDCA cycle into the development of these processes, this impact could be reduced. Further, potential customer integration benefits have to be weighed against increased total costs of transportation at shipping points to drive reductions in costs at the subsequent downstream warehouses and their processes by incorporating them into the continuous improvement process.

Component Six – Quality Assurance

The significant correlations for component six are Cleanliness, Inventory Integrity, Quality Measurement Statistics, Product and Process Quality, and Metrics and KPI Boards. The sixth component explained 5.9% of the variance observed in the data. This component seems to be primarily measuring an underlying factor corresponding to basic lean principles in relation to quality assurance within processes, inventory, and workplace organization. This factor relates the high correlation of workplace organization and cleanliness, inventory integrity, and product and process quality. Quality assurance is attained through the lean practices of quality measurement statistics and metrics and key performance indicator boards which communicate the status towards plan of important warehouse measurements. Workplace organization and cleanliness have been correlated to increased quality in processes due to the structure and discipline developed in 5S as part of lean warehousing.

Component Seven – People

The significant correlations for component seven were Teamwork and Empowerment, Employee Recognition, and Leadership Roles. The seventh component explained 5.3% of the variance observed in the data in this analysis. This component seems to be primarily measuring an underlying factor related to the basic lean principle of people. The lean principles of teamwork and empowerment, employee recognition, and leadership roles all relate to the interaction of management and associates in the warehouse. Furthermore, employee empowerment and employee engagement were identified by Liker (2004) as a fundamental principle of implementing lean through problem solving techniques and increasing individual responsibility to associates.

Component Eight – Inventory Management

The significant correlations for component eight were Velocity Slotting, Layout and Zones, and Routing Travel. The eighth component explained 4.6% of the variance observed in the data. This component seems to be primarily measuring an underlying factor related to the basic lean warehousing principles of inventory management for velocity slotting, layout and zones, and routing and travel paths. This component measures the importance in managing efficiency and reducing worker travel due to the dynamic nature of warehousing and responding to changes in customer demand. Obviously, in warehousing, inventory management is of particular importance; the associated lean practices have similar importance.

Component Nine – Material Flow

The significant correlations for component nine were Lead Time Tracking and Inventory Turns. The ninth component explained 4.1% of the variance observed in the data. This component seems to be primarily measuring an underlying factor related to basic lean principles of material flow where lead times are tracked and inventory turns managed at the process level, at the function level, and at the warehouse inventory reorder points. Managing material and inventory flow reduces the amount of work in process and manages inventory levels to reduce congestion and eliminate lean wastes of inventory, overproduction, and travel.

Component Ten – Information Sharing

The significant correlations for component ten were Process Control Boards, Standard Operating Procedures, Employee Suggestions, Five-Why and Root Cause Analysis, and Error Proofing. The tenth component explained 3.7% of the variance observed in the data. This component seems to be primarily measuring an underlying factor related to the basic lean principle of information sharing. Information sharing enables employee empowerment and aligns resources on priorities, processes, and continuous improvement plans. Information sharing empowers employees to understand actual versus planned performance, expectations, and work in process flow. Subsequently, uncovering problems and root cause analysis ensures that resources are focused on continuous improvement and that the most efficient methods for performing tasks are leveraged in standard operating procedures.

Component Eleven – Point-of-Use-Storage

The significant correlations for component eleven were Point of Use Storage and negatively Quick Changeover. The eleventh component explained 3.3% of the variance observed in the data. This component seems to be primarily measuring an underlying factor related to basic lean principle of point of use storage. The practice of storing materials, supplies, and equipment at the point of use drives efficiencies when performing tasks. Interestingly, point-of-use-storage was found to be negatively correlated with quick changeover due to shifting from one function to another which may be due to the amount of employee involvement required to develop strong point of use techniques and then a subsequent reluctance to shift associates to other activities to respond to changes in work flow. This may also be a result of increased training required to perform tasks as work stations become more complicated when performing tasks at the point of use.

Component Twelve – Inventory Strategy

The significant correlations for component twelve were Commodity Grouping and Order Frequency. The twelfth component explained 2.9% of the variance observed in the data. This component seems to be primarily measuring an underlying factor related to the basic lean principle of inventory strategy. Commodity grouping organizes work and inventory into similar elements which increases the accuracy of predicting standardized work elements and the time it takes to complete work. Order frequency reduces the amount of work in process and inventory required to cover up inefficiencies. Both commodity grouping and order frequency are key elements of an inventory strategy in lean warehousing, and it is not surprising that they are correlated in a single component.

Component Thirteen – Employee Development

The significant correlations for component thirteen were Cross-Training and Power Distance. The thirteenth component explained 2.7% of the variance observed in the data. This component seems to be primarily measuring an underlying factor related to the basic lean principle of employee development. Employee development consists of the lean principles of cross-training which enables single employees to perform multiple tasks, and power distance relates to the amount of time managers and supervisors focus on where the work is actually being performed. The correlation of these two elements is not surprising since management needs to be involved in training employees, increasing employee empowerment and shifting resources to respond to changing customer demand.

Component Fourteen– Workplace Organization

The significant correlations for component fourteen were Five S, Signage and Shadow Boards, and Leveled Flow and Work. The fourteenth component explained 2.5% of the variance observed in the data. This component seems to be primarily measuring the underlying factor related to the basic lean principle of workplace organization. Workplace organization was a key element in developing a visual workplace as discussed by Liker (2004) and important to developing a lean warehouse. The lean practices of Five S and signage and shadow boards are tools utilized to drive workplace organization. Similarly, leveled flow and work require the development of visual controls, and workplace organization techniques increase the understanding of where there is work in process to level work flow.

Component Fifteen – Employee Retention

The significant correlations for component fifteen were Absenteeism, Turnover, and Layoffs. The fifteenth component explained 2.4% of the variance observed in the data. This component seems to be primarily measuring an underlying factor related to the basic lean principle of employee retention. Employee retention was measured in lean warehousing by measuring the absenteeism, turnover, and layoff rates in the warehouses sampled. This component measures the importance placed on maintaining a positive work environment without employee fear, job stress, or the displacement of associates. Furthermore, lean warehousing invests more time and training in employees through cross-training and empowerment, making it more important to retain employees, thus creating process experts for problem solving and building in quality.

Component Sixteen – Quality Systems

The significant correlations for component sixteen were Preventative Maintenance and Quality Measurement Statistics. The sixteenth component explained 2.1% of the variance observed in the data. This component seems to be primarily measuring an underlying factor related to the basic lean principle of developing quality systems. Quality systems are developed by quality measurement statistics and managed through the practice of preventative maintenance to drive increased up time of tools, equipment, and machinery. These quality systems enhance the ability to identify additional opportunities for improvement and maintain process stability to root cause errors and to prevent errors from occurring.

Component Seventeen – First-In-First-Out

The significant correlations for component seventeen were First-In-First-Out (FIFO). The seventeenth component explained 1.8% of the variance observed in the data. This component seems to be primarily measuring an underlying factor related to the basic lean principle of first-in-first-out. First-in-first-out is the lean principle for managing material flow and ensuring that material is processed in the same order in which it was planned through the use of visual controls and techniques. When product is planned and processed in line with customer demand in a FIFO manner, pull systems are sustained. This is important in lean warehousing since there are not physical barriers, such as a manufacturing line, to ensure material flow is in line with downstream customer requirements.

Other Lean Practices

The lean practices not found to be significantly correlated in any of the underlying factors measuring lean warehousing were common processes and best practices, communication strategy, value stream mapping, lean tracking, Andon systems, supply and material management, identification of problem parts, and work in process. These results do not mean that they are not important lean practices, rather that there were other lean practices measuring the underlying independent factors. Furthermore, some of these practices may not be as important in measuring lean warehousing versus lean manufacturing, or may be more advanced lean practices than were observed in the data. Consequently, future iterations of the lean implementation assessment tool would not require those evaluation items related to these lean practices, ensuring only significant measures are included. Therefore, fifty of the fifty-eight lean practices were found to be significant for measuring lean warehousing factors.

Revised Lean Implementation Assessment Tool Structure

Based on the results from the factor analysis, a new structure for lean implementation assessment in warehousing was derived and illustrated in Table 26. Only five of the fifty significant lean practices were found to be significantly correlated with more than one of the factors, namely PDCA, travel distance, process control boards, level flow and work, and quality metrics. Consequently, the revised structure of the lean implementation assessment tool and corresponding output could be revised to illustrate the progression on the seventeen significant factors.

Furthermore, the revised structure could help with the development of training modules to correspond to the seventeen factors outlining continuous improvement and problem solving, building in quality, pull systems, standardized processes, customer integration, quality assurance, people, inventory management, material flow, information sharing, point of use storage, inventory strategy, employee development, workplace organization, employee retention, quality systems, and first in first out. Additionally, the lean implementation assessment tool output would provide insight into the progression of each of the seventeen factors and specific actions for further growth and opportunities for improvement.

Table 26: Lean Implementation Assessment Tool Factors and Practices (Items in red are in multiple factors)

Practice / Factor	Lean Practice	Lean Practice	Lean Practice	Lean Practice	Lean Practice
1 Continuous Improvement	(A3) One Page Reports	Management Style	Kaizen Events	Systems View	PDCA
2 Building-in-Quality	Inspection & Autonomation	Technology & Equipment	Demand Stabilization	Safety & Ergonomics	Cross-Docking
3 Pull Systems	Pull Systems	Kanban Systems	Cellular Structure	SPC	-
4 Standardized Processes	Batch Sizes	Standard Work Dispatches	Travel Distance	Leveled Flow & Work	Process Control Boards
5 Customer Integration	PDCA	Visual Controls	Loading and Unloading	Supplier Integration	-
6 Quality Assurance	Cleanliness	Inventory Integrity	Quality Metrics	Product & Process Quality	Metrics & KPI Boards
7 People	Teamwork & Empowerment	Employee Recognition	Leadership Roles	-	-
8 Inventory Management	Velocity Slotting	Layout & Zones	Routing & Travel Paths	Travel Distance	-
9 Material Flow	Lead Time Tracking	Inventory Turns	-	-	-
10 Information Sharing	Process Control Boards	SOPs	Employee Suggestions	5 Why & Root Cause Analysis	Error Proofing
11 Point-of-Use-Storage	Point-of-Use-Storage	Quick Changeover	-	-	-
12 Inventory Strategy	Commodity Grouping	Order Frequency	-	-	-
13 Employee Development	Cross-Training	Power Distance	-	-	-
14 Workplace Organization	Five S	Signage & Shadow Boards	Leveled Flow & Work	-	-
15 Employee Retention	Turnover, Layoffs, & Absenteeism	-	-	-	-
16 Quality System	Preventative Maintenance	Quality Metrics	-	-	-
17 FIFO	FIFO	-	-	-	-

CHAPTER VII
CONCLUSIONS

Introduction

This research provided a common framework and identification methodology for lean warehousing and the corresponding lean principles and lean practices. A lean implementation assessment tool was developed and validated using the comprehensive framework developed in the literature review. The lean implementation assessment tool was applied in twenty-eight warehouses across the United States, Canada, and Europe collecting data and providing actionable feedback to warehouses with regard to lean warehousing implementation. The subsequent data analysis provided further insight into the underlying factors being measured in warehouses implementing lean warehousing and the significant factors associated with measuring lean warehousing. The statistical analysis provided insight into the applicability of the lean practices, potential future research, and a pared down structure for future lean implementation assessments. This section outlines summaries of all the key findings, conclusions, and the corresponding implications on lean implementation assessment and lean warehousing implementation in general.

Literature Review Findings

The literature review and analysis of the key lean authors revealed eight lean principles which were leveraged to organize the structure of the fifty-eight lean practices identified from the literature. The structure developed from examining the lean literature and the theoretical framework of Ohno (1986), Shingo (1989), Womack, Jones, and Roos (1990), Womack and Jones (1996), and Liker (2004) revealed the eight lean principles of standardized work, people, quality assurance, visual management, workplace organization, lot sizing, material flow, and continuous improvement. Fifty-eight corresponding lean practices were identified from the literature review and were stratified into the eight lean principles by topic applicability to provide the structure for the lean implementation assessment tool. A summary of the structure developed can be seen in CHAPTER II, Table 3. The detailed framework developed from the literature operationalized the lean principles and lean practices for the development of the implementation assessment tool. Furthermore, the literature review provided the methodology for conducting the research outlining the required steps.

Lean Implementation Assessment Tool Development

A lean implementation assessment tool was developed using the structure developed in the literature review which can be seen in CHAPTER II, Table 3. The lean implementation assessment tool operationalized the structure of the eight lean principles and stratified fifty-eight lean practices by developing multiple, specific evaluation points for each of the fifty-eight lean practices. The evaluation points developed were a mix of nominal, ordinal, and interval measures designed to measure the implementation levels of each lean practice corresponding to the lean constructs identified.

Consequently, the lean implementation assessment tool was comprised of two-hundred-eight individual evaluation points which were assessed for six key functions identified in warehousing operations. The six key major functional areas applicable within each warehouse were inbound operations, outbound operations, inventory control, material returns, general facility operations, and warehouse office functions. The corresponding scores and totals were tabulated into various graphs by total, lean construct, lean principle, and function to provide graphical representation and identification of opportunities and strengths for feedback and data collection. The intent of the lean implementation assessment tool was to provide useful and specific ideas for further lean warehousing implementation in industry.

Data Collection

The lean implementation assessments were completed in twenty-five different warehouses with twenty-eight samples across the United States, Canada, and Europe within the Menlo Worldwide organization throughout the calendar year of 2007. The warehouses examined had various exposures and implementation levels of lean warehousing principles and practices with varying degrees of success. The eight lean constructs, fifty-eight lean practices, and two-hundred-eight individual evaluation points were examined for each of the applicable six functional areas during each of the twenty-eight lean implementation assessments conducted.

The data collected resulted in 9,744 individual evaluation points, 1,624 compiled lean practice scores, and 224 overall construct scores for the twenty-eight lean implementation assessments completed. The assessments were completed by individual assessors and groups of assessors each with the participation of warehouse managers, lean coordinators, and relevant associates. The impact of assessor and inter-rater agreement was not found to be significant, but the lean implementation assessment tool was found to be applicable across warehouse industries, technologies, and geographical regions. Consequently, different assessors do not drive statistically significantly different results in assessments ensuring the lean implementation assessment tool can be used accurately by different assessors and provide accurate results.

Tool Validity

The lean implementation assessment tool development and structure followed the types of validity outlined in Babbie (2004). Face, criterion, construct, and content validity were addressed in the identification of the eight lean constructs and fifty-eight lean practices and operationalization into the two-hundred-eight evaluation items. An expert panel of lean warehousing professionals was leveraged to further examine the lean implementation assessment tool validity and gather feedback from usage and implementation of the feedback from the lean implementation assessment tool. The validity was analyzed by the expert panel and through statistical analysis to ensure the actual lean implementation assessment tool output measured the intended lean constructs and lean practices.

The output was found to be consistent with subjective analysis by the lean expert panel and the effect of the assessor was not found to be statistically significant. These results confirm the methodology and validity for developing the lean implementation assessment tool, the operationalization of the lean constructs and lean practices, and the data collection practices measured the intended concepts associated with lean warehousing.

Statistical Analysis

The statistical analysis examined the descriptive statistics for Range, Minimum, Maximum, Mean, Standard Deviation, Variance, Skewness, and Kurtosis statistics for each of the lean practices developed and corresponding evaluation points. The data were checked for normality, correlation, and interdependency before conducting factor analysis as described by Johnson (1998). Finally, factor analysis was performed for sixteen factors and seventeen significant factors and the corresponding outputs examined including the Scree Plot, QQ-Plots, Principal Components Analysis, and Rotated Components Matrix. It was found that seventeen significant factors best described the data collected and were subsequently used for drawing conclusions and making inferences about lean warehousing.

Results

Various numbers of underlying factors were examined in detail, and it was found that seventeen underlying factors best described the variance observed in the data and fit the data. From the Factor Analysis, there were seventeen significant factors observed in the data measuring lean warehousing related to continuous improvement and problem solving, building in quality, pull systems, standardized processes, customer integration, quality assurance, people, inventory management, material flow, information sharing, point of use storage, inventory strategy, employee development, workplace organization, employee retention, quality systems, and first in first out.

Furthermore, the lean practices for each of the underlying factors were found to be significant based on the significant correlation coefficients greater than 0.5 for each of the significant factors. The significant lean practices were determined by examining the rotated component matrix for the model with seventeen significant underlying factors and provided the corresponding framework to interpret the results, draw conclusions, and make inferences for future research.

What Tools When???

The framework presented in this research provides insight into the seventeen underlying factors describing the variance in the data from the twenty-eight lean implementation assessments conducted. This framework provides additional insight into the importance of the progression of lean warehousing implementation for training and subsequent lean implementation assessments. The seventeen significant underlying factors determined are a key finding of this research and provide the framework for analyzing the results, making conclusions, and driving future research in lean warehousing.

Consequently, from the Factor Analysis, the seventeen significant factors observed in the data measuring lean warehousing related to continuous improvement and problem solving, building in quality, pull systems, standardized processes, customer integration, quality assurance, people, inventory management, material flow, information sharing, point of use storage, inventory strategy, employee development, workplace organization, employee retention, quality systems, and first in first out. Subsequently, training and implementation techniques could leverage these seventeen factors and importance be placed on the lean practices corresponding to their significance.

The most significant factor found for assessing lean warehousing was related to continuous improvement and problem solving, which correlated most significantly to (A3) One Page Reports, Management Style, Kaizen Events, Systems View, and Plan-Do-Check-Act (PDCA). Thus, these lean practices were found to be fundamental to implementing lean warehousing principles, and a corresponding importance should be placed on them when training managers, supervisors, and associates. This indicates that the process of continuous improvement and problem solving through engaging employees is more significant than the other specific lean practices. The continuous improvement and problem solving factor outlines the underlying philosophy and methodology for applying the other lean practices. Furthermore, continuous improvement and problem solving techniques were specifically identified as a fundamental principle of lean manufacturing by all five authors, Ohno (1986), Shingo (1989), Womack et al. (1990), Womack and Jones (1996), and Liker (2004), as seen in Table 1 in CHAPTER II.

Additionally, only five of the fifty significant lean practices were found to be significantly correlated with more than one of the factors, namely PDCA, travel distance, process control boards, level flow and work, and quality metrics. These results confirm the importance of these lean practices in more than one of the underlying factors and that their evaluation points may be measuring more than one underlying factor. Consequently, subsequent lean implementation assessment tool development should take these results into account and try to isolate the evaluation points to the underlying factors or to develop training and implementation techniques for the lean practices specifically related to each of the underlying factors.

The lean practices not found to be significantly correlated in any of the underlying factors measuring lean warehousing were common processes and best practices, communication strategy, value stream mapping, lean tracking, Andon systems, supply and material management, identification of problem parts, and work in process. These lean practices may be higher level lean concepts that were either not yet being leveraged as intended in the warehouses examined, measured as intended by the lean implementation assessment tool, or not significant practices in lean warehousing. Consequently, the results examined in detail found that most of these lean practices were being used in many of the warehouses examined and are a significant part of implementing lean warehousing at the organizations examined.

For example, value stream mapping is conducted as an instrumental lean practice in developing the continuous improvement plans for all the warehouses examined at Menlo Worldwide. It may be that these lean practices were equally leveraged and consequently not significant for explaining the variance in the data, but are important from a planning and strategy deployment perspective. Additional research would need to be conducted to determine whether or not these lean practices should be measured and are leveraged similarly in other organizations.

Conclusions

In conclusion, after examining the literature, developing the lean implementation assessment tool, collecting data, and performing statistical analysis, it was found that the most significant factor related to measuring lean warehousing was continuous improvement and problem solving. This key underlying factor was highly correlated to the lean practices of (A3) One Page Reports, Management Style, Kaizen Events, Systems View, and Plan-Do-Check-Act (PDCA) which are fundamental practices of lean warehousing.

It is not surprising that these are the most significant lean practices since (A3) One Page Reports provide formal documentation and structure for facilitating and communicating Kaizen Events in the Plan-Do-Check-Act (PDCA) methodology. Furthermore, Management Style and Systems View are related to these lean practices by understanding how the different functions and pieces fit together, while engaging employees from different functions in continuous improvement activities. The lean warehousing philosophy is fundamentally about continuous improvement and getting people involved in driving continuous improvement, while the other lean practices, tools, and techniques are specific methods for driving out specific wastes as they are observed.

Consequently, it follows that building in quality, pull systems, standardized processes, customer integration, and the other underlying factors measuring lean warehousing would explain less of the variance observed in the data. Therefore, the training and implementation strategy should be tailored to match the amount of variance explained for each of the underlying factors and corresponding lean practices in the same progression. This approach would provide a foundation and structure for continuous improvement to occur and then build upon that with more specific tools and techniques to eliminate waste by building in quality, developing pull systems, and the like. The approach would leverage the lean philosophy and then the application of the specific tools based on specific business requirements, customer involvement, and prioritization developed in the continuous improvement plan for each facility.

Research Questions

The main research question in this dissertation was to determine which underlying factors were sufficient for assessing lean manufacturing implementation and usage in traditional, manual warehousing environments. This was done through the operationalization of the lean constructs and lean practices identified in the literature and the subsequent development of the lean implementation assessment tool and evaluation points, then applying the tool in twenty-eight warehouses.

Furthermore, the data gathered from the application of the lean implementation assessment tool allowed for detailed multivariate statistical analysis, which identified seventeen underlying and interrelated factors significant for measuring lean principles and practices in warehousing. The comprehensive list of lean principles and corresponding lean practices identified from the literature was then pared down based on multivariate statistical analysis and the resultant list compared to the comprehensive list. Furthermore, the data analysis conducted addressed any differences in means between assessors and any impact on potentially subjective evaluation points on the overall assessment of facility lean implementation and usage and found not to be significant. The comprehensive approach taken ensured that the lean implementation assessment tool provided valid and reliable output for analysis and actionable output for managers implementing lean in their warehouses.

The intent of this research was not only to develop a lean implementation assessment tool and better understand lean principles and practices, but to provide useful output for lean warehousing implementation in practice. The specific identification of lean principles, lean practices, and evaluation points provide the input for actionable output and understanding of implementation progress and a method for comparison between facilities. Furthermore, the statistical analysis provided additional insight into the training and implementation strategies that should be employed for implementing lean warehousing.

Implications

The main implication from this research is that the specific tools applied in lean warehousing are not as significant as providing the programmatic approach to problem solving and continuous improvement inherent in the lean principles. Consequently, the most significant factors in measuring lean warehousing are developing a continuous improvement plan, conducting continuous improvement activities (Kaizen events), and getting people engaged in the continuous improvement process. The other lean principles and lean practices can be applied in subsequent continuous improvement activities as wastes are identified and prioritized based on the specific circumstances inherent in each facility.

These results follow the observations from the application of the lean implementation assessment tool in practice since some warehouses excelled at implementing standardized work, while others did well in visual management, or various combinations of the lean principles and lean practices. The various combinations of successful implementation of the lean principles and lean practices all did have a common theme, a programmatic approach to continuous improvement and problem solving. This programmatic approach observed leverages the five significant lean practices identified from the factor analysis (A3) One Page Reports, Management Style, Kaizen Events, Systems View, and Plan-Do-Check-Act (PDCA). Subsequently, it is the continuous improvement and problem solving approach that is the most significant underlying factor for implementing lean warehousing, not necessarily one of the specific lean tools.

Future Research

This research has provided the framework for the development of a pared-down and updated lean implementation assessment tool operationalized into the seventeen factor structure identified through the multivariate analysis. The results of this future analysis would be communicated and incorporated into further development of lean implementation assessment tools, warehouse continuous improvement plans, and lean implementation strategies. Furthermore, incorporating additional applications and providing feedback to warehousing managers implementing lean principles and lean practices over time will provide additional insight into the progression of lean warehousing implementation. Additionally, the training programs developed for lean warehousing implementation can leverage these results and be structured accordingly. The efficacy of the results and applications can be compared to future lean implementation assessment scores, comparisons, and data analysis to determine if the conclusions found in this research remain valid or if continuous improvement is required.

Additionally, there are numerous other non-traditional industries beginning to implement lean principles and lean practices outside of manufacturing that require the same detailed analysis and corresponding feedback as developed in this analysis and provided by the lean implementation assessment tool. Many office functions are implementing lean manufacturing principles, such as transportation management services, and information technology services. The same questions need to be answered for these industries through the development of a comprehensive analysis of the lean principles and practices and the development of an industry specific lean implementation assessment tool that provides actionable output for managers implementing lean. Any subsequent statistical analysis will provide direction identifying the underlying factors, applicable lean practices, and implications for lean implementation strategies.

This analysis provides the framework, methodology, and analysis to conduct future research in lean warehousing and in other industries implementing lean manufacturing principles and concepts. Specific lean principles and lean practices can be implemented and developed following a similar approach of continuous improvement and problem solving through engaging the people doing the work with similar success. The identification of best practices and communicating the progress to management over time will provide better information for making resource allocations and decisions about the success of the lean implementation initiatives.

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APPENDICES

APPENDIX A:
LEAN IMPLEMENTATION ASSESSMENT TOOL

Following are the details for the two-hundred eight evaluation points developed for the fifty-eight lean practices and eight lean constructs identified in this research. Furthermore, the following outlines the purpose, methodology, and location for measuring each individual evaluation point for all of the lean constructs and lean practices identified. This information is to help the assessor to perform the lean assessment and provide additional insight to facility personnel when implementing the various lean principles and practices. The lean implementation assessment tool used in this research was completed for each of the items in a Microsoft Excel workbook and scoring tabulated for each.

Each of the lean constructs and lean practices were assessed for all the major functional areas identified within a warehouse, namely inbound operations, outbound operations, inventory control, material returns, general facility operations, and warehouse office functions. The lean implementation assessment tool evaluation items developed required the use of a combination of nominal, ordinal, and interval measurement items, scaled to identify specific levels of implementation of the various lean constructs within the different facility functions. This methodology was followed for each of the twenty eight lean implementation assessments conducted for this research and the corresponding feedback summarized for each warehouse.

Standardized Processes:

	Item	Evaluation Point	Purpose	Methodology	Where?
SOPs	**Exist**	Are there current SOPs for each major operation/process in each function? (0 = No, there aren't current/existing SOPs.) (1 = Yes, there are some current SOPs created for some major processes.) (2 = Yes, there are current SOPs created for all major processes.)	To create documented standard processes for all operators to perform each operation with the same best method with minimal process variation facilitating process improvement.	Verify existence of SOPs posted, in books, files, etc. Confirm current processes match SOPs by evaluating audit information, process observation, and discussion with personnel.	Floor
	Posted	Are there current SOPs posted for each major operation/process in each function? (0 = No, there are not existing and/or current SOPs posted.) (1 = Yes, there are current SOPs posted for each of the major processes.)	To provide visual direction and reminders to workers about the proper work practices and processes to be performed.	Look in individual areas for posted SOPs in general vicinity where the operations are being performed.	Floor
	Audit	Are there regular SOP audits conducted of each major operation in each function, particularly key workers and processes. (0 = No, SOP audits are not conducted..) (1 = Yes, some SOP audits are conducted.) (2 = Yes, many SOP audits are conducted regularly & results documented, monthly.)	To ensure operators are following SOPs, that SOPs are current, operators are trained properly, facilitate continuous improvement, identify best practices, & validate effectiveness.	View supervisor or SOP auditor documentation, results, pareto analysis of problems. Verify audits are performed regularly through conversations with manager, supervisor, and employees.	Floor
	Development	What level of worker/team lead/supervisor participation is there in creating the SOPs? (0 = None) (1 = Developed Externally) (2 = Internal Facility Coordinator) (3 = Individual Area Supervisor) (4 = Supervisor & Team Lead) (5 = Management, Team Lead, & Workers)	Involving operators in SOP development encourages continuous improvement, empowers workers to make decisions about work practices, enhances process ownership, and idea sharing.	Verify authorship of SOPs, through documentation and communication with manager, supervisors, and workers.	Floor
	Exceptions, Priorities, etc.	Do the SOPs address exception processes, priority processes, and other activities? (0 = No, SOPs are not developed and/or do not address exceptions, priorities, etc.) (1 = Yes, SOPs address some exceptions.) (2 = Yes, SOPs address most exceptions, priority, and other unique activities.)	Unique, exception , priority, and other activities need to be addressed in SOPs to ensure workers understand what the processes are associated with handling those activities.	Verify SOPs address unique activities, through documentation and communication with manager, supervisors, and workers.	Floor
	SOPs				

	Item	Evaluation Point	Purpose	Methodology	Where?
Standardized Work Cycles, Dispatches, Planning	**Exist**	Are there standardized work dispatches, units, etc. for each major function process? (0 = No, there is not standardized work.) (1 = Yes, there are some standardized work units, etc. for major processes.) (2 = Yes, there are standardized work units, etc. for all major processes.)	Standardized work units determine process pace, timing expectations, enhances process understanding of variability and stability, allows planning, tracking, etc.	Verify by examining visual management tools, process control boards, dispatch boards, planning, etc. in each area.	Floor
	Cycle Lengths	What are the standardized work unit planned cycle lengths? (0 = None) (1 = >60 Minutes) (2 = 30 - 60 Minutes) (3 = 20 - 30 Minutes) (4 = 15 - 20 Minutes) (5 = < 15 Minutes)	Smaller standardized work cycle lengths increase process resolution, bring problems to surface quicker, reduce batch sizes, queuing, and WIP.	Verify through visual management tools, process control boards, dispatch quantities, etc. in each area.	Floor
	Dispatch Sizes	How were the dispatch sizes determined? (0 = There is not standardized work units determined for processes.) (1 = Using a "rule of thumb" methodology.) (2 = Balancing operator travel, process resolution & accuracy, and unit of time accountability & planning.)	Balancing dispatch sizes with worker travel and process resolution, accuracy, etc. minimizes wastes due to WIP, inventory, variation, travel time, batching, queue time, etc.	Discuss dispatch creation process with process improvement coordinator, manager, supervisor, and workers. Examine documentation and analysis for determining unit size.	Office or Floor
	Daily Work Planned by Dispatches	Are the daily work activities planned using the standardized work units, dispatches, setting targets & tracking progress, etc.? (0 = No, the daily activities are not planned using the standardized work dispatches.) (1 = Yes, the daily activities are planned using the standardized work dispatches.)	Planning the daily work based on standardized work units increases visibility for determining individual, departmental, and functional status versus expectations, manpower adjustments, etc.	Verify through visual management tools, process control boards, work dispatch processes, etc. in each area.	Floor
	Work Flow Planned for Day	Are the daily work activities planned to balance manpower and work flow between processes/operations in each function? (0 = No, the daily work activities are not planned for the day within each function.) (1 = Yes, the daily work activities are planned for the day within each function.)	To balance and plan the progression of work flow sequentially from dispatch, travel, return, etc. for the individual processes in each function throughout the warehouse.	Verify through visual management tools, process control boards, manpower planning in each area of the work and manpower planning, dispatching, etc.	Floor
	Work Flow Leveled Between Areas	Are the daily work activities balanced between each area, leveling the flow between processes, workers, areas, etc.? (0 = No, daily work activities aren't leveled between processes, workers, & areas.) (1 = Yes, daily work activities are leveled between processes, workers, & areas.)	To plan start time, end time, balanced flow, activities, manpower, etc. for each individual operation & process to balance the flow within the entire function.	Verify through visual management tools, process control boards, manpower planning between areas and functions of the work and manpower planning, dispatching, etc.	Floor
	Item	**Evaluation Point**	**Purpose**	**Methodology**	**Where?**

Commodity Grouping	**Work Delineated by Commodity**	Are the standardized work units delineated by commodity or work type groupings? (0 = No, the standardized work units are not delineated by similar work types.) (1 = Yes, some work units are grouped.) (2 = Yes, most work units are grouped by type of work, commodity, etc.)	The variation in expectations and differences among work units types can be minimized by grouping similar work unit types and developing corresponding standards for the work units.	Work unit delineations can be seen from manpower planning, process control boards, dispatch boards, etc. based on variation in daily work activities and separation of similar work.	Floor
	Standards Developed for Different Commodities	Are there separate standard time unit expectations for the corresponding separate standardized work unit delineations? (0 = No, there are not separate standards for the different types work units.) (1 = Yes, there are separate standards for the different types work units.)	Separate standards for the different work unit types increase planning accuracy and understanding in the variation of daily work activities and manpower requirements.	Work unit delineations can be seen from manpower planning, process control boards, dispatch boards, etc. based on variation in daily work activities and separation of similar work.	Floor
	Commodity Grouping				
Common Processes & Best Practices	**Identified**	Are best practices identified for common functions and processes within each work area, i.e. exception processes, follow-up items, special actions, supplies, etc.? (0 = No, best practices are not identified.) (1 = Yes, best practices are identified.)	The use of common processes encourages each function to use the best possible method for any given process.	Verify best practices exist for common processes, the identification methodology, communication procedures, and documentation.	Floor
	Followed & SOPs	Are best practices followed and reflected in the all the pertinent SOPs for each area? (0 = No, best practices are not identified, followed, or reflected in the SOPs.) (1 = Yes, best practices are identified, followed, and reflected in the SOPs.)	Following the best practice and reflecting it in the SOP ensures the best method is being utilized for each process.	Cross-check SOPs between functions for common processes and verify best practice is being utilized by workers through observation and communication with supervisors and workers.	Floor
	Shared Internally	Are best practices regularly discussed and shared internally between functions? (0 = No, best practices are not identified.) (1 = Yes, some best practices are discussed informally by the manager or supervisors.) (2 = Yes, all best practices are formally captured by the manager or supervisors.)	Communicating best practices within the facility enhances continuous improvement in all areas, increasing input from all functions, and reducing overall waste in the facility.	Discuss the methodology for determining and sharing best practices within the facility with manager, supervisors, workers, meeting frequency, and best practice analysis procedures.	Office or Floor
	Shared Externally	Are best practices regularly shared externally between facilities & operations? (0 = No, best practices are not discussed.) (1 = Yes, some best practices are discussed informally, externally between facilities.) (2 = Yes, all best practices are formally discussed externally between facilities.)	Communicating best practices across facilities enhances continuous improvement throughout the organization, reducing overall waste, shared ideas, learnings, etc.	Discuss the sharing process between facilities, the methodology for determining best practices, etc. with managers and supervisors, the meeting frequency, and best practice analysis.	Office
	Item	**Evaluation Point**	**Purpose**	**Methodology**	**Where?**
	Trailer	Are trailers received pre-sorted, pre-	Standardized receiving	Determine if inbound	Dock

	Receiving	staged, etc. to match inbound processes? (0 = No, trailers are not pre-sorted.) (1 = <20%, Seldom) (2 = 20%-40%, Occasionally) (3 = 40% - 60%, About Half) (4 = 60% - 80%, Usually) (5 = >80%, Always)	trailers allows for predictability in unloading processes, decreasing variation in times, and enhancing planning functions.	material is presorted to receiving specifications to minimize handling, etc. of receiving material.	
	Trailer Shipping	Are trailers shipped pre-sorted, pre-staged, etc. to match downstream processes? (0 = No, trailers are not pre-sorted.) (1 = <20%, Seldom) (2 = 20%-40%, Occasionally) (3 = 40% - 60%, About Half) (4 = 60% - 80%, Usually) (5 = >80%, Always)	Staging and shipping standardized trailers minimizes handling at the shipping dock and reduces downstream handling, etc. for the customer.	Determine if outbound dispatches are organized based on shipping staging and loading requirements to minimize handling, etc.	Dock
	Trailer Loading & Unloading				
Routing & Travel Paths	**Facility Travel Paths Determined by Type**	Are the picking and put-away travel paths determined by part type delineations, commodity , similar work types, etc.? (0 = No, similar work is not grouped.) (1 = Yes, some similar work is grouped.) (2 = Yes, most similar work types are grouped for routing, travel paths, etc.)	Leveraging similarities among parts reduces the amount of variation within standard work units and daily work activities, by grouping similar work types together.	Determine if the dispatching and put-away procedures group similar work types automatically or manually during sortation procedures.	IC & Floor
	Facility Travel Paths Determined by Velocity	Are the picking and put-away travel paths leveraged by movement and sales velocity to minimize travel distances/frequencies? (0 = No, the routing and travel paths static regardless of movement & sales velocity.) (1 = Yes, the routing and travel paths dynamic with movement & sales velocity.)	Leveraging work movement and sales velocity of parts reduces travel time to warehouse locations by having high volume & traffic parts located near final destinations.	Determine if routing and travel paths use serpentine calculations to account for movement and volume to minimize travel distances and if inventory locations are dynamic with item velocity.	IC & Floor
	Customer Delivery Routes	Are delivery routes for customers set up on "milk runs" for daily, frequent delivery? (0 = No, customer delivery routes are static and/or are not frequent delivery runs.) (1 = Yes, customer delivery routes are set up using a "milk run" methodology for frequent delivery, leveling facility demand.)	"Milk run" delivery systems allows for maximum responsiveness to customers for frequent order delivery, reducing inventory requirements, and balancing batching and queuing.	Examine customer delivery frequency and patterns used for the facility.	Floor & Office
	Routing & Travel Paths				

People:

	Item	Evaluation Point	Purpose	Methodology	Where?
Safety & Ergonomics	**Safety Practices, Processes, & Procedures**	Employee's have a formal avenue to openly voice, share, and regularly address safety concerns at the facility. (0 = No, Not Present.) (1 = Yes, Captured.)	Providing an avenue for employees to share concerns regarding safety allows for increased visibility to potential problems and prevent potential incidents.	Exhibited through facility or departmental safety teams, organized First Responder Teams with regular meetings, cross-functional participation to capture specific concerns.	Office
		Employee safety is addressed formally by supervision and management in meetings. (0 = Not Addressed) (1 = Overall Monthly) (2 = Overall Bi-Monthly) (3 = Departmentally Weekly) (4 = Departmentally Bi-Weekly) (5 = Departmentally Daily)	Maintaining a safe work environment is fundamental to the overall goals of respecting people, maintaining integrity, continuous improvement, and making overall progress.	Observed in morning meetings by evaluator, informal discussions with supervisors and workers, and management planning activities.	Office & Floor
		Safety concerns are addressed in a timely manner by a cross-functional, integrated team of employees, supervision, and management. (0 = Never) (1 = Seldom) (2 = Occasionally) (3 = Half the Time) (4 = Usually) (5 = Always)	Illustration that supervision and management take safety concerns seriously and adequately address problems as they arise.	Captured with meeting frequency, action items from meeting minutes, and resolution times observed from action item outcomes of safety meetings.	Office & Floor
	Recordables	Safe work practices are followed consistently. The number of lost work days and recordables during the last year: (0 = >Five Incidents/Not Visually Tracked) (1 = Four Incidents) (2 = Three Incidents) (3 = Two Incidents) (4 = One Incident) (5 = No Incidents)	Employee actions are consistent with safe work practices, adhered to consistently, and enforced consistently by employees, supervisors, and management.	Observed through recordable injuries and lost work time data occurrence frequencies.	Office & Floor
	Safety & Ergonomics				

	Item	Evaluation Point	Purpose	Methodology	Where?
Leadership Direction/Roles	**Leadership Direction and Change Initiation**	Was the lean change initiative originated within the facility or driven externally. (0 = No, the lean implementation initiative is driven by an external champion.) (1 = Yes, the lean implementation initiative is driven by an internal champion.)	Having an internal lean champion and advocate within the facility ensures constancy of purpose and sustaining effort for improvements.	Observe and question who dictates and initiates lean changes that are to be made within the facility.	Lean Tracking Area and Floor
		What organizational levels originated, supported, and have advocated the lean implementation initiative in the facility? (0 = None) (1 = Corporate Directive) (2 = Facility Manager) (3 = Supervisors) (4 = Facility Manager & Supervisors) (5 = Management and Associates)	The dissemination of the lean implementation initiative throughout the organization encourages participation from all employees, illustrating the importance and long-term focus.	Observed through level of involvement and participation in lean activities and training, and who initiates/involved in lean support for projects and improvements.	Lean Tracking Area and Floor
	Urgency	The sense of urgency and understanding of need to implement lean. (0 = None) (1 = Very Little, Manager) (2 = Little, Some Supervisors) (3 = Somewhat, All Supervisors) (4 = To A Great Extent, Team Leads) (5 = Completely, Employees)	Implementing Lean principles has to be an important objective for the personnel involved for successful implementation and containment.	Observation of facility dynamics, personnel responsible for project action items, informal discussion with employees, supervisors, and manager.	Lean Tracking Area and Floor
	Leadership Roles and Change Participation	Lean implementation activities are conducted, orchestrated, participated in by what organizational level in the facility? (0 = None) (1 = Corporate) (2 = Facility Manager) (3 = Supervisors) (4 = Facility Manager & Supervisors) (5 = Management and Associates)	Cross-functional and multi-level involvement encourages all employees to participate in continuous improvement activities, providing additional ideas, solutions, and feedback.	Observe who facilitates and participates in Kaizen events and other change or improvement activities.	Lean Tracking Area and Floor
	Percent of Continuous Improvement Activities Initiated by Workers	The percent of continuous improvement activities initiated by workers. (0 = None) (1 = <10%) (2 = 10% - 20%) (3 = 20% - 30%) (4 = 30% - 40%) (5 = >40%)	Worker involvement is important to sustaining improvements and empowering the workforce.	Observed through formally documented suggestions, suggestion process, and the corresponding implemented suggestions.	Office, Lean Tracking Area, or Floor
	Leadership Direction/Roles				

	Item	Evaluation Point	Purpose	Methodology	Where?
Management Style	**Autocratic or Democratic**	Feedback and concerns are encouraged and included before making changes and taking actions. (0 = None) (1 = Very Little, Manager) (2 = Little, Supervisor Involved) (3 = Somewhat, Team Lead Involved) (4 = To A Great Extent, Many Employees) (5 = Completely, All Affected Employees)	Input, feedback, and concerns are valued from all levels of the organization increasing employee buy-in and uncovering potential problems/concerns before implementation..	Observed through Kaizen and change project participation, who the lean champions and change project item owners, and subjectively in informal discussions with manager, supervisor, and employees.	Office & Floor
	Bureaucratic	Employees, Supervisors, and Managers are encouraged to try improvement ideas, to encourage innovation and creativity to enrich job responsibilities. (0 = Formal) (1 = Verbal Corporate) (2 = Manager) (3 = Supervisor) (4 = Team Lead) (5 = Individual Authority)	The current state, barriers and roadblocks to continuous improvement are constantly being challenged in a fear-free environment with creative problem-solving, innovation, and minimal bureaucracy.	Subjective assessment of organizational fear and limitations present for individuals to openly try improvement ideas without formal documentation and justification, within reason.	Office & Floor
	Improvement Goal Setting Process & Support	The organizational level involved in determining facility, function, and department goals. (0 = None) (1 = Corporate) (2 = Facility Manager) (3 = Supervisors) (4 = Facility Manager & Supervisors) (5 = Management and Associates)	Manager, supervisor, and employee participation in determining facility goals empowers employees, enhances achievement feasibility, and increases buy in.	Gathered from lean plan progress, tracking, and action item owners. Verified through informal conversations with employees, supervisors, and managers.	Office & Floor
	Goal Attainment Process & Support	The organizational level involved in identifying improvement activities to achieve facility, function, and department goals. (0 = None) (1 = Corporate) (2 = Facility Manager) (3 = Supervisors) (4 = Facility Manager & Supervisors) (5 = Management and Associates)	Manager, supervisor, and employee participation in determining facility goal attainment process further empowers employees, enhancing achievement feasibility, and increases buy in.	Gathered from lean plan progress, tracking, and action item owners. Verified through informal conversations with employees, supervisors, and managers.	Office & Floor
	Management Style				

	Item	Evaluation Point	Purpose	Methodology	Where?
Cross-Training	**Cross-Training Matrix**	Are employee functional job training activities visual tracked with a cross-training matrix? (0 = No, Cross-training are not tracked and/or not current.) (1 = Yes, Cross-training activities are tracked and current.)	Visual Management of Cross-Training allows management to assess employee abilities at-a-glance to level flow and manpower plan within and between each function in the facility.	Existence of Cross-Training Matrix Boards for functions updated monthly. Random employees informally asked about cross-training activities to ensure board is accurate and current.	Floor at Board
	Workers Cross-Trained Within Functions	What percentage of employees have been cross-trained to perform additional functions within of their primary function? (0 = None) (1 = <20%) (2 = 20% - 40%) (3 = 40% - 60%) (4 = 60% - 80%) (5 = >80%)	Encourages manpower planning, analysis, and sharing to level work flow within each functional area.	Information captured from Cross-Training Matrix Board in each department.	Floor at Board
	Workers Cross-Trained Across Functions	What percentage of employees have been cross-trained to perform additional functions outside of their primary function? (0 = None) (1 = <20%) (2 = 20% - 40%) (3 = 40% - 60%) (4 = 60% - 80%) (5 = >80%)	Encourages manpower planning, analysis, and sharing to level work flow across each functional area.	Information captured from Cross-Training Matrix Board in each department.	Floor at Board
	Cross-Training				
Teamwork, Team Leaders, & Empowerment	**Work Teams Utilized for Daily Activities**	Daily work activities are organized into team functions. (0 = Daily work team structure does not exist.) (1 = Daily work team structure exists.)	Team-based activities provide enriched work environments and enhance problem-solving activities.	Organizational structure defines existence of teams and specific functions.	Office & Floor
	Team Lead Functions	Team leads are utilized as initial point of contact for problem-solving, resolution, and employee directing activities. (0 = N/A) (1 = <20%, Seldom) (2 = 20%-40%, Occasionally) (3 = 40% - 60%, About Half) (4 = 60% - 80%, Usually) (5 = >80%, Always)	Team leads provide support to solve low-level problems without involving supervision. Supervisors are otherwise freed to focus on facilitating continuous improvement and growth.	Through random observation of area as problems arise, degree to which team leads are leveraged, and informal conversation with employees, team leads, supervisors, and managers.	Office & Floor
	Team Problem Solving Activities	Problem-Solving activities are organized into team based functions. (0 = An autonomous problem-solving team structure does not exist.) (1 = An autonomous problem-solving team structure exists.)	Teams are used to gain multiple perspectives for problem-resolution and enhance worker buy in.	The existence of autonomous problem-solving teams for specified low-level problems that can be solved at the operator or team lead level.	Office & Floor

	Item	Evaluation Point	Purpose	Methodology	Where?
	Team Problem Solving Practices	Employees are empowered, utilize, participate, initiate, and lead problem-solving activities autonomously, without significant management involvement. (0 = Autonomous Problem-Solving does not occur regularly.) (1 = Autonomous Problem-Solving does occur regularly.)	Employees practice, exhibit the initiative, and adhere to the lean initiative, originating problem-solving and resolution activities individually and autonomously.	Autonomous problem-solving teams are used regularly to solve problems with minimal management involvement, observed directly or through documentation or informally.	Office & Floor
	Teamwork, Team Leaders, & Empowerment				
Power Distance and Management Daily Involvement	**Supervisor Involvement**	Supervisor desks are collocated in functional area, accessible to employees. (0 = Supervisor desk is located elsewhere.) (1 = Supervisor desk is located in area.)	Enhancing supervisor visibility and accessibility.	Visually determine location of supervisor desk and proximity to area, employees, and various functions.	Floor
		What percentage of the day do Supervisors spend on the shop-floor, during normal working hours? (0 = None) (1 = <20%) (2 = 20% - 40%) (3 = 40% - 60%) (4 = 60% - 80%) (5 = >80%)	Supervisors spending significant time on the shop-floor developing team leaders and employees, and directing and facilitating daily activities.	Direct observation of work practices, assessment of daily out-of-area activities required, and informal conversation with manager, supervisor, and employees.	Floor
	Manager Involvement	What percentage of the day do Managers spend on the shop-floor, during normal working hours? (0 = None) (1 = <20%) (2 = 20% - 40%) (3 = 40% - 60%) (4 = 60% - 80%) (5 = >80%)	Managers spending significant time on the shop-floor linking departments, developing supervisors, and providing problem-solving support.	Direct observation of work practices, assessment of daily out-of-area activities required, and informal conversation with manager, supervisor, and employees.	Floor
	Power Distance and Management Daily Involvement				
Employee Recognition & Compensation	**Individual Outstanding Performers Identified**	Individuals who meet, exceed, or achieve objectives are recognized on a regular basis through an employee recognition program? (0 = There is not an individual recognition program present or not used regularly.) (1 = There is an individual recognition program present and it is used regularly.)	Provide additional intrinsic incentive and recognition for individuals to meet and exceed individual performance targets in order to achieve overall facility goals.	Existence and regular usage of recognition programs for high achieving individuals with monthly recognition, observed directly or through documentation.	Office
	Individual Performance Rewards	Individuals who meet, exceed, or achieve performance objectives are rewarded through additional compensation/rewards? (0 = There is not an individual reward program present or not used regularly.) (1 = There is an individual reward program present and it is used regularly.)	Provides additional extrinsic incentive for individuals to meet and exceed individual performance targets in order to achieve overall facility goals.	Existence and regular usage of reward programs for high achieving individuals with monthly reward, observed directly or through documentation.	Office

	Item	Evaluation Point	Purpose	Methodology	Where?
	Group Outstanding Performers Identified	Groups who meet, exceed, or achieve objectives are recognized on a regular basis through a group recognition program? (0 = There is not a group recognition program present or not used regularly.) (1 = There is a group recognition program present and it is used regularly.)	Provides additional recognition and intrinsic incentive for individuals to cooperate as a group to meet and exceed group-level performance targets in order to achieve overall facility goals.	Existence and regular usage of recognition programs for high achieving groups with monthly recognition, observed directly or through documentation.	Office
	Group Performance Rewards	Groups who meet, exceed, or achieve performance objectives are rewarded through additional compensation/rewards? (0 = There is not a group reward program present or not used regularly.) (1 = There is a group reward program present and it is used regularly.)	Provides additional extrinsic incentive for individuals to cooperate as a group to meet and exceed group-level performance targets in order to achieve overall facility goals.	Existence and regular usage of recognition programs for high achieving group with monthly rewards, observed directly or through documentation.	Office
	Employee Recognition & Compensation				
Communication Strategy	**Open Practices**	Facility/dept metric/KPI performance. (0 = None) (1 = Very little - Some basic info Posted) (2 = Little - General facility info Shared) (3 = Somewhat - Most facility info posted/discussed) (4 = To A Great Extent, Most dept/facility info posted/discussed) (5 = Completely, Dept/facility info posted/discussed)	Open communication of facility performance and departmental performance limits fear of uncertainty among employees and enhances understanding of expectations and achievements.	The frequency, currency, and amount of facility/dept metric and KPI performance information posted and shared with associates, observed from boards and performance/information sharing meetings.	Office & Tracking Area
	Worker Input & Concerns Voiced & Addressed	There is an avenue for workers to openly share common concerns, issues, and problems regularly with other employees, supervisors, and management. (0 = There is not a forum available.) (1 = There is a regular forum for discussion, resolution, and addressing common issues.)	Provide a mechanism to gather feedback from workers, uncover common problems, issues, and concerns to be addressed and communicated at the group level.	Directly or indirectly observed open forum for discussion of common concerns, through informal discussions, minutes, action items, resolutions, outcomes, etc. from meetings.	Floor
		Employee concerns and questions are addressed in a timely manner. (0 = The concerns are not addressed to those affected before/at the next meeting.) (1 = The concerns are addressed to those affected before/at the next meeting.)	Illustrate that employee input and concerns are important to supervisors and management.	Directly or indirectly observed open forum for discussion of common concerns, through informal discussions, minutes, action items, resolutions, outcomes, etc. from meetings.	Floor & Action Items

	Item	Evaluation Point	Purpose	Methodology	Where?
	Daily Plan Communication	Are there daily meetings with associates and supervision/management where the daily plans, performance, etc. are shared . (0 = There are not daily meetings with associates where plans, etc. are shared.) (1 = There are daily meetings with associates where plans, etc. are shared.)	Daily communication with associates increases awareness of work plans, individual and departmental performance, goals, assignments, improvements, changes, etc. on a daily basis.	Observe start of shift meetings to examine items communicated to associates on a daily basis regarding daily plan, performance, etc.	Floor
Absenteeism, Layoffs, & Turnover	**Absenteeism**	The facility daily unplanned absenteeism rate during the six months? (0 = >5%, Absenteeism Rates Unknown) (1 = 4% - 5%) (2 = 3% - 4%) (3 = 2% - 3%) (4 = 1% - 2%) (5 = <1%)	Absenteeism is related to employee job satisfaction, enrichment, and fulfillment and describes the type of work environment for employees.	Calculated based on employment documentation information, otherwise scored as zero is non-existent or not current, i.e. through previous month.	Office
	Layoffs	The percent layoffs versus total facility staffing levels during the last six months? (0 = >25% or Employment turnover information not documented or current) (1 = 20% - 25%) (2 = 15% - 20%) (3 = 10% - 15%) (4 = 5% - 10%) (5 = <5%)	Layoffs can lead to distrust and dissatisfaction among the employees, which can be detrimental to productivity and continuous improvement.	Calculated based on employment documentation information, otherwise scored as zero is non-existent or not current, i.e. through previous month.	Office
	Turnover	The personnel turnover rate for the facility during the last six months? (0 = >25% or Employment turnover information not documented or current) (1 = 20% - 25%) (2 = 15% - 20%) (3 = 10% - 15%) (4 = 5% - 10%) (5 = <5%)	Worker turnover is an indication of many potential cultural problems, including environmental stress, excessive overtime, worker dissatisfaction, etc.	Calculated based on employment documentation information, otherwise scored as zero is non-existent or not current, i.e. through previous month.	Office
	Absenteeism, Layoffs, & Turnover				

Quality Assurance:

	Item	Evaluation Point	Purpose	Methodology	Where?
5 Whys, Root Cause & Pareto	**5 Why & Root Cause Analysis used in Problem Solving Practices**	Are structured problem solving methodologies used to determine the root causes of problems as they arise? (0 = No, structured, formal problem solving methods are not used.) (1 = Yes, structured, formal problem solving methods are used.)	To provide a formal process for identifying and rectifying problems as they arise.	Observe problem solving teams and root cause analysis methodologies, documentation, and outcomes.	Quality Area & Floor
		The percentage of daily work activity problems that are solved using 5 Why-type methodologies? (0 = None) (1 = <20%, Seldom) (2 = 20% - 40%, Occasionally) (3 = 40% - 60%, ~ Half) (4 = 60% - 80%, Usually) (5 = >80%, Always)	Root cause analysis problem solving methodologies should facilitate the resolution of fundamental, underlying problems, not simply symptoms or conditions.	Observe problem solving teams and root cause analysis methodologies, documentation, and outcomes.	Quality Area & Floor
		Problem occurrence frequency data is captured and collected as problems arise. (0 = No, formal, common problem collection process is used.) (1 = Yes, formal, common problem collection process is used to uncover frequent, common problems.)	Data collection is important for understanding common problems to identify roadblocks and potential points for continuous improvements.	Verify data collected and analysis procedures, actions, and outcomes.	Quality Area & Floor
	Identify Areas for Improvement using Pareto Analysis, etc.	Pareto analysis is used to determine common and frequently occurring problems to better illuminate items that need additional focus and problem resolution. (0 = No analysis is conducted.) (1 = Yes, pareto analysis, etc. is used to identify common and frequent problems.)	Pareto analysis helps identify the most commonly occurring problems and prioritizes corrective action and continuous improvement focus and time.	Verify analysis conducted from data gathered and resulting action items and outcomes.	Quality Area & Floor
	5 Whys, Root Cause & Pareto				

	Item	Evaluation Point	Purpose	Methodology	Where?
Inspection & Autonomation	**Inspection Processes**	Are there quality verification/inspection procedures in place for each function? (0 = No, processes are not developed.) (1 = Yes, there are quality verification and inspection procedures developed.) (2 = Yes, the quality verification and inspection procedures developed and used.)	Quality verification and inspection procedures in functions ensures that the standard operating procedures for each process are performed with minimal errors.	Examine SOPs, techniques, tools, and daily work practices used.	Quality Area & Floor
	Auto-nomation	Are there "built-in" system quality verification procedures for processes to automatically identify potential quality problems immediately? (0 = No, processes are not developed.) (1 = Yes, some processes are developed.) (2 = Yes, many processes are used.)	Building in quality detection and using automatic detection and identification procedures increases the likelihood that errors are detected.	Examine SOPs, techniques, tools, and daily work practices used.	Quality Area & Floor
		Inspection & Autonomation			
Error Proofing Methodology	**Self-Directed Error Detection**	Are there processes "built-in" to the SOP for self-detection of quality errors, i.e. using Noren Tags, RF Scanners, etc.? (0 = No, processes are not developed.) (1 = Yes, some processes are developed.) (2 = Yes, many processes are used.)	Using procedures, equipment, etc. that help detect errors minimizes the likelihood of errors going undetected to the customer.	Examine SOPs, techniques, tools, and daily work practices used.	Quality Area & Floor
	Employee Feedback & Corrective Action Practices	Are there corrective action and feedback gathering procedures to rectify quality problems and correct problems encountered when they occur? (0 = No, structured processes exist.) (1 = Yes, structured processes exist for gathering feedback and corrective actions.)	Capturing worker feedback and developing corrective action procedures ensures worker concerns are addressed and retraining, support, etc. are given to workers committing errors.	Examine regular quality and error detection procedures and practices.	Quality Area & Floor
	Quality Circles	Are there self-directed quality circles that discuss quality problems when they are uncovered and the corrective actions taken? (0 = No, Quality Circles are not used.) (1 = Yes, some Quality Circles are used.) (2 = Yes, Quality Circles are used daily to discuss quality issues and problems.)	Quality Circles provide a formal meeting for discussion, corrective actions, and explanation of errors after they occur to share root causes and prevent similar errors.	Observe regular quality circle activities and corresponding preparation, actions, and outcomes.	Quality Area & Floor

	Item	Evaluation Point	Purpose	Methodology	Where?
	Corrective Action Sharing	Are corrective actions shared with other employees, functions, etc when applicable? (0 = No, cross-functional sharing.) (1 = Yes, sometimes cross-functional sharing is conducted irregularly.) (2 = Yes, cross-functional sharing is conducted regularly.)	Sharing corrective actions and lessons learned increases organizational learning and reduces the likelihood similar errors will be committed by adding additional focus to common problems.	Examine regular quality meetings and participation.	Quality Area & Floor
	Error Proofing Methodology				
Inventory Integrity	**Cycle Count Frequency**	The percent of actual cycle counts performed daily versus department goals? (0 = None performed, no goals, etc.) (1 = <80%) (2 = 80% - 85%) (3 = 85% - 90%) (4 = 90% - 95%) (5 = >95%)	Cycle counts provide insight into inventory integrity, verifying quantities, and limiting potential errors and wasted motion, movement, etc.	Compare current cycle count information and data collected to targets tracked on boards, walls, etc.	IC
	Cycle Count Classification	Delineation and differing cycle count requirements for A, B, C velocity classifications. (0 = No, there are no part delineations for velocity or cycle count requirements.) (1 = Yes, there are part delineations for velocity and cycle count requirements.)	Assigning differing frequencies to different velocity classifications prioritizes cycle counting for higher volume, more frequently accessed locations, etc.	Determine if there are delineations in parts based on velocity made in WMS, discuss with IC supervisors and workers, and whether those are used for cycle count targets, etc.	IC
	Inventory Accuracy, Adjustments, Condition	The percent of actual daily adjustments made to inventory versus department goals? (0 = Not tracked, no goals, etc.) (1 = >95%) (2 = 90% - 95%) (3 = 85% - 90%) (4 = 80% - 85%) (5 = <80%)	The amount of inventory adjustments made provide insight into the inventory integrity and potential issues affecting inventory accuracy and the effectiveness of inventory management.	Compare current inventory adjustments information and data collected to targets tracked on boards, walls, etc.	IC
	Stock Out Process	Are there processes defined to exhaust items with "stock outs" and minimizing backorders, unmet orders, referrals, etc.? (0 = No stock out rectification processes exist or processes are not followed.) (1 = Stock out rectification processes exist and are followed to limit unmet orders, etc.)	Stock outs, unmet orders, backorders, referrals, etc. can directly affect end customers and impact overall system effectiveness with regard to customer satisfaction with products and service.	Follow stock out procedures from order picker associate to inventory control and examine process, effectiveness, frequency of use, thoroughness, and process documentation.	IC
	Inventory Integrity				

	Item	Evaluation Point	Purpose	Methodology	Where?
Product & Process Quality	**Product Quality**	The percent of quality defects attributed to product quality versus department goals? (0 = Not tracked, no goals, etc.) (1 = >95%) (2 = 90% - 95%) (3 = 85% - 90%) (4 = 80% - 85%) (5 = <80%)	The percent of defects associated with product quality prioritizes potential problems associated with individual operations, handling, or value added services.	Compare current product quality information and data collected to targets tracked on boards, walls, etc. may be determined from root cause quality analysis.	Office, Lean Tracking Area, or Floor
	Process Quality	The percent of quality defects attributed to process quality versus department goals? (0 = Not tracked, no goals, etc.) (1 = >95%) (2 = 90% - 95%) (3 = 85% - 90%) (4 = 80% - 85%) (5 = <80%)	The percent of defects associated with process quality prioritizes potential problems associated with inbound and outbound processes and potential root cause analysis/rectification.	Compare current process quality information and data collected to targets tracked on boards, walls, etc. may be determined from root cause quality analysis.	Office, Lean Tracking Area, or Floor
		Product & Process Quality			
Quality Measurements, Metrics, & Statistics	**Picking Error Rates**	The actual picking error rates versus departmental goals, lower is better? (0 = Not tracked, no goals, etc.) (1 = >95%) (2 = 90% - 95%) (3 = 85% - 90%) (4 = 80% - 85%) (5 = <80%)	Lower picking error rates versus targets describes the performance versus expectations and reduces subsequent wastes.	Compare and divide current picking error rate information and data collected to targets tracked on boards, walls, etc.	Quality Area & Floor
	Corrective Action Methodology	Is there a formal picking error rate corrective action methodology and process for improvement, issue resolution? (0 = No, corrective action procedures or resolution process exists or is in use.) (1 = Yes, corrective action procedures and resolution processes exists and are in use.)	Providing a formal corrective action procedure and improvements helps ensure that the same mistakes will not be made continually.	Examine SOPs, techniques, tools, and daily work practices used.	Quality Area & Floor
	Scrap Rates	The actual scrap rates versus departmental goals, lower is better? (0 = Not tracked, no goals, etc.) (1 = >95%) (2 = 90% - 95%) (3 = 85% - 90%) (4 = 80% - 85%) (5 = <80%)	Lower scrap rates versus targets describes the performance versus expectations and reduces subsequent wastes.	Compare and divide current scrap rate information and data collected to targets tracked on boards, walls, etc.	Quality Area & Floor
	Corrective Action Methodology	Is there a formal scrap rate corrective action methodology and process for improvement, issue resolution? (0 = No, corrective action procedures or resolution process exists or is in use.) (1 = Yes, corrective action procedures and resolution processes exists and are in use.)	Providing a formal corrective action procedure and improvements helps ensure that the same mistakes will not be made continually.	Examine SOPs, techniques, tools, and daily work practices used.	Quality Area & Floor

	Item	Evaluation Point	Purpose	Methodology	Where?
	Damage Rates	The actual damage rates versus departmental goals, lower is better? (0 = Not tracked, no goals, etc.) (1 = >95%) (2 = 90% - 95%) (3 = 85% - 90%) (4 = 80% - 85%) (5 = <80%)	The facility damage rate versus expectations describes performance and increased performance reduces overall waste.	Compare and divide current damage rate information and data collected to targets tracked on boards, walls, etc.	Quality Area & Floor
	Corrective Action Methodology	Is there a formal damage corrective action methodology and process for improvement, issue resolution? (0 = No, corrective action procedures or resolution process exists or is in use.) (1 = Yes, corrective action procedures and resolution processes exists and are in use.)	Providing a formal corrective action procedure and improvements helps ensure that the same mistakes will not be made continually.	Examine SOPs, techniques, tools, and daily work practices used.	Quality Area & Floor
	Rework Rates	The actual rework rates versus departmental goals, lower is better? (0 = Not tracked, no goals, etc.) (1 = >95%) (2 = 90% - 95%) (3 = 85% - 90%) (4 = 80% - 85%) (5 = <80%)	The facility rework rate versus expectations describes performance and increased performance reduces overall waste.	Compare and divide current rework rate information and data collected to targets tracked on boards, walls, etc.	Quality Area & Floor
	Corrective Action Methodology	Is there a formal rework corrective action methodology and process for improvement, issue resolution? (0 = No, corrective action procedures or resolution process exists or is in use.) (1 = Yes, corrective action procedures and resolution processes exists and are in use.)	Providing a formal corrective action procedure and improvements helps ensure that the same mistakes will not be made continually.	Examine SOPs, techniques, tools, and daily work practices used.	Quality Area & Floor
	Delivery Rates	The actual delivery rates versus departmental goals, higher is better? (0 = Not tracked, no goals, etc.) (1 = <97%) (2 = 97%% - 98%) (3 = 98% - 99%) (4 = 99% - 100%) (5 = >100%)	The facility delivery rate versus expectations describes performance and increased performance reduces overall waste.	Compare and divide current delivery information and data collected to targets tracked on boards, walls, etc.	Quality Area & Floor
	Corrective Action Methodology	Is there a formal delivery rate corrective action methodology and process for improvement, issue resolution? (0 = No, corrective action procedures or resolution process exists or is in use.) (1 = Yes, corrective action procedures and resolution processes exists and are in use.)	Providing a formal corrective action procedure and improvements helps ensure that the same mistakes will not be made continually.	Examine SOPs, techniques, tools, and daily work practices used.	Quality Area & Floor

Item	Evaluation Point	Purpose	Methodology	Where?
Order Fill/Denial Rates	The actual order fill and denial rates versus departmental goals, higher is better? (0 = Not tracked, no goals, etc.) (1 = <97%) (2 = 97%% - 98%) (3 = 98% - 99%) (4 = 99% - 100%) (5 = >100%)	The facility order fill rate versus expectations describes performance and increased performance reduces overall waste.	Compare and divide current order fill rate information and data collected to targets tracked on boards, walls, etc.	Quality Area & Floor
Corrective Action Methodology	Is there a formal order fill rate corrective action methodology and process for improvement, issue resolution? (0 = No, corrective action procedures or resolution process exists or is in use.) (1 = Yes, corrective action procedures and resolution processes exists and are in use.)	Providing a formal corrective action procedure and improvements helps ensure that the same mistakes will not be made continually.	Examine SOPs, techniques, tools, and daily work practices used.	Quality Area & Floor
Quality Measurements, Metrics, & Statistics				

Visual Management:

	Item	Evaluation Point	Purpose	Methodology	Where?
Value Stream Mapping	**VSM Training**	Value stream mapping training levels for facility personnel. (0 = None) (1 = Manager trained) (2 = Some Supervisors trained.) (3 = All Supervisors trained.) (4 = Team Leads trained.) (5 = Some workers trained.)	Analyzing and understanding the current state value stream map of processes is the first step in continuous improvement and making progress.	Evaluate lean training documentation, lean progress boards, etc. to determine the facility personnel who have completed value stream mapping training.	Lean Tracking Area and Floor
	Current State Processes Mapped	The percent of current state value stream maps created for key processes. (0 = None) (1 = <20%) (2 = 20% - 40%) (3 = 40% - 60%) (4 = 60% - 80%) (5 = >80%)	Continuous improvement is achieved through process improvement implementation activities.	Evaluate value stream mapping documentation and key facility processes for each function.	Lean Tracking Area and Floor
	Future State Processes Mapped	The percent of future state value stream maps created for key process. (0 = None) (1 = <20%) (2 = 20% - 40%) (3 = 40% - 60%) (4 = 60% - 80%) (5 = >80%)	Continuous improvement is achieved through process improvement implementation activities.	Evaluate value stream mapping documentation and key facility processes for each function.	Lean Tracking Area and Floor
	Future State Processes Implemented	The percent of future state value stream maps implemented for key processes. (0 = None) (1 = <20%) (2 = 20% - 40%) (3 = 40% - 60%) (4 = 60% - 80%) (5 = >80%)	Continuous improvement is achieved through process improvement implementation activities.	Validate future state value stream maps and process improvement implementations for key processes, etc.	Lean Tracking Area and Floor
	Lean Vision	The facility six-month lean vision: (0 = The facility does not have a six-month lean vision or is not making progress commensurate to achieving the vision.) (1 = The facility has a six-month lean vision and is making progress commensurate to achieving the the vision.)	Continuous improvement is achieved through process improvement implementation activities.	Determine whether there is an appropriate six-month lean vision for the facility and assess the progress towards implementing the vision.	Lean Tracking Area and Floor
	Value Stream Mapping				

	Item	Evaluation Point	Purpose	Methodology	Where?
Process Control Boards	**Development & Posting**	Have process control boards been developed and posted in processes? (0 = No, boards are not present/developed.) (1 = Yes, some processes have developed and posted boards.) (2 = Yes, most processes have developed and posted boards.)	To enhance visibility and allow everyone to understand the function plan, status, progression, and performance at a glance.	Visual inspection of functional areas, process control board development, and existence.	Floor
	Standardized Work Unit Cohesion	Were process control boards developed in accord with standardized work units? (0 = No, boards are not present/developed.) (1 = Yes, some processes were developed in accord with standardized work units.) (2 = Yes, most processes were developed in accord with standardized work units.)	To ensure process control boards are being used to plan and manage daily activities.	Visual inspection of functional areas and process control boards.	Floor
	Planning	Are process control boards used to plan daily work activities? (0 = No, boards are not present/developed.) (1 = Yes, some processes daily activities are planned using process control boards.) (2 = Yes, most processes daily activities are planned using process control boards.)	To ensure process control boards are being used to plan and manage daily activities.	Visual inspection of functional areas and process control boards.	Floor
	Usage	Are process control boards used, updated, & leveraged regularly to manage processes? (0 = No, boards are not present/developed.) (1 = Yes, some processes are managed by leveraging process control boards.) (2 = Yes, most processes are managed by leveraging process control boards.)	To ensure process control boards are being used, updated, and leveraged regularly.	Visual inspection of functional areas and process control boards.	Floor
	Resolution	Process control board resolution: (0 = No, boards are not present/developed.) (1 = >60 Minutes) (2 = 30 - 60 Minutes) (3 = 20 - 30 Minutes) (4 = 15 - 20 Minutes) (5 = < 15 Minutes)	The resolution of the process control board determines the accuracy with which the boards data represents.	Visual inspection of functional areas and process control boards.	Floor
	Functional Planning	Are process control boards used to plan daily work activities? (0 = No, boards are not present/developed.) (1 = Yes, some processes daily activities are planned using process control boards.) (2 = Yes, most processes daily activities are planned using process control boards.)	To ensure process control boards are being used to plan and manage daily activities.	Visual inspection of functional areas and process control boards.	Floor

	Item	Evaluation Point	Purpose	Methodology	Where?
	Manpower Planning	Are process control boards used to plan daily work activities? (0 = No, boards are not present/developed.) (1 = Yes, some processes daily activities are planned using process control boards.) (2 = Yes, most processes daily activities are planned using process control boards.)	To ensure process control boards are being used to plan and manage daily activities.	Visual inspection of functional areas and process control boards.	Floor
	Process Control Boards				
Metrics & KPI Boards	**Productivity Tracking**	Productivity rates are tracked and displayed regularly versus facility and departmental goals? (0 = Productivity information is not tracked, displayed, and/or not current, etc.) (1 = Productivity information is tracked, displayed, and current, etc.)	Tracking productivity and displaying information illustrates facility and departmental performance versus expectations, progress, and opportunities for improvement.	Examine productivity tracking information and display information for facility and department.	Office or Floor
	Productivity Performance	The actual productivity rates versus departmental and facility goals, where a higher ratio is better? (0 = Not tracked, no goals, etc.) (1 = <85%) (2 = 85% - 90%) (3 = 90% - 95%) (4 = 95% - 100%) (5 = >100%)	Achieving productivity expectations is an outcome of process improvements, manpower planning, and other lean activities.	Divide actual departmental and facility performance versus expectations.	Office or Floor
	Quality Tracking	Quality rates are tracked and displayed regularly versus facility and departmental goals? (0 = Quality information is not tracked, displayed, and/or current, etc.) (1 = Quality information is tracked, displayed, and current, etc.)	Tracking quality and displaying information illustrates facility and departmental performance versus expectations, progress, and opportunities for improvement.	Examine quality tracking information and display information for facility and department.	Office or Floor
	Quality Performance	The actual quality rates versus departmental and facility goals, where a lower ratio is better? (0 = Not tracked, no goals, etc.) (1 = >100%) (2 = 95% - 100%) (3 = 90% - 95%) (4 = 85% - 90%) (5 = <85%)	Achieving quality expectations is an outcome of process improvements, manpower planning, and other lean activities.	Divide actual departmental and facility performance versus expectations.	Office or Floor
	On Time Shipment Tracking	On Time Shipment rates are tracked and displayed regularly versus facility and departmental goals? (0 = On Time Shipment information is not tracked, displayed, and/or current, etc.) (1 = On Time Shipment information is tracked, displayed, and current, etc.)	Tracking on time shipment and displaying information illustrates facility and departmental performance versus expectations, progress, and opportunities for improvement.	Examine on time shipment tracking information and display information for facility and department.	Office or Floor

	Item	Evaluation Point	Purpose	Methodology	Where?
	On Time Shipment Performance	The actual on time shipment rates versus departmental and facility goals, where a higher ratio is better? (0 = Not tracked, no goals, etc.) (1 = <85%) (2 = 85% - 90%) (3 = 90% - 95%) (4 = 95% - 100%) (5 = >100%)	Achieving on time shipment is an outcome of process improvements, manpower planning, and other lean activities in order to achieve customer satisfaction.	Divide actual departmental and facility performance versus expectations.	Office or Floor
	On Time Receiving Tracking	On Time Receiving rates are tracked and displayed regularly versus facility and departmental goals? (0 = On Time Receiving information is not tracked, displayed, and/or current, etc.) (1 = On Time Receiving information is tracked, displayed, and current, etc.)	Tracking on time receiving and displaying information illustrates facility and departmental performance versus expectations, progress, and opportunities for improvement.	Examine on time receiving tracking information and display information for facility and department.	Office or Floor
	On Time Receiving Performance	The actual on time receiving rates versus departmental and facility goals, where a higher ratio is better? (0 = Not tracked, no goals, etc.) (1 = <85%) (2 = 85% - 90%) (3 = 90% - 95%) (4 = 95% - 100%) (5 = >100%)	Achieving on time receiving expectations is an outcome of process improvements, manpower planning, and other lean activities in order to increase availability, order fill rates, etc.	Divide actual departmental and facility performance versus expectations.	Office or Floor
	Customer Staisfaction Tracking	Customer Satisfaction rates are tracked and displayed regularly versus facility and departmental goals? (0 = Customer Satisfaction information is not tracked, displayed, and/or current, etc.) (1 = Customer Satisfaction information is tracked, displayed, and current, etc.)	Tracking customer satisfaction and displaying information illustrates facility and departmental performance versus expectations, progress and improvement opportunities.	Examine customer satisfaction tracking information and display information for facility and department.	Office or Floor
	Customer Satisfaction Performance	The actual customer satisfaction rates versus departmental and facility goals, where a higher ratio is better? (0 = Not tracked, no goals, etc.) (1 = <85%) (2 = 85% - 90%) (3 = 90% - 95%) (4 = 95% - 100%) (5 = >100%)	Achieving customer satisfaction expectations is an outcome of process improvements, manpower planning, and other lean activities.	Divide actual departmental and facility performance versus expectations.	Office or Floor
	Facility KPI Tracking	Key Performance Indicators are tracked and displayed regularly versus facility and departmental goals? (0 = KPI information is not tracked, displayed, and/or current, etc.) (1 = KPI information is tracked, displayed, and current, etc.)	Tracking KPI performance and displaying illustrates facility and departmental performance versus expectations, progress, and opportunities for improvement.	Examine KPI tracking information and display information for facility and department.	Office or Floor

	Item	Evaluation Point	Purpose	Methodology	Where?
	Facility KPI Performance	The percent of KPIs being achieved are, where higher is better? (0 = Not tracked, no goals, etc.) (1 = <85%) (2 = 85% - 90%) (3 = 90% - 95%) (4 = 95% - 100%) (5 = 100%)	Achieving KPI expectations is an outcome of process improvements, manpower planning, and other lean activities.	Divide actual departmental and facility performance versus expectations.	Office or Floor
		Metrics & KPI Boards			
Lean Tracking	**Lean Tracking**	Lean implementation Tracking Board/Area. (0 = No, Lean implementation activities are not being tracked and/or are not current.) (1 = Yes, Lean implementation activities are tracked and current.)	Tracking and documenting facility changes and progress illustrates the achievements and accomplishments.	Information captured from Lean Tracking Board/Area.	Lean Tracking Area
	Lean Training	Lean Training Tracking Board. (0 = Lean training activities are not tracked and/or are not current.) (1 = Yes, Lean training activities are tracked and are current.)	Tracking lean training adds visibility and importance to training activities.	Information captured from Lean Training & Tracking Board/Area.	Lean Tracking Area
	Manager Training	(0 = Manager has not completed.) (1 = Manager completed Lean 101.) (2 = Manager facilitated one lean activity.) (3 = Manager completed Lean 201.) (4 = Manager facilitated 2nd lean activity.) (5 = Manager with Lean Trainer status.)	Managers provide the daily organizational support to ensure roadblocks are removed, coordinate facility improvement activities, and work among the various functions.	Information captured from Lean Training & Tracking Board/Area.	Lean Tracking Area
	Supervisor Training	(0 = Supervisor has not completed.) (1 = Supervisor completed Lean 101.) (2 = Supervisor facilitated 1 lean activity.) (3 = Supervisor completed Lean 201.) (4 = Supervisor facilitated 2 lean activity.) (5 = Supervisor with Lean Trainer status.)	Supervisors provide the daily reinforcement, training, and expertise to initiate changes and sustain improvements.	Information captured from Lean Training & Tracking Board/Area.	Lean Tracking Area

	Item	Evaluation Point	Purpose	Methodology	Where?
	Worker Training	Employee lean training achievements. (0 = None have completed Lean Training.) (1 = <25% have completed Lean 101.) (2 = <25% Lean 101 & 1 lean activity.) (3 = 25%-75% have completed Lean 101.) (4 = 25%-75% Lean 101 & 1 lean activity.) (5 = >75% Lean 101 & 2+ lean activities.)	Employee understanding is increased by training and participation in continuous improvement of daily work activities.	Information captured from Lean Training & Tracking Board/Area.	Lean Tracking Area
	Lean Tracking				
Visual Controls	**Staging**	Are there visual control mechanisms to manage staging, FIFO, etc., i.e. cones, etc.) (0 = No, visual control mechanism exists.) (1 = Yes, some staging processes are managed by visual control mechanisms.) (2 = Yes, most staging processes are managed by visual control mechanisms.)	Visual control mechanisms enhance process integrity and reduce wastes, by eliminating searching and stabilizing processes.	Examine staging processes and SOPs for use of visual control mechanisms to manage staging.	Floor
Visual Controls	**Pull**	Are there visual control mechanisms to manage material flow, pull, etc.) (0 = No, visual control mechanism exists.) (1 = Yes, some material flow processes are managed by visual control mechanisms.) (2 = Yes, most material flow processes are managed by visual control mechanisms.)	Visual control mechanisms enhance process integrity and reduce wastes, by eliminating searching and stabilizing processes.	Examine material flow processes and SOPs for use of visual control mechanisms to manage material flow.	Floor
	Visual Controls				
Andon Systems	**Existence**	Is there a mechanism to trigger support from team lead, supervisors, etc. when quality problems arise? (0 = No, there is not a mechanism to trigger support when quality issues arise.) (1 = Yes, there is a mechanism to trigger support when quality issues arise.)	Andon Systems provide instantaneous feedback and trigger support from the appropriate personnel when quality problems arise.	Determine if there is a visual, auditory, etc. mechanism to trigger support from the appropriate personnel when quality problems arise.	Floor
Andon Systems	**Usage**	Are quality problem support systems used by workers to get support from team leads, supervisors, etc. to solve quality problems? (0 = No, the mechanism to trigger support when quality issues arise is not used.) (1 = Yes, the mechanism to trigger support when quality issues arise is used.)	Andon Systems must be used to be effective.	Determine the extent to which the mechanism is used to trigger support when quality problems arise.	Floor
	Andon Systems				

	Item	Evaluation Point	Purpose	Methodology	Where?
(A3) One Page Reports	**Training**	The facility personnel that have completed A3 One Page Report Training: (0 = None) (1 = Manager completed training.) (2 = Some Supervisors completed training.) (3 = All Supervisors completed training.) (4 = Some Team Leads completed training.) (5 = Some workers completed training.)	A3 One Page Reporting allows for systematic documentation of projects to enhance organizational learning and documentation of changes and results.	Examine the lean training tracking for A3 One Page Reporting training to determine the personnel who have completed training.	Lean Tracking Area
	Usage	The number of A3 One Page Reports completed during last six months: (1 = 1 Report & corresponding project.) (2 = 2 Reports & corresponding projects.) (3 = 3 Reports & corresponding projects.) (4 = 4 Reports & corresponding projects.) (5 = 5+ Reports & corresponding projects.)	The more A3 One Page Reports that have been completed indicate the amount of progress and continuous improvement being made throughout the facility.	Examine the lean tracking area to determine the number of A3 One Page Reports that have been completed during the last six months.	Lean Tracking Area
	(A3) One Page Reports				

Workplace Organization:

	Item	Evaluation Point	Purpose	Methodology	Where?
5S	**5S Training**	5S Workplace Organization training levels for facility personnel. (0 = None) (1 = Manager trained) (2 = Some Supervisors trained.) (3 = All Supervisors trained.) (4 = Team Leads trained.) (5 = Some workers trained.)	To train personnel in a methodology for developing a place for everything and having everything in its place in the facility.	Check lean tracking area for manager, supervisor, and worker 5S WPO Training accomplishments.	Lean Tracking Area
	Sort	Have the necessary materials, equipment, machines, and supplies been determined? (0 = No, sorting was not present/done.) (1 = Yes, some of the necessary materials, equipment, etc. have been identified.) (2 = Yes, most of the necessary materials, equipment, etc. have been identified.)	To sort out what material, equipment, machines, and supplies are needed in the workplace to perform the work and which are not.	Verify area sort process and that existing materials, equipment, machines, and supplies are required for daily work activities. Perhaps, documentation or evidence of "red-tag event."	Floor
	Set in Order	Have the materials, etc. been set in order, organized, and visually represented? (0 = No, organizing was not present/done.) (1 = Yes, some of the necessary materials, equipment, etc. have been organized.) (2 = Yes, most of the necessary materials, equipment, etc. have been organized.)	To set in order, organize, and visually represent the essential material, equipment, machines, and supplies to minimize travel, motion, and searching movements.	Verify area organization and visual representation of materials, equipment, machines, and supplies was conducted and represents current processes, i.e. taped outlines, painted areas, etc.	Floor
	Shine	Have the necessary materials, equipment, etc. been shined, cleaned, and inspected? (0 = No, shining was not present/done.) (1 = Yes, some of the necessary materials, equipment, etc. have been shined.) (2 = Yes, most of the necessary materials, equipment, etc. have been shined.)	To shine, clean, and inspect all of the work areas, equipment, and machines.	Examine material, equipment, machines, and supplies are shined, cleaned, and inspected to be in working condition, free of debris, etc.	Floor
	Standardize	Is daily time being devoted to maintaining 5S WPO, checklists being completed, schedule created and being adhered to? (0 = No, maintenance of initiative was not present/done.) (1 = Yes, some processes are maintained.) (2 = Yes, most processes are maintained.)	To standardize the workplace organization initiative and maintain improvements daily by allocating time, creating checklists, and developing schedules for maintenance.	Examine daily checklists and schedules are being completed, are up to date, and that time is being devoted daily for maintenance. Also inspect areas for compliance.	Floor

	Item	Evaluation Point	Purpose	Methodology	Where?
	Sustain	Are 5S WPO practices being audited regularly by supervisors and manager.? (0 = No, regular auditing is not being done.) (1 = Yes, some regular WPO process audits are being conducted by management.) (2 = Yes, numerous, regular WPO process audits are being conducted by mgmt.)	To sustain the initiative by making it a part of everyday business by auditing, providing feedback, and managers, supervisors, and employees verifying compliance to the process.	Examine supervisor and manager audits and the corresponding feedback given to employees regarding regular 5S WPO process audits.	Floor
	5S				
Signage & Shadow Boards	**Signage Usage**	Is there appropriate signage identifying work areas, staging, flow, traffic, etc.? (0 = No, there is not sufficient signage.) (1 = Yes, there is some signage present to identify areas, staging, material flow, etc.) (2 = Yes, signage clearly identifies areas, staging, material flow, traffic, etc.)	Signage eliminates guesswork in determining where material, equipment, etc. are to be staged, moved, etc.	Examine areas and functions to determine if there is appropriate signage marking and identifying work areas, staging, flow, traffic, etc.	Floor
	Standard Signage	Does signage conform to Menlo common signage template for colors, sizing etc.? (0 = No, signage does not conform to template and/or not sufficient signage.) (1 = Yes, signage conforms to common template and there is appropriate signage.)	Using Menlo common signage template standardizes colors, sizes, etc. across facilities commonly identifying and marking safety, functions, areas, parking, etc.	Compare signage to Menlo common signage template for colors, sizing, etc.	Floor
	Shadow Boards	Are shadow boards present, used, and filled for necessary materials, equipment, supplies, etc. identifying storage locations? (0 = No, shadow boards are not present, used, and/or filled, etc.) (1 = Yes, shadow boards are present, used, and filled, etc.)	Shadow boards provide specific places for equipment, supplies, etc. which eliminates searching, movement, etc.	Examine areas and functions for shadow board storage for materials, equipment, supplies, etc.	Floor
	Signage & Shadow Boards				

	Item	Evaluation Point	Purpose	Methodology	Where?
Cleanliness	**Overall Cleanliness**	The overall cleanliness of functions. (0 = Extremely dirty, full of dunnage, etc.) (1 = Some areas with dunnage, etc.) (2 = Few areas with dunnage, etc.) (3 = More than few traces of dunnage, etc.) (4 = Area has few traces of dunnage, etc.) (5 = Area is clean, free of dunnage, etc.)	Keeping areas clean, free of dunnage, debris, etc. enhances the work environment, reduces waste, reduces errors, increases safety, illustrates facility professionalism, etc.	Rate overall functions cleanliness based on the amount of dunnage, debris, etc. present in work areas accumulated during the work day and present at the end of the work day.	Floor
	Aisle Cleanliness	The individual aisle cleanliness. (0 = Extremely dirty, full of debris, etc.) (1 = Some areas with debris, etc.) (2 = Few areas with debris, etc.) (3 = More than few traces of debris, etc.) (4 = Few traces of debris, dunnage, etc.) (5 = All aisles clean, free of debris, etc.)	Keeping aisles clean, clear, free of dunnage, debris, etc. enhances the work environment, reduces waste, reduces errors, increases safety, illustrates facility professionalism, etc.	Rate aisle cleanliness based on the amount of dunnage, debris, etc. present in aisles accumulated during the work day and present at the end of the work day.	Floor
	Location Cleanliness	The individual location cleanliness. (0 = Extremely dirty, full of dunnage, etc.) (1 = Some bins with dunnage, etc.) (2 = Few bins with dunnage, etc.) (3 = More than few traces of dunnage, etc.) (4 = Bins have few traces of dunnage, etc.) (5 = Bins are clean, free of dunnage, etc.)	Keeping locations clean, clear, free of dunnage, debris, etc. enhances the work environment, reduces waste, reduces errors, increases safety, illustrates facility professionalism, etc.	Rate location cleanliness based on the amount of dunnage, debris, etc. present in aisles accumulated during the work day and present at the end of the work day.	Floor
	Cleanliness				

	Item	Evaluation Point	Purpose	Methodology	Where?
Supply & Material Management	**Critical Supplies Identified**	Supplies critical to accomplishing major daily work activities have been identified for each function. (0 = No, supplies critical to accomplishing daily activities have not been identified.) (1 = Yes, supplies critical to accomplishing daily activities have been identified.)	Identifying critical supplies determines which supplies, materials, etc. are required to perform daily work activities.	Review documentation for identifying critical supplies and what those supplies are.	Floor
	Critical Supply Management Process	A management process has been developed and is utilized for critical supplies, etc. (0 = No process developed and/or utilized.) (1 = Yes, there is a process developed and utilized for some critical supplies.) (2 = Yes, there is a process developed and utilized for most critical supplies.)	Developing and utilizing a management process for critical supplies, materials, etc. ensures that there are enough to perform daily work activities and without unnecessary inventory.	Review critical supply management processes, kanbans, documentation, stocking procedures, daily checklists, etc.	Floor
	Non-Critical Supply Management Process Developed & Utilized	Non-critical supplies, etc have been identified and a management process has been developed and is utilized. (0 = No, there is not a process developed and/or utilized for non-critical supplies.) (1 = Yes, there is a process developed and utilized for non-critical supplies.)	Managing, developing, and utilizing a management process for non-critical supplies, materials, etc. ensures inventory levels are appropriate and available when needed.	Review non-critical supply, identification process, items, management processes, kanbans, documentation, stocking procedures, daily checklists, etc.	Floor
	Supply & Material Management				

	Item	Evaluation Point	Purpose	Methodology	Where?
Point of Use Storage	**POUS Equipment**	Are there mechanisms developed and utilized for point of use storage for equipment to minimize worker motion? (0 = No, there are not mechanisms developed and/or utilized for equipment.) (1 = Yes, there are mechanisms developed and utilized for equipment.)	Point of Use Storage reduces travel time, handling, motion, searching, etc. for equipment before use by workers.	Examine storage areas for equipment to determine if the storage locations are in the same place as the usage locations.	Floor
	POUS Material	Are there mechanisms developed and utilized for point of use storage for material to minimize worker motion? (0 = No, there are not mechanisms developed and/or utilized for materials.) (1 = Yes, there are mechanisms developed and utilized for materials.)	Point of Use Storage reduces travel time, handling, motion, searching, etc. for material before use by workers.	Examine storage areas for material to determine if the storage locations are in the same place as the usage locations.	Floor
	POUS Supplies	Are there mechanisms developed and utilized for point of use storage for supplies to minimize worker motion? (0 = No, there are not mechanisms developed and/or utilized for supplies.) (1 = Yes, there are mechanisms developed and utilized for supplies.)	Point of Use Storage reduces travel time, handling, motion, searching, etc. for supplies before use by workers.	Examine storage areas for supplies to determine if the storage locations are in the same place as the usage locations.	Floor
	Point of Use Storage				
ID Problem Parts Areas	**Problem Area**	Are there appropriate areas identified, utilized, and storage mechanisms developed for problem items requiring further action? (0 = No are identified and/or utilized.) (1 = Yes, some areas identified and used.) (2 = Yes, there are areas identified and utilized consistently for problem items.)	Having a consistent problem area for staging and storing parts that require further action centralizes items for resolution, reduces searching, creates a common location, minimizing wastes, etc.	Examine functional areas, inventory control, etc. for problem areas, future action areas, and other common locations used for storing and staging items requiring additional action.	Floor
	Status Documents	Are there appropriate documentation mechanisms developed and utilized for problem items requiring further action? (0 = None are documented/identified.) (1 = Yes, some are documented/identified.) (2 = Yes, there is documentation, etc. developed and utilized consistently.)	Documenting and identifying the problem, reason, and other information reduces the amount of time for rectifying issues, reduces searching, motion and other wastes during resolution.	Examine documentation mechanisms for and identification procedures for problem items and ensure that documentation and identification procedures are being used consistently.	Floor
	ID Problem Parts Areas				

Lot Sizing:

	Item	Evaluation Point	Purpose	Methodology	Where?
Batch Sizes	**Batching & Consistency**	Material flow is managed in pre-specified batch sizes and adhered to consistently throughout the daily work activities. (0 = No, batches not pre-specified/used.) (1 = Yes, some processes use consistently.) (2 = Yes, most processes use consistent batch sizes.)	Using consistent batch sizes stabilizes work flow and provides predictable process times for each batch.	Examine material flow and movement between processes for consistent batch sizes used throughout daily activities.	Floor
	Batch Sizes Used	How much work do the batch sizes used between operations represent? (0 = Unknown, More Than 2 Hours) (1 = 60 -120 Minutes) (2 = 30 -60 Minutes) (3 = 15 -30 Minutes) (4 = More Than One-Piece - 15 Minutes) (5 = One-Piece Flow)	The batches between operations, processes, work stations, etc. represent WIP and wastes due to extra handling, movement, motion, etc.	Determine the work associated with batches according to work standards, process times, etc.	Floor
	Material Handling	What quantities are used to move material, items, parts, etc. between processes? (0 = Unknown, Large Batches/Quantities) (1 = Multiple Unit Loads) (2 = Single Unit Load) (3 = Multiple Small Batches/Totes) (4 = Small Batch/Tote) (5 = Single Piece)	Large batches increase inventory, waste, lead times, hide problems, cover inefficiencies, and reduce process stabilization.	Observe material handling and movement quantities between processes.	Floor
	Batch Sizes				
WIP	**Overall WIP**	The overall amount of WIP present in standard hours of work waiting to be processed in an area. (0 = Unknown, > 8 Hours) (1 = 4 - 8 Hours) (2 = 2 - 4 Hours) (3 = 1 - 2 Hours) (4 = 0.5 - 1 Hours) (5 = < 0.5 Hours)	WIP represents inventory and the corresponding wastes due to opportunity costs, handling, motion, etc.	Examine overall WIP and compare to standard hours of work to be processed.	Floor
	External Function WIP	The amount of WIP present in standard hours of work waiting to be processed as a buffer between functions. (0 = Unknown, > 8 Hours) (1 = 4 - 8 Hours) (2 = 2 - 4 Hours) (3 = 1 - 2 Hours) (4 = 0.5 - 1 Hours) (5 = < 0.5 Hours)	Buffering between external functions can help level flow and protects against process variation in small quantities when managed by pull systems, but large quantities encourage numerous wastes.	Examine external function WIP in standard hours of work to be processed.	Floor

	Item	Evaluation Point	Purpose	Methodology	Where?
	Internal Process WIP	The amount of WIP present in standard hours of work waiting to be processed as a buffer between processes. (0 = Unknown, > 8 Hours) (1 = 4 - 8 Hours) (2 = 2 - 4 Hours) (3 = 1 - 2 Hours) (4 = 0.5 - 1 Hours) (5 = < 0.5 Hours)	Buffering between internal processes can help level flow and protects against process variation in small quantities when managed by pull systems, but large quantities encourage numerous wastes.	Examine internal process WIP in standard hours of work to be processed.	Floor
	WIP Staging	The amount of staging devoted to WIP holding inventory waiting to be processed. (0 = Unknown, > 4 Staging Lanes) (1 = 3 - 4 Staging Lanes) (2 = 2 - 3 Staging Lanes) (3 = 1 - 2 Staging Lanes) (4 = 0.5 - 1 Staging Lanes) (5 = < 0.5 Staging Lanes)	WIP staging indicates the amount of WIP associated with processes and indicates the amount of space required for material waiting for the next process.	Determine the amount of space associated with WIP staging used for holding inventory between processes, functions, etc.	Floor
	Staging Processes	The number of staging processes and intermediate queuing used to move material through a given function or operation. (0 = Unknown, Staged 5+ Times) (1 = Staged 4 Times) (2 = Staged 3 Times) (3 = Staged 2 Times) (4 = Staged 1 Time) (5 = Not Staged)	The number of times material is moved and staged represents the number of times material is picked up, moved, set down, etc. increasing wasted motion, movement, etc.	Determine the number of times material is staged as it is moved through functions or operations.	Floor
	Waiting Time	The total amount of time items spend waiting to be processed between functions, operations, etc. as WIP. (0 = Unknown, > 8 Hours) (1 = 4 - 8 Hours) (2 = 2 - 4 Hours) (3 = 1 - 2 Hours) (4 = 0.5 - 1 Hours) (5 = < 0.5 Hours)	The cumulative amount of time material spends in staging is entirely non-value-added increasing order fulfillment, processing, etc. lead time.	Determine the amount of time associated with material as it is staged waiting for the next process between functions and operations.	Floor
	WIP				

	Item	Evaluation Point	Purpose	Methodology	Where?
Kanban Systems	**Kanban System**	Is there a kanban system developed to trigger production, processing, etc.? (0 = No, there is not a kanban system.) (1 = Yes, some processes have a kanban system that trigger production, etc.) (2 = Yes, most processes have a kanban system that trigger production, etc.)	Kanban systems manage WIP levels and provide the mechanism for triggering processes and ensuring the pull system.	Determine if kanban systems are used to trigger process and material flow and movement within and between functions, processes, operations.	Floor
	Kanban Inventory	The amount of work triggered by the kanban system for a given operation. (0 = None/Unknown, > 8 Hours) (1 = 4 - 8 Hours) (2 = 2 - 4 Hours) (3 = 1 - 2 Hours) (4 = 0.5 - 1 Hours) (5 = < 0.5 Hours)	The amount of work the kanban signals directly impacts the amount of WIP inventory level in the system at any given time.	Compare the kanban pull signal and corresponding batch size for processes against work standards to assess the amount of work triggered through the pull system operations.	Floor
	Usage	The kanban system is regularly used and manages inventory levels, production, etc.? (0 = No, there is not a kanban system.) (1 = Yes, the kanban system is regularly used for some of the processes.) (2 = Yes, the kanban system is regularly used for most of the processes)	Usage and integrity of the kanban system ensures that pull systems and WIP inventory levels are maintained at the pre-specified levels.	Determine if the kanban systems is rigorously and consistently used to manage WIP inventory and as the pull signal for processes, operations, and functions.	Floor
	Kanban Systems				
Quick Changeover	**Change Time**	The amount of time to change from process to process, operation to operation, etc.? (0 = Unknown, > 2 Hours) (1 = 1 - 2 Hours) (2 = 20 - 60 Minutes) (3 = 10 - 20 minutes) (4 = 5 - 10 Minutes) (5 = < 5 Minutes)	Managing process shifts, changeovers, etc. enhances the responsiveness to changes in customer demand and reduces the amount of WIP inventory necessary to manage variability.	Watch changeover times associated with shifts in functions, etc. and discuss the time associated with shifting manpower, equipment, etc. with personnel.	Floor
	Process Balancing	The amount of times that processes are balanced and changeovers made? (0 = Unknown, None) (1 = 1 Time) (2 = 2 Times) (3 = 3 Times) (4 = 4 Times) (5 = 5+ Times)	Balancing processes daily as variation and problems are encountered allows functions to maintain leveled flow and leveled output.	Watch functions, process control boards, manpower planning, etc. to determine the responsiveness in balancing processes, operations, functions, etc. and discuss with personnel.	Floor
	Quick Changeover				

	Item	Evaluation Point	Purpose	Methodology	Where?
Lead Time Tracking	**Lead Time**	The amount of lead time associated with processes from start to finish. (0 = Unknown, > 8 Hours) (1 = 4 - 8 Hours) (2 = 2 - 4 Hours) (3 = 1 - 2 Hours) (4 = 0.5 - 1 Hours) (5 = < 0.5 Hours)	The lead time of order processing and other processes illustrates the amount of time associated with value-added and non-value-added activities.	Process lead time is the amount of time associated with all the processing, movement, staging, etc. from start to finish of an operation.	Floor
	Department Lead Time	The amount of lead time associated with function processes from start to finish. (0 = Unknown, > 8 Hours) (1 = 4 - 8 Hours) (2 = 2 - 4 Hours) (3 = 1 - 2 Hours) (4 = 0.5 - 1 Hours) (5 = < 0.5 Hours)	Function lead time illustrates which processes are responsible for added lead time and where the potential leverage points may be for improvements.	Function lead time is the amount of time associated with all the processes within each function from start to finish of all operations.	Floor
	Lead Time Tracking				
Inventory Turns	**Inventory Turns**	The number of annual inventory turns. (0 = Unknown, Less Than One) (1 = 1 Time) (2 = 2 Times) (3 = 3 Times) (4 = 4 Times) (5 = 5+ Times)	Inventory turnover indicates how much inventory exists on material and how quickly facility stock is being worked through and shipped to fulfill customer orders, etc.	Annual sales volume versus average annual inventory volume determines annual inventory turns.	Office & Floor
	WIP Turns	The number of daily WIP turns. (0 = Unknown, Less Than One) (1 = 1 Time) (2 = 2 Times) (3 = 3 Times) (4 = 4 Times) (5 = 5+ Times)	Daily WIP turnover indicates how quickly material is being processed through the facility, department, function, etc.	Daily WIP turnover can be determined by assessing the number of times the docks are turned over, queues are filled and processed, etc.	Office & Floor
	Inventory Turns				

	Item	Evaluation Point	Purpose	Methodology	Where?
Order Frequency	**Frequency**	Customer orders are placed, accepted, processed, etc. over what time span basis? (0 = Unknown, Larger Than Weekly Basis) (1 = Each Week) (2 = Multiple Times/Week) (3 = Each Day) (4 = Multiple Times/Day) (5 = Hourly Basis)	Ordering frequency allows for Just-In-Time delivery of materials to minimize wastes of inventory, motion, movement, and opportunity costs.	Examine and observe material ordering policies & practices, discuss with appropriate personnel, and observe ordering practices.	Office & Floor
	EOQ versus Space	Order frequency balances ordering, setup, and opportunity costs versus added space, handling, truck filling, and movement requirements. (0 = Unknown, Balance is not attempted.) (1 = Some orders placed w/ cost balance.) (2 = Usually orders placed w/ cost balance)	There is a balance between added holding costs, opportunity cost, handling costs, etc. and ordering costs, setup costs, etc. to be balanced to minimize wastes and ensure availability.	Examine and observe material ordering policies & practices, discuss with appropriate personnel, and observe ordering practices.	Office & Floor
	Sell One, Buy One	Customers are encouraged to place orders on a "sell one, buy one" basis and the benefits explained for leveling workload. (0 = Sell one, buy one approach is not utilized, explained, and/or attempted.) (1 = Some customers sell one, buy one.) (2 = Most customers sell one, buy one.)	Using final customer sales activity as the pull-system trigger levels internal system variation with respect to ordering, inventory, movement, etc. by aggregating customer demand variation.	Examine and observe customer ordering policies, practices, and incentives, discuss with appropriate personnel, and observe ordering practices.	Office & Floor
	Order Frequency				

Material Flow:

	Item	Evaluation Point	Purpose	Methodology	Where?
Pull Systems	**Pull System Development**	Simple visual mechanisms that trigger material movement, processing, etc. from customer demand are developed. (0 = No, pull systems are not developed.) (1 = Yes, pull systems at some processes.) (2 = Yes, pull systems are developed and mechanisms exist for most processes.)	Pull systems manage inventory levels reducing the wastes associated with WIP, inventory, etc. producing and moving material in accord with customer demand.	Examine processes and discuss production, process, movement signals with personnel to determine the existence of pull systems.	Floor
	Pull System Usage	Simple visual mechanisms that trigger material movement, processing, etc. from customer demand are used regularly. (0 = No, pull systems are not used.) (1 = Yes, some pull systems are used.) (2 = Yes, many pull systems are developed and mechanisms used regularly.)	Using the pull system ensures the associated benefits and waste reductions are achieved.	Examine processes and discuss production, process, movement signals with personnel to determine the usage of the pull systems.	Floor
	Pull Systems				
Leveled Flow & Work	**Between Functions**	Is daily material and work flow regularly leveled between functions/departments? (0 = No, material/work flow is not leveled.) (1 = Yes, daily material and work flow is regularly leveled between some functions.) (2 = Yes, daily material and work flow is regularly leveled between most functions.)	Leveling daily material and work flow regularly ensures that material movement and work is balanced between functions throughout the facility, reducing WIP, bottlenecks, inventory, etc.	Analyze functional and departmental interaction to understand material and work flow balancing frequency. Examine process control boards, manpower planning, etc.	Floor
	Within Functions	Is daily material and work flow regularly leveled within each function/department? (0 = No, material/work flow is not leveled.) (1 = Yes, daily material and work flow is regularly leveled within some functions.) (2 = Yes, daily material and work flow is regularly leveled within most functions.)	Leveling daily material and work flow regularly ensures that material movement and work is balanced within each function throughout the facility, reducing WIP, bottlenecks, inventory, etc.	Analyze individual function and department material and work flow balancing process and frequency. Examine process control boards, manpower planning, etc.	Floor
	Leveled Flow & Work				

	Item	Evaluation Point	Purpose	Methodology	Where?
FIFO	**FIFO Planning & Scheduling**	Individual function & process scheduling of daily work are planned on a FIFO basis? (0 = No, scheduling is not FIFO based.) (1 = Yes, some scheduling, planning, ordering, etc. is managed on a FIFO basis.) (2 = Yes, most scheduling, planning, ordering, etc. is managed on a FIFO basis.)	Using FIFO methodology for managing and scheduling processes and functions enhances responsiveness rates and reduces the likelihood for potential timing errors, problems, etc.	Examine work scheduling processes for daily work activities for each function and process to determine if there are processes to ensure FIFO is maintained and that those processes are used.	Floor
	FIFO Processes	Material flow is managed on a "First In, First Out" FIFO basis? (0 = No, FIFO material flow is not used.) (1 = Yes, some material flow is managed on a FIFO basis.) (2 = Yes, most material flow is managed on a FIFO basis.)	FIFO methodology maximizes process responsiveness, order fulfillment, availability, etc.	Examine material flow processes to determine if processes exist and are used to ensure material is moved through processes maintaining FIFO.	Floor
	Maintaining FIFO	Are there visual controls, process controls, etc. to ensure FIFO is maintained? (0 = No process exists to ensure FIFO.) (1 = Yes, there are some processes to ensure FIFO is maintained.) (2 = Yes, most operations have processes to ensure FIFO is maintained.)	The visual controls, process controls, etc. are the mechanisms that ensure FIFO is maintained in each function and throughout the facility.	Examine areas for visual controls, SOPs, and actual operations for process controls that ensure FIFO is maintained. Cones, indicator lights, etc. may be used to manage FIFO.	Floor
	FIFO				
Layout & Zones	**Facility Layout by Zone & Type**	Is the facility layout based on grouping similar items and inventory types together in zones within the warehouse? (0 = No, the facility layout does not group similar items into zones in the warehouse.) (1 = Yes, the facility layout groups similar items into zones in the warehouse.)	Grouping similar items allows for better planning of work, standardized work units and processes, equipment isolation, racking configurations, worker movement, etc.	Determine if the slotting methodology, location identification, etc. groups the warehouse into similar items and zones within the warehouse. May be visible on floor or in WMS logic.	IC & Floor
	Location Layout	Is the facility layout based on placing faster movers closer to shipping areas, closer to travel aisles, and in mid-level locations? (0 = No, the facility layout does not place faster movers closer to shipping, etc.) (1 = Yes, the facility layout places faster movers closer to shipping, aisles, etc.)	Placing the fastest moving items in the locations closest to shipping areas, travel aisles, and in mid-level locations minimizes travel, motion, etc. required for picking, put-away, etc.	Examine facility layout, WMS logic, and/or slotting methodology to determine location identification parameters for velocity, sales, etc. characteristics.	IC & Floor

	Item	Evaluation Point	Purpose	Methodology	Where?
	Department Layout	Are individual process layouts based on grouping similar items, faster movers, etc. closer to their intended final destination reducing movement, motion, travel, etc.? (0 = Process layouts do not enhance flow.) (1 = Some process layouts enhance flow.) (2 = Most process layouts enhance flow.)	Individual process layouts should be determined to enhance material flow, work flow, worker movement, etc. to minimize wastes due to movement, motion, travel, etc.	Visually examine individual floor processes and operations to determine the extent to which material and work flow grouped to minimize travel, movement, motion, etc.	Floor
	Layout & Zones				
Velocity & Slotting	**Initial Velocity Slotting**	Is there logic for determining specific inventory locations for items based on sales, velocity, classifications, etc.? (0 = No, there is not any specific logic for slotting items into inventory locations.) (1 = Yes, there is specific logic for slotting items into inventory locations.)	Initial slotting practices place items into optimal locations based on various dimensions to minimize travel, motion, movement, etc. for picking, put-away, etc. operations.	Examine WMS logic or slotting methodology to determine location identification parameters for velocity, sales, etc. characteristics.	IC & Floor
	Slotting Maintenance	Is there an inventory slotting/maintenance plan to manage inventory changes, slotting, locations, consolidation, etc.? (0 = No maintenance plan exists.) (1 = Yes, there is an plan to manage some of the changing inventory dimensions.) (2 = Yes, there is a comprehensive plan.)	Maintaining slotting of inventory ensures items remain in optimal configuration, consolidated, etc. as parts move through sales life cycles, demand changes, and other changes.	Examine inventory control daily slotting and inventory maintenance plan to determine the extent to which inventory integrity can be made for location placement, quantities, etc.	IC & Floor
	Top Velocity Movers Location	What number of top movers are in premium locations to minmize travel distance, etc.? (0 = Unknown, no velocity moves made.) (1 = < 20) (2 = 20 - 40) (3 = 40 - 60) (4 = 60 - 80) (5 = > 80)	The velocity slotting moves must be performed regularly to maintain the optimal inventory configuration.	Examine inventory control functions, boards, etc. to determine if daily slotting moves are being made and compare against departmental targets.	IC & Floor
	Velocity & Slotting				

	Item	Evaluation Point	Purpose	Methodology	Where?
Travel Distance	**Function Material Movement**	Do individual functions/processes material flow minimize material travel distance? (0 = No flow and travel is not minimized.) (1 = Yes, some functions and processes material flow travel distance is minimized.) (2 = Yes, most functions and processes material flow travel distance is minimized.)	Minimizing material travel distance for individual functions and processes reduces the amount of material flow wasted motion, movement, travel, etc. in each function and process.	Examine material flow and the corresponding travel distance associated with each function and process to determine the extent to which travel is minimized.	Floor
	Function Personnel Movement	Do individual functions/processes material flow minimize worker travel distance? (0 = No, flow and travel is not minimized.) (1 = Yes, some functions and processes material flow travel distance is minimized.) (2 = Yes, most functions and processes material flow travel distance is minimized.)	Minimizing worker travel distance for individual functions and processes reduces the amount of worker wasted motion, movement, travel, etc. in each function and process.	Examine worker travel distance with the corresponding material flow to determine the extent to which travel is minimized.	IC & Floor
	WMS Logic	Does the WMS picking, put-away, etc. logic minimize travel distance using serpentine paths, etc.? (0 = No, WMS does not minimize travel distance or is not used.) (1 = Yes, WMS minimizes travel distance for picking, put-away, etc..)	Using serpentine travel paths in conjunction with velocity slotting procedures minimizes travel distance for picking, put-away, etc. Additionally, motion and movement are reduced.	Examine WMS logic and travel path determination methodology to determine the travel distances associated with the travel paths.	Floor
	Travel Distance				
Cellular Structure	**Cellular Work Structure**	Are individual processes and layouts organized into a cellular structure that leverages single and multiple operators across functional activities? (0 = No, cellular structure is not used.) (1 = Yes, some cellular structure is used.) (2 = Yes, most processes are cellular.)	Cellular structures maximize worker cross-training, minimize work travel, material travel, waiting time, staging, etc. for items as they move through processes.	Examine process layouts and operations working to determine the extent which cellular structures are used to leverage single operators across multiple functions to minimize waiting, travel, etc.	Floor
	Material Flow Management	Does the cellular structure provide material flow management by leveraging kanbans, pull systems, one/small batch flow, etc.? (0 = No, the cells do not provide material flow management mechanisms.) (1 = Yes, the cells provide material flow management mechanisms.)	The material flow through the cell ensures WIP, inventory, waiting, staging, etc. are reduced.	Watch and discuss with workers the material flow through cells and the management mechanism that trigger material movement through processes.	Floor

	Item	Evaluation Point	Purpose	Methodology	Where?
	Manpower Management	Can the cells be expanded, contracted, or leveraged depending on demand, work, and process requirements daily? (0 = No, cells do not provide manpower management and balancing mechanisms.) (1 = Yes, cells provide manpower management and balancing mechanisms.)	Expansion and contraction of work cells ensures that manpower, processes, and work flow are leveled, that capacity equals demand, and that responsiveness is attained.	Examine manpower planning, adjustments, movement, etc. as daily activities are planned, adjusted, and balanced to meet customer demand and level work and material flow.	Floor
	Work Flow	Does the cellular structure manage work flow in a manner that minimizes material travel, worker motion, worker travel, etc.? (0 = No, the cellular structure does not adequately minimize travel, motion, etc.) (1 = Yes, the cellular structure does not adequately minimize travel, motion, etc.)	The cell structure design should minimize worker travel, material travel, motion, movement, etc.	Assess cellular structure and watch material, worker, and equipment movement through work cells to assess the amount of motion, movement, travel, etc.	Floor
	Cellular Structure				
Demand Stabilization	**Facility Demand Leveling Mechanisms**	Are there facility mechanisms to level demand and/or manage manpower requirements across days and weeks? (0 = No demand leveling mechanisms exist.) (1 = Yes, some demand leveling is done.) (2 = Yes, many demand leveling mechanisms are used.)	Leveling facility demand reduces work requirement variation, enhancing planning and reducing requirements for inventory safety stock. Plan big outbound days with small inbound days, etc.	Watch and discuss planning activities, ordering practices, etc. with personnel to determine the extent that demand is leveled across facility activities, between inbound, outbound, etc.	Office and Floor
	Function Demand Leveling Mechanisms	Are there functional mechanisms to level demand and/or manage manpower requirements across days and weeks? (0 = No demand leveling mechanisms exist.) (1 = Yes, some demand leveling is done.) (2 = Yes, many demand leveling mechanisms are used.)	Leveling internal process and function demand reduces work requirement variation between days, weeks, etc. within inbound, outbound, VAS, daily requirements and corresponding planning.	Watch and discuss functional activities with personnel to determine the extent that demand is leveled within functional activities for inbound, outbound, VAS, etc. daily/weekly output.	Office and Floor
	Demand Stabilization				

	Item	Evaluation Point	Purpose	Methodology	Where?
Cross-Docking	**Cross-Docking Process**	Items that are cross-docked are moved, staged, wait a minimal amount of times. (0 = No, cross-docked items are not minimally moved, staged, and/or wait.) (1 = Yes, cross-docked items are minimally moved, staged, and/or wait.)	Cross-docking eliminates put-away, storage, and picking activities, as well as IC activities and all the waste associated with each.	Examine cross-docking area, procedures, SOPs, and discuss with personnel to determine the cross-docking process effectiveness and corresponding staging and waiting times for items.	Floor
	Cross-Docking Staging	The items that are to be cross-docked are placed into adequate staging, clearly identifiable, marked, etc. for shipment. (0 = No, cross-docking staging is not properly visually marked, identifiable, etc.) (1 = Yes, cross-docking staging is properly visually marked, identifiable, etc.)	Cross-docking staging needs to be identifiable, adequately marked, etc. to ensure that material is properly located and is shipped to the proper destination.	Examine cross-docking area, procedures, SOPs, and discuss with personnel to determine the staging visual management adequacy.	Floor
	Percentage of Business	What percentage of actual daily shipping activities are cross-docked versus potential receiving cross-docking opportunities? (0 = Cross-docking is not done/unknown.) (1 = < 20%) (2 = 20% - 40%) (3 = 40% - 60%) (4 = 60% - 80%) (5 = > 80%)	Maximum value can be achieved from cross-docking all material for which there is an opportunity to cross-dock material.	Examine cross-docking opportunities against actual cross-docking achievements by cross referencing parts being shipped against parts being received versus actual cross-docking numbers.	Floor
	Cross-Docking				

Continuous Improvement:

	Item	Evaluation Point	Purpose	Methodology	Where?
PDCA	**Deming Cycle: Plan Do Check Act**	A six-month lean implementation project plan for the facility and each functional area organized by priority, potential impact, and perceived benefits has been created, with the baseline data collected, initial data analysis performed, and improvement targets set. (0 = No) (1 = Yes)	To plan facility, functional, and departmental lean project implementation and process improvement, capture baseline data, determine actual improvements to be made, and estimate potential benefits.	Verification of the creation, posting, and communication of six-month lean plan and action items prioritization, deliverables, background data analysis, and input gathered from personnel.	Lean Tracking Area & Floor
		The actions required to implement the lean project plan have been made, action items completed, etc. (0 = No) (1 = Yes)	To physically make the changes, execute the plan, and implement the project.	The initial actions have been taken to implement the lean plan and appropriately documented, which can be verified from work area and project plan tracking.	Lean Tracking Area & Floor
		The improvement outcomes and expectations have been compared on performance, productivity, and/or quality, with feedback gathered from affected customers, employees, and/or functions, and further refinements determined. (0 = No) (1 = Yes)	To check and study the results of the changes to identify additional improvements and changes to achieve project goals and success.	View formal documentation of changes via A3s, etc. illustrating before and after comparisons, capturing progress, and documentation of any applicable feedback gathered.	Lean Tracking Area & Floor
		A sustainment plan with milestones, corrective actions, training, rollout, etc. has been developed. The lessons learned and best practices have been communicated internally and externally. The next steps and projects have been determined. (0 = No) (1 = Yes)	Take additional actions to improve the project, plan additional projects and next steps, standardize the process, and share the results within the organization.	A sustainment plan has been determined for project actions, milestones, training, rollout, etc. The lessons learned and best practices have been shared. The next steps and actions outlined.	Lean Tracking Area & Floor
	Improvement Sustainment	Projects and corresponding benefits have been sustained over the long-term. The changes in work practices have been indoctrinated into the standard work practices, SOPs, training, and culture. (0 = No) (1 = Yes)	Ensure improvements, projects, and changes in work practices are sustained long-term to prevent slippage in productivity, quality, performance, and work practices..	Verification of sustainment by checking areas where projects were implemented, interviewing affected personnel, supervisors, and manager.	Floor & Office
	PDCA				

	Item	Evaluation Point	Purpose	Methodology	Where?
Kaizen Events	**Frequency**	The number of formal annual Kaizen events conducted at the facility. (0 = None) (1 = 1 or 2 Annual Kaizen Events.) (2 = 3 or 4 Annual Kaizen Events.) (3 = 5 or 6 Annual Kaizen Events.) (4 = 7 or 8 Annual Kaizen Events.) (5 = 9 or 10 Annual Kaizen Events.)	The frequency of formal Kaizen events illustrate the level of facility commitment to lean implementation and continuous improvement.	Observed from lean project plan, formal documentation, and informal communication with employees, supervisors, and manager.	Office, Lean Tracking Area, & Floor
	Outcomes	The number of formal annual Kaizen events providing significant improvement to the facility or department w/ sustained results. (0 = None) (1 = 1 to 2 Kaizen Events.) (2 = 3 or 4 Kaizen Events.) (3 = 5 or 6 Kaizen Events.) (4 = 7 or 8 Kaizen Events.) (5 = 9 or 10 Kaizen Events.)	The level of success garnered from Kaizen events illustrates the potential impact of lean improvements, the level of organizational support, and the importance of continuous improvement.	Observed from lean project plan, formal documentation, and informal communication with employees, supervisors, and manager.	Office, Lean Tracking Area, & Floor
	Kaizen Events				
Employee Suggestions	**Existence of Suggestion and Reward Programs**	A process is developed and implemented to formally capture, track, recognize, and reward implemented continuous improvement ideas provided by employees. (0 = No) (1 = Yes)	To encourage and reward employee participation in the lean implementation and continuous improvement process a formal program with incentives should be in place.	Suggestion program verification.	Office
	Frequency of Employee Suggestions	The percent of employees who submit formal employee suggestions annually. (0 = None) (1 = <20%) (2 = 20% - 40%) (3 = 40% - 60%) (4 = 60% - 80%) (5 = >80%)	The usage of the program gages the level of involvement and engage of employees in the lean implementation and continuous improvement program.	Suggestion program tracking data.	Office
	Implementation Rate for Employee Suggestions	The implementation rate for formally submitted employee suggestions. (0 = None) (1 = <20%) (2 = 20% - 40%) (3 = 40% - 60%) (4 = 60% - 80%) (5 = >80%)	The validity of employee suggestions and perceived usefulness of management to implement suggestions enlightens management and worker relations and program success and usefulness.	Suggestion program tracking data.	Office

	Item	Evaluation Point	Purpose	Methodology	Where?
	Employee Suggestion Implementation Decision Making Team	The level of organizational involvement when analyzing suggestions for adoption, and implementation during the continuous improvement decision making process and analysis. (0 = None) (1 = Corporate) (2 = Facility Manager) (3 = Supervisors) (4 = Facility Manager & Supervisors) (5 = Management and Associates)	Empowering workers to make decisions about work practices and the participative nature of management worker relations enhances job satisfaction, enriches work, and illustrates trust in people.	Suggestion program tracking data.	Office
	Employee Suggestions				
Understand Systems View	**Manager Understand Function Impacts on Overall Facility Goals**	Manager understands the impact of individual functions and departments on overall facility performance and improvement. (0 = None) (1 = Very Little) (2 = Little) (3 = Somewhat) (4 = To A Great Extent) (5 = Completely)	Manager understands the facility interdependencies, operations, and work units and their impact on overall facility performance to prioritize improvements and plan lean implementation and sustainment.	Subjective assessment of manager's understanding of interdependency of facility functions and their relative impact on overall facility performance.	Office
	Manager 's Systems View	Manager understands the impact of various actions and interdependency of individual functions and departments on overall facility performance and improvement. (0 = None) (1 = Very Little) (2 = Little) (3 = Somewhat) (4 = To A Great Extent) (5 = Completely)	Understanding the interdependency of the work functions is instrumental in manpower planning, prioritizing improvements, and leveling facility work flow within and between functions.	Subjective assessment of manager's understanding of interdependency of facility functions and their relative impact on overall facility performance.	Office
	Supervisor Understand Function Impacts on Overall Facility Goals	Supervisor understands the impact of individual functions and departments on overall facility performance and improvement. (0 = None) (1 = Very Little) (2 = Little) (3 = Somewhat) (4 = To A Great Extent) (5 = Completely)	Supervisor understands the function interdependencies, operations, and work units and their impact on overall facility performance to prioritize improvements and plan lean implementation and sustainment.	Subjective assessment of supervisor's understanding of interdependency of facility functions and their relative impact on overall facility performance.	Office
	Supervisor's System View	Supervisor understands the impact of various actions and interdependency of individual functions and departments on overall facility performance and improvement. (0 = None) (1 = Very Little) (2 = Little) (3 = Somewhat) (4 = To A Great Extent) (5 = Completely)	Understanding the interdependency within and between work functions is instrumental in manpower planning, prioritizing improvements, and leveling work flow within functions.	Subjective assessment of supervisor's understanding of interdependency of facility functions and their relative impact on overall facility performance.	Office
	Understand Systems View				

	Item	Evaluation Point	Purpose	Methodology	Where?
Preventative Maintenance	**Machines**	Is there a PM plan for machines? (0 = None) (1 = PM Plan Exists) (2 = Daily PM Checklists Posted) (3 = Daily PM Checklists Completed Regularly) (4 = Common Problem Capture Mechanism Exists) (5 = Common Problems Root Causes Are Solved)	Preventative maintenance plans helps ensure machines are available when needed, unexpected breakdowns are infrequent, and that machines are in acceptable operating condition.	Observed through preventative maintenance procedures, shop-floor checklists, and planning schedules.	Lean Tracking Area and Floor
	Equipment	Is there a PM plan for equipment? (0 = None) (1 = PM Plan Exists) (2 = Daily PM Checklists Posted) (3 = Daily PM Checklists Completed Regularly) (4 = Common Problem Capture Mechanism Exists) (5 = Common Problems Root Causes Are Solved)	Preventative maintenance plans helps ensure equipment is available when needed, unexpected breakdowns are infrequent, and that equipment is in acceptable operating condition.	Observed through preventative maintenance procedures, shop-floor checklists, and planning schedules.	Lean Tracking Area and Floor
	Preventative Maintenance				
Supplier Integration	**Trailer Staging Status**	Inbound and Outbound parts are sequenced and pre-sorted to minimize handling. (0 = N/A) (1 = <20%, Seldom) (2 = 20%-40%, Occasionally) (3 = 40% - 60%, About Half) (4 = 60% - 80%, Usually) (5 = >80%, Always)	The amount of material handling, material sortation, and potential for errors can be reduced by leveraging pre-sorted materials.	Observed through formal documentation of sortation requirements and standardized staging processes and coordination with Inbound Suppliers and Outbound Customers.	Lean Tracking Area and Floor
	Suppliers Worked With	The number of suppliers worked with to enhance inter-organizational cooperation. (0 = None) (1 = 1 Supplier), (2 = 2 Suppliers) (3 = 3 Suppliers) (4 = 4 Suppliers) (5 = 5+ Suppliers)	The more suppliers that are worked with the better the relationships and coordination across organizations, reducing potential duplication of work and processes.	Observed through formal documentation of improvement projects and process specifications.	Lean Tracking Area and Floor
	Supplier Integration				

	Item	Evaluation Point	Purpose	Methodology	Where?
SPC	**SPC Training**	Statistical Process Control Training and activities have been completed by: (0 = None) (1 = Use Corporate Facilitator) (2 = Single Individual, Novice) (3 = Single Individual, Intermediate) (4 = Single Individual, Mastery) (5 = Multiple Individuals, Various levels)	Increase the tools in the lean toolbox for identifying problems and solutions. Additionally, providing an increased understanding of process variation and its effects on work.	Observed from Lean Training Board.	Lean Tracking Area and Floor
	SPC Tools Used	Statistical Process Control usage: (0 = None) (1 = Single w/ corporate facilitator.) (2 = Multiple w/ corporate support.) (3 = Single occurrence autonomously.) (4 = Multiple occurrences autonomously.) (5 = Assist and facilitate other facilities.)	The level of manager, supervisor, and employee involvement illustrates the importance of understanding initiatives and usefulness of various tools.	Observed from project implementation documentation and completed action items.	Lean Tracking Area and Floor
	SPC				
Technology & Equipment	**Integration of Technology**	Technology solutions used for problem resolution simplify processes and reduce redundancy. (0 = Not Utilized, Go to next Construct & Score next Evaluation Point as Zero.) (1 = Yes Utilized, Proceed to next Evaluation Point in Item.)	Appropriate use of technology takes advantage of automation when applicable, reducing the work to be performed manually.	Subjective observation of simplifying processes and reducing redundancy with technology solutions.	Lean Tracking Area and Floor
	User Friendliness of Technology and Equipment	Technology and equipment solutions are easily learned and used. (0 = None) (1 = Very Little, Technical Skills Required) (2 = Little, Some Technical Skills Required) (3 = Somewhat, Management Required) (4 = To A Great Extent, Team Lead) (5 = Completely, All Employees)	Technology solutions are easy to use, consequently increasing the likelihood that they will be used.	Subjective observation of technology solutions and assessment of skill level required for applicable resolutions.	Lean Tracking Area and Floor
	Technology & Equipment				

APPENDIX B:

LEAN IMPLEMENTATION ASSESSMENT TOOL OUTPUT EXAMPLES

Table 27: Scoring Summary Output

1		SOPs	Standardized Work/Planning	Commodity Grouping	Common Processes & Best Practices	Trailer Loading & Unloading	Routing & Travel Paths				Construct Weight	Standardized Processes	Possible
Standardized Processes	A1	1.890	2.112	2.558	1.279	1.733	0.494				0.125	**1.678**	**5.0**
	A2	3.047	3.164	3.333	2.820	2.733	0.552				0.125	**2.608**	**5.0**
	A3	3.949	4.094	4.612	4.612	3.616	4.244				0.125	**4.188**	**5.0**
	A4	4.486	4.486	5.000	5.000	4.267	4.840				0.125	**4.680**	**5.0**
2		**Safety & Ergonomics**	**Leadership Direction/Roles**	**Management Style**	**Teamwork & Empowerment**	**Cross-Training**	**Distance & MGMT Involve**	**Recognition & Compensation**	**Communication Strategy**	**Absenteeism & Turnover**	**Construct Weight**	**People**	**Possible**
People	A1	1.468	1.650	1.483	2.645	1.575	1.575	5.000	2.122	1.233	0.125	**2.083**	**5.0**
	A2	3.343	3.079	2.983	3.895	3.393	3.393	5.000	3.750	2.864	0.125	**3.522**	**5.0**
	A3	4.281	3.976	3.924	4.520	4.302	4.302	5.000	4.520	3.864	0.125	**4.299**	**5.0**
	A4	4.782	4.540	4.517	4.855	4.789	4.789	5.000	4.855	4.512	0.125	**4.738**	**5.0**
3		**5 Whys, Root Cause & Pareto**	**Inspection & Autonomation**	**Error Proofing Methodology**	**Inventory Integrity**	**Product & Process Quality**	**Quality Metrics**				**Construct Weight**	**Quality Assurance**	**Possible**
Quality Assurance	A1	3.270	0.000	0.000	1.444	1.733	1.027				0.125	**1.246**	**5.0**
	A2	3.895	2.500	2.143	2.277	2.733	1.860				0.125	**2.568**	**5.0**
	A3	4.520	4.419	3.953	3.847	3.616	3.333				0.125	**3.948**	**5.0**
	A4	4.855	5.000	4.286	4.390	4.267	3.973				0.125	**4.462**	**5.0**
4		**Value Stream Mapping**	**Process Control Boards**	**Metrics & KPI Boards**	**Lean Tracking**	**Visual Controls**	**Andon Systems**	**(A3) One Page Reports**			**Construct Weight**	**Visual Management**	**Possible**
Visual Management	A1	2.126	0.657	1.860	2.264	0.000	0.000	1.733			0.125	**1.234**	**5.0**
	A2	3.079	2.305	3.333	3.146	2.209	4.419	2.733			0.125	**3.032**	**5.0**
	A3	3.976	3.010	4.360	3.960	2.791	5.000	3.616			0.125	**3.816**	**5.0**
	A4	4.540	4.521	4.806	4.501	4.709	5.000	4.267			0.125	**4.621**	**5.0**
5		**5S**	**Signage & Shadow Boards**	**Cleanliness**	**Supply & Material MGMT**	**Point of Use Storage**	**ID Problem Parts Areas**				**Construct Weight**	**Workplace Organization**	**Possible**
Workplace Organization	A1	1.078	0.959	1.899	1.919	1.279	1.919				0.125	**1.509**	**5.0**
	A2	2.178	2.878	2.899	2.878	3.837	1.919				0.125	**2.765**	**5.0**
	A3	3.178	3.750	3.822	3.750	4.012	2.500				0.125	**3.502**	**5.0**
	A4	4.357	4.709	4.434	4.709	4.787	4.419				0.125	**4.569**	**5.0**
6		**Batch Sizes**	**WIP**	**Kanban Systems**	**Quick Changeover**	**Lead Time Tracking**	**Inventory Turns**	**Order Frequency**			**Construct Weight**	**Lot Sizing**	**Possible**
Lot Sizing	A1	1.860	1.899	0.685	1.733	1.733	1.733	0.685			0.125	**1.475**	**5.0**
	A2	3.014	2.899	2.093	2.733	2.733	2.733	2.093			0.125	**2.614**	**5.0**
	A3	3.944	3.822	2.778	3.616	3.616	3.616	2.778			0.125	**3.453**	**5.0**
	A4	4.709	4.434	4.057	4.267	4.267	4.267	4.057			0.125	**4.294**	**5.0**
7		**Pull Systems**	**Leveled Flow & Work**	**FIFO**	**Layout & Zones**	**Velocity & Slotting**	**Travel Distance**	**Cellular Structure**	**Demand Stabilization**	**Cross-Docking**	**Construct Weight**	**Material Flow**	**Possible**
Material Flow	A1	0.930	0.959	0.145	0.276	0.182	1.116	1.488	0.930	2.126	0.125	**0.906**	**5.0**
	A2	1.919	3.169	2.500	3.169	2.355	3.000	3.302	2.500	3.405	0.125	**2.813**	**5.0**
	A3	2.645	3.823	2.645	3.823	2.682	3.116	3.686	2.645	4.186	0.125	**3.250**	**5.0**
	A4	4.564	4.564	4.709	4.782	3.786	4.651	4.453	4.564	4.568	0.125	**4.516**	**5.0**
8		**PDCA**	**Kaizen Events**	**Employee Suggestions**	**Understand Systems View**	**Preventative Maintenance**	**Supplier Integration**	**SPC**	**Technology & Equipment**		**Construct Weight**	**Continuous Improvement**	**Possible**
Continuous Improvement	A1	5.000	2.233	1.983	1.733	1.733	1.733	1.733	2.694		0.125	**2.355**	**5.0**
	A2	5.000	3.233	2.983	2.733	2.733	2.733	2.733	3.527		0.125	**3.209**	**5.0**
	A3	5.000	4.233	3.924	3.616	3.616	2.733	3.616	4.360		0.125	**3.998**	**5.0**
	A4	5.000	4.767	4.517	4.267	4.267	4.267	4.267	4.806		0.125	**4.520**	**5.0**

Facility Overall Lean Assessment

	Total	Possible
A1	**1.561**	**5.0**
A2	**2.891**	**5.0**
A3	**3.807**	**5.0**
A4	**4.550**	**5.0**

Lean Constructs:

Figure 15: Overall Lean Construct Score Graph illustrates the overall lean construct score on multiple assessments over time with the different color line segments representing various assessments. Any potential deficiencies or points of success can be identified and leveraged accordingly, with additional analysis of each lean construct achieved by evaluating the lean constructs independently to further identify opportunities for improvement and points of success.

Specifically, Figure 15 illustrates growth over time between each of the fictitious assessments. Furthermore, some of the inferences that can be garnered from the first assessment, dark blue, are that material flow and visual management were two lean constructs where the facility had opportunity to improve. Conversely, the lean construct for continuous improvement and people were scored relatively high in comparison.

Overall Construct Score Graph

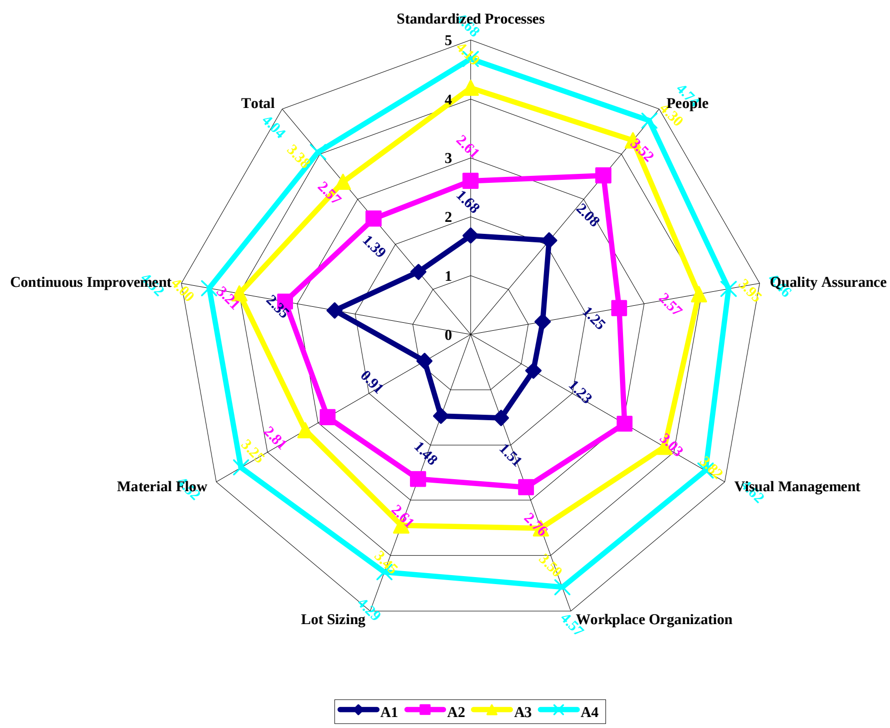

Figure 15: Overall Lean Construct Score Graph

Standardized Processes:

Figure 16: Standardized Processes Lean Construct Score Graph illustrates the scoring on the standardized processes lean construct over multiple fictitious assessments over time. On the graph it can be seen that an opportunity for improvement in the first two assessments, dark blue and pink, relates to the routing and travel paths methodology used while, the commodity grouping techniques are scored relatively high during those same assessments. Consequently, an opportunity for improvement identified in the first two assessments would be routing and travel paths methodologies. Using the corresponding evaluation points, facility personnel can determine strategies that will improve their operations at the shop-floor level with this regard.

Standardized Processes Score Graph

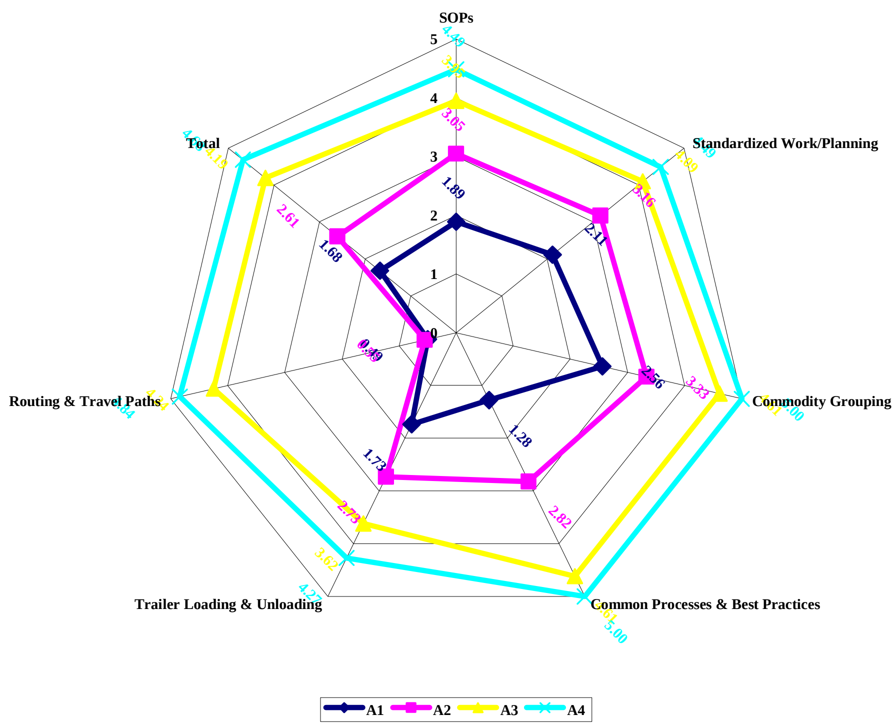

Figure 16: Standardized Processes Lean Construct Score Graph

People:

Figure 17: People Lean Construct Score Graph illustrates the scoring on the people lean construct over multiple fictitious assessments over time. On the graph for the first assessment, dark blue, it can be seen that there is an opportunity for improvement in the first assessment on all of the People dimensions with the exception of employee recognition and compensation where the score was extremely high. This information may help identify a best practice at work in the organization that can be shared for this lean practice, while identifying the other opportunities for improvement with Safety and Ergonomics, Leadership Direction and Roles, Management Style, Cross-Training, Teamwork and Empowerment, Power Distance and Daily Involvement, Communication Strategy, and Absenteeism, Layoffs, and Turnover.

People Score Graph

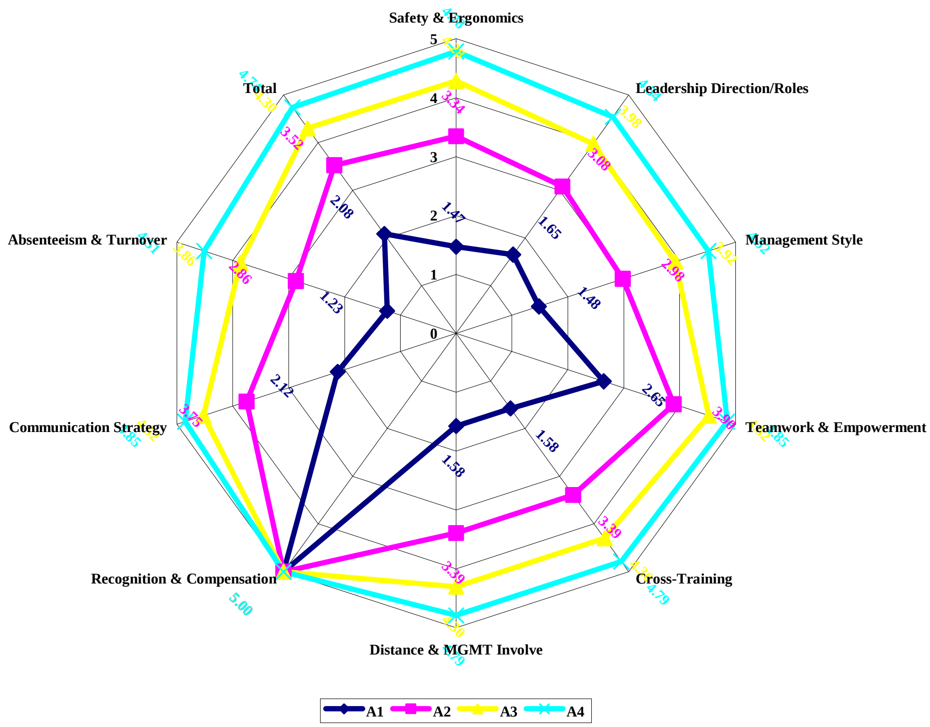

Figure 17: People Lean Construct Score Graph

Quality Assurance:

Figure 18: Quality Assurance Lean Construct Score Graph illustrates the scoring on the quality assurance lean construct over multiple fictitious assessments over time. On the graph for the first assessment in dark blue, it can be seen that an opportunity for improvement in the two lean practices related to Inspection and Autonomation and Error Proofing Methodology. Conversely, the score observed for Five Whys, Root Cause, and Pareto Analysis was fairly high indicating that the root-cause and identification procedures and that the development of the subsequent process around building in quality would be an opportunity for improvement, which was addressed in subsequent assessments. Furthermore, Inventory Integrity, Product and Process Quality, and Quality Metrics are all other areas for improvement identified from the graph.

Quality Assurance Score Graph

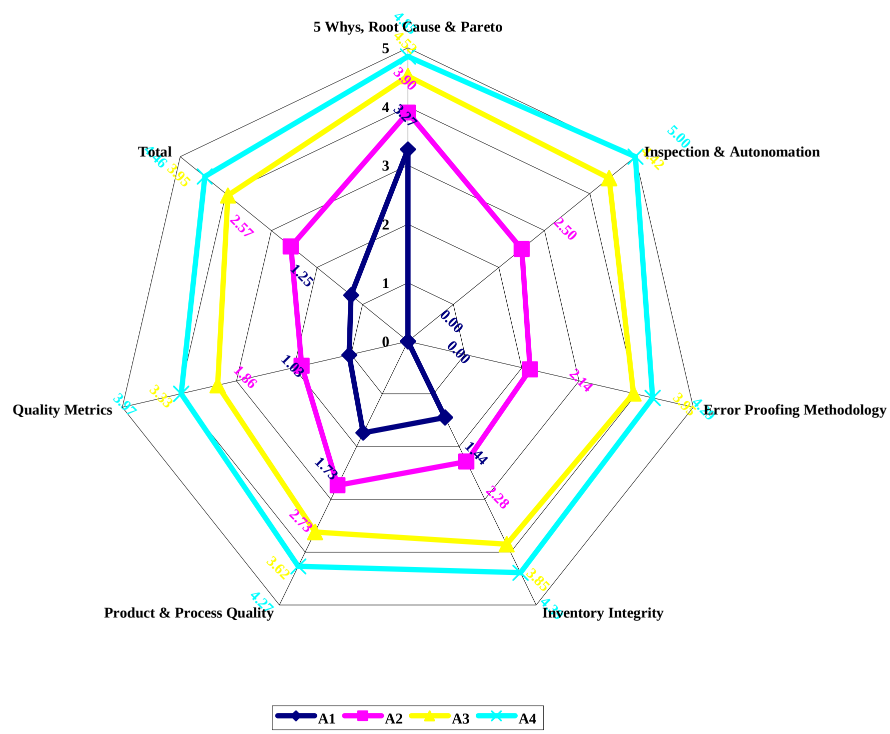

Figure 18: Quality Assurance Lean Construct Score Graph

Visual Management:

Figure 19: Visual Management Lean Construct Score Graph illustrates the scoring on the visual management lean construct over multiple fictitious assessments over time. On the graph for the first assessment, dark blue, it can be seen that the two opportunities for improvement are with the lean practices Process Control Boards and Andon Systems. The other lean practices for Value Stream Mapping, Metrics and Key Performance Indicator (KPI) Boards, Lean Tracking, Visual Controls, and (A3) One-Page Reports all have similar scores and opportunity for growth which was achieved in subsequent assessments.

Visual Management Score Graph

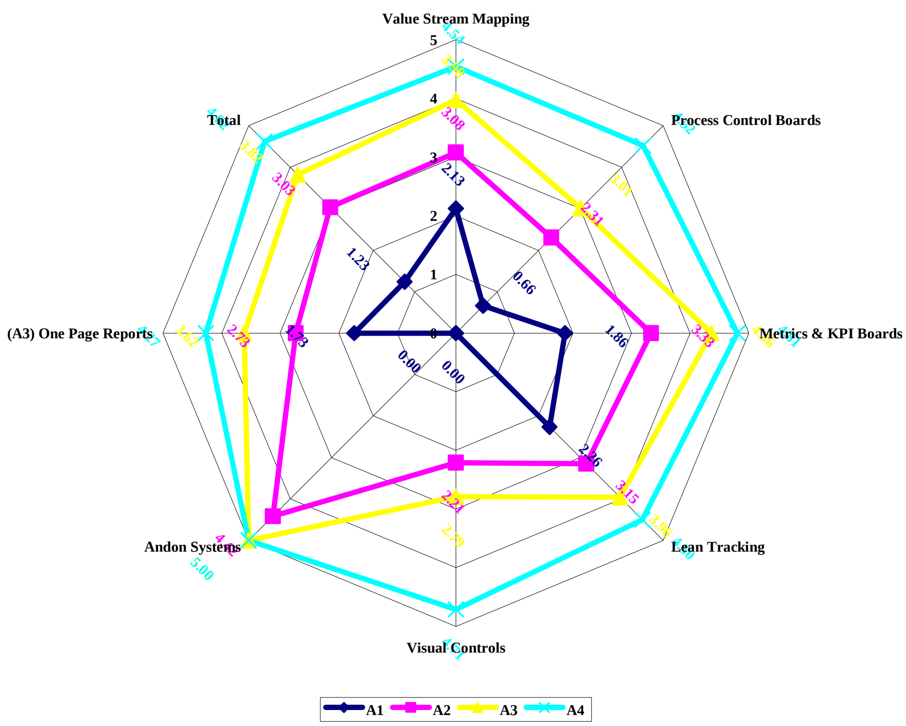

Figure 19: Visual Management Lean Construct Score Graph

Workplace Organization:

Figure 20: Workplace Organization Lean Construct Score Graph illustrates the scoring on the workplace organization lean construct over multiple fictitious assessments over time. On the graph for the first assessment, dark blue, it can be seen that the largest opportunities for improvement are with the lean practices of 5S, Signage and Shadow Boards, and Point of Use Storage (POUS). The other lean practices of Cleanliness, Supply and Material Management (MGMT), and Identification of Problem Parts Areas also show opportunities for improvement which increased in each of the subsequent lean implementation assessments over time.

Workplace Organization Score Graph

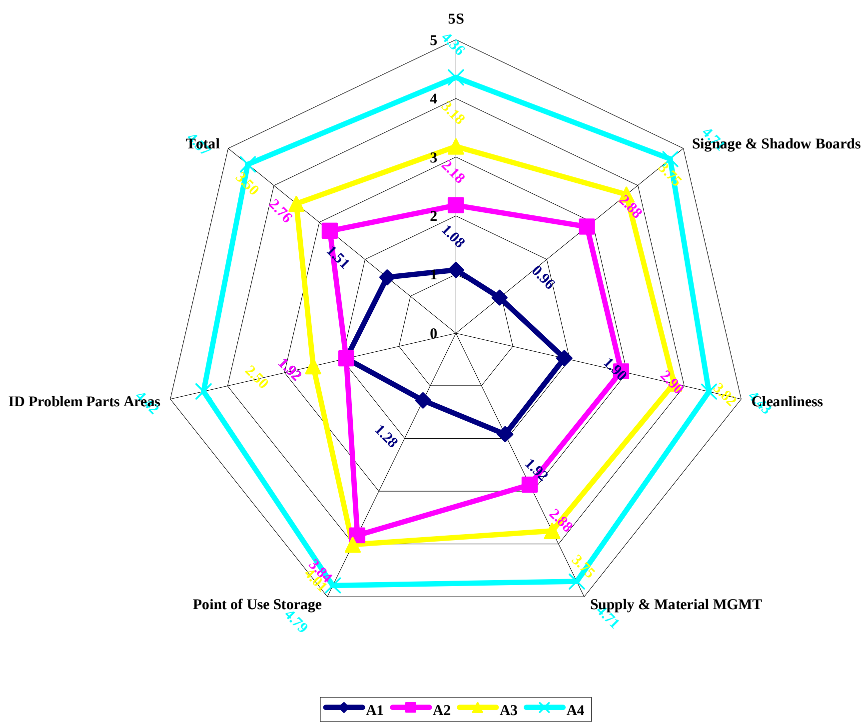

Figure 20: Workplace Organization Lean Construct Score Graph

Lot Sizing:

Figure 21: Lot Sizing Lean Construct Score Graph illustrates the scoring on the lot sizing lean construct over multiple fictitious assessments over time. On the graph for the first lean assessment in dark blue, it can be seen that the two lean practices with the largest opportunities for improvement are Kanban Systems and Order Frequency. The other lean practices of Batch Sizes, Work in Process (WIP), Quick Changeover, Lead Time Tracking, and Inventory Turns increased in subsequent lean assessments consistently as well as the two identified for improvement. The lot sizing lean construct is important to gauging the amount of work in process and the systems developed to manage the work in process in the warehouse.

Lot Sizing Score Graph

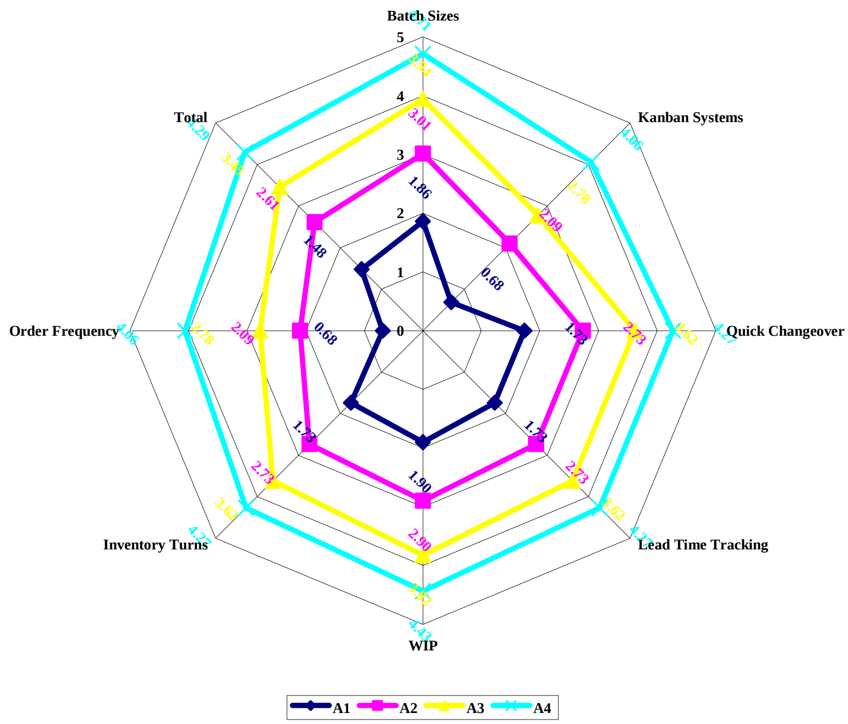

Figure 21: Lot Sizing Lean Construct Score Graph

Material Flow:

Figure 22: Material Flow Lean Construct Score Graph illustrates the scoring on the material flow lean construct over multiple fictitious assessments over time. On the graph for the first assessment in dark blue it can be seen that there is an opportunity for improvement with regard to the entire lean construct with the only exception of Cross-Docking. The other lean practices of Pull Systems, Leveled Flow and Work, First-In-First-Out (FIFO), Layout and Zones, Velocity and Slotting, Travel Distance, Cellular Structure, and Demand Stabilization all have significant opportunity for improvement identified from the first lean implementation assessment. This may require additional training and a concerted effort from the management team to drive improvement of Material Flow as a concept with corresponding training and continuous improvement activities.

Material Flow Score Graph

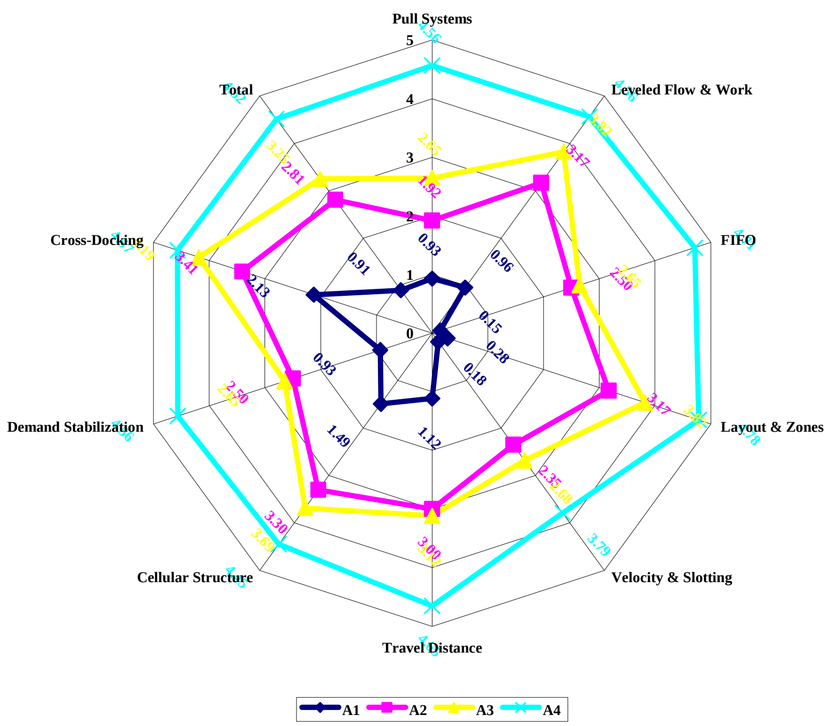

Figure 22: Material Flow Lean Construct Score Graph

Continuous Improvement:

Figure 23: Continuous Improvement Lean Construct Score Graph illustrates the scoring on the continuous improvement lean construct over multiple fictitious assessments over time. On the graph for the first assessment, dark blue, it can be seen that the Plan-Do-Check-Act (PDCA) score is a key strength and may be an opportunity to be leveraged as a best practice across accounts. The other lean practices for Kaizen Events, Employee Suggestions, Understand Systems View, Preventative Maintenance, Supplier Integration, Statistical Process Control (SPC), and Technology and Equipment all have comparable scores and seem to grow at a consistent rate across assessments. If it were seen that from one assessment to another slippage occurs, countermeasures would need to be developed and a root cause understood to prevent further deterioration of the lean practice.

Continuous Improvement Score Graph

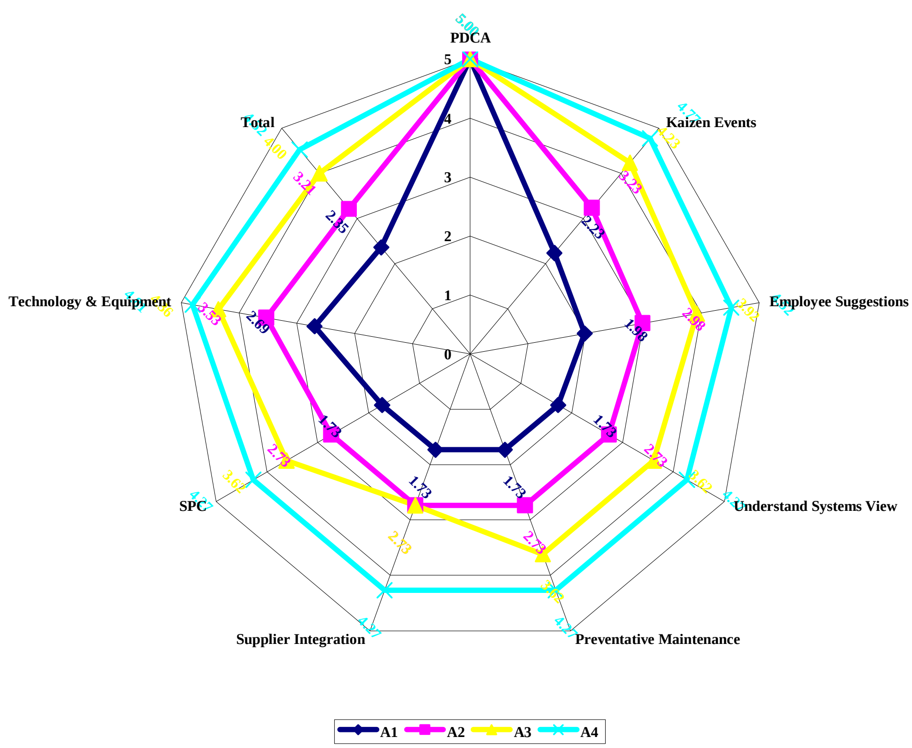

Figure 23: Continuous Improvement Lean Construct Score Graph

APPENDIX C:
PROJECT TIMELINE

<u>Phase 1 – Development: Create Proposal and Identify Lean Constructs</u>

(January 2006 – June 2006)

- Develop the dissertation proposal document = 6 Months
    - Detailed examination of the academic literature.
    - Identify the key constructs of lean warehousing.
    - Gain committee and university approval.
    - Determine potential organizations.

<u>Phase 2 – Definition: Onsite Operational Definition of Lean Constructs</u>

(July 2006 – September 2006)

- Operationally define and develop lean constructs in various facilities. = 3 Months

<u>Phase 3 – Validation: Conduct Initial Onsite Assessment, Pilot, and Implement Changes</u>

(October 2006 – December 2006)

- Conduct actual lean assessment in single facility to validate tool. = 3 Months

<u>Phase 4 – Data Collection: Conduct Twenty-Eight Additional Assessments</u>

(January 2007 – December 2007)

- Complete twenty-eight lean assessments in twenty-five facilities. = 12 Months

<u>Phase 5 – Completion: Finalize Dissertation Document</u>

(January 2008 – January 2009)

- Complete writing and analysis of dissertation and defend. <u>= 13 Months</u>

= 37 Months

APPENDIX D:

SPEARMAN RHO CORRELATION MATRIX

Table 28: Spearman Rho Correlation Matrix

Spearman's rho Correlations	SOPs	StndWork Dispatches	Commodity Group	CommonPrcs BestPractices	Load Unload	Routing Travel
SOPs						
Correlation Coefficient	1.000	0.171	0.205	0.115	-0.287	0.082
Sig. (2-tailed)	.	0.383	0.296	0.559	0.138	0.680
N		28	28	28	28	28
StndWorkDispatches						
Correlation Coefficient		1.000	0.151	0.037	-0.012	0.203
Sig. (2-tailed)		.	0.442	0.851	0.951	0.299
N			28	28	28	28
CommodityGroup						
Correlation Coefficient			1.000	0.015	0.062	0.021
Sig. (2-tailed)			.	0.938	0.756	0.916
N				28	28	28
CommonPrcsBestPractices						
Correlation Coefficient				1.000	-0.255	0.017
Sig. (2-tailed)				.	0.190	0.932
N					28	28
LoadUnload						
Correlation Coefficient					1.000	-0.034
Sig. (2-tailed)					.	0.863
N						28
RoutingTravel						
Correlation Coefficient						1.000
Sig. (2-tailed)						.
N						

Table 28: Spearman Rho Correlation Matrix

Spearman's rho Correlations	Safety Ergonomics	Leadership Roles	Mgmt Style	Cross Training	Teamwork Empowerment	Power Distance
SOPs						
Correlation Coefficient	0.031	0.395	0.151	0.066	0.242	0.051
Sig. (2-tailed)	0.874	0.037	0.443	0.740	0.215	0.796
N	28	28	28	28	28	28
StndWorkDispatches						
Correlation Coefficient	0.124	0.069	0.086	-0.074	0.059	-0.009
Sig. (2-tailed)	0.529	0.727	0.663	0.708	0.767	0.965
N	28	28	28	28	28	28
CommodityGroup						
Correlation Coefficient	-0.147	-0.186	-0.158	-0.058	-0.147	0.200
Sig. (2-tailed)	0.455	0.342	0.422	0.769	0.454	0.307
N	28	28	28	28	28	28
CommonPrcsBestPractices						
Correlation Coefficient	0.591	0.438	0.334	0.032	0.202	0.148
Sig. (2-tailed)	0.001	0.020	0.082	0.871	0.304	0.454
N	28	28	28	28	28	28
LoadUnload						
Correlation Coefficient	-0.350	-0.444	-0.252	0.180	-0.079	0.055
Sig. (2-tailed)	0.067	0.018	0.196	0.360	0.688	0.781
N	28	28	28	28	28	28
RoutingTravel						
Correlation Coefficient	-0.082	-0.061	-0.050	0.165	-0.057	-0.017
Sig. (2-tailed)	0.678	0.759	0.802	0.401	0.775	0.931
N	28	28	28	28	28	28

Table 28: Spearman Rho Correlation Matrix

Spearman's rho Correlations	EE Recognition	Communication Strategy	Turnover Layoff	FiveWhy RootCause	Inspection Autonomation	Error Proofing
SOPs						
Correlation Coefficient	0.311	0.044	-0.213	0.400	0.012	0.295
Sig. (2-tailed)	0.107	0.823	0.277	0.035	0.953	0.127
N	28	28	28	28	28	28
StndWorkDispatches						
Correlation Coefficient	0.121	0.301	0.004	0.135	0.143	0.179
Sig. (2-tailed)	0.541	0.119	0.984	0.493	0.467	0.362
N	28	28	28	28	28	28
CommodityGroup						
Correlation Coefficient	0.026	-0.014	0.140	0.301	0.030	-0.104
Sig. (2-tailed)	0.894	0.942	0.477	0.120	0.878	0.599
N	28	28	28	28	28	28
CommonPrcsBestPractices						
Correlation Coefficient	0.078	0.367	0.383	0.243	0.451	0.180
Sig. (2-tailed)	0.695	0.055	0.044	0.213	0.016	0.358
N	28	28	28	28	28	28
LoadUnload						
Correlation Coefficient	-0.357	-0.212	0.260	-0.153	-0.355	-0.290
Sig. (2-tailed)	0.062	0.280	0.182	0.436	0.064	0.134
N	28	28	28	28	28	28
RoutingTravel						
Correlation Coefficient	0.192	-0.108	-0.138	-0.150	-0.148	-0.073
Sig. (2-tailed)	0.327	0.583	0.484	0.445	0.452	0.711
N	28	28	28	28	28	28

Table 28: Spearman Rho Correlation Matrix

Spearman's rho Correlations	Inventory Integrity	ProductProcess Quality	Quality MeasStats	VSM	Process ControlBoards	Metrics KPIBoards
SOPs						
Correlation Coefficient	0.008	-0.078	-0.113	0.188	0.413	0.272
Sig. (2-tailed)	0.967	0.692	0.566	0.338	0.029	0.161
N	28	28	28	28	28	28
StndWorkDispatches						
Correlation Coefficient	-0.177	-0.125	-0.205	0.073	0.475	-0.144
Sig. (2-tailed)	0.368	0.525	0.295	0.712	0.011	0.465
N	28	28	28	28	28	28
CommodityGroup						
Correlation Coefficient	0.182	0.443	0.304	-0.218	0.047	0.566
Sig. (2-tailed)	0.354	0.018	0.116	0.265	0.812	0.002
N	28	28	28	28	28	28
CommonPrcsBestPractices						
Correlation Coefficient	0.364	-0.218	-0.059	0.412	-0.185	0.207
Sig. (2-tailed)	0.057	0.265	0.765	0.029	0.346	0.291
N	28	28	28	28	28	28
LoadUnload						
Correlation Coefficient	-0.111	0.057	-0.014	-0.253	0.127	-0.136
Sig. (2-tailed)	0.574	0.772	0.945	0.194	0.520	0.490
N	28	28	28	28	28	28
RoutingTravel						
Correlation Coefficient	0.002	-0.377	-0.252	0.151	-0.053	0.177
Sig. (2-tailed)	0.992	0.048	0.197	0.444	0.788	0.368
N	28	28	28	28	28	28

Table 28: Spearman Rho Correlation Matrix

Spearman's rho Correlations	Lean Tracking	Visual Controls	AndonSys	A3	FiveS	Signage ShadowBoards	Cleanliness	Supply MtrlMgmt	POUS
SOPs									
Correlation Coefficient	0.265	-0.132	-0.168	0.244	0.040	0.122	-0.057	0.262	-0.221
Sig. (2-tailed)	0.174	0.504	0.394	0.211	0.838	0.535	0.772	0.178	0.259
N	28	28	28	28	28	28	28	28	28
StndWorkDispatches									
Correlation Coefficient	-0.007	0.075	0.001	0.318	-0.091	-0.097	-0.299	0.075	-0.103
Sig. (2-tailed)	0.973	0.704	0.997	0.100	0.645	0.624	0.122	0.706	0.600
N	28	28	28	28	28	28	28	28	28
CommodityGroup									
Correlation Coefficient	-0.009	-0.085	-0.280	0.212	-0.125	0.145	0.079	0.126	-0.133
Sig. (2-tailed)	0.965	0.666	0.149	0.280	0.526	0.462	0.690	0.524	0.499
N	28	28	28	28	28	28	28	28	28
CommonPrcsBestPractices									
Correlation Coefficient	0.283	-0.420	0.195	0.311	0.420	0.144	0.161	0.167	-0.055
Sig. (2-tailed)	0.145	0.026	0.319	0.107	0.026	0.463	0.413	0.397	0.783
N	28	28	28	28	28	28	28	28	28
LoadUnload									
Correlation Coefficient	-0.193	0.425	0.167	-0.125	-0.199	0.145	-0.116	0.128	0.305
Sig. (2-tailed)	0.326	0.024	0.394	0.526	0.311	0.462	0.556	0.518	0.114
N	28	28	28	28	28	28	28	28	28
RoutingTravel									
Correlation Coefficient	0.016	-0.042	-0.197	0.012	-0.259	0.067	0.024	-0.436	0.065
Sig. (2-tailed)	0.934	0.830	0.315	0.953	0.183	0.735	0.903	0.020	0.743
N	28	28	28	28	28	28	28	28	28

Table 28: Spearman Rho Correlation Matrix

Spearman's rho Correlations	IDProblem Parts	Batch Sizes	WIP	Kanban Systems	Quick Changeover	LeadTime Tracking	Inv Turns	Order Freq
SOPs								
Correlation Coefficient	-0.074	0.280	0.046	-0.002	0.082	0.025	0.273	0.175
Sig. (2-tailed)	0.710	0.150	0.818	0.991	0.680	0.900	0.160	0.372
N	28	28	28	28	28	28	28	28
StndWorkDispatches								
Correlation Coefficient	0.053	0.704	0.246	0.217	0.272	-0.188	0.204	0.146
Sig. (2-tailed)	0.790	0.000	0.208	0.267	0.162	0.338	0.299	0.457
N	28	28	28	28	28	28	28	28
CommodityGroup								
Correlation Coefficient	-0.321	0.407	-0.172	0.142	0.229	0.032	0.106	0.555
Sig. (2-tailed)	0.096	0.032	0.381	0.471	0.242	0.873	0.591	0.002
N	28	28	28	28	28	28	28	28
CommonPrcsBestPractices								
Correlation Coefficient	-0.196	-0.142	0.409	0.034	0.105	0.037	-0.023	0.248
Sig. (2-tailed)	0.318	0.472	0.031	0.865	0.596	0.851	0.907	0.202
N	28	28	28	28	28	28	28	28
LoadUnload								
Correlation Coefficient	0.081	-0.117	-0.213	0.257	-0.429	-0.226	-0.210	-0.150
Sig. (2-tailed)	0.680	0.553	0.276	0.187	0.023	0.247	0.283	0.447
N	28	28	28	28	28	28	28	28
RoutingTravel								
Correlation Coefficient	-0.131	0.183	0.195	0.179	0.059	-0.367	-0.349	0.101
Sig. (2-tailed)	0.506	0.352	0.321	0.363	0.766	0.055	0.069	0.608
N	28	28	28	28	28	28	28	28

Table 28: Spearman Rho Correlation Matrix

Spearman's rho Correlations	Pull Systems	Leveled FlowWork	FIFO	Layout Zones	Velocity Slotting	Travel Distance	Cell Structure	Demand Stabilization
SOPs								
Correlation Coefficient	-0.023	0.231	0.194	0.221	0.080	0.297	-0.291	0.325
Sig. (2-tailed)	0.908	0.238	0.323	0.259	0.686	0.125	0.133	0.092
N	28	28	28	28	28	28	28	28
StndWorkDispatches								
Correlation Coefficient	0.280	0.508	0.216	0.284	0.120	0.430	-0.091	0.296
Sig. (2-tailed)	0.148	0.006	0.268	0.144	0.544	0.022	0.647	0.127
N	28	28	28	28	28	28	28	28
CommodityGroup								
Correlation Coefficient	0.103	0.303	0.073	0.266	0.087	0.464	-0.024	0.130
Sig. (2-tailed)	0.603	0.117	0.711	0.171	0.659	0.013	0.902	0.511
N	28	28	28	28	28	28	28	28
CommonPrcsBestPractices								
Correlation Coefficient	-0.112	0.345	0.224	0.168	0.098	0.134	0.005	0.302
Sig. (2-tailed)	0.572	0.072	0.252	0.391	0.619	0.496	0.981	0.118
N	28	28	28	28	28	28	28	28
LoadUnload								
Correlation Coefficient	0.113	-0.260	-0.262	0.198	-0.008	-0.144	0.181	-0.210
Sig. (2-tailed)	0.567	0.182	0.179	0.313	0.969	0.465	0.358	0.282
N	28	28	28	28	28	28	28	28
RoutingTravel								
Correlation Coefficient	0.240	0.279	0.240	0.450	0.395	0.364	0.171	-0.104
Sig. (2-tailed)	0.219	0.151	0.219	0.016	0.037	0.057	0.383	0.597
N	28	28	28	28	28	28	28	28

Table 28: Spearman Rho Correlation Matrix

Spearman's rho Correlations	Cross Docking	PDCA	Kaizen Events	Employee Suggestion	Systems View	Preventative Maint	Supplier Integration	SPC	Tech Equip
SOPs									
Correlation Coefficient	0.207	0.463	0.127	0.248	0.189	-0.199	-0.174	0.034	0.076
Sig. (2-tailed)	0.291	0.013	0.521	0.203	0.334	0.309	0.376	0.863	0.699
N	28	28	28	28	28	28	28	28	28
StndWorkDispatches									
Correlation Coefficient	-0.035	0.128	0.347	-0.237	0.065	-0.193	0.060	0.074	0.283
Sig. (2-tailed)	0.860	0.517	0.071	0.224	0.743	0.326	0.760	0.709	0.144
N	28	28	28	28	28	28	28	28	28
CommodityGroup									
Correlation Coefficient	0.028	0.218	0.156	0.087	0.037	-0.199	0.155	-0.160	-0.002
Sig. (2-tailed)	0.889	0.265	0.427	0.658	0.853	0.310	0.431	0.415	0.993
N	28	28	28	28	28	28	28	28	28
CommonPrcsBestPractices									
Correlation Coefficient	-0.538	0.325	0.101	0.326	0.252	-0.061	-0.443	-0.049	0.327
Sig. (2-tailed)	0.003	0.091	0.609	0.091	0.196	0.757	0.018	0.803	0.089
N	28	28	28	28	28	28	28	28	28
LoadUnload									
Correlation Coefficient	0.192	-0.556	-0.191	0.022	-0.064	0.070	0.576	0.112	0.023
Sig. (2-tailed)	0.328	0.002	0.331	0.911	0.746	0.723	0.001	0.571	0.909
N	28	28	28	28	28	28	28	28	28
RoutingTravel									
Correlation Coefficient	0.229	0.108	-0.086	-0.157	-0.271	0.013	-0.234	0.186	-0.408
Sig. (2-tailed)	0.242	0.585	0.664	0.426	0.163	0.946	0.231	0.344	0.031
N	28	28	28	28	28	28	28	28	28

Table 28: Spearman Rho Correlation Matrix

SafetyErgonomics	Safety Ergonomics	Leadership Roles	Mgmt Style	Cross Training	Teamwork Empowerment	Power Distance
Correlation Coefficient	1.000	0.670	0.398	0.149	0.440	-0.024
Sig. (2-tailed)	.	0.000	0.036	0.450	0.019	0.904
N		28	28	28	28	28
LeadershipRoles						
Correlation Coefficient		1.000	0.580	0.153	0.672	0.064
Sig. (2-tailed)		.	0.001	0.436	0.000	0.745
N			28	28	28	28
MgmtStyle						
Correlation Coefficient			1.000	0.245	0.372	0.241
Sig. (2-tailed)			.	0.209	0.051	0.217
N				28	28	28
CrossTraining						
Correlation Coefficient				1.000	0.265	0.303
Sig. (2-tailed)				.	0.172	0.117
N					28	28
TeamworkEmpowerment						
Correlation Coefficient					1.000	0.046
Sig. (2-tailed)					.	0.817
N						28
PowerDistance						
Correlation Coefficient						1.000
Sig. (2-tailed)						.
N						

Table 28: Spearman Rho Correlation Matrix

SafetyErgonomics	EE Recognition	Communication Strategy	Turnover Layoff	FiveWhy RootCause	Inspection Autonomation	Error Proofing
Correlation Coefficient	0.211	0.520	0.267	0.277	0.491	0.112
Sig. (2-tailed)	0.280	0.005	0.170	0.154	0.008	0.571
N	28	28	28	28	28	28
LeadershipRoles						
Correlation Coefficient	0.493	0.341	-0.081	0.334	0.428	0.168
Sig. (2-tailed)	0.008	0.075	0.683	0.082	0.023	0.393
N	28	28	28	28	28	28
MgmtStyle						
Correlation Coefficient	0.194	0.324	0.009	0.182	0.411	0.279
Sig. (2-tailed)	0.323	0.092	0.964	0.355	0.030	0.150
N	28	28	28	28	28	28
CrossTraining						
Correlation Coefficient	-0.029	-0.204	0.118	-0.167	0.084	-0.007
Sig. (2-tailed)	0.884	0.297	0.549	0.395	0.670	0.974
N	28	28	28	28	28	28
TeamworkEmpowerment						
Correlation Coefficient	0.543	0.443	0.126	0.370	0.239	0.091
Sig. (2-tailed)	0.003	0.018	0.524	0.053	0.220	0.646
N	28	28	28	28	28	28
PowerDistance						
Correlation Coefficient	0.056	-0.007	0.056	-0.148	-0.001	-0.198
Sig. (2-tailed)	0.779	0.970	0.779	0.452	0.994	0.312
N	28	28	28	28	28	28

Table 28: Spearman Rho Correlation Matrix

SafetyErgonomics	Inventory Integrity	Product ProcessQuality	Quality MeasStats	VSM	Process ControlBoards	Metrics KPIBoards
Correlation Coefficient	0.295	-0.141	0.027	0.199	0.085	0.063
Sig. (2-tailed)	0.128	0.475	0.892	0.310	0.666	0.751
N	28	28	28	28	28	28
LeadershipRoles						
Correlation Coefficient	0.437	-0.222	0.018	0.382	0.092	-0.028
Sig. (2-tailed)	0.020	0.257	0.929	0.045	0.642	0.888
N	28	28	28	28	28	28
MgmtStyle						
Correlation Coefficient	0.037	-0.106	-0.016	0.565	-0.031	-0.178
Sig. (2-tailed)	0.853	0.592	0.937	0.002	0.875	0.365
N	28	28	28	28	28	28
CrossTraining						
Correlation Coefficient	0.079	-0.085	-0.032	0.184	0.130	0.295
Sig. (2-tailed)	0.690	0.667	0.871	0.350	0.510	0.128
N	28	28	28	28	28	28
TeamworkEmpowerment						
Correlation Coefficient	0.176	-0.303	-0.128	0.304	0.096	0.125
Sig. (2-tailed)	0.371	0.117	0.516	0.116	0.627	0.525
N	28	28	28	28	28	28
PowerDistance						
Correlation Coefficient	0.012	-0.027	0.191	0.233	-0.099	0.353
Sig. (2-tailed)	0.953	0.892	0.330	0.232	0.617	0.066
N	28	28	28	28	28	28

Table 28: Spearman Rho Correlation Matrix

SafetyErgonomics	Lean Tracking	Visual Controls	Andon Sys	A3	FiveS	Signage ShadowBoards	Cleanliness	Supply MtrlMgmt	POUS
Correlation Coefficient	0.212	-0.380	0.035	0.331	0.391	-0.162	0.096	0.214	-0.048
Sig. (2-tailed)	0.279	0.046	0.859	0.085	0.040	0.412	0.628	0.274	0.807
N	28	28	28	28	28	28	28	28	28
LeadershipRoles									
Correlation Coefficient	0.290	-0.339	0.291	0.458	0.464	-0.013	0.009	0.425	-0.074
Sig. (2-tailed)	0.135	0.077	0.133	0.014	0.013	0.948	0.966	0.024	0.709
N	28	28	28	28	28	28	28	28	28
MgmtStyle									
Correlation Coefficient	0.460	-0.270	0.132	0.634	0.313	0.007	-0.139	0.383	-0.123
Sig. (2-tailed)	0.014	0.165	0.503	0.000	0.105	0.974	0.481	0.044	0.534
N	28	28	28	28	28	28	28	28	28
CrossTraining									
Correlation Coefficient	0.128	0.037	-0.121	-0.025	0.194	0.183	-0.018	0.373	0.149
Sig. (2-tailed)	0.518	0.851	0.539	0.899	0.323	0.352	0.928	0.051	0.450
N	28	28	28	28	28	28	28	28	28
TeamworkEmpowerment									
Correlation Coefficient	0.185	-0.264	0.468	0.179	0.397	-0.026	-0.254	0.269	-0.094
Sig. (2-tailed)	0.347	0.175	0.012	0.363	0.036	0.894	0.192	0.166	0.635
N	28	28	28	28	28	28	28	28	28
PowerDistance									
Correlation Coefficient	0.186	-0.115	-0.177	0.126	0.281	0.484	0.393	0.254	0.255
Sig. (2-tailed)	0.343	0.561	0.367	0.524	0.148	0.009	0.039	0.191	0.190
N	28	28	28	28	28	28	28	28	28

Table 28: Spearman Rho Correlation Matrix

SafetyErgonomics	IDProblem Parts	Batch Sizes	WIP	Kanban Systems	Quick Changeover	LeadTime Tracking	Inv Turns	Order Freq
Correlation Coefficient	-0.251	0.143	0.505	-0.289	0.196	0.056	0.051	-0.041
Sig. (2-tailed)	0.198	0.467	0.006	0.136	0.316	0.778	0.797	0.837
N	28	28	28	28	28	28	28	28
LeadershipRoles								
Correlation Coefficient	-0.196	0.012	0.320	-0.223	0.213	-0.020	0.272	0.089
Sig. (2-tailed)	0.317	0.952	0.096	0.253	0.277	0.918	0.161	0.654
N	28	28	28	28	28	28	28	28
MgmtStyle								
Correlation Coefficient	0.002	-0.097	0.407	-0.165	0.028	0.290	0.205	0.193
Sig. (2-tailed)	0.992	0.623	0.032	0.402	0.886	0.134	0.294	0.324
N	28	28	28	28	28	28	28	28
CrossTraining								
Correlation Coefficient	-0.133	0.057	0.295	-0.279	-0.118	0.066	-0.164	-0.109
Sig. (2-tailed)	0.501	0.775	0.128	0.150	0.549	0.738	0.404	0.580
N	28	28	28	28	28	28	28	28
TeamworkEmpowerment								
Correlation Coefficient	-0.122	-0.160	0.124	-0.081	-0.023	-0.110	0.226	-0.077
Sig. (2-tailed)	0.537	0.416	0.531	0.682	0.909	0.576	0.247	0.698
N	28	28	28	28	28	28	28	28
PowerDistance								
Correlation Coefficient	-0.113	0.018	0.391	-0.191	-0.313	0.024	-0.115	-0.040
Sig. (2-tailed)	0.567	0.927	0.039	0.330	0.105	0.904	0.559	0.838
N	28	28	28	28	28	28	28	28

Table 28: Spearman Rho Correlation Matrix

SafetyErgonomics	Pull Systems	Leveled FlowWork	FIFO	Layout Zones	Velocity Slotting	Travel Distance	Cell Structure	Demand Stabilization
Correlation Coefficient	-0.192	0.365	0.311	-0.047	0.029	0.072	-0.343	0.396
Sig. (2-tailed)	0.328	0.056	0.107	0.811	0.884	0.716	0.074	0.037
N	28	28	28	28	28	28	28	28
LeadershipRoles								
Correlation Coefficient	0.026	0.338	0.157	-0.056	0.092	-0.125	-0.219	0.461
Sig. (2-tailed)	0.895	0.078	0.424	0.775	0.642	0.526	0.264	0.013
N	28	28	28	28	28	28	28	28
MgmtStyle								
Correlation Coefficient	0.082	0.000	0.393	0.119	-0.040	0.118	0.006	0.223
Sig. (2-tailed)	0.679	0.999	0.039	0.547	0.839	0.551	0.975	0.255
N	28	28	28	28	28	28	28	28
CrossTraining								
Correlation Coefficient	-0.125	0.175	0.285	-0.217	0.021	-0.143	-0.073	0.275
Sig. (2-tailed)	0.526	0.374	0.142	0.266	0.915	0.466	0.713	0.157
N	28	28	28	28	28	28	28	28
TeamworkEmpowerment								
Correlation Coefficient	0.072	0.209	0.148	-0.100	-0.020	-0.322	-0.113	0.360
Sig. (2-tailed)	0.714	0.285	0.453	0.611	0.918	0.095	0.568	0.060
N	28	28	28	28	28	28	28	28
PowerDistance								
Correlation Coefficient	-0.056	0.059	0.195	0.022	0.034	0.044	-0.082	0.023
Sig. (2-tailed)	0.778	0.765	0.320	0.910	0.865	0.825	0.680	0.908
N	28	28	28	28	28	28	28	28

Table 28: Spearman Rho Correlation Matrix

SafetyErgonomics	Cross Docking	PDCA	Kaizen Events	Employee Suggestion	Systems View	Preventative Maint	Supplier Integration	SPC	Tech Equip
Correlation Coefficient	-0.678	0.340	0.198	0.176	0.353	0.161	-0.263	0.112	0.543
Sig. (2-tailed)	0.000	0.077	0.312	0.370	0.065	0.414	0.176	0.570	0.003
N	28	28	28	28	28	28	28	28	28
LeadershipRoles									
Correlation Coefficient	-0.466	0.512	0.238	0.274	0.547	0.109	-0.256	0.217	0.313
Sig. (2-tailed)	0.012	0.005	0.222	0.159	0.003	0.580	0.189	0.267	0.105
N	28	28	28	28	28	28	28	28	28
MgmtStyle									
Correlation Coefficient	-0.166	0.472	0.501	0.023	0.696	0.231	-0.324	0.108	-0.068
Sig. (2-tailed)	0.398	0.011	0.007	0.908	0.000	0.236	0.092	0.584	0.733
N	28	28	28	28	28	28	28	28	28
CrossTraining									
Correlation Coefficient	0.014	-0.004	-0.213	0.102	0.255	0.240	0.065	0.212	0.028
Sig. (2-tailed)	0.943	0.982	0.277	0.606	0.191	0.219	0.743	0.280	0.887
N	28	28	28	28	28	28	28	28	28
TeamworkEmpowerment									
Correlation Coefficient	-0.292	0.191	-0.068	0.226	0.443	0.173	-0.121	0.425	0.346
Sig. (2-tailed)	0.132	0.330	0.732	0.247	0.018	0.380	0.540	0.024	0.072
N	28	28	28	28	28	28	28	28	28
PowerDistance									
Correlation Coefficient	0.063	0.064	-0.029	0.266	0.065	-0.111	0.029	0.019	-0.245
Sig. (2-tailed)	0.751	0.747	0.882	0.171	0.743	0.575	0.884	0.922	0.208
N	28	28	28	28	28	28	28	28	28

Table 28: Spearman Rho Correlation Matrix

EERecognition	EE Recognition	Communication Strategy	Turnover Layoff	FiveWhy RootCause	Inspection Autonomation	Error Proofing
Correlation Coefficient	1.000	0.458	-0.071	0.089	0.061	0.005
Sig. (2-tailed)	.	0.014	0.719	0.652	0.756	0.982
N		28	28	28	28	28
CommunicationStrategy						
Correlation Coefficient		1.000	0.280	0.340	0.308	0.178
Sig. (2-tailed)		.	0.149	0.077	0.111	0.364
N			28	28	28	28
TurnoverLayoff						
Correlation Coefficient			1.000	-0.120	-0.139	-0.237
Sig. (2-tailed)			.	0.542	0.480	0.225
N				28	28	28
FiveWhyRootCause						
Correlation Coefficient				1.000	0.409	0.662
Sig. (2-tailed)				.	0.030	0.000
N					28	28
InspectionAutonomation						
Correlation Coefficient					1.000	0.474
Sig. (2-tailed)					.	0.011
N						28
ErrorProofing						
Correlation Coefficient						1.000
Sig. (2-tailed)						.
N						

Table 28: Spearman Rho Correlation Matrix

EERecognition	Inventory Integrity	Product ProcessQuality	Quality MeasStats	VSM	Process ControlBoards	Metrics KPIBoards
Correlation Coefficient	0.173	-0.021	0.147	0.015	0.076	0.240
Sig. (2-tailed)	0.379	0.914	0.457	0.941	0.701	0.218
N	28	28	28	28	28	28
CommunicationStrategy						
Correlation Coefficient	0.011	-0.171	0.001	0.250	0.105	0.098
Sig. (2-tailed)	0.957	0.384	0.997	0.200	0.597	0.619
N	28	28	28	28	28	28
TurnoverLayoff						
Correlation Coefficient	0.017	0.125	-0.281	-0.021	-0.191	0.185
Sig. (2-tailed)	0.933	0.527	0.148	0.914	0.329	0.347
N	28	28	28	28	28	28
FiveWhyRootCause						
Correlation Coefficient	-0.031	-0.176	0.061	0.101	0.338	0.199
Sig. (2-tailed)	0.874	0.371	0.758	0.608	0.079	0.309
N	28	28	28	28	28	28
InspectionAutonomation						
Correlation Coefficient	0.136	0.017	0.212	0.282	0.048	0.044
Sig. (2-tailed)	0.489	0.933	0.278	0.146	0.808	0.824
N	28	28	28	28	28	28
ErrorProofing						
Correlation Coefficient	-0.273	-0.194	-0.155	0.306	0.327	-0.020
Sig. (2-tailed)	0.161	0.322	0.430	0.114	0.089	0.919
N	28	28	28	28	28	28

Table 28: Spearman Rho Correlation Matrix

EERecognition	Lean Tracking	Visual Controls	Andon Sys	A3	FiveS	Signage ShadowBoards	Cleanliness	Supply MtrlMgmt	POUS
Correlation Coefficient	0.251	-0.177	0.275	0.161	0.471	0.151	0.243	0.172	0.145
Sig. (2-tailed)	0.198	0.367	0.156	0.413	0.011	0.443	0.213	0.381	0.463
N	28	28	28	28	28	28	28	28	28
CommunicationStrategy									
Correlation Coefficient	0.298	-0.412	0.267	0.339	0.530	-0.112	0.012	-0.053	-0.154
Sig. (2-tailed)	0.123	0.029	0.170	0.077	0.004	0.571	0.953	0.788	0.435
N	28	28	28	28	28	28	28	28	28
TurnoverLayoff									
Correlation Coefficient	0.029	-0.273	-0.016	-0.232	0.214	0.054	0.163	0.134	-0.080
Sig. (2-tailed)	0.884	0.160	0.935	0.234	0.275	0.785	0.408	0.497	0.685
N	28	28	28	28	28	28	28	28	28
FiveWhyRootCause									
Correlation Coefficient	0.214	-0.186	0.281	0.262	0.073	-0.074	-0.303	0.011	-0.266
Sig. (2-tailed)	0.275	0.345	0.148	0.177	0.713	0.707	0.117	0.955	0.171
N	28	28	28	28	28	28	28	28	28
InspectionAutonomation									
Correlation Coefficient	0.166	-0.113	0.290	0.391	0.312	-0.334	-0.112	0.195	-0.237
Sig. (2-tailed)	0.398	0.567	0.134	0.039	0.106	0.082	0.571	0.321	0.225
N	28	28	28	28	28	28	28	28	28
ErrorProofing									
Correlation Coefficient	0.266	-0.040	0.270	0.070	0.072	-0.135	-0.338	-0.056	-0.227
Sig. (2-tailed)	0.172	0.841	0.165	0.724	0.715	0.495	0.079	0.776	0.246
N	28	28	28	28	28	28	28	28	28

Table 28: Spearman Rho Correlation Matrix

EERecognition	IDProblem Parts	Batch Sizes	WIP	Kanban Systems	Quick Changeover	LeadTime Tracking	Inv Turns	Order Freq
Correlation Coefficient	-0.039	0.107	0.300	0.047	-0.038	-0.235	0.191	-0.064
Sig. (2-tailed)	0.845	0.587	0.121	0.812	0.848	0.228	0.329	0.745
N	28	28	28	28	28	28	28	28
CommunicationStrategy								
Correlation Coefficient	0.098	0.112	0.361	0.216	0.251	-0.141	0.232	-0.019
Sig. (2-tailed)	0.619	0.570	0.059	0.269	0.197	0.474	0.235	0.922
N	28	28	28	28	28	28	28	28
TurnoverLayoff								
Correlation Coefficient	-0.257	-0.272	0.077	-0.046	-0.183	-0.119	0.135	-0.099
Sig. (2-tailed)	0.187	0.162	0.698	0.818	0.350	0.545	0.495	0.618
N	28	28	28	28	28	28	28	28
FiveWhyRootCause								
Correlation Coefficient	-0.259	0.124	-0.215	0.096	0.399	0.011	0.121	0.458
Sig. (2-tailed)	0.183	0.530	0.273	0.625	0.035	0.957	0.538	0.014
N	28	28	28	28	28	28	28	28
InspectionAutonomation								
Correlation Coefficient	0.016	0.175	0.277	0.053	0.407	0.078	-0.072	0.476
Sig. (2-tailed)	0.937	0.373	0.153	0.788	0.031	0.691	0.716	0.011
N	28	28	28	28	28	28	28	28
ErrorProofing								
Correlation Coefficient	-0.129	0.052	-0.022	-0.032	0.297	0.212	0.090	0.425
Sig. (2-tailed)	0.513	0.793	0.913	0.873	0.125	0.279	0.648	0.024
N	28	28	28	28	28	28	28	28

Table 28: Spearman Rho Correlation Matrix

EERecognition	Pull Systems	Leveled FlowWork	FIFO	Layout Zones	Velocity Slotting	Travel Distance	Cell Structure	Demand Stabilization
Correlation Coefficient	0.177	0.453	0.139	0.222	0.375	0.076	-0.157	0.085
Sig. (2-tailed)	0.368	0.016	0.480	0.257	0.049	0.700	0.425	0.666
N	28	28	28	28	28	28	28	28
CommunicationStrategy								
Correlation Coefficient	0.253	0.355	0.348	0.231	0.058	0.167	-0.074	0.203
Sig. (2-tailed)	0.195	0.064	0.069	0.236	0.768	0.396	0.708	0.300
N	28	28	28	28	28	28	28	28
TurnoverLayoff								
Correlation Coefficient	-0.191	-0.073	-0.127	0.118	-0.059	-0.130	-0.170	-0.130
Sig. (2-tailed)	0.329	0.714	0.519	0.549	0.767	0.509	0.387	0.509
N	28	28	28	28	28	28	28	28
FiveWhyRootCause								
Correlation Coefficient	0.227	0.145	0.325	0.137	-0.180	0.074	0.089	0.354
Sig. (2-tailed)	0.246	0.463	0.091	0.486	0.359	0.709	0.653	0.065
N	28	28	28	28	28	28	28	28
InspectionAutonomation								
Correlation Coefficient	0.151	0.268	0.380	-0.120	-0.298	0.102	-0.057	0.758
Sig. (2-tailed)	0.443	0.168	0.046	0.542	0.123	0.606	0.773	0.000
N	28	28	28	28	28	28	28	28
ErrorProofing								
Correlation Coefficient	0.168	-0.030	0.296	0.139	-0.060	0.113	0.136	0.285
Sig. (2-tailed)	0.393	0.882	0.127	0.481	0.762	0.568	0.491	0.142
N	28	28	28	28	28	28	28	28

Table 28: Spearman Rho Correlation Matrix

EERecognition	Cross Docking	PDCA	Kaizen Events	Employee Suggestion	Systems View	Preventative Maint	Supplier Integration	SPC	Tech Equip
Correlation Coefficient	0.025	0.330	0.160	0.096	0.133	0.144	-0.167	0.315	0.065
Sig. (2-tailed)	0.899	0.086	0.417	0.629	0.500	0.464	0.396	0.103	0.742
N	28	28	28	28	28	28	28	28	28
CommunicationStrategy									
Correlation Coefficient	-0.367	0.398	0.388	0.230	0.240	0.113	-0.238	0.274	0.314
Sig. (2-tailed)	0.054	0.036	0.041	0.240	0.219	0.566	0.223	0.159	0.103
N	28	28	28	28	28	28	28	28	28
TurnoverLayoff									
Correlation Coefficient	-0.114	-0.264	-0.309	0.113	0.142	-0.198	-0.062	-0.096	0.087
Sig. (2-tailed)	0.562	0.175	0.109	0.568	0.470	0.312	0.753	0.627	0.659
N	28	28	28	28	28	28	28	28	28
FiveWhyRootCause									
Correlation Coefficient	-0.316	0.527	0.210	0.423	0.360	0.143	-0.261	0.324	0.370
Sig. (2-tailed)	0.101	0.004	0.284	0.025	0.060	0.468	0.179	0.093	0.053
N	28	28	28	28	28	28	28	28	28
InspectionAutonomation									
Correlation Coefficient	-0.659	0.465	0.433	0.094	0.307	0.129	-0.455	0.355	0.495
Sig. (2-tailed)	0.000	0.013	0.021	0.633	0.112	0.513	0.015	0.063	0.007
N	28	28	28	28	28	28	28	28	28
ErrorProofing									
Correlation Coefficient	-0.231	0.438	0.260	0.118	0.264	0.103	-0.436	0.327	0.285
Sig. (2-tailed)	0.237	0.020	0.182	0.552	0.175	0.604	0.020	0.089	0.141
N	28	28	28	28	28	28	28	28	28

Table 28: Spearman Rho Correlation Matrix

InventoryIntegrity	Inventory Integrity	Product ProcessQuality	Quality MeasStats	VSM	Process ControlBoards	Metrics KPIBoards
Correlation Coefficient	1.000	0.256	0.347	0.151	-0.201	0.327
Sig. (2-tailed)	.	0.189	0.070	0.443	0.304	0.089
N		28	28	28	28	28
ProductProcessQuality						
Correlation Coefficient		1.000	0.548	-0.261	0.154	0.245
Sig. (2-tailed)		.	0.003	0.179	0.434	0.208
N			28	28	28	28
QualityMeasStats						
Correlation Coefficient			1.000	-0.355	0.141	0.245
Sig. (2-tailed)			.	0.064	0.475	0.208
N				28	28	28
VSM						
Correlation Coefficient				1.000	-0.117	0.072
Sig. (2-tailed)				.	0.554	0.717
N					28	28
ProcessControlBoards						
Correlation Coefficient					1.000	-0.005
Sig. (2-tailed)					.	0.981
N						28
MetricsKPIBoards						
Correlation Coefficient						1.000
Sig. (2-tailed)						.
N						

Table 28: Spearman Rho Correlation Matrix

InventoryIntegrity	Lean Tracking	Visual Controls	Andon Sys	A3	FiveS	Signage ShadowBoards	Cleanliness	Supply MtrlMgmt	POUS
Correlation Coefficient	-0.187	-0.117	-0.021	0.174	0.300	0.322	0.366	0.302	0.047
Sig. (2-tailed)	0.342	0.553	0.914	0.377	0.121	0.095	0.056	0.119	0.811
N	28	28	28	28	28	28	28	28	28
ProductProcessQuality									
Correlation Coefficient	-0.031	0.169	-0.336	-0.031	-0.117	0.059	0.246	0.297	-0.138
Sig. (2-tailed)	0.874	0.391	0.081	0.876	0.553	0.764	0.206	0.124	0.485
N	28	28	28	28	28	28	28	28	28
QualityMeasStats									
Correlation Coefficient	0.156	0.024	-0.127	0.212	0.220	0.275	0.449	0.170	0.117
Sig. (2-tailed)	0.427	0.902	0.519	0.279	0.260	0.156	0.016	0.387	0.552
N	28	28	28	28	28	28	28	28	28
VSM									
Correlation Coefficient	0.156	-0.147	0.078	0.333	0.065	0.058	-0.263	-0.025	-0.352
Sig. (2-tailed)	0.428	0.456	0.693	0.083	0.742	0.768	0.176	0.899	0.067
N	28	28	28	28	28	28	28	28	28
ProcessControlBoards									
Correlation Coefficient	0.290	0.117	-0.135	0.097	-0.213	-0.166	-0.232	0.129	0.013
Sig. (2-tailed)	0.135	0.552	0.495	0.625	0.278	0.400	0.235	0.512	0.946
N	28	28	28	28	28	28	28	28	28
MetricsKPIBoards									
Correlation Coefficient	0.148	-0.204	-0.301	-0.121	0.258	0.426	0.382	0.067	-0.120
Sig. (2-tailed)	0.452	0.297	0.120	0.541	0.186	0.024	0.045	0.734	0.542
N	28	28	28	28	28	28	28	28	28

Table 28: Spearman Rho Correlation Matrix

InventoryIntegrity	IDProblem Parts	Batch Sizes	WIP	Kanban Systems	Quick Changeover	LeadTime Tracking	Inv Turns	Order Freq
Correlation Coefficient	-0.320	-0.044	0.014	-0.015	0.284	-0.059	0.105	0.172
Sig. (2-tailed)	0.097	0.825	0.942	0.940	0.143	0.766	0.596	0.381
N	28	28	28	28	28	28	28	28
ProductProcessQuality								
Correlation Coefficient	-0.005	0.187	-0.159	0.029	0.097	0.303	0.255	0.187
Sig. (2-tailed)	0.978	0.340	0.419	0.884	0.622	0.117	0.191	0.340
N	28	28	28	28	28	28	28	28
QualityMeasStats								
Correlation Coefficient	0.099	0.192	-0.023	0.189	0.123	0.193	0.018	0.021
Sig. (2-tailed)	0.618	0.328	0.909	0.336	0.534	0.324	0.926	0.915
N	28	28	28	28	28	28	28	28
VSM								
Correlation Coefficient	-0.150	-0.188	0.179	-0.213	0.167	0.226	0.090	0.271
Sig. (2-tailed)	0.447	0.339	0.362	0.277	0.397	0.247	0.649	0.163
N	28	28	28	28	28	28	28	28
ProcessControlBoards								
Correlation Coefficient	0.198	0.563	0.117	0.204	0.200	-0.053	0.188	-0.029
Sig. (2-tailed)	0.312	0.002	0.552	0.298	0.306	0.791	0.338	0.885
N	28	28	28	28	28	28	28	28
MetricsKPIBoards								
Correlation Coefficient	-0.355	0.171	0.047	0.023	0.174	-0.042	0.004	0.247
Sig. (2-tailed)	0.063	0.384	0.813	0.906	0.377	0.832	0.986	0.205
N	28	28	28	28	28	28	28	28

Table 28: Spearman Rho Correlation Matrix

InventoryIntegrity	Pull Systems	Leveled FlowWork	FIFO	Layout Zones	Velocity Slotting	Travel Distance	Cell Structure	Demand Stabilization
Correlation Coefficient	0.021	0.374	-0.180	-0.050	0.359	0.019	-0.024	0.224
Sig. (2-tailed)	0.914	0.050	0.360	0.802	0.060	0.922	0.903	0.252
N	28	28	28	28	28	28	28	28
ProductProcessQuality								
Correlation Coefficient	0.008	-0.163	-0.226	0.040	0.053	0.196	-0.029	0.102
Sig. (2-tailed)	0.967	0.408	0.247	0.840	0.789	0.317	0.883	0.605
N	28	28	28	28	28	28	28	28
QualityMeasStats								
Correlation Coefficient	0.106	0.122	0.136	-0.166	0.074	0.120	0.087	0.192
Sig. (2-tailed)	0.590	0.538	0.489	0.398	0.709	0.543	0.659	0.327
N	28	28	28	28	28	28	28	28
VSM								
Correlation Coefficient	0.077	-0.025	0.282	0.135	0.182	0.037	0.143	0.273
Sig. (2-tailed)	0.696	0.899	0.146	0.492	0.353	0.853	0.467	0.159
N	28	28	28	28	28	28	28	28
ProcessControlBoards								
Correlation Coefficient	0.324	0.099	0.150	0.293	-0.062	0.197	0.072	0.300
Sig. (2-tailed)	0.093	0.615	0.447	0.130	0.755	0.314	0.715	0.121
N	28	28	28	28	28	28	28	28
MetricsKPIBoards								
Correlation Coefficient	0.050	0.332	0.337	0.085	0.236	0.248	-0.005	0.230
Sig. (2-tailed)	0.801	0.084	0.079	0.669	0.226	0.203	0.980	0.238
N	28	28	28	28	28	28	28	28

Table 28: Spearman Rho Correlation Matrix

InventoryIntegrity	Cross Docking	PDCA	Kaizen Events	Employee Suggestion	Systems View	Preventative Maint	Supplier Integration	SPC	Tech Equip
Correlation Coefficient	-0.435	0.009	-0.018	0.233	0.137	0.045	0.211	-0.197	0.238
Sig. (2-tailed)	0.021	0.962	0.928	0.233	0.487	0.818	0.282	0.314	0.222
N	28	28	28	28	28	28	28	28	28
ProductProcessQuality									
Correlation Coefficient	0.112	-0.118	0.220	-0.104	0.057	0.096	0.371	-0.125	0.049
Sig. (2-tailed)	0.572	0.551	0.260	0.598	0.772	0.626	0.052	0.526	0.803
N	28	28	28	28	28	28	28	28	28
QualityMeasStats									
Correlation Coefficient	-0.053	0.162	0.233	0.343	0.042	0.593	0.306	0.155	0.124
Sig. (2-tailed)	0.788	0.412	0.233	0.074	0.831	0.001	0.114	0.430	0.531
N	28	28	28	28	28	28	28	28	28
VSM									
Correlation Coefficient	-0.305	0.256	0.214	-0.080	0.220	-0.150	-0.291	0.014	-0.152
Sig. (2-tailed)	0.114	0.188	0.275	0.687	0.261	0.446	0.133	0.942	0.441
N	28	28	28	28	28	28	28	28	28
ProcessControlBoards									
Correlation Coefficient	0.173	0.205	0.276	0.255	0.221	0.205	0.204	0.449	0.351
Sig. (2-tailed)	0.378	0.295	0.155	0.190	0.258	0.296	0.297	0.017	0.067
N	28	28	28	28	28	28	28	28	28
MetricsKPIBoards									
Correlation Coefficient	-0.014	0.236	-0.142	0.395	-0.191	0.058	-0.120	0.094	-0.024
Sig. (2-tailed)	0.942	0.227	0.471	0.037	0.331	0.769	0.544	0.634	0.904
N	28	28	28	28	28	28	28	28	28

Table 28: Spearman Rho Correlation Matrix

LeanTracking	Lean Tracking	Visual Controls	Andon Sys	A3	FiveS	Signage ShadowBoards	Cleanliness	Supply MtrlMgmt	POUS
Correlation Coefficient	1.000	-0.287	0.085	0.324	0.231	-0.077	0.017	0.112	0.080
Sig. (2-tailed)	.	0.138	0.667	0.093	0.236	0.695	0.930	0.571	0.685
N		28	28	28	28	28	28	28	28
VisualControls									
Correlation Coefficient		1.000	0.066	-0.132	-0.388	-0.094	-0.032	0.081	0.394
Sig. (2-tailed)		.	0.737	0.502	0.041	0.635	0.873	0.680	0.038
N			28	28	28	28	28	28	28
AndonSys									
Correlation Coefficient			1.000	0.104	0.361	-0.090	-0.287	0.126	0.091
Sig. (2-tailed)			.	0.597	0.059	0.649	0.139	0.522	0.645
N				28	28	28	28	28	28
A3									
Correlation Coefficient				1.000	0.163	0.042	-0.158	0.301	-0.140
Sig. (2-tailed)				.	0.408	0.831	0.421	0.119	0.478
N					28	28	28	28	28
FiveS									
Correlation Coefficient					1.000	0.398	0.425	0.457	0.092
Sig. (2-tailed)					.	0.036	0.024	0.015	0.643
N						28	28	28	28
SignageShadowBoards									
Correlation Coefficient						1.000	0.456	0.276	0.083
Sig. (2-tailed)						.	0.015	0.155	0.676
N							28	28	28
Cleanliness									
Correlation Coefficient							1.000	0.070	0.337
Sig. (2-tailed)							.	0.722	0.079
N								28	28
SupplyMtrlMgmt									
Correlation Coefficient								1.000	0.188
Sig. (2-tailed)								.	0.337
N									28

Table 28: Spearman Rho Correlation Matrix

POUS	IDProblem Parts	Batch Sizes	WIP	Kanban Systems	Quick Changeover	LeadTime Tracking	Inv Turns	Order Freq
Correlation Coefficient	0.140	0.011	0.407	0.092	-0.440	-0.279	-0.217	-0.322
Sig. (2-tailed)	0.478	0.957	0.032	0.640	0.019	0.150	0.268	0.095
N	28	28	28	28	28	28	28	28
IDProblemParts								
Correlation Coefficient	1.000	0.129	0.223	0.525	-0.039	-0.168	-0.114	-0.351
Sig. (2-tailed)	.	0.514	0.253	0.004	0.844	0.392	0.564	0.067
N		28	28	28	28	28	28	28
BatchSizes								
Correlation Coefficient		1.000	0.285	0.208	0.357	-0.102	0.087	0.149
Sig. (2-tailed)		.	0.142	0.289	0.062	0.605	0.659	0.450
N			28	28	28	28	28	28
WIP								
Correlation Coefficient			1.000	0.026	-0.056	-0.017	-0.062	-0.068
Sig. (2-tailed)			.	0.897	0.776	0.933	0.752	0.730
N				28	28	28	28	28
KanbanSystems								
Correlation Coefficient				1.000	0.179	-0.334	0.153	0.119
Sig. (2-tailed)				.	0.362	0.082	0.438	0.547
N					28	28	28	28
QuickChangeover								
Correlation Coefficient					1.000	0.002	0.176	0.523
Sig. (2-tailed)					.	0.993	0.370	0.004
N						28	28	28
LeadTimeTracking								
Correlation Coefficient						1.000	0.418	0.239
Sig. (2-tailed)						.	0.027	0.221
N							28	28
InvTurns								
Correlation Coefficient							1.000	0.163
Sig. (2-tailed)							.	0.407
N								28

Table 28: Spearman Rho Correlation Matrix

LeanTracking	IDProblem Parts	Batch Sizes	WIP	Kanban Systems	Quick Changeover	LeadTime Tracking	Inv Turns	Order Freq
Correlation Coefficient	0.306	0.119	0.427	0.320	-0.036	0.167	0.340	0.042
Sig. (2-tailed)	0.114	0.547	0.023	0.097	0.856	0.397	0.077	0.833
N	28	28	28	28	28	28	28	28
VisualControls								
Correlation Coefficient	0.152	0.192	-0.247	0.037	-0.248	-0.171	-0.211	-0.129
Sig. (2-tailed)	0.439	0.327	0.205	0.851	0.204	0.385	0.281	0.513
N	28	28	28	28	28	28	28	28
AndonSys								
Correlation Coefficient	0.172	-0.291	-0.087	0.247	-0.123	-0.255	-0.031	0.034
Sig. (2-tailed)	0.380	0.134	0.658	0.205	0.533	0.191	0.875	0.865
N	28	28	28	28	28	28	28	28
A3								
Correlation Coefficient	0.185	0.353	0.331	0.059	0.232	0.148	0.028	0.330
Sig. (2-tailed)	0.347	0.066	0.086	0.767	0.234	0.451	0.887	0.086
N	28	28	28	28	28	28	28	28
FiveS								
Correlation Coefficient	-0.015	-0.156	0.402	-0.002	0.031	-0.085	0.139	-0.068
Sig. (2-tailed)	0.939	0.429	0.034	0.990	0.877	0.667	0.481	0.729
N	28	28	28	28	28	28	28	28
SignageShadowBoards								
Correlation Coefficient	-0.282	-0.131	-0.006	-0.134	-0.147	0.063	-0.075	-0.032
Sig. (2-tailed)	0.146	0.506	0.978	0.497	0.455	0.750	0.706	0.871
N	28	28	28	28	28	28	28	28
Cleanliness								
Correlation Coefficient	-0.109	-0.069	0.195	-0.086	-0.195	-0.296	-0.214	-0.295
Sig. (2-tailed)	0.581	0.729	0.320	0.665	0.319	0.126	0.275	0.128
SupplyMtrlMgmt								
Correlation Coefficient	-0.086	0.118	0.282	-0.140	-0.109	0.177	0.333	0.154
Sig. (2-tailed)	0.663	0.550	0.145	0.478	0.580	0.367	0.084	0.434
POUS								
Correlation Coefficient	0.140	0.011	0.407	0.092	-0.440	-0.279	-0.217	-0.322
Sig. (2-tailed)	0.478	0.957	0.032	0.640	0.019	0.150	0.268	0.095

Table 28: Spearman Rho Correlation Matrix

LeanTracking	Pull Systems	Leveled FlowWork	FIFO	Layout Zones	Velocity Slotting	Travel Distance	Cell Structure	Demand Stabilization
Correlation Coefficient	0.389	-0.052	0.482	0.309	0.104	0.259	0.412	0.075
Sig. (2-tailed)	0.041	0.794	0.009	0.110	0.597	0.183	0.029	0.706
N	28	28	28	28	28	28	28	28
VisualControls								
Correlation Coefficient	0.180	-0.165	-0.024	-0.053	0.111	-0.020	0.069	-0.093
Sig. (2-tailed)	0.358	0.402	0.902	0.788	0.574	0.920	0.727	0.636
N	28	28	28	28	28	28	28	28
AndonSys								
Correlation Coefficient	0.249	0.095	-0.106	-0.047	-0.074	-0.451	0.298	0.102
Sig. (2-tailed)	0.201	0.632	0.593	0.812	0.707	0.016	0.124	0.605
N	28	28	28	28	28	28	28	28
A3								
Correlation Coefficient	0.121	0.380	0.291	0.264	0.200	0.418	0.014	0.391
Sig. (2-tailed)	0.539	0.046	0.132	0.175	0.307	0.027	0.945	0.039
N	28	28	28	28	28	28	28	28
FiveS								
Correlation Coefficient	-0.049	0.400	0.162	-0.185	0.092	-0.139	-0.227	0.277
Sig. (2-tailed)	0.806	0.035	0.411	0.345	0.640	0.480	0.244	0.153
N	28	28	28	28	28	28	28	28
SignageShadowBoards								
Correlation Coefficient	-0.210	0.210	-0.038	0.017	0.467	0.013	-0.044	-0.090
Sig. (2-tailed)	0.283	0.284	0.846	0.933	0.012	0.947	0.824	0.649
N	28	28	28	28	28	28	28	28
Cleanliness								
Correlation Coefficient	-0.145	0.140	-0.027	-0.013	0.241	0.027	-0.264	-0.208
Sig. (2-tailed)	0.463	0.478	0.891	0.948	0.216	0.890	0.174	0.289
SupplyMtrlMgmt								
Correlation Coefficient	-0.102	0.199	-0.029	-0.096	-0.028	0.014	-0.297	0.387
Sig. (2-tailed)	0.605	0.310	0.885	0.625	0.887	0.946	0.125	0.042
POUS								
Correlation Coefficient	0.169	0.045	-0.092	0.174	0.194	0.025	0.096	-0.392
Sig. (2-tailed)	0.389	0.819	0.642	0.377	0.321	0.898	0.628	0.039

Table 28: Spearman Rho Correlation Matrix

LeanTracking	Cross Docking	PDCA	Kaizen Events	Employee Suggestion	Systems View	Preventative Maint	Supplier Integration	SPC	Tech Equip
Correlation Coefficient	0.131	0.675	0.460	0.459	0.329	0.459	-0.331	0.455	-0.075
Sig. (2-tailed)	0.505	0.000	0.014	0.014	0.087	0.014	0.085	0.015	0.706
N	28	28	28	28	28	28	28	28	28
VisualControls									
Correlation Coefficient	0.122	-0.406	-0.036	-0.283	-0.246	-0.032	0.486	-0.006	-0.033
Sig. (2-tailed)	0.538	0.032	0.856	0.145	0.207	0.872	0.009	0.975	0.867
N	28	28	28	28	28	28	28	28	28
AndonSys									
Correlation Coefficient	-0.323	0.037	0.080	0.045	0.240	0.136	-0.153	0.367	0.306
Sig. (2-tailed)	0.094	0.852	0.686	0.818	0.219	0.490	0.438	0.055	0.113
N	28	28	28	28	28	28	28	28	28
A3									
Correlation Coefficient	-0.241	0.566	0.750	-0.060	0.361	0.140	-0.050	-0.079	0.089
Sig. (2-tailed)	0.216	0.002	0.000	0.760	0.059	0.476	0.799	0.691	0.654
N	28	28	28	28	28	28	28	28	28
FiveS									
Correlation Coefficient	-0.307	0.292	0.097	0.419	0.178	0.228	-0.243	0.148	0.294
Sig. (2-tailed)	0.112	0.131	0.623	0.026	0.364	0.244	0.212	0.453	0.129
N	28	28	28	28	28	28	28	28	28
SignageShadowBoards									
Correlation Coefficient	0.210	-0.084	-0.200	0.223	-0.140	0.156	0.208	-0.234	-0.209
Sig. (2-tailed)	0.282	0.672	0.307	0.254	0.476	0.427	0.289	0.230	0.286
Cleanliness									
Correlation Coefficient	-0.004	-0.087	-0.215	0.377	-0.261	0.047	-0.043	-0.136	-0.158
Sig. (2-tailed)	0.983	0.660	0.271	0.048	0.180	0.813	0.829	0.490	0.422
SupplyMtrlMgmt									
Correlation Coefficient	-0.064	0.109	0.248	0.133	0.449	0.031	0.225	-0.066	0.355
Sig. (2-tailed)	0.748	0.581	0.203	0.501	0.017	0.877	0.249	0.741	0.064
POUS									
Correlation Coefficient	0.137	-0.178	-0.090	0.205	0.027	0.076	0.344	0.101	0.035
Sig. (2-tailed)	0.486	0.365	0.649	0.295	0.890	0.699	0.073	0.609	0.860

Table 28: Spearman Rho Correlation Matrix

IDProblemParts	IDProblem Parts	Batch Sizes	WIP	Kanban Systems	Quick Changeover	LeadTime Tracking	Inv Turns	Order Freq
Correlation Coefficient	1.000	0.129	0.223	0.525	-0.039	-0.168	-0.114	-0.351
Sig. (2-tailed)	.	0.514	0.253	0.004	0.844	0.392	0.564	0.067
N		28	28	28	28	28	28	28
BatchSizes								
Correlation Coefficient		1.000	0.285	0.208	0.357	-0.102	0.087	0.149
Sig. (2-tailed)		.	0.142	0.289	0.062	0.605	0.659	0.450
N			28	28	28	28	28	28
WIP								
Correlation Coefficient			1.000	0.026	-0.056	-0.017	-0.062	-0.068
Sig. (2-tailed)			.	0.897	0.776	0.933	0.752	0.730
N				28	28	28	28	28
KanbanSystems								
Correlation Coefficient				1.000	0.179	-0.334	0.153	0.119
Sig. (2-tailed)				.	0.362	0.082	0.438	0.547
N					28	28	28	28
QuickChangeover								
Correlation Coefficient					1.000	0.002	0.176	0.523
Sig. (2-tailed)					.	0.993	0.370	0.004
N						28	28	28
LeadTimeTracking								
Correlation Coefficient						1.000	0.418	0.239
Sig. (2-tailed)						.	0.027	0.221
N							28	28
InvTurns								
Correlation Coefficient							1.000	0.163
Sig. (2-tailed)							.	0.407
N								28
OrderFreq								
Correlation Coefficient								1.000
Sig. (2-tailed)								.
N								

Table 28: Spearman Rho Correlation Matrix

IDProblemParts	Pull Systems	Leveled FlowWork	FIFO	Layout Zones	Velocity Slotting	Travel Distance	Cell Structure	Demand Stabilization
Correlation Coefficient	0.335	-0.079	-0.015	0.010	-0.243	-0.022	0.354	0.007
Sig. (2-tailed)	0.082	0.689	0.940	0.961	0.213	0.912	0.065	0.974
N	28	28	28	28	28	28	28	28
BatchSizes								
Correlation Coefficient	0.288	0.596	0.372	0.192	0.163	0.619	-0.086	0.378
Sig. (2-tailed)	0.137	0.001	0.051	0.328	0.407	0.000	0.664	0.047
N	28	28	28	28	28	28	28	28
WIP								
Correlation Coefficient	0.083	0.369	0.285	0.313	0.167	0.403	-0.113	0.211
Sig. (2-tailed)	0.675	0.053	0.141	0.105	0.397	0.034	0.567	0.280
N	28	28	28	28	28	28	28	28
KanbanSystems								
Correlation Coefficient	0.743	0.118	0.143	0.360	-0.066	0.290	0.576	0.063
Sig. (2-tailed)	0.000	0.551	0.466	0.060	0.740	0.134	0.001	0.749
N	28	28	28	28	28	28	28	28
QuickChangeover								
Correlation Coefficient	0.377	0.335	0.165	-0.006	-0.040	0.205	0.164	0.525
Sig. (2-tailed)	0.048	0.081	0.402	0.974	0.842	0.295	0.405	0.004
N	28	28	28	28	28	28	28	28
LeadTimeTracking								
Correlation Coefficient	-0.380	-0.307	0.101	-0.231	0.062	0.193	-0.028	0.087
Sig. (2-tailed)	0.046	0.112	0.609	0.236	0.752	0.325	0.886	0.659
N	28	28	28	28	28	28	28	28
InvTurns								
Correlation Coefficient	0.207	-0.098	0.064	-0.025	0.083	0.168	0.016	0.087
Sig. (2-tailed)	0.292	0.619	0.747	0.899	0.675	0.392	0.934	0.661
N	28	28	28	28	28	28	28	28
OrderFreq								
Correlation Coefficient	0.256	0.109	0.094	0.344	0.053	0.433	0.162	0.441
Sig. (2-tailed)	0.189	0.580	0.635	0.073	0.789	0.022	0.411	0.019
N	28	28	28	28	28	28	28	28

Table 28: Spearman Rho Correlation Matrix

IDProblemParts	Cross Docking	PDCA	Kaizen Events	Employee Suggestion	Systems View	Preventative Maint	Supplier Integration	SPC	Tech Equip
Correlation Coefficient	0.360	0.085	0.332	-0.002	-0.040	0.214	0.004	0.187	-0.076
Sig. (2-tailed)	0.060	0.668	0.085	0.993	0.838	0.274	0.982	0.341	0.702
N	28	28	28	28	28	28	28	28	28
BatchSizes									
Correlation Coefficient	0.022	0.341	0.482	-0.127	-0.053	0.010	0.183	0.085	0.254
Sig. (2-tailed)	0.913	0.075	0.009	0.520	0.788	0.958	0.353	0.666	0.193
N	28	28	28	28	28	28	28	28	28
WIP									
Correlation Coefficient	-0.091	0.372	0.401	0.082	0.220	0.059	-0.196	0.190	0.176
Sig. (2-tailed)	0.646	0.051	0.034	0.677	0.260	0.766	0.318	0.334	0.370
N	28	28	28	28	28	28	28	28	28
KanbanSystems									
Correlation Coefficient	0.257	0.188	0.284	0.306	-0.018	0.270	0.032	0.428	0.040
Sig. (2-tailed)	0.187	0.337	0.143	0.113	0.928	0.164	0.873	0.023	0.841
N	28	28	28	28	28	28	28	28	28
QuickChangeover									
Correlation Coefficient	-0.242	0.523	0.353	0.136	0.075	0.091	-0.143	0.121	0.133
Sig. (2-tailed)	0.215	0.004	0.065	0.490	0.706	0.644	0.467	0.539	0.501
N	28	28	28	28	28	28	28	28	28
LeadTimeTracking									
Correlation Coefficient	-0.034	0.143	0.243	-0.224	0.174	0.195	0.129	-0.280	0.055
Sig. (2-tailed)	0.865	0.467	0.213	0.253	0.375	0.320	0.511	0.149	0.782
N	28	28	28	28	28	28	28	28	28
InvTurns									
Correlation Coefficient	0.064	0.257	0.263	0.136	0.293	0.058	0.154	0.017	0.152
Sig. (2-tailed)	0.747	0.187	0.176	0.491	0.130	0.770	0.435	0.932	0.439
N	28	28	28	28	28	28	28	28	28
OrderFreq									
Correlation Coefficient	-0.225	0.469	0.442	-0.029	0.142	-0.162	-0.211	0.047	0.067
Sig. (2-tailed)	0.249	0.012	0.019	0.885	0.471	0.411	0.280	0.813	0.733
N	28	28	28	28	28	28	28	28	28

Table 28: Spearman Rho Correlation Matrix

PullSystems	Pull Systems	Leveled FlowWork	FIFO	Layout Zones	Velocity Slotting	Travel Distance	Cell Structure	Demand Stabilization
Correlation Coefficient	1.000	0.067	0.272	0.428	0.040	0.222	0.669	0.110
Sig. (2-tailed)	.	0.736	0.162	0.023	0.839	0.256	0.000	0.579
N		28	28	28	28	28	28	28
LeveledFlowWork								
Correlation Coefficient		1.000	0.294	0.049	0.286	0.324	-0.192	0.398
Sig. (2-tailed)		.	0.129	0.803	0.140	0.092	0.327	0.036
N			28	28	28	28	28	28
FIFO								
Correlation Coefficient			1.000	-0.029	-0.035	0.371	0.114	0.290
Sig. (2-tailed)			.	0.883	0.858	0.052	0.562	0.134
N				28	28	28	28	28
LayoutZones								
Correlation Coefficient				1.000	0.395	0.584	0.255	-0.151
Sig. (2-tailed)				.	0.037	0.001	0.190	0.442
N					28	28	28	28
VelocitySlotting								
Correlation Coefficient					1.000	0.394	0.067	-0.147
Sig. (2-tailed)					.	0.038	0.734	0.454
N						28	28	28
TravelDistance								
Correlation Coefficient						1.000	-0.023	0.126
Sig. (2-tailed)						.	0.909	0.523
N							28	28
CellStructure								
Correlation Coefficient							1.000	-0.188
Sig. (2-tailed)							.	0.338
N								28
DemandStabilization								
Correlation Coefficient								1.000
Sig. (2-tailed)								.
N								

Table 28: Spearman Rho Correlation Matrix

PullSystems	Cross Docking	PDCA	Kaizen Events	Employee Suggestion	Systems View	Preventative Maint	Supplier Integration	SPC	Tech Equip
Correlation Coefficient	0.145	0.374	0.425	0.312	0.163	0.280	0.027	0.626	-0.109
Sig. (2-tailed)	0.460	0.050	0.024	0.106	0.406	0.149	0.890	0.000	0.580
N	28	28	28	28	28	28	28	28	28
LeveledFlowWork									
Correlation Coefficient	-0.282	0.321	0.195	0.021	0.025	-0.025	-0.072	-0.031	0.368
Sig. (2-tailed)	0.146	0.096	0.320	0.917	0.899	0.898	0.717	0.874	0.054
N	28	28	28	28	28	28	28	28	28
FIFO									
Correlation Coefficient	-0.088	0.538	0.319	0.219	0.086	0.419	-0.334	0.328	-0.037
Sig. (2-tailed)	0.655	0.003	0.098	0.264	0.664	0.026	0.083	0.088	0.853
N	28	28	28	28	28	28	28	28	28
LayoutZones									
Correlation Coefficient	0.201	0.242	0.404	0.043	0.092	-0.143	-0.059	0.192	-0.128
Sig. (2-tailed)	0.306	0.215	0.033	0.828	0.640	0.469	0.766	0.328	0.515
N	28	28	28	28	28	28	28	28	28
VelocitySlotting									
Correlation Coefficient	-0.018	0.079	0.130	-0.139	-0.240	0.100	0.274	-0.135	-0.108
Sig. (2-tailed)	0.926	0.688	0.510	0.480	0.219	0.611	0.158	0.495	0.584
N	28	28	28	28	28	28	28	28	28
TravelDistance									
Correlation Coefficient	0.107	0.416	0.584	-0.129	-0.072	-0.041	0.009	-0.107	0.027
Sig. (2-tailed)	0.589	0.028	0.001	0.513	0.717	0.834	0.962	0.589	0.890
N	28	28	28	28	28	28	28	28	28
CellStructure									
Correlation Coefficient	0.199	0.176	0.212	0.198	0.061	0.408	-0.006	0.349	-0.288
Sig. (2-tailed)	0.310	0.370	0.280	0.312	0.759	0.031	0.976	0.069	0.137
N	28	28	28	28	28	28	28	28	28
DemandStabilization									
Correlation Coefficient	-0.425	0.440	0.341	0.126	0.195	0.107	-0.142	0.347	0.511
Sig. (2-tailed)	0.024	0.019	0.076	0.522	0.320	0.586	0.470	0.070	0.005
N	28	28	28	28	28	28	28	28	28

Table 28: Spearman Rho Correlation Matrix

CrossDocking	Cross Docking	PDCA	Kaizen Events	Employee Suggestion	Systems View	Preventative Maint	Supplier Integration	SPC	Tech Equip
Correlation Coefficient	1.000	-0.100	-0.109	-0.047	-0.157	0.073	0.170	-0.007	-0.614
Sig. (2-tailed)	.	0.613	0.580	0.812	0.425	0.712	0.388	0.970	0.001
N		28	28	28	28	28	28	28	28
PDCA									
Correlation Coefficient		1.000	0.640	0.353	0.321	0.266	-0.449	0.330	0.009
Sig. (2-tailed)		.	0.000	0.065	0.096	0.172	0.017	0.087	0.964
N			28	28	28	28	28	28	28
KaizenEvents									
Correlation Coefficient			1.000	-0.102	0.265	0.200	-0.067	0.133	0.115
Sig. (2-tailed)			.	0.605	0.173	0.306	0.735	0.501	0.559
N				28	28	28	28	28	28
EmployeeSuggestion									
Correlation Coefficient				1.000	0.199	0.324	-0.117	0.418	0.131
Sig. (2-tailed)				.	0.310	0.093	0.552	0.027	0.505
N					28	28	28	28	28
SystemsView									
Correlation Coefficient					1.000	0.169	-0.018	0.226	0.244
Sig. (2-tailed)					.	0.391	0.927	0.247	0.210
N						28	28	28	28
PreventativeMaint									
Correlation Coefficient						1.000	0.088	0.502	0.029
Sig. (2-tailed)						.	0.655	0.007	0.883
SupplierIntegration									
Correlation Coefficient							1.000	-0.157	0.103
Sig. (2-tailed)							.	0.425	0.601
SPC									
Correlation Coefficient								1.000	0.149
Sig. (2-tailed)								.	0.448
TechEquip									
Correlation Coefficient									1.000
Sig. (2-tailed)									.

APPENDIX E:
SIXTEEN FACTOR ANALYSIS

Factor analysis was first completed using one less factor than was statistically significant, sixteen, using proper Factor Analysis procedures. The corresponding results can be seen in Table 29: Total Variance Explained Sixteen Factors and the corresponding pared down rotated components matrix can be seen in Table 32: Pared Down Rotated Components Matrix Sixteen Factors. The results seen for sixteen factors did not explain the variance as well as the results seen for seventeen factor analysis.

Table 29: Total Variance Explained Sixteen Factors

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	9.805	17.201	17.201	9.805	17.201	17.201	4.792	8.407	8.407
2	5.511	9.668	26.869	5.511	9.668	26.869	4.249	7.455	15.862
3	5.008	8.786	35.655	5.008	8.786	35.655	4.216	7.396	23.258
4	4.504	7.902	43.557	4.504	7.902	43.557	3.979	6.980	30.238
5	3.882	6.811	50.368	3.882	6.811	50.368	3.647	6.398	36.636
6	3.409	5.981	56.349	3.409	5.981	56.349	3.575	6.272	42.908
7	3.094	5.428	61.778	3.094	5.428	61.778	3.127	5.485	48.393
8	2.669	4.683	66.460	2.669	4.683	66.460	3.034	5.324	53.716
9	2.324	4.077	70.538	2.324	4.077	70.538	2.947	5.170	58.886
10	2.004	3.515	74.053	2.004	3.515	74.053	2.886	5.062	63.949
11	1.916	3.361	77.414	1.916	3.361	77.414	2.742	4.810	68.758
12	1.580	2.772	80.186	1.580	2.772	80.186	2.695	4.728	73.486
13	1.503	2.638	82.823	1.503	2.638	82.823	2.545	4.464	77.950
14	1.418	2.488	85.312	1.418	2.488	85.312	2.483	4.356	82.306
15	1.345	2.360	87.672	1.345	2.360	87.672	2.393	4.198	86.504
16	**1.229**	**2.156**	**89.828**	**1.229**	**2.156**	**89.828**	**1.894**	**3.324**	**89.828**
17	.992	1.741	91.568						
18	.924	1.620	93.189						
19	.709	1.244	94.432						
20	.647	1.135	95.568						
21	.623	1.092	96.660						
22	.528	.926	97.586						
23	.475	.833	98.419						
24	.305	.535	98.954						
25	.275	.483	99.437						
Extraction Method: Principal Component Analysis.									

Table 30: Component Transformation Matrix Sixteen Factors

Component Matrix																
	Component															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
StndWorkDispatches	.325	.314	.074	-.223	.123	-.293	.541	.105	-.247	-.125	-.089	.191	-.126	.109	-.060	.042
CommodityGroup	.123	.250	.477	-.411	.068	.274	-.032	.253	-.240	.254	-.231	.079	.118	.006	-.350	.002
CommonPrcsBestPractices	.519	-.354	.086	.037	-.346	.074	-.063	.152	-.066	.283	-.259	-.166	-.109	.093	.278	.093
LoadUnload	-.527	.070	-.023	.151	.301	-.055	.268	.577	-.008	.239	-.015	-.039	.019	.160	.039	-.159
RoutingTravel	-.032	.346	.120	.096	-.668	.200	.307	.054	.086	-.212	.218	-.015	.116	-.049	.035	-.225
SafetyErgonomics	.650	-.536	-.015	-.057	.009	-.154	.153	-.068	-.134	-.115	-.040	-.251	-.005	.092	.191	-.176
LeadershipRoles	.735	-.416	-.025	-.025	.008	-.175	-.124	-.096	-.062	-.165	.217	.188	.080	-.201	.045	-.201
MgmtStyle	.683	-.154	-.088	.062	-.136	-.395	-.265	.050	.174	.079	.060	-.041	.152	-.049	-.059	-.283
CrossTraining	.068	-.219	.215	.223	-.061	-.015	.357	.420	.511	-.319	-.153	.156	.119	.093	.122	-.164
TeamworkEmpowerment	.492	-.401	-.306	.029	.063	.005	.121	.064	-.157	-.132	.415	.236	.232	.107	-.207	-.019
PowerDistance	.124	-.161	.463	.280	-.171	-.094	-.019	.412	.265	-.061	-.240	.035	.089	-.189	-.236	.116
EERecognition	.449	-.060	.253	.307	-.112	.056	.016	-.266	-.354	-.140	.483	.132	.061	-.102	-.198	.180
CommunicationStrategy	.642	-.006	-.091	.161	-.016	-.119	.079	-.017	-.347	.229	.015	-.051	-.069	.352	-.175	-.082
TurnoverLayoff	-.034	-.336	.085	.060	-.128	-.076	-.051	.270	-.562	.071	-.315	.025	.313	.296	.277	-.053
FiveWhyRootCause	.513	.075	-.362	-.249	.045	.387	-.076	.319	-.077	-.054	-.036	-.163	-.209	.038	-.371	-.066
InspectionAutonomation	.705	-.086	-.319	-.224	.097	.193	.204	-.028	.217	.192	-.116	-.108	.228	-.115	.076	.136
ErrorProofing	.417	.179	-.478	-.207	-.087	.202	-.084	.291	.059	-.250	.128	-.267	-.223	-.089	.024	.167
InventoryIntegrity	.246	-.214	.616	-.061	.098	.447	-.179	-.103	.056	.117	.261	.091	.115	-.026	.238	-.230
ProductProcessQuality	-.075	.139	.420	-.358	.565	-.072	-.303	-.059	-.158	.074	-.052	-.177	.316	-.161	.074	.024
QualityMeasStats	.212	.123	.452	.163	.554	.349	-.234	-.190	.216	.098	.062	-.238	.064	.056	-.121	-.053
VSM	.411	.019	-.178	-.080	-.474	-.278	-.134	.204	.344	.136	.117	.237	.020	-.001	.227	.060
ProcessControlBoards	.281	.406	.069	-.007	.438	-.070	.144	.161	-.170	-.467	-.045	-.106	-.242	-.066	.051	-.251
MetricsKPIBoards	.189	.007	.616	-.035	-.180	.525	-.090	.186	-.056	-.224	-.100	.039	.169	.078	-.032	.184
LeanTracking	.572	.399	-.002	.469	.005	-.150	-.256	-.057	-.025	-.218	-.168	-.144	.047	.023	-.050	.042
VisualControls	-.358	.317	-.009	.045	.320	-.042	.380	.129	.214	.015	.245	-.109	.309	-.102	-.001	.196
AndonSys	.178	-.219	-.560	.417	.250	.189	.093	.222	-.007	.270	.178	.024	-.138	-.046	-.079	.229
A3	.618	.212	.136	.053	-.034	-.287	.125	-.165	.227	.443	-.036	.010	-.007	.079	-.233	-.241
FiveS	.448	-.452	.181	.458	.100	.069	.014	-.160	-.009	.179	-.070	.179	-.238	.114	-.008	.242
SignageShadowBoards	-.109	-.138	.596	.202	-.076	.062	-.233	.282	.244	.061	.133	.176	-.401	.132	-.086	.045
Cleanliness	-.014	-.319	.679	.329	-.006	.218	-.008	-.293	-.081	-.038	-.119	-.241	.052	-.161	.025	.005
SupplyMtrlMgmt	.367	-.282	.343	.090	.437	-.375	-.088	.312	.055	-.013	-.006	.229	.046	-.226	-.011	.089
POUS	-.093	.049	.277	.562	.190	-.313	.261	.203	.116	.131	.109	-.136	-.127	-.120	-.023	.175
IDProblemParts	-.137	.351	-.190	.401	.347	-.097	.079	-.469	.122	.156	-.216	.183	-.136	-.035	.113	-.041
BatchSizes	.343	.566	.312	-.314	.204	-.094	.378	-.183	-.016	-.225	-.107	.110	-.049	.045	-.086	.086
WIP	.526	.091	.197	.386	-.169	-.417	.190	-.047	.041	-.078	-.158	-.148	-.011	-.133	.275	.122
KanbanSystems	.147	.644	-.124	.313	.068	.294	-.020	.010	-.160	.297	-.123	.170	.106	.114	.209	.105
QuickChangeover	.371	.256	-.088	-.478	.128	.343	-.002	-.184	.122	-.053	-.040	.235	-.260	.054	.237	-.206
LeadTimeTracking	.202	.052	-.007	-.439	.143	-.337	-.505	.080	.292	-.091	.033	-.206	-.065	.307	.095	.252
InvTurns	.290	.096	.030	-.139	.148	-.281	-.523	.057	-.322	-.182	.157	.301	.115	.187	.143	.242
OrderFreq	.442	.272	.096	-.471	-.095	.294	-.188	.391	.070	.241	.067	.127	-.027	-.309	.093	.092
PullSystems	.262	.682	-.211	.355	.052	.275	.015	.110	-.104	.103	.132	.199	.226	-.100	.135	-.031
LeveledFlowWork	.434	-.088	.455	.000	-.091	.181	.471	-.233	-.002	.102	-.049	.281	-.203	.210	.000	.017
FIFO	.457	.140	-.183	.044	-.231	.117	.193	-.033	.310	-.144	-.165	-.028	.402	.421	-.236	.154

Table 30: Component Transformation Matrix Sixteen Factors

Component Matrix																
	Component															
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
LayoutZones	.221	.502	.144	.093	-.371	-.127	.179	.265	-.411	.152	.143	-.286	-.071	-.193	.086	-.134
VelocitySlotting	.057	.189	.560	.004	-.337	-.060	.040	.053	-.017	.056	.568	-.159	-.175	.154	.130	.105
TravelDistance	.406	.514	.492	-.248	-.216	-.286	.138	-.032	-.048	-.105	-.059	-.205	.015	.089	.008	.115
CellStructure	-.141	.721	-.123	.309	-.162	.182	-.267	.196	.064	.091	.078	.079	-.026	.145	.159	-.040
DemandStabilization	.646	-.144	.037	-.333	.289	.224	.258	.039	.233	-.089	-.065	.187	.075	-.102	.196	.018
CrossDocking	-.454	.413	.065	.198	.034	-.302	-.341	.050	-.085	-.333	-.234	.328	-.110	-.040	-.033	.045
PDCA	.779	.312	-.004	.028	-.135	.069	-.289	-.144	.121	-.056	-.086	.034	-.111	-.119	-.143	-.052
KaizenEvents	.621	.416	.023	-.161	.112	-.361	-.068	-.192	.109	.345	-.041	-.056	.020	-.117	-.013	.023
EmployeeSuggestion	.328	-.117	.040	.537	.121	.399	-.253	.255	-.136	-.124	-.281	-.020	-.152	-.064	-.005	-.156
SystemsView	.582	-.046	-.114	.163	.270	-.312	-.183	.337	-.093	.052	.034	.041	.037	.011	-.121	-.223
PreventativeMaint	.259	.195	-.054	.430	.337	.211	-.258	-.095	.287	-.195	.190	-.245	.035	.372	.095	-.097
SupplierIntegration	-.393	.127	.323	-.068	.570	-.194	.111	.226	.071	.108	.288	.038	.041	.226	.051	-.189
SPC	.467	.105	-.280	.602	.228	.209	.173	-.021	-.094	-.183	.034	-.026	.141	-.137	.094	.102
TechEquip	.424	-.297	-.096	-.291	.515	.129	.340	.162	-.134	-.058	.044	-.143	-.212	.044	.196	.197

Extraction Method: Principal Component Analysis.
a 16 components extracted.

Table 31: Rotated Component Transformation Matrix Sixteen Factors

Rotated Component Matrix																
	Component															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
StndWorkDispatches	.120	.031	.121	.806	-.286	-.141	.019	.037	.114	.091	-.014	-.027	.025	.087	.060	.036
CommodityGroup	.045	.028	-.016	.266	.223	-.101	.042	.073	-.089	.872	-.041	-.019	-.091	.031	.115	.055
CommonPrcsBestPractices	.275	-.049	.402	-.178	-.049	.343	.184	.109	-.153	.075	.121	.034	.036	.340	.493	-.008
LoadUnload	-.170	.125	-.091	-.072	-.110	-.812	-.082	.061	-.230	.035	.144	-.151	.218	-.048	.146	-.091
RoutingTravel	-.080	.211	-.157	.077	-.174	.169	.602	-.015	.021	-.012	.248	-.460	-.137	-.222	-.069	.216
SafetyErgonomics	.353	-.387	.484	.125	.096	.209	.028	.133	.243	-.288	.060	-.011	-.045	.084	.433	-.008
LeadershipRoles	.477	-.205	.288	.018	.038	.326	-.026	.042	.617	-.115	.167	.106	-.168	.026	.103	-.189
MgmtStyle	.818	-.093	.105	-.109	-.032	.211	.031	.097	.242	-.096	.179	.162	-.020	-.082	.100	.038
CrossTraining	-.009	-.091	.111	.074	-.029	-.180	.019	-.034	-.018	-.161	.886	-.148	.023	.055	.043	.178
TeamworkEmpowerment	.162	-.098	.285	-.075	-.140	-.030	-.078	.177	.814	-.078	.011	.014	-.063	.060	.074	.189
PowerDistance	.144	-.115	-.121	-.046	.103	.114	.050	-.001	-.033	.304	.650	-.036	.418	.131	.029	.028
EERecognition	.069	.089	-.019	.126	.214	.328	.317	-.056	.732	.012	-.141	-.060	.191	.220	-.042	-.015
CommunicationStrategy	.502	.107	.118	.197	-.004	.027	.048	.238	.279	-.023	-.266	-.036	.054	.337	.350	.207
TurnoverLayoff	-.091	-.024	-.014	-.080	-.076	-.070	-.058	-.139	.070	.106	.030	.056	.049	.000	.915	.009
FiveWhyRootCause	.157	.048	.231	.054	-.016	.098	-.103	.832	.106	.264	-.083	-.031	-.187	.022	-.026	.151
InspectionAutonomation	.322	.115	.797	.039	-.040	.235	-.186	.152	.064	.086	.009	.010	-.063	-.057	-.052	.234
ErrorProofing	-.001	.143	.313	.041	-.206	.239	.114	.727	.011	-.074	-.015	.192	-.067	-.169	-.137	.036
InventoryIntegrity	.038	-.003	.242	-.153	.626	.013	.324	-.227	.201	.225	.189	-.014	-.363	.159	.064	-.196
ProductProcessQuality	.015	-.074	.065	.180	.535	-.179	-.125	-.237	-.081	.351	-.185	.387	.033	-.366	.038	-.248
QualityMeasStats	.136	.132	.103	.022	.897	-.107	-.038	.023	-.031	.095	-.010	.099	.015	.120	-.223	.039
VSM	.436	.126	.163	-.183	-.507	.217	.267	-.035	.021	-.022	.301	.267	-.128	.046	-.050	.065
ProcessControlBoards	.070	.142	-.045	.690	.230	-.114	-.056	.403	.054	-.184	.114	.032	-.061	-.170	-.007	-.252
MetricsKPIBoards	-.297	.077	.030	.092	.429	.255	.303	.040	.077	.474	.372	.038	-.065	.127	.190	.168
LeanTracking	.427	.424	-.172	.255	.249	.399	-.021	.227	.077	-.208	.099	.173	.243	-.007	.078	.136
VisualControls	-.249	.202	.134	.123	.011	-.466	.027	-.183	-.038	-.026	.031	-.040	.333	-.333	-.361	.117
AndonSys	.007	.293	.336	-.352	-.164	-.158	-.290	.374	.259	-.189	-.104	-.085	.301	.301	-.086	-.032
A3	.853	.075	.127	.213	.048	.012	.076	-.094	-.022	.097	-.047	-.123	.005	.220	-.137	.190
FiveS	.157	-.011	.213	-.087	.208	.218	-.125	-.065	.246	-.123	.099	.005	.205	.743	.124	-.028
SignageShadowBoards	-.030	-.121	-.305	-.164	.218	-.149	.328	.024	-.080	.178	.402	.139	.042	.539	-.114	-.180
Cleanliness	-.124	-.211	-.017	-.048	.665	.275	.150	-.297	-.011	.033	.125	-.257	.243	.190	.169	-.124
SupplyMtrlMgmt	.321	-.151	.150	.157	.147	-.131	-.204	-.088	.310	.147	.411	.339	.294	.143	.036	-.350
POUS	.092	.098	-.064	.089	.092	-.278	.118	-.105	-.043	-.186	.204	-.093	.672	.215	-.123	-.168
IDProblemParts	.092	.417	-.146	.156	.089	-.026	-.416	-.295	-.210	-.380	-.203	-.125	.030	.170	-.264	-.077
BatchSizes	.082	.108	.089	.889	.095	.047	.074	-.077	-.028	.171	-.021	.061	-.105	-.015	-.231	.134
WIP	.407	.136	.159	.337	-.019	.361	.194	-.144	-.030	-.303	.257	.022	.405	.091	.172	-.061
KanbanSystems	.034	.889	.014	.108	.045	-.006	-.029	-.021	-.117	.088	-.161	-.025	-.020	.103	.076	.083
QuickChangeover	.065	.160	.305	.302	.042	.123	-.024	.148	-.095	.058	-.052	.080	-.727	.082	-.182	-.084
LeadTimeTracking	.219	-.228	.055	.012	.029	.006	.079	.159	-.222	-.026	-.037	.843	-.102	-.081	-.085	.135
InvTurns	.095	.149	-.153	.132	-.029	.106	-.002	-.023	.384	.078	-.098	.745	-.102	-.004	.213	-.106
OrderFreq	.180	.263	.377	.015	-.088	.138	.229	.256	-.051	.628	.129	.209	-.242	-.080	-.136	-.225
PullSystems	.114	.922	.023	.108	.014	.002	.044	.091	.169	.035	-.014	-.105	-.016	-.140	-.082	.026
LeveledFlowWork	.085	-.048	.267	.415	.117	.109	.202	-.221	.125	.120	.120	-.262	-.177	.604	.033	.134
FIFO	.186	.161	.187	.122	-.051	.195	-.027	.098	.084	-.005	.195	.014	-.021	-.011	.008	.852
LayoutZones	.257	.323	-.062	.286	-.153	.057	.574	.191	-.061	.147	-.143	-.255	.240	-.193	.225	-.207
VelocitySlotting	.013	-.014	-.073	.088	.109	-.069	.900	-.096	.054	.041	-.013	.099	.081	.172	-.080	-.047

Table 31: Rotated Component Transformation Matrix Sixteen Factors

Rotated Component Matrix																
	Component															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
TravelDistance	.290	.021	-.008	.656	.070	.206	.495	-.069	-.173	.208	.014	.181	.096	-.091	.029	.158
CellStructure	-.003	.767	-.361	-.096	-.043	-.086	.230	.141	-.232	-.029	.013	.076	-.086	-.063	-.087	.058
DemandStabilization	.138	-.010	.711	.303	.103	.097	-.151	.051	.180	.111	.304	.091	-.300	.066	-.084	-.001
CrossDocking	-.188	.220	-.764	.184	-.115	.024	-.206	-.112	-.140	-.041	.136	.260	.061	-.090	-.062	-.189
PDCA	.544	.261	.049	.188	.151	.546	.046	.287	.094	.099	.054	.118	-.164	.091	-.160	.068
KaizenEvents	.723	.203	.230	.326	.003	.160	.026	-.079	-.092	.122	-.218	.232	.046	-.027	-.192	-.010
EmployeeSuggestion	.056	.303	-.059	-.131	.393	.211	-.217	.439	.090	-.034	.314	-.148	.063	.257	.312	-.169
SystemsView	.617	.086	.055	.080	.029	-.129	-.172	.318	.328	-.016	.142	.199	.109	.015	.193	-.120
PreventativeMaint	.135	.348	-.006	-.075	.562	-.091	.030	.254	.058	-.474	.079	.211	-.059	.057	-.101	.266
SupplierIntegration	-.057	-.046	-.116	.153	.237	-.835	.057	-.189	-.024	.000	.035	.160	.012	-.054	-.102	-.149
SPC	.051	.530	.267	.108	.181	.198	-.199	.213	.370	-.348	.102	-.163	.273	.029	.036	.045
TechEquip	-.110	-.182	.724	.326	.076	-.167	-.140	.318	.145	-.066	-.059	.158	-.001	.180	.107	-.155

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a Rotation converged in 23 iterations.

Table 32: Pared Down Rotated Components Matrix Sixteen Factors

Component	1
A3	0.85347
MgmtStyle	0.81753
KaizenEvents	0.72320
SystemsView	0.61685
PDCA	0.54379
CommunicationStrategy	0.50229

Component	2
PullSystems	0.92176
KanbanSystems	0.88889
CellStructure	0.76743
SPC	0.53001

Component	3
InspectionAutonomation	0.79704
TechEquip	0.72430
DemandStabilization	0.71070
CrossDocking	-0.76418

Component	4
BatchSizes	0.88884
StndWorkDispatches	0.80576
ProcessControlBoards	0.68984
TravelDistance	0.65588

Component	5
QualityMeasStats	0.89735
Cleanliness	0.66501
InventoryIntegrity	0.62598
PreventativeMaint	0.56201
ProductProcessQuality	0.53521
VSM	-0.50660

Component	6
PDCA	0.54556
VisualControls	-0.46580
LoadUnload	-0.81153
SupplierIntegration	-0.83523

Component	7
VelocitySlotting	0.89997
RoutingTravel	0.60201
LayoutZones	0.57380

Component	8
FiveWhyRootCause	0.83234
ErrorProofing	0.72706

Component	9
TeamworkEmpowerment	0.81397
EERecognition	0.73151
LeadershipRoles	0.61712

Component	10
CommodityGroup	0.87206
OrderFreq	0.62756

Component	11
CrossTraining	0.88589
PowerDistance	0.64985

Component	12
LeadTimeTracking	0.84253
InvTurns	0.74495

Component	13
POUS	0.67201
QuickChangeover	-0.72684

Component	14
FiveS	0.74335
LeveledFlowWork	0.60398
SignageShadowBoards	0.53868

Component	15
TurnoverLayoff	0.91477

Component	16
FIFO	0.85196

Table 33: Component Transformation Matrix Sixteen Factors

Component Transformation Matrix																
Component	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
1	.571	.131	.441	.264	.105	.365	.063	.261	.308	.033	.106	.123	-.063	.178	.097	.091
2	.094	.651	-.271	.440	-.017	-.038	.193	.068	-.266	.110	-.156	.051	-.039	-.247	-.278	.084
3	-.007	-.197	-.151	.260	.522	-.025	.416	-.362	-.066	.356	.285	.027	.102	.213	.069	-.141
4	.074	.429	-.276	-.210	.208	.044	-.063	-.027	.156	-.425	.211	-.268	.480	.281	.095	.001
5	-.033	.048	.211	.234	.458	-.487	-.529	.050	.096	-.091	-.104	.249	.068	.003	-.153	-.224
6	-.473	.303	.254	-.244	.380	.124	.015	.281	.006	.254	.019	-.319	-.347	.129	-.048	.120
7	-.163	-.075	.397	.479	-.263	-.258	.071	-.143	.029	-.114	.078	-.577	.166	.077	-.052	.176
8	-.024	.115	.036	-.092	-.252	-.420	.114	.476	-.024	.312	.503	.130	.210	-.088	.246	-.131
9	.188	-.077	.161	-.232	.044	-.055	-.016	-.087	-.337	-.174	.511	.099	-.094	.018	-.605	.277
10	.397	.191	.246	-.375	-.091	-.278	.022	-.249	-.265	.348	-.377	-.139	.105	.294	.024	-.081
11	-.029	.009	.064	-.202	.005	-.295	.575	.030	.560	-.163	-.192	.094	-.032	-.066	-.365	-.105
12	-.060	.243	-.192	.072	-.356	-.034	-.277	-.352	.392	.216	.270	.069	-.378	.342	-.120	-.119
13	.042	.166	.136	-.164	.129	-.047	-.113	-.417	.283	.193	.113	.031	.109	-.589	.215	.428
14	-.027	-.010	-.139	.063	.046	-.358	.125	.047	-.059	-.204	-.108	.268	-.251	.359	.338	.627
15	-.161	.292	.382	-.024	-.053	.029	.216	-.302	-.245	-.411	.136	.232	-.226	-.081	.327	-.369
16	-.426	.094	.235	.026	-.164	.260	.013	-.073	-.005	.156	-.115	.476	.517	.250	-.170	.178

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

Component Plot in Rotated Space Sixteen Factors

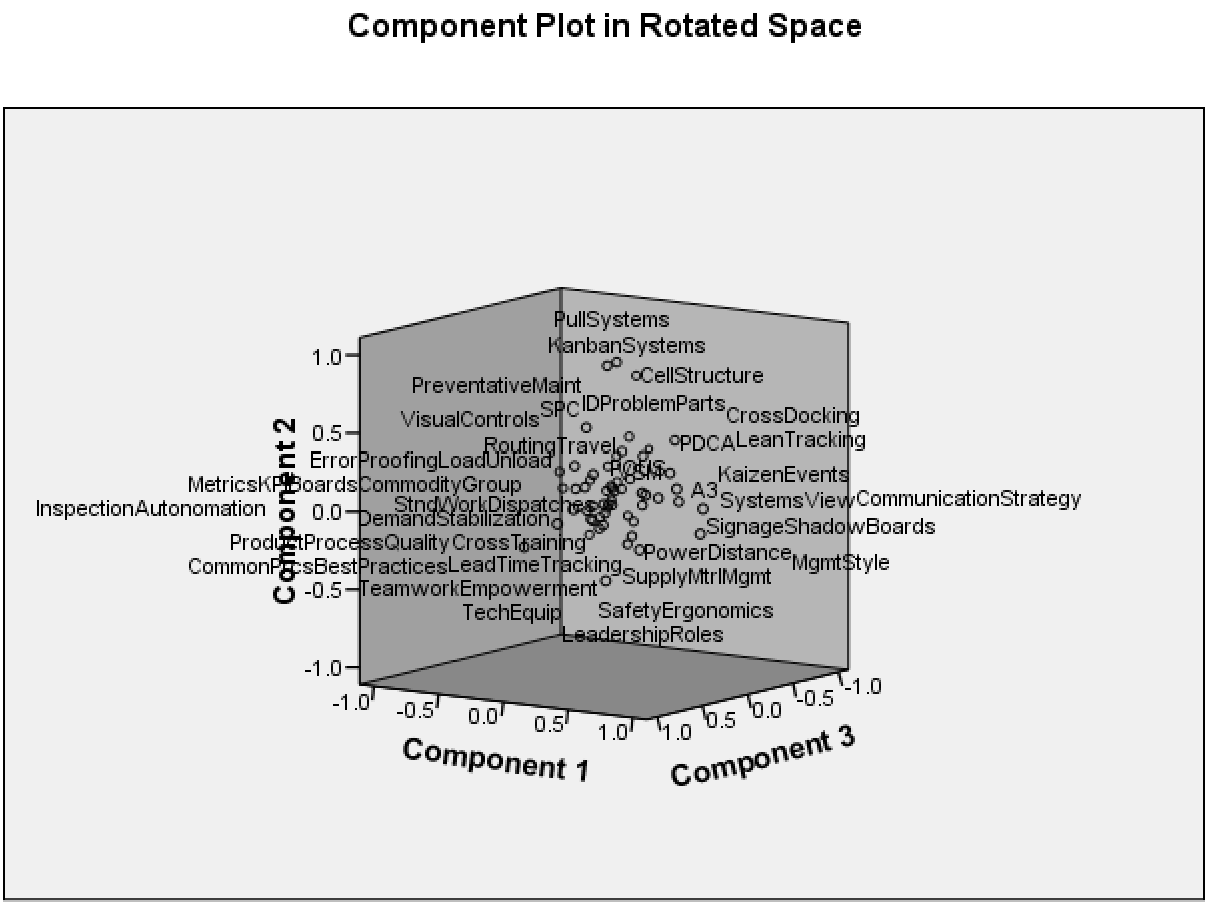

Figure 24: Component Plot in Rotated Space Sixteen Factors

APPENDIX F:
SEVENTEEN FACTOR ANALYSIS

Factor analysis was completed using all seventeen statistically significant factors, using proper Factor Analysis procedures. The corresponding results can be seen in Table 34: Component Matrix Seventeen Factors and the corresponding rotated components matrix can be seen in Table 35: Component Transformation Matrix Seventeen Factors. The results for seventeen factors explained the variance and the results better than that seen for sixteen factor analysis.

Table 34: Components Matrix Seventeen Factors

Component Matrix[a]																	
	Component																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
SOPs	.507	.201	.176	-.068	-.025	-.177	-.104	.094	-.341	-.398	.011	-.389	-.118	-.118	-.105	.005	.199
StndWorkDispatches	.336	.317	.057	-.218	.124	-.271	.549	.120	-.255	-.034	-.094	-.060	.093	.188	-.031	.039	-.159
CommodityGroup	.137	.279	.464	-.395	.072	.284	-.041	.255	-.157	.293	-.223	-.144	.070	-.162	-.293	-.003	-.245
CommonPrcsBestPractices	.508	-.364	.094	.040	-.344	.086	-.057	.137	.046	.327	-.252	.048	-.154	.171	.154	.098	.056
LoadUnload	-.531	.073	-.027	.151	.301	-.050	.266	.571	.082	.242	-.008	-.011	-.005	.102	-.081	-.157	.119
RoutingTravel	-.025	.351	.095	.103	-.666	.219	.300	.061	.034	-.203	.211	.140	.080	-.069	.041	-.225	-.160
SafetyErgonomics	.632	-.554	.004	-.058	.009	-.138	.165	-.071	-.098	.032	-.048	.321	-.115	.117	.093	-.173	.010
LeadershipRoles	.737	-.421	.000	-.031	.005	-.190	-.124	-.087	-.115	-.158	.212	-.052	.174	-.137	.154	-.201	-.004
MgmtStyle	.677	-.172	-.089	.061	-.137	-.389	-.236	.023	.238	.077	.062	.068	.055	-.135	-.051	-.284	.013
CrossTraining	.063	-.213	.218	.227	-.060	.001	.358	.410	.436	-.405	-.162	.092	.239	.096	.048	-.163	-.061
TeamworkEmpowerment	.488	-.422	-.282	.018	.060	-.013	.105	.085	-.215	-.123	.411	-.043	.303	-.066	-.250	-.021	.038
PowerDistance	.129	-.135	.467	.287	-.171	-.092	-.016	.401	.255	-.135	-.240	-.075	.020	-.259	-.091	.113	.017
EERecognition	.460	-.049	.252	.310	-.113	.044	.003	-.239	-.413	-.077	.478	-.047	.105	-.138	-.086	.176	-.112
CommunicationStrategy	.641	-.025	-.101	.162	-.017	-.114	.084	-.012	-.268	.313	.021	-.035	-.071	.218	-.337	-.082	.267
TurnoverLayoff	-.047	-.335	.100	.060	-.128	-.074	-.048	.271	-.410	.385	-.320	.344	.331	.192	.006	-.048	.075
FiveWhyRootCause	.517	.050	-.365	-.254	.046	.367	-.105	.336	-.118	-.084	-.036	-.090	-.308	-.027	-.286	-.070	-.055
InspectionAutonomation	.684	-.131	-.336	-.220	.102	.226	.214	-.048	.282	.161	-.111	.099	.052	-.201	.056	.138	-.005
ErrorProofing	.422	.150	-.484	-.216	-.088	.184	-.104	.302	-.008	-.256	.120	.112	-.337	.008	.088	.167	.108
InventoryIntegrity	.241	-.192	.613	-.043	.104	.462	-.183	-.114	.100	.119	.263	.034	.171	.020	.184	-.227	.015
ProductProcessQuality	-.067	.166	.416	-.346	.567	-.068	-.289	-.073	-.070	.203	-.054	.251	.067	-.281	.061	.026	.071
QualityMeasStats	.209	.132	.424	.182	.559	.361	-.231	-.208	.244	.056	.064	.119	-.147	-.075	-.167	-.053	-.049
VSM	.411	.004	-.180	-.084	-.475	-.270	-.113	.178	.376	.016	.123	-.170	.193	.079	.172	.064	.372
ProcessControlBoards	.303	.415	.050	-.004	.437	-.084	.129	.188	-.278	-.377	-.060	.125	-.200	.093	.137	-.252	.144
MetricsKPIBoards	.199	.038	.609	-.019	-.175	.525	-.114	.197	-.092	-.160	-.108	.134	.155	-.021	-.097	.185	.125
LeanTracking	.583	.386	-.038	.473	.004	-.158	-.249	-.060	-.042	-.140	-.177	.193	-.058	-.032	-.065	.042	-.021

Table 34: Components Matrix Seventeen Factors

Component Matrix[a]																	
	Component																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
VisualControls	-.355	.318	-.027	.049	.321	-.026	.383	.125	.204	-.049	.245	.116	.080	-.279	-.052	.199	.322
AndonSys	.155	-.267	-.564	.407	.249	.180	.081	.222	.037	.203	.188	-.188	-.103	.006	-.005	.227	-.212
A3	.621	.204	.109	.063	-.032	-.254	.157	-.193	.312	.303	-.020	-.243	-.063	-.049	-.251	-.243	.017
FiveS	.438	-.456	.190	.460	.100	.068	.012	-.159	-.007	.104	-.061	-.274	-.025	.219	-.010	.241	.122
SignageShadowBoards	-.096	-.096	.606	.210	-.076	.050	-.239	.276	.216	-.095	.139	-.340	-.137	.289	-.044	.043	.077
Cleanliness	-.013	-.284	.687	.342	-.004	.222	-.014	-.286	-.099	-.003	-.121	.137	-.166	-.190	.062	.006	.182
SupplyMtrlMgmt	.375	-.262	.360	.092	.434	-.384	-.077	.306	.064	-.039	-.005	-.154	.164	-.153	.136	.087	-.072
POUS	-.089	.062	.265	.566	.188	-.303	.274	.195	.144	.071	.114	-.060	-.212	-.068	.056	.174	-.209
IDProblemParts	-.131	.340	-.214	.399	.345	-.101	.083	-.466	.073	.007	-.207	-.298	.017	.071	.121	-.038	.185
BatchSizes	.364	.583	.280	-.300	.208	-.068	.385	-.173	-.082	-.207	-.114	-.013	.061	.067	-.054	.083	-.057
WIP	.523	.084	.173	.394	-.169	-.388	.220	-.063	.086	.014	-.163	.217	-.065	-.002	.298	.124	-.140
KanbanSystems	.151	.623	-.178	.321	.071	.302	-.026	.007	-.078	.321	-.114	-.095	.212	.108	.071	.110	.117
QuickChangeover	.369	.240	-.108	-.470	.134	.358	-.007	-.186	.091	-.098	-.040	-.148	.061	.306	.252	-.205	-.007
LeadTimeTracking	.202	.051	-.005	-.438	.143	-.334	-.475	.045	.344	-.059	.028	.255	-.110	.280	-.088	.254	-.101
InvTurns	.302	.103	.034	-.141	.145	-.306	-.516	.059	-.295	-.011	.149	.081	.373	.213	.037	.243	-.017
OrderFreq	.446	.268	.077	-.460	-.090	.304	-.191	.376	.150	.196	.075	-.187	.035	-.171	.263	.091	-.113
PullSystems	.261	.651	-.272	.363	.055	.285	.010	.107	-.048	.154	.134	-.003	.298	-.103	.136	-.029	.082
LeveledFlowWork	.433	-.076	.445	.015	-.086	.216	.472	-.227	-.014	.049	-.044	-.238	.105	.316	-.032	.016	-.226
FIFO	.451	.113	-.206	.047	-.228	.139	.198	-.044	.281	-.171	-.171	.225	.258	.026	-.519	.156	.126
LayoutZones	.235	.507	.111	.101	-.370	-.112	.184	.270	-.312	.303	.144	.128	-.265	-.131	.159	-.133	.094
VelocitySlotting	.068	.220	.545	.018	-.334	-.039	.053	.043	.029	.088	.568	.102	-.179	.224	.040	.107	.066
TravelDistance	.426	.539	.461	-.231	-.213	-.254	.163	-.041	-.014	-.003	-.065	.226	-.107	.041	-.058	.116	.054
CellStructure	-.141	.703	-.179	.317	-.159	.188	-.263	.178	.137	.125	.079	.038	.101	.208	.075	-.039	-.120
DemandStabilization	.643	-.155	.037	-.327	.293	.240	.252	.039	.185	-.166	-.066	-.061	.193	-.023	.204	.021	.121
CrossDocking	-.425	.442	.063	.192	.028	-.342	-.347	.067	-.187	-.327	-.243	-.166	.174	.086	.068	.042	-.079
PDCA	.791	.300	-.030	.033	-.134	.065	-.288	-.148	.082	-.122	-.085	-.130	-.087	-.077	-.017	-.055	-.111
KaizenEvents	.621	.399	-.015	-.151	.114	-.327	-.028	-.226	.230	.325	-.030	-.065	-.058	-.119	.040	.023	.054
EmployeeSuggestion	.332	-.121	.036	.536	.120	.364	-.286	.275	-.185	-.113	-.284	-.066	-.127	.013	.054	-.156	.128
SystemsView	.584	-.060	-.116	.159	.267	-.324	-.174	.330	-.037	.099	.035	-.016	.045	-.033	-.093	-.226	-.208
PreventativeMaint	.245	.168	-.092	.438	.340	.218	-.252	-.115	.288	-.157	.180	.370	-.057	.281	-.143	-.094	-.066
SupplierIntegration	-.387	.153	.319	-.061	.570	-.185	.122	.215	.120	.100	.291	.021	.087	.167	-.098	-.186	.095
SPC	.451	.063	-.315	.604	.229	.215	.164	-.013	-.106	-.082	.025	.203	.100	-.112	.146	.102	-.113
TechEquip	.419	-.309	-.080	-.292	.516	.131	.326	.177	-.149	-.017	.041	.065	-.202	.177	.155	.200	.049
Extraction Method: Principal Component Analysis.																	
a. 17 components extracted.																	

Table 35: Component Transformation Matrix Seventeen Factors

Component Transformation Matrix

Component	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	.552	.449	.140	.269	.376	.072	.323	.062	.142	.270	-.037	.083	.088	.146	.052	.061	.103
2	.083	-.318	.610	.427	-.088	-.051	-.271	.225	.071	.145	-.047	.121	-.142	-.239	-.278	.029	.068
3	-.004	-.230	-.243	.286	-.098	.688	-.037	.326	.040	-.084	.135	.234	.218	.256	.053	-.039	-.126
4	.057	-.242	.428	-.234	.051	.100	.142	-.043	-.275	.072	.517	-.359	.171	.284	.087	.268	.011
5	-.031	.248	.054	.172	-.526	.241	.063	-.540	.237	.144	.074	-.041	-.127	.012	-.149	.317	-.229
6	-.444	.335	.329	-.220	.134	.296	-.036	.022	-.333	.047	-.347	.330	.019	.123	-.093	.207	.132
7	-.109	.356	-.072	.536	-.249	-.193	.014	.078	-.569	-.193	.167	-.167	.142	-.010	-.004	-.109	.120
8	-.092	.118	.099	-.169	-.354	-.310	-.028	.159	.130	.389	.217	.422	.459	-.022	.253	-.126	-.083
9	.340	.185	-.007	-.247	-.120	.009	-.411	.018	.128	-.347	-.030	-.068	.460	.050	-.442	.112	.203
10	.340	.198	.241	-.171	-.202	.029	-.203	.082	-.074	-.422	.119	.251	-.452	.113	.404	-.091	-.138
11	-.019	.092	.015	-.204	-.303	-.069	.557	.571	.084	-.126	-.043	-.093	-.165	-.037	-.350	.109	-.141
12	-.121	.188	-.040	-.004	.024	.206	-.112	.253	.202	-.039	.115	-.234	.037	-.574	.407	.400	.248
13	-.047	-.176	.331	.091	-.110	.061	.442	-.256	.177	-.454	-.270	.018	.349	-.112	.236	-.215	.160
14	-.142	-.043	.014	.200	-.091	-.294	-.168	.191	.250	-.036	-.371	-.238	.027	.569	.281	.342	-.007
15	-.129	.247	.231	.009	.215	.094	-.169	.092	.084	-.039	-.080	-.346	.199	-.115	.011	-.274	-.717
16	-.420	.230	.109	.084	.192	-.033	-.021	.008	.469	-.171	.468	.021	-.165	.230	-.162	-.260	.267
17	.071	.080	.070	-.167	-.326	.284	-.092	.081	.001	.360	-.211	-.412	-.118	.106	.083	-.503	.353

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

Component Plot in Rotated Space Seventeen Factors

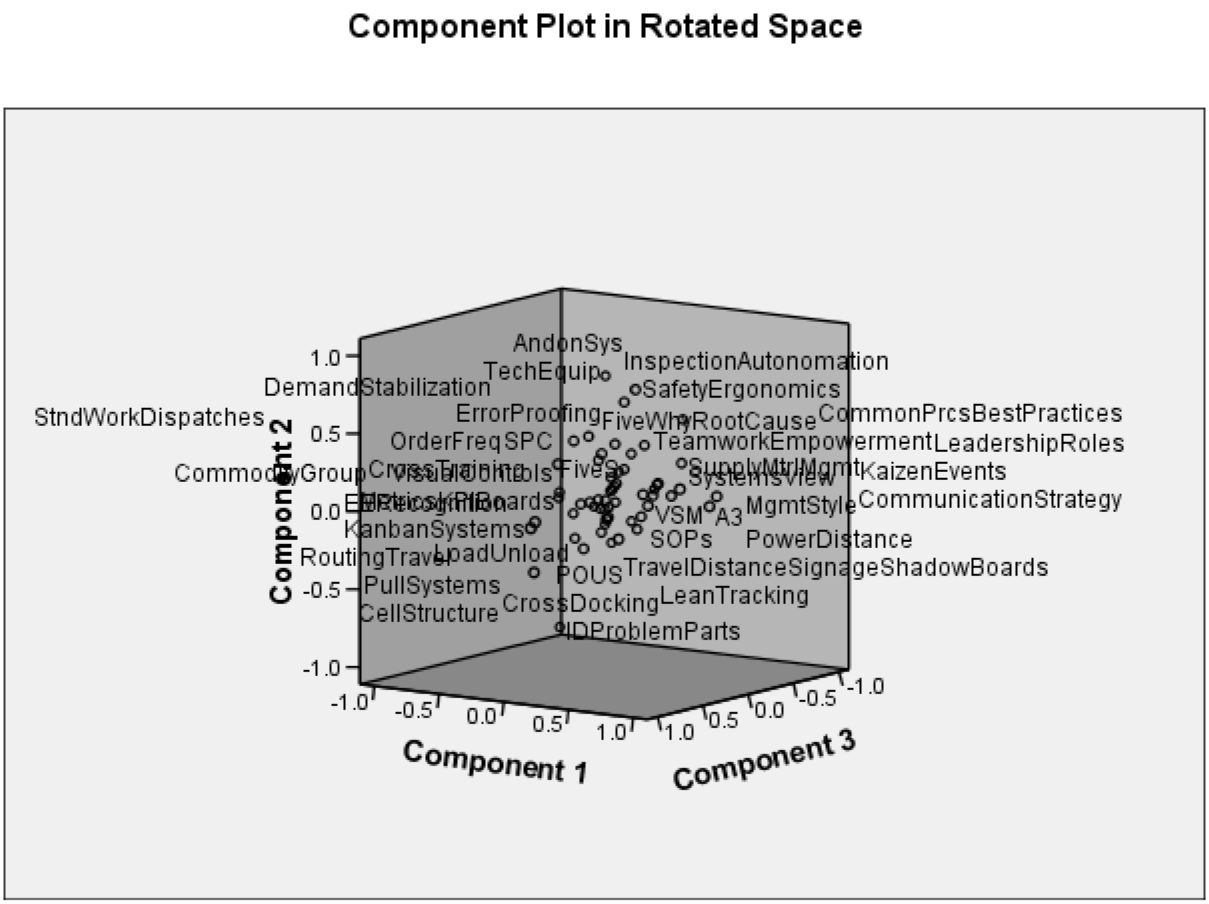

Figure 25: Component Plot in Rotated Space Seventeen Factors

VITA

Eric Benjamin Sobanski

Candidate for the Degree of

Doctorate of Philosophy

Dissertation: ASSESSING LEAN WAREHOUSING: DEVELOPMENT AND VALIDATION OF A LEAN ASSESSMENT TOOL

Major Field: Industrial Engineering and Management

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- Oklahoma State University (Fall 2002 – Fall 2005)
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- Xerox Corporation Consultant (December 2005 – May 2006)
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- Menlo Logistics (May 2005 – August 2005)
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Major Field: Industrial Engineering and Management

Scope and Method of Study:

This research was undertaken to fill a gap in the academic literature and in practice by developing a comprehensive lean implementation assessment tool for warehousing operations implementing lean manufacturing principles and techniques. Furthermore, the results from the application of the lean implementation assessment tool are analyzed to better understand the practical implementation and underlying factors of lean warehousing. Consequently, the research outcomes are two-fold, both filling the gap in the development of a comprehensive warehousing lean implementation assessment tool and providing insight into the actual implementation of lean warehousing.

Findings and Conclusions:

The eight lean constructs that are measured in the lean implementation assessment tool developed in this research are visual management, standardized processes, continuous and leveled flow, pull systems, workplace organization, empowered employees, quality assurance, and continuous improvement. The lean constructs were operationally defined with respect to the associated lean practices to measure implementation and utilization on various evaluations points comprising the various warehousing processes in a facility. From the Factor Analysis, the seventeen significant factors observed in the data measuring lean warehousing related to continuous improvement and problem solving, building in quality, pull systems, standardized processes, customer integration, quality assurance, people, inventory management, material flow, information sharing, point of use storage, inventory strategy, employee development, workplace organization, employee retention, quality systems, and first in first out.

ADVISER'S APPROVAL: Dr. Camille DeYong