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A Structured Methodology For Tailoring And Deploying Lean Manufacturing Systems

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A STRUCTURED METHODOLOGY FOR TAILORING AND DEPLOYING LEAN MANUFACTURING SYSTEMS

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DEDICATION

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CHAPTER 1:

OVERVIEW

Humanity's concern with improving processes and their management has been reflected in the writings of many important theorists from Agricola to Adam Smith (Voss, 1995). Developing an efficient and profitable production operation requires complete focus on every aspect of the process. Whether manufacturing a single unit or multiple products with diverse options and complexities, the goal is still the same: to generate the highest profit with stable long-term growth and customer satisfaction while using the least number of direct or indirect inputs in the fastest time. In the early 19^{th} century, when skilled craftsmen were being replaced with unskilled mass production workers, the potential for error and product defects increased, but with demand high and supply low, customers tolerated the inferior products (Dennis, 2007). When mass production was first utilized during the 19^{th} century by the United States meat packing industry and British shipyards, it triggered a process that is still evolving today. Manufacturing a product containing a multitude of complexities makes manufacturing a single part difficult; when adding variety, production complexity and risks increase exponentially.

Manufacturing in the United States has helped not only to make products for consumers, but also to generate wealth for the people and the economy. The manufacturing environment has expanded outside the United States and created a global market and an exponential surge of entrants into the manufacturing sector (Achanga, Shehab, Roy, & Nelder, 2006). This increase in competition has forced western, high labor wage countries, such as the United States and the United Kingdom, to decrease the number of small manufacturing enterprises in an effort to use low cost countries for a strategic advantage. In *The Machine that Changed the World,* Womack explained how an organization improved operational performance by utilizing the principles of lean manufacturing to eliminate waste in the systems and add consumer value (Womack & Jones, 1994). Lean manufacturing is highly regarded as the premier manufacturing system for managing and guiding industrial enterprises. Its framework is vastly different from Taylor's *Principles of Scientific Management* (Nightingale & Mize, 2002; Panizzolo, 1998). Pioneered by Toyota, the lean production system's approach eliminates unnecessary steps, aligns all steps in an activity to have continuous flow, and recombines traditional labor into cross-functional teams. Dedicated to the system's approach and continually striving for improvement, companies can develop, produce, and distribute products with less human effort, space, tools, time, and overall expense (Davies, 2005; Liker, 1997; Shah & Ward, 2003). Lean manufacturing production reduces waste and significantly increases communication within the supply chain for improved integration (Scherrer-Rathje, Boyle, & Deflorin, 2009).

Given the turbulence created by the global manufacturing competition, lean manufacturing has become the most prominent survival strategy in the industry. Many companies have made a concerted effort to implement lean philosophies based on waste reduction through continuous improvement via structured problem solving (Scherrer-Rathje et al., 2009). The benefits of many continuous improvement tools can be identified throughout the array of manufacturing companies that have made strides to gain improvements, but the trouble lies within the sustainability of the improvement activities (Davies, 2005). A great deal of research is focused on lean production tools and how they improve operational performance.

Despite the clear links between using lean production tools and improved operational performance, many companies that try to implement lean practices fail (Balle, 2005). The sustainability issues are not always due to a lack understanding the practices, as they have been the focus of extensive research for decades but potentially due to not properly determining the required tools to manage performance (Pavnaskar, Gershenson & Jambekar, 2003). Failures can be attributed to improper deployment planning, in particular, the inability to tailor the lean program to the particular business or facility (Wilson, 2013). To increase the likelihood of success in deployment, this research will develop a structured methodological approach allowing organizations to effectively tailor and deploy the program for their lean transformation.

Research Objectives

The primary objective of this dissertation is to develop a structured methodology for tailoring and deploying lean manufacturing systems (LMS) to the specific business requirements. While lean is a system with many architectural tools to help refine a business to its highest competitive level, “One of the most vexing and enduring puzzles of lean is that many plants try to go lean, few succeed” (Balle, 2005). With lean being a structured process of identifying and eliminating waste through problem-solving methodologies, there are mix of critical characteristics that could be leading indicators of whether the deployment will be successful. The objective of the methodology contained within this research will be to determine an implementation strategy to provide a competitive business advantage while ensuring defined, planned, and deployed improvement activities are sustained. Many organizations achieve immediate benefits from these continuous improvement activities, but fail to fully realize and sustain the benefits of their hard-fought gains (Davies, 2005; Holweg, 2007; Wilson, 2013).

The dissertation will define a methodology, which should be utilized by businesses to create deployment plans for proper lean tool selection and to properly support the specified business requirements. The deployment plan will ensure that their performance systems will allow them to both maintain and improve their position in their respective markets based on operation performance requirements.

Lean tends to aim at an ideal state based on perfection (Liker, 2004). While aiming for perfection may be unrealistic, not aiming for perfection is aiming to have mistakes (Nightingale & Mize, 2002). The ultimate goal of deployment of LMS is to create infrastructure to manage and control operational performance, while also creating a pathway for structured and sustainable continuous improvement (Rahman, Laosirihongthong, & Sohal, 2010). The methodology developed in this research will provide a framework based on specified business impacts. This research will not focus on the assessing leanness relative to the typical lean assessment, which focus on the measuring the usage of lean tools. While lean assessments have played a key role in helping some implementation efforts, there is still a significant struggle to deploy the LMS and gain the sustained system performance (Jorgensen, Matthiesen, Neilsen, & Johansen, 2007). Given the significant support for increased business benefits by using lean production tools, it is necessary to better understand how to put together an effective deployment plan and how to appropriately tailor the systems so initial deployment attempts are successful (Scherrer-Rathje et al., 2009). The Lean Enterprise Self-Assessment Tool (LESAT) assists in understanding how and where assessments have been used and derives from the first study to mention the concept of tailoring the level of leanness (Nightingale & Mize, 2002).

This research will focus on four phases of the deployment process by (a) focusing on the infrastructure that relates to the business practices and values of lean, (b) developing an understanding of which business metrics require focus, (c) selecting the tools that best fit those metrics, and (d) tailoring a deployment plan. The research will be designed around the planning phases and understanding what resources are available and what is required to make the required deployments. The pre-deployment work is grounded in the concept of assessing key variables of managerial focus related to: (a) problem solving, (b) employee empowerment, (c) practices related to training and developing associates, and (d) quality management in relation to lean manufacturing (Boyer, 1996). This early assessment pinpoints these areas of importance related to a successful implementation. The progression of research on assessing LMS has redirected the body of lean research to a focus on the utilization of tools and if they correlate with improved performance (Miller, 2013; Narayanamurthy & Gurumurthy, 2016; Nightingale & Mize, 2002). The refocus on the predictive variables should help by linking the existence of consistent practices to LMS to guide a simplified planning and deployment methodology.

The next part of this dissertation will develop a process to determine the most appropriate performance-based operations metrics and the selection of proper lean tools to provide performance control mechanisms as well as establish the baseline system to deliver structured and sustainable improvement activities. While lean practice has historically focused too much on tools to drive improvement on many different performance fronts, a systematic process for the selection of the tools and the relationship to actual performance controls are important to a business and still lack clear definition (Bellisario & Pavlov, 2018). The proposed methodology will emphasize determining business objectives needed for success. This will blend business and financial objectives with some of the planned outputs from control as well as to guide future continuous improvement activities. Creating a plan of ideal state based on perfection is unrealistic in most cases, and might even harm the business in the process. As such, an objective and quantitative method is needed to set lean deployment objectives that are most appropriate for the business given its strengths, trends, and opportunities within its industry, as well as its goals (Bellsario & Pavlov, 2018).

Deployment tools must be tailored to fit the product, process, and people for successful implementation. In any development of these systems, many different resources must be utilized and many cases the process can be somewhat ad hoc. This in turn may overwhelm the system, creating a scenario where not enough attention is given to certain areas, progress is slowed, or motivation lost (Wilson, 2013). After determining the objectives and tools needed to accomplish the activities, the tools' interactions will be modeled to understand some level of effort to perform the required implementation. For modeling of the tool selection to support the deployment of the LMS, earlier work from product development literature will be expanded and applied to operations management for controlling the complexity of successful LMS deployment (Williams, 2013). Companies often implement LMS without understanding the magnitude of projects and the requirements of the tasks needed for the improvements. This research would fill the gaps in methodologies for the deployment of LMS relative to the implementation effort by accounting for complexity based on the assessment of precursory deployment variables, performance management system requirements, and the lean tools selected to control or improve aspects of performance. Along with effort/complexity, the methodology would also provide information regarding resource allocations to understand whether enough dedicated resources exist to accomplish the set deployment planning activities. This methodology is aimed at providing a quantitative measure based on the quantity of projects the business performance required. It provides reference for whether the organization is correctly positioned for a successful deployment. If the information is not favorable, it provides the ability to tailor projects or add resources to accomplish the goal.

CHAPTER 2:

PRE-ASSESSMENT FOR LEAN SYSTEMS DEPLOYMENT

In *The Machine that Changed the World,* Womack and Jones (1994) described the way organizations could improve operational performance by utilizing the principles of lean manufacturing to eliminate waste throughout business and add consumer value (Womack & Jones, 1994). Since this first introduction of a lean manufacturing system (LMS), many industries and business have attempted to leverage waste reduction and value-added philosophies to maintain or gain a competitive advantage (Balle, 2005; Davies, 2005; Doolen & Hacker, 2005; Kumar & Kumar, 2014; Narayanamurthy & Gurumurthy, 2016). Many of the philosophies of LMS differ from traditional practices due to the mentality and attitude built around the management philosophy of *genchi genbutsu*, which emphasizes the notion that a person must physically see a problem in order to understand it thoroughly (Balle, 2005; Davies, 2005; Davies & Kochhar, 2002). Unlike traditional practices, LMS encourages high levels of associate engagement in the entire organization and higher levels of visibility performance measurement across a business (Balle, 2005). This critical trait of LMS has a profound impact on the human element of manufacturing because it requires that this essential resource be properly fostered and developed (Panizzolo, 1998).

While LMS has been shown to be instrumental in the meteoric rise of multinational firms, such as Toyota, Western companies have predominantly failed in their attempts to sustain the implementation of such systems (Narayanamurthy & Gurumurthy, 2016). Many of the failures of LMS stem more from current practices within organizations than changes in systems and structures by implementing LMS (Wilson, 2013). An assumption persists that many companies will not be successful in their first attempt at LMS (Scherrer-Rathje et al., 2009). The paradigms that lean is a cost-reduction process or a toolbox of continuous improvement methodologies do not account for the cultural aspects of lean philosophies (Atkinson, 2010; Denning, 2011). Organizations are more likely to make a transition from current practices and methodologies when faced with less than desirable performance in their current state (Jørgensen Boer, & Gertsen, 2003). The philosophies of lean consistently promote a process that drives large-scale changes when applied within an organization, starting from a change in management thought processes, rational deployment of resources, education and training of staff, and allocation of funds, among others (Kumar & Kumar, 2014). Studies have also provided evidence that most organizational implementation and change efforts fail or do not meet expected targets due to the lack of ability to identify and address the issues associated with organizational change (McLean & Antony, 2014). In most cases, the proper culture that does exist to support lean is created accidentally, as a default of the values of the founders or owner, and not as a direct result of the desire to implement lean (Atkinson, 2010). In committing to lean-based manufacturing, the implementors must understand that the cross-functional nature of the system permeates all management functions and is not limited to floor-based operations (Puvanasvaran, Megat, Tang, Muhamad, & Hamouda, 2008).

Through surveys on Indian-based manufacturing companies, Kumar and Kumar (2014) identified some key barriers to LMS implementation as the absence of management focus, a drive to create a sense of urgency, support, a long-term vision, labor resources, capital funding, communication, idea innovation, understanding time requirements, proper training, understanding lean, and implementation knowledge. The dearth of all these facets contributed to relapse to previous practices. Other research has identified the failures that can be attributed to a lack of top management commitment and involvement, communication with shop floor workers, selection of projects, and training, among other issues (Albliwi, Abdul Halim Lim, & Van der Wiele, 2014). It has also been shown that there is a fundamental misunderstanding of what the Toyota Production System is in industrial practice due to a lack of interest in the functionality of the processes, underlying practices, and how these might counter current established practices (Liker & Rother, 2011).

As there are several reasons for this failure, this research hypothesizes that a pre-requisite for any successful deployment of LMS is the proper pre-implementation assessment of the readiness of a facility and its workforce. In addition, there is no universal approach to lean manufacturing, and the system must be tailored and deployed in stages to meet the particular needs and priorities of a firm. Most academic literature on LMS focuses on its tools, philosophies, and implementation. This chapter reviews the academic literature and uses the recent evolution in LMS research to develop pre-assessment tools to enable the successful implementation of LMS. This review will also examine the most prominent LMS assessment tools and how and what they measure in an organization. The key contribution of this chapter is the development of an effective blueprint for carrying out the pre-implementation assessment of the readiness of a facility to successfully manage the LMS deployment process.

Literature Review: LMS Assessment Tools

Most attempts to implement lean have not been sustainable (Balle, 2005). Upwards of 95% of all lean implementations are reported to fail or not meet planned performance expectations (Wilson, 2013). Thus, this literature review focuses on lean manufacturing implementation issues and the current state of lean assessment tools for the quantitative measurement of implementation progress. The literature highlights the notion that an assessment tool is believed to be an objective measurement to monitor the progress of lean implementation and assist with navigating and staying the course (Albliwi et al., 2014; Atkinson, 2010; Liker & Rother, 2011; McLean & Antony, 2014).

Lean assessment derives from the change model that Gunneson (1996) created. This model was the first quantitative measurement of critical activities to guide a transition initiative. The evolution of this process for quantitatively assessing leanness derives from a framework to measure the level of usage and the gap between a current state and ideal state of LMS implementation (Karlsson & Åhlström, 1996). Academia and industry have both gravitated to the expansion of Karlsson and Åhlström's (1996) initial models to focus on a multitude of elements, such as continuous improvement, lean tools and methodologies, employee morale, training, and customer satisfaction (Narayanamurthy & Gurumurthy, 2016). As of 2016, researchers had found that 87% of assessment methodology research focuses on the manufacturing sector, 41% is based on single case studies, and 85% is based on the usage of tools versus performance-based measurement key performance indicators (KPIs) (Narayanamurthy & Gurumurthy, 2016). The majority of assessment models utilize a 5-point Likert scale, which is the most common scale (Vivares, Sarache, & Hurtado, 2018).

The research of Karlsson and Åhlström (1996) was the foundation to guide researchers at MIT to develop a body of research and integrate their findings into a lean enterprise model (LEM; Nightingale & Mize, 2002). LEM was then expanded with the development of lean aerospace initiative (LAI) with the premise of using a more comprehensive quantitative measurement model known as the lean enterprise self-assessment tool (LESAT). LESAT is a tool for self-assessing the present state of leanness in an enterprise by leveraging the three key attributes of reducing waste and costs, creating customer value, and empowering the workforce (Nightingale & Mize, 2002). The LESAT was also used in conjunction with Mahalanobis distance measurement to prioritize lean efforts by quantifying largest opportunities relative to ideal state comparisons (Srinivasaraghavan & Allada, 2006).

The development of a more rapid version of measuring leanness was based on a brief 20-question survey, which Goodson (2002) applied to 11 categories to provide a quantitative measurement of the current state of a manufacturing plant or business. The lean assessment process was expanded and evaluated through a survey to measure both the type and extent of practices being implemented within electronics organizations as part of their overall manufacturing strategy. The organizations ranged from companies with less than 10 to more than 100 associates (Doolen & Hacker, 2005). In the electronics manufacturing sector, there is evidence that these types of organizations struggled to fit lean practices into their organizations during the assessment process (Doolen & Hacker, 2005).

There has also been research that correlated the systematic adoption of lean from the application of the training to concrete problematic situations related to inefficiency and ineffectiveness (De Zan & De Toni, 2015). The assessment methodology has also been demonstrated to show the interrelationship between lean contexts. A confirmatory factor analysis assessment methodology was applied to characterize the overlap of the various tools and techniques to show the quantitative connection and synergistic nature of lean manufacturing principles (Shah & Ward, 2007). Shah and Ward (2003) focused on developing an objective measurement framework for the principles' most relevant dimensions.

Table 1 displays the major assessment tools designed to evaluate the progress of lean practices and principles in an organization. As seen in the table, these tools heavily rely on the principles that Karlsson and Åhlström (1996) introduced more than 20 years ago. Quantitative lean assessment has continued to produce research that highlights the benefits of LMS (Miller, 2013; Narayanamurthy & Gurumurthy, 2016; Shah & Ward, 2007; Vivares et al., 2018). The evolution and application in practice of the assessment methodology has helped foster prestigious industry awards such as the Shingo Prize (Miller, 2013). While these tools have gained LMS exposure, owing to their ability to improve performance in operations and cost reduction, there is still a considerable struggle to implement and sustain the principles (Mann, 2015).

The assessment research of Boyer (1996) revealed the characteristics that influence the success of an LMS program based on leadership support at the managerial level. Boyer (1996) argued that the success of LMS rests in infrastructural investment in leadership in four areas: (a) group problem-solving, (b) quality leadership, (c) employee training, and (d) employee empowerment. The focus revolved around items that are less capital intensive but support financial improvement. These nonfinancial investments encompassed mentality, competency, and skills and contrast with the majority of LMS research, which has focused on the usage of tools and not the skills needed (Balle, 2005; Cua, McKone, & Schroeder, 2001; Davies, 2005; Dennis, 2007; Krafcik, 1988; Liker, 1997; Nightingale & Mize, 2002; Womack & Jones, 1994). The research Boyer conducted evaluated the constructs of lean rather than covering the applied tools and techniques and revealed a correlation to improved performance and waste reduction.

Gaps in the Assessment/Maturity Process

Several researchers identified a lack of clarity in the readiness of an organization to adapt its culture to the principles and philosophies of LMS (Albliwi et al., 2014; Atkinson, 2010; Liker & Rother, 2011; McLean & Antony, 2014). Understanding the current state (not relative to leanness) of an organization provides insight into how the modeling proposed in this research might offer practitioners with a better methodology and toolset to plan the tailoring and deployment of more sustainable lean programs. The cultural dimensions in the proposed model play against eight of most prominent lean concepts: leadership, empowerment, strengthening customer and supplier relations, training, departmental relations, and teamwork (Kumar & Kumar, 2014).

Table 1

Major LMS Assessment Tools Developed by Key Researchers in the Field

Author	Year	Area of Use	Industry	Measurement
Boyer	1996	Research	Manufacturing	Quality leadership, group problem-solving, training, worker empowerment
Karlsson & Åhlström	1996	Research		Elimination of waste, continuous improvement, zero defects, JIT, pull, multifunctional team, decentralization of responsibilities, integrated functions, vertical information systems
Goodson	2002	Industry	Manufacturing	Rapid plant assessment
Nightingale & Mize	2002	Industry	Aerospace	LESAT lean transformational & leadership, lifecycle processes & enabling infrastructure
Doolen & Hacker	2005	Research	Electronics	Manufacturing equipment & processes, shop floor management, new product development, supplier management, customer relationships & workforce management
Allada & Srinivasaraghavan	2006	Research	Manufacturing	Uses LESAT with the application of Mahalanobis distance
Shah & Ward	2007	Research	Manufacturing	Supplier related- supplier feedback, JIT delivery & developing suppliers Customer-related- Involved customers Internally related- Pull, flow, low set-up, controlled processes, productive maintenance & involved employees
Ihezie & Hargrove	2009	Industry	Manufacturing	SLAT-Inventory, team approach, processes, maintenance, lay/material handling, suppliers, set-up, quality, scheduling & process control
Åhlström & Malmbrandt	2013	Research	Service Industry	Enablers- employee training, management commitment & employee understanding Lean practices- customer value, identify waste, flow, standardize work, workload balancing, pull, quality, visualization, multifunctional employees & continuous improvement performance
Leonard & Pakdil	2014	Research	Manufacturing	Time effectiveness, quality, process, cost human resources, delivery, customer, inventory
Maasouman & Demirli	2015	Industry	Manufacturing	Leanness- people, facilities, working conditions, production processes, quality, JIT & leadership
De Zan & De Toni	2015	Research	Manufacturing/HR	Supporting functions, just-in-time, value analysis & mapping, performance competitive advantage
Shepard	2015	Research	Education	Reformed vision of curriculum, cognitive & constructivist learning theories & classroom assessment

The LMS assessment methodology has some key benefits and has drastically improved sustainability in the implementation process. However, there is a paucity of studies that evaluate the current functionality of LMS organizations in relation to their functionality prior to LMS implementation. The body of work Kenneth Boyer conducted lends itself to developing a more structured methodology for analyzing the characteristics of a company in its current state, prior to implementation. Thus, Boyer's work offers an opportunity to assess organizational readiness to adopt LMS practices and principles by applying his findings to assessments before an organization or company implements lean.

As Boyer was publishing his assessment-based research, Karlsson and Åhlström (1996) discussed the tools and techniques that influence and support lean philosophies. While prior literature focused on creating a measurement system to gauge the amount of change, Karlsson and Åhlström's (1996) study focused on measuring the progress of lean tools rather than on understanding the skills, behaviors, and competencies required to support the systems. Karlsson and Åhlström theorized that by applying certain tools to LMS, progress could be made towards an improved lean state. They argued that the tools and techniques most critical for LMS success are the elimination of waste, continuous improvement, zero defects, just-in-time, pull instead of push, multi-functional teams, decentralized responsibilities, integrated functions, and vertical information systems. They believed that by understanding and using these tools and techniques, a common method for measuring the change process of becoming lean could be developed (Karlsson & Åhlström 1996). Their method was not aimed at understanding key skill characteristics but at measuring the progress of change. This methodology runs in contrast to Boyer's (1996) method, which focused on assessing skills that promised to improve the LMS transition and is the foundation for the pre-assessment methodology in this research.

This rest of the literature review on LMS covers the most relevant articles in the areas of (a) problem solving, (b) employee empowerment, (c) employee development and training, and (d) quality systems management.

Problem solving. Solving problems is the most fundamental element of the LMS continuous improvement principle. LMS principles are primarily based on holistically tracking performance, leveraging data to identify opportunities, and then applying standard tools that address specific issues (Pavnaskar et al., 2003). The fundamentals of lean are based on the ability to continuously improve through problem-solving (Forrester, 1995). Often, problem-solving in LMS requires a significant degree of performance measurement to systematically construct solutions to issues. The problems identified with LMS require that employees have some level of autonomy in their ability to address those problems (Sobek & Smalley, 2008).

The renowned pioneer W. Edwards Deming developed a prominent problem-solving method in LMS known as plan, do, check, and act (PDCA) and applied it across LMS as a fundamental practice (Dennis, 2007; Drucker, 1990; Krafcik, 1988; Liker, 1997; Womack & Jones, 1994). More than a tool, PDCA is a critical process contained in every LMS tool. When comparing the industry or application-based literature to the key components of a successful lean framework, it follows that organizations need to have the ability to problem-solve for the successful implementation of LMS to occur. It has also been identified that sustaining any type of continuous improvement-based culture requires a commitment to training and development (Puvanasvaran et al., 2008). When problem-solving becomes structured within an organization, it creates a common technical language that expands learning competencies (Itabashi-Campbell, 2013; Puvanasvaran et al., 2008).

The A3 methodology, which was founded on lean evolution, couples several different elements. By utilizing the key principles relative of the PDCA process involving problem-solving, the methodology incorporates a standardized format, the (A3) paper size, standardized processes, visual management principles, and cross-functional collaboration (Sobek & Smalley). At the foundation of lean is structured continuous improvement, which is grounded in problem solving or problem resolution. The problem-solving process also incorporates key elements of information and performance sharing that is designed to be comprehensively beneficial and align expectations across lower working-level associates all the way to top leadership. The key here is why there is a need to improve or maintain control over the different areas of manufacturing performance (Scherrer-Rathj et al., 2009). Having existing processes and practices in place that are more cross-functional inadvertently reflects shared performance and working cross functionally does not necessarily derive from lean planning or the thought of making the transformation to an LMS-based company. As identified earlier, some cultures have not necessarily developed prior to a lean implementation, but others have the existing cultural process of getting employees involved as early as possible when leaders have decided to begin the lean journey (Scherrer-Rathje et al., 2009).

Research has revealed that, across multiple business sectors, the ability to relate information flow to performance increases transparency and is a key construct of problem-solving near the sources of control (Brady, Tzortzopoulos, Rooke, Formoso, & Tezel, 2018). The importance of clearly defining performance requirements and the ability to comprehend the need for directional change, which includes the ability to maintain consistent focus relative to the progress of the defined objectives (Ruiz-Benítez, López, & Real, 2018). Relative to problem-solving, the expectation to display performance to create awareness in a cross-functional manner helps to foster the identification of deficiencies in performance (Varisco, Johnnson, Mejvik, Schiraldi, & Zhu, 2018). The ability to share performance allows large portions (if not everyone) to understand the relationship between their output and expectations. Lean typically fails when the transformation is rushed, used superficially, and is not directed by a structured process of supporting performance relative to expected performance (Fadnavis, 2015).

Understanding how problem-solving techniques are applied in a workplace culture could validate the readiness of company to embark on the journey of lean. Therefore, understanding cultural and interpersonal aspects of group problem-solving is critical, given that communication and collaboration are dominant processes in LMS and group problem-solving. Problems may be identified in a top-down or bottom-up manner with potential solutions. If limits of escalation are developed, leaders work together to find the root causes of problems by using deep statistical or logical analyses (Scherrer-Rathje et al., 2009; Wojtaszak & Bialy, 2015).

Employee empowerment. Case studies have shown that worker empowerment is founded on enhanced autonomy through a distribution of responsibility for improved control of manufacturing processes (Pavnaskar et al., 2003). As stated earlier, another key element of LMS is gaining the maximum utilization of human resources (Leveridge, 2016). Just because a company has not embarked on the lean transformation that does not mean that cultural habits for integrating employees at lower working levels with more autonomy and decision-making ability have not been established. Lean manufacturers have emphasized the benefits of workplace structure and organization for employees by way of autonomy, enhanced skills, and empowerment, each of which contributes to the continuous improvement of work processes (Perez Toralla, Falzon, & Morais, 2012). The ability to provide structure and definition related to decision-making elevates the process of empowerment to be more cross-functional (Hasle, 2013).

Managers functionalize employee involvement in lean manufacturing by committing to the following four principles: empowerment, training, effort-reward, and communication (Marin-Garcia & Bonavia, 2015). Employee empowerment that creates improved communication in direct reports and behavioral patterns that mitigate supervisors' risks is an effective tactic through which to build trust in decision making among working-level associates (Atkins, 2016). When the workforce has been empowered to identify issues and work toward a resolution, upward communication is improved (Khim Ling, Curatola, Rogers, & Banerjee, 2016). Leadership can enhance this process by recognizing employee contributions with positive support and value-added behaviors rather than just expecting these outputs (W. Johnson, 2016). It has been shown that employee empowerment is enhanced when collaboration and alignment of performance objectives are fostered (Scherrer-Rathje et al., 2009). Gaps in communication has been one of the most detrimental issues to lean system implementation (Jørgensen et al., 2003).

How employees are providing feedback influences their direct involvement in an organization's decision-making processes and managerial tactics (Cirjaliu & Draghici, 2016). These types of feedback include "visual control, goal deployment, short daily meetings, two-way communication flow, and a system of continuous improvement" (Poksinska, Swartling, & Drotz, 2013, p. 886). To empower employees effectively, Poksinska et al. (2013) cited transformational leadership behaviors as the most effective in inspiring and monitoring employees. However, there is a need to implement the proper management control systems so that such behaviors are not solely required due to the strong supporting management structures (C. Johnson, 2016). Lean manufacturers have emphasized the benefits of work organizations for employees. These include autonomy, enhanced skills, and empowerment, each of which contributes to the continuous improvement of work processes (Perez Toralla et al., 2012). Accordingly, managers have developed supporting structures to empower employees and endow them with more responsibility and autonomy in daily management processes (Bamber, Stanton, Bartram, & Ballardie, 2014). Studies have shown that that empowering employees within a lean framework requires minimal additional planning since it is based on establishing trust (Jones, Latham, & Betta, 2013).

Employee development & training. A popular quote by Henry Ford regarding training is that “the only thing worse than training a person and having them leave is not training them and having them stay” (Ford, 2018). Training of associates has been shown as necessary in order to develop an increased sense of collectivism amongst the workforce, which is then more empowered and capable of shouldering increased responsibility (Bortolotti, Boscari, & Danese, 2015). Especially in manufacturing, there is a focus on maintaining physical equipment and assets but the human resource is not prized as highly (Dombrowski & Mielke, 2014). Through the understanding of business requirements, supervisors have the ability to build and increase skills and competencies since people are one of the few appreciating assets in an organization (Sterling & Boxall, 2013).

Self-regulated learning (SRL) has been identified as producing significant autonomy among well-trained employees who benefit from consistent opportunities to continuously learn and were able to display improved productivity and more effective problem-solving (Harms, 2015). Further, tactics to optimize each type of problem-solving, such as SRL and team learning, should be employed to synthesize optimal, situation-specific solutions (Harms, 2015). Progression of skill and competency development in lean process management has shown to be a fundamental element of optimizing the business more holistically but also understanding that the systems need tailoring considerations to best fit each business (Fullerton, Kennedy, & Widener, 2014).

However, the content on problem-solving and employee empowerment are not typically self-developed and required some level of structured development (Shah & Ward, 2007). Given that LMS philosophy is driven by learning and problem-solving, an approach of planned, structured skill progression may be ideal for training employees in LMS (Fadnavis, 2015). On-site training programs can reinforce the lean, six-sigma principles of group problem-solving success. When compared to unsuccessful lean organizations, organizations that successfully implement LMS tend to exhibit higher institutional collectivism by creating processes to articulate the requirements of the business along with the value and importance of the associates across the business and down to a lower level of associates (Bortolotti, Romano, & Nicoletti, 2009).

The 4P model for lean implementation is comprised of planning for the long-term, processes (waste elimination), people and partnership (empowering employees and pleasing stakeholders), and problem solving (Dombrowski & Mielke, 2014). While the researchers on 4Ps utilize a comprehensive system to sustainably implement and continuously improve lean production systems, there still needs to be a more concerted focus on the processes rather than the professional education and training portions of the problem-solving sector (Dombrowski, & Mielke, 2014). The benefit of conceptual learning involves a structured approach to comprehension and provides a higher level of system sustainability (Chee Ming, Kathawala, & & Sawalha, 2015).

In lean, there is a consistent focus on continuous improvement, which drives high-performance organizations in general. In addition, a unique characteristic of successful lean manufacturers is the ability to establish a low level of personnel assertiveness (Bortolotti et al., 2015). In a study on transformational and transactional leadership, Deichmann and Stam (2015) found a correlation between developing employees' commitment, with an emphasis on organizational ideation geared towards synthesizing creative ideas, which allowed the employees to directly contribute to the competitiveness of the organization. Dombrowski and Mielke (2014) also showed how self-development among employees, *gemba*, and *hoshin kanri* assisted in successfully implementing LMS. To reach the full potential of LMS—and to improve quality, flexibility, and customer response time—there must be a commitment to a holistic business strategy, rather than a discrete methodology specific to operations (Fullerton et al., 2014). To achieve greater outcomes, managerial investment in meticulous and supportive training must occur over a sufficient period. Sterling and Boxall (2013) labeled this approach as an "ability-motivation-opportunity" framework that can be used to enact relevant theories in the real-world and emphasize a systemic methodology for learning and training. Conceptual learning involves a structured approach to comprehension, while practitioners of ISO 9000 follow operational learning, which focuses on unstructured influences from peers and management (Chee Ming et al., 2015).

Quality systems management. In lean manufacturing, the system performance is ultimately aimed at customer satisfaction. In most manufacturing environments, the manufacturers must become ISO/TF16949 certified. The audit process to become certified and maintain this certification is, in many instances, similar to LMS philosophies, but there is a much higher level of success in implementing these quality systems. Organizations oriented toward perpetual improvement auditing, in contrast to mere compliance with a standard, are more particular about being certified by reputable auditing firms. This is due to their ability to construct insightful audits, thereby improving an organization's satisfaction with the certification (Castka, Prajogo, Sohal, & & Yeung, 2015). Creating and managing documents for process failure mode, and effect analysis (PFMEA), control plans, initial process studies, and measurement system analysis (MSA) require a massive commitment on the part of managers and other regulatory employees (Lundgren, Hedlind, & Kjellberg, 2015). To bring a product from design through to manufacturing, systematic process planning is a necessary managerial function. In undertaking such planning, every process and operation must be optimized to derive the highest product quality from the overall process chain (Lundgren et al., 2015). Lundgren et al. (2015) called for a more comprehensive approach to ensure quality as a result of an integrated production process in the manufacturing industry. There is also a strong correlation between the implementation of advanced levels of ISO 9000 implementation and how product and process flow (Huo, Han, & Prajogo, 2014). Lo et al. (2013) were interested in how contextual factors modulated the efficacy of ISO 9000. These contextual factors were studied at the level of the entire firm—including technologic intensity, labor productivity, and labor intensity—and at the industry level—including efficiency level, competitiveness, sales growth, and ISO 9000 adoption level.

In advanced systems implementation, there is a much higher level of governance and understanding about how to leverage the system for optimization in support of the idea of measuring the readiness of a company prior to implementation since the basic implementation of ISO nets no significant improvement where companies with advanced levels of ISO implementation had observed improvements in both product and process flows (Huo et al., 2014). This is key in understanding that if a company can demonstrate the structure and standardization to implement and maintain a quality system, there is a great likelihood that implementing lean will be successful.

Just as understanding the need for implementing LMS is important, it is equally important to weigh the relative benefits from certification against the goals and costs (Castka et al., 2015). The selection of a third-party auditor fosters a strong drive to improve and achieve greater reputation. Leveraging the more rigorous auditing processes typically offsets the cost of improved performance. The ability to create common objectives and interlink both the quality focus and lean systems helps to create standardization as well as develop better knowledge flow from a tactical to an explicit knowledge base (Ringena, Aschehouga, Holtskogb, & Ingvaldsen, 2014). Ringena et al.'s (2014) study also revealed that in many organizations lean manufacturing and quality assessment are frequently disparate departments and ethos; although they have overlapping goals, they do not integrate communication nor have organizational alignment. Firms with low levels of technologic intensity and labor productivity as well as high labor intensity benefitted more from ISO 9000 adoption (Lo, Wiengarten, Humphreys, Yeung, & Cheng, 2013). Conversely, firms in low-efficiency industries with high competition and sales growth as well as low levels of ISO 9000 adoption also benefitted more from ISO 9000 adoption (Lo, Wiengarten, Humphreys, Yeung, & Cheng, 2013).

Pre-Assessment Methodology

This research looks at current behaviors as a precursor to understanding their direct relation to the four identified areas pertinent to the implementation of LMS. The culture of a business, as well as the environment in which it operates, can contribute to the failure of an initiative (McLean & Antony, 2014). Overall, the literature review guided the development of the pre-assessment methodology outlined in Table 2. The lean readiness assessment derives from the premise that creating a measurement to expose underlying factors would support LMS practices or identify gaps that would make implementation more difficult. The purpose of this assessment is not to measure implementation or the adoption level but to objectively assess the readiness of the firm to implement LMS. The intent in developing the assessment was to also ensure that a simple process that could be easily utilized in industry and by practitioners.

Table 2

Lean Readiness Assessment

Variable Description	Measure	Rating Criteria (1 = most aligned; 5 = largest gap in behaviors)	Score
Problem Solving (P_s)	Methodology Continuity (M_c)	1 = Common problem-solving (PS) methodologies used in training to continue development. 2 = PS used in standard meetings to drive practice. 3 = PS used, but little standardization. 4 = Minimal examples of structured PS. 5 = No examples of structured PS.	$P_s = \frac{(M_c + I_s + C_i)}{3}$
	Information Collection & Sharing (I_s)	1 = Vivid examples of visual management tools and multiple displays of key performance metrics. 2 = Good examples of visual management tools and key performance metrics used throughout business. Examples of using information to correct issues. 3 = Moderate examples of collecting and sharing performance information. 4 = Limited examples of sharing and communication of performance information. 5 = No examples of collecting or sharing performance information.	
	Continuous Improvement (C_i)	1 = Rich examples of PS in all facets of business; planned reviews to create a systematic approach and make steady improvement in a proactive manner. 2 = Good examples of PS and used within different functional groups. 3 = Moderate examples of PS; initiating a system for PS as a directive. 4 = Very few examples of a formal method of PS; more individual based. 5 = Problem solving not used as an improvement tool.	
Employee Empowerment (E)	Work Groups (W_g)	1 = Implementation of work teams very evident; support for the team's ideas are brought up by the team. Leadership works as support for the teams. 2 = Organization of work team is a strategy of the company; plans and signs of implementation are evident.	$E = \frac{(W_g + E_f)}{2}$

		3 = Moderate examples of organized team/group work. 4 = Minimal examples of people working together, either management or labor. 5 = No indication of people working in collaborative efforts.	
	Feedback to Employees (E_f)	1 = Recognition is given to employees for exemplary performance; information openly shared and vision and mission of business can be seen throughout business; actions are taken by leadership to address issues identified through continuous improvement activities. 2 = Performance metrics are consistently shared throughout the business/facility. 3 = Performance data is shared, but there is minimal understanding of how to use information. 4 = Minimal examples of performance displayed, and employees are not familiar with performance data. 5 = No examples of information sharing; no performance evaluations used on the floor.	
Associate Development (A_d)	Planned Training (P_t)	1 = Extensive training program based on skill development needs not tied to hours, but development equipment. Focus on skills and competence not specifically measuring success off-hour of training. Also, follow to make sure required skills are being practiced and adding value to the company. 2 = Good structured training based on developing skill and measurements of training hours. 3 = Moderate training activity; some specific training metrics relative to certain skills beyond basic job functions. 4 = Minimal employee training. 5 = No employee training.	$A_d = P_t$
Quality Management (Q_m)	Auditing (A)	1 = Very structured internal and external auditing system; heavy focus on continuous improvement. 2 = Good auditing practices internally and externally; limited focus on continuous improvement. 3 = Auditing both internally and externally but mainly for compliance. 4 = Very limited auditing. 5 = No auditing of process compliance.	$Q_m = \frac{(A + D_c)}{2}$
	Documentation Control (D_c)	1 = Extensive documentation control; systems-based integration. 2 = Good documentation control that is moderately integrated. 3 = Moderate documentation control; done specifically to meet requirements. 4 = Minimal documentation control; no requirements. 5 = No documentation control.	

Constructing an assessment with the variables and eight measures serves as the foundation to measure organizational readiness/alignment for LMS deployment. The four variables are (a) problem solving, (b) employee empowerment, (c) employee training and development, and (d) quality management. The eight measures are (a) methodology continuity, (b) information collection and sharing, (c) continuous improvement, (d) workgroups, (e) feedback to employees, (f) planned training, (g) auditing, and (h) documentation control.

For ease of application, the structure of the assessment shares some commonalities with systems engineering to create a simplified pathway for LMS adoption. The five-point Likert scale was used because of its popularity, ease of use, and ability to lend itself to a variety of statistical analyses. For the quantification of the areas being analyzed, the scale was reversed, where 1 = the highest level of conformance to the criteria and 5 = no level of conformance matching the criteria. The scale reversal derives from the need to have a quantitative measure that will increase in magnitude based on the understanding that there will be an increased level of required work to meet the expected outcome(s). The lean readiness multiplier (LRM) is aimed at providing a factor similar to a measure of “work” or “effort” and can be adapted as necessary. When the scores of the LRA are higher, the assessment will indicate that more required work content or effort will be required for LMS deployment.

The process for using the assessment begins with determining a strategy for assessing a company. This process occurs by first identifying or analyzing departments and areas to receive the assessment. Because lean is such a holistic system, it typically encompasses all aspects of a company from finance and human resources to operations, purchasing, logistics, etc. These areas need to be part of the review for researchers to gain an understanding of commonalities among practices.

The rating criteria were validated through examples by determining whether there are or are not sufficiently rich examples to validate the score within the area of assessment. It is expected that there will not be any preparation required prior to performing the audit. It is best to capture as close to normal business conditions as possible and not to allow the team to build data and falsely enhance the scoring.

As for rating any given variable or measure, one should objectively examine the current state. This could entail careful observations, discussions, interviews, reviews of relevant records, and documentation. The assessment should also capture or document sufficiently rich examples to validate the score within the area of assessment. It is expected that there will not be any preparation required prior to performing the audit other than an understanding of the core functional processes. It is best to capture as close to normal business conditions as possible and not to allow the team to build data to falsely enhance the scoring.

The methodology is aimed to be simple and should be looked at as information and evidence gathering for the express purpose of creating a successful implementation plan. The first consideration is determining the type of person(s) to conduct the assessment. It is beneficial if the assessor(s) has experience in or been actively involved in quality based internal or external 3rd party audits. This is aimed to ensure that the assessor(s) has some understanding for how these areas are managed internally and how the practices are performed on the floor.

It is also beneficial to obtain knowledge in regard to these practices at both the management level from oversight and participation and then how they are used in the floor-based activities. It should be a blend of interviewing, walking the floor operations with management members that are responsible, go and see who, what, where, when and why things are happening, and review of documentation and performance reports. The same type of activity needs to occur with operators/associates to understand if the activities are actually occurring as they are believed/supposed to occur. Adherence to procedures is important with the lean practices since the standardization is founded on the adherence to planned procedures and protocols in effort to meet the performance expectations. It is also key to understand if the newly develop procedures are overly complicated and are difficult to be adhered to, which can create situations where people are forced to deviate or improvise due to procedures not being properly designed.

The assessment needs to be based in the areas in which the concept of a lean deployment is being focused or aimed at. If this is a companywide directive, it would then be necessary to evaluate all the different facilities of global locations. As discussed later in the Chapter 4, size of the facility influences the implementation. These considerations are discussed later but also apply to the pre-deployment assessment and can guide this process and break the deployment plan into successive efforts that the organization can manage.

The assessment process should be based in interviewing people close to understanding of the processes, procedures and protocols to help provide information to guide a successful deployment. As part of the assessment the assessor is to question procedure and protocols but also to understand the pertinent performance information relative to the business.

The key item to remember about this methodology is that it is about procuring relevant information regarding areas that can contribute to developing a successful deployment strategy.

Validation Case Studies

To validate the proposed methodology, this assessment was used on two different businesses. Using the methodology is different from a product development process in that the requirements are self-imposed based on what is determined to be an optimal positioning for competitiveness and viability of the business relative to lean systems. The assessment is aimed at manufacturing-based businesses, but it can still provide insight about any type of manufacturing-based business sector. The methodology was applied to vastly different manufacturing-based businesses in these case studies. However, both businesses have a need to implement lean to become more competitive and be as efficient and effective as possible.

Case 1: Home Décor Manufacturing Business. The first test of the assessment was used on a 60-year-old home décor manufacturing business located in a rural area with a very consistent workforce (see Table 3). It produced home décor products in high volumes (24,000–35,000 pcs/day). The facility is more than 60 years into production and has stayed consistent with its procedures and practices since its founding. The workforce of the business had been constantly stable since starting and typically has personnel working for their entire careers in the business.

Table 3

Lean Readiness Assessment: Home Décor Company

Variable Description	Measure	Variable	Score	Variable Description Aggregate	Lean Readiness Multiplier
Problem Solving (P_s)	Methodology continuity	M_c	4	4.3	
	Information collection & sharing	I_s	5		
	Continuous improvement	C_i	4		
Employee Empowerment (E)	Work Groups	W_g	5	5	**4.5**
	Feedback to employees	E_f	5		
Associate Development (A_d)	Planned training	P_t	4	4	
Quality Management (Q_m)	Auditing	A	5	4.5	
	Documentation control	D_c	4		

Case 2: Automotive Engineering Company. The second was a 60-year-old automotive engineering company that was in the process of transitioning from being primarily an

engineering company, to a tier 1 supplier as a large original equipment manufacturer (OEM; see Table 4). The company is a green field start-up automotive tier 1 business unit in the United States. This company is the start-up division of a highly technical engineering company with modest experience as a tier 1 supplier but never as a U.S. tier 1. The base of its manufacturing experience is in customized powertrain development and engineering. While this is an automotive-based company, the volumes of the production were lower and focused more on premium and niche vehicles in the range of 7,000–35,000 components per year. The workforce is all new to the organization and built directly to support the efforts of starting and growing the business in the North American market.

Table 4

Lean Readiness Assessment: Automotive Engineering Company

Variable Description	Measure	Variable	Score	Variable Description Aggregate	Lean Readiness Multiplier
Problem Solving (P_s)	Methodology continuity	M_c	2	2.33	
	Information collection & sharing	I_s	3		
	Continuous improvement	C_i	2		
Employee Empowerment (E)	Work Groups	W_g	3	3	**2.8**
	Feedback to employees	E_f	3		
Associate Development (A_d)	Planned training	P_t	2.5	2.5	
Quality Management (Q_m)	Auditing	A	4	3.5	
	Documentation control	D_c	3		

Approach: Interviews

Interviewing was the methodology used in the LRT. The interviewing process was chosen since it is the most common method used in assessment tools such as LESAT and the

Shingo Award for Operational Excellence. The questions in this method were very pointed and could come directly from the assessment. As with the Shingo Prize, the interviewer expects the interviewee to be able to provide examples about the areas under consideration. The burden of proof falls on the interviewee to provide the needed examples to justify the scoring in the process. If companies are using the different facets of the LRA, providing explicit examples should be relatively easy. This is based on going to the source and seeing evidence that supports verbal discussions. The purpose of the LRA is to get the most accurate status of the defined areas (quality, manufacturing/operations, maintenance, materials, purchasing, and engineering) so as to provide a quantitative measurement of readiness prior to implementing lean. The assessments were performed over a single day by selecting departments and verifying the type of infrastructures, tools, and practices. The assessment was also based on ensuring that all areas were engaged in activities that could support and produce a more efficient and effective company.

Case 1: Home Décor Manufacturing Business. The maturity level of the company was heavily influenced in the areas of problem solving and empowerment of the team members. The people had some autonomy in decision making, but there was not a clearly defined way of communicating and elevating issues. Most of the problem solving occurred in a reactive state when issues arose that were limiting the ability to operate manufacturing.

The focus of the study was to determine the quantity of the issues and continue to keep things in process. Numerous opportunities existed to apply structured problem solving in an effort to make improvements and to prevent reoccurrence. There was not any evidence of tracking and/or required actions that would lead to a permanent resolution to the specified issues. Some other noteworthy items in utilizing the assessment that supported the high score (low performance) rating were based on the evidence that the process lacked stability and quality, but the data from the performance and the standard for required performance were not readily available for people to see. The only data that were readily available were monthly performance metrics relative to the effect of the cost of goods sold (COGS). The desired outcomes from a performance requirement were understood, but the data for people to leverage planned action were not accessible. From a financial standpoint, the process grew organically instead of being driven from live data to compare to the actual performance data of hourly or even daily performance. There was significant evidence that people had different understandings of how the manufacturing process was controlled. Operators and supervisory personnel would make changes to the process based on their experiences because of the belief that “their way was better.” This occurrence created conflict amongst the different shifts and groups operating key manufacturing processes.

As a common thread among the data, some infrastructure relative to training was heavily based on the current person as well as structured, built, and maintained documentation. The training occurred solely on the job. There was basic documentation on HR policies and environmental protocols but not on quality or operator positions. There was also no list of key competencies to place personnel into positions. There were numerous examples of new personnel getting placed in complicated or difficult jobs, yet lessons were not leveraged or learned to evolve documentation or prevent repetitive issues. The company lacked the infrastructure to maintain documentation and link influences among functional groups to align and create flow diagrams of influence and ownership. Many times, responsibilities and ownership were unclear when issues occurred and in preparation to address known issues for reoccurrence. The process was strictly personnel-driven in nature.

At first observation, the general housekeeping and organization of general usage items did not have any documented infrastructure or methodologies. Even in the visual appearance of the supermarket areas, there is not a common part identification method. This study's visual management type identification helped to distinguish between nonconforming and conforming parts. From a quality control perspective, there was evidence that parts damaged in the process and known to be nonconforming were passed through the entire process and were not separated prior to shipments with acceptable products. These basic observations could be made at a glance on a walk-through of the facility. Upon investigation, there was no standardized process for how to handle this type of scenario with a containment or method to protect the customer. It appeared as if it was common to let the customer sort the defects and then issue them a back charge. The process both in manufacturing and business infrastructure was heavily based on personality-driven practices, which led to significant variation in how people discovered the optimal way to perform. There were also no requirements for auditing, and without a process of documentation, auditing could not occur.

As seen in Table 3 and in the documentation listed, there is significant evidence of a gap for the company in the required performance that correlates to LMS. The activity of assessing a process or a business that has known deficiencies is a litmus to determine whether there are concerns before embarking on an LMS.

Case 2: Automotive Engineering Company. The second test of the LRT occurred in a Greenfield engineering and automotive company. While these are different areas, there were numerous opportunities to understand if present business practices could support the fundamentals of lean implementation.

The area of problem solving provided many examples to support the referenced score in Table 4. There were numerous examples that highlighted a common methodology as well as documentation for permanent corrective action. There were also strong examples of documented issues and improvement opportunities in which the organization covered different quality perspectives, operational performance improvement, and process control improvements. There were examples of quality performance and daily operational performance readily available for all employees, such as protecting the customer, applying forms of containment on products ready to ship, error proofing the process, updating all documentation to prevent issues, and utilizing an ERP system to prevent neglect of the issues identified in the process. The ERP system was also integrated to escalate and remind owners of corrective action of timing requirements for resolution. If actions were not taken, the system automatically escalated the issue to high management levels.

Employee experience in the company ranged from 1–2 years, but all the personnel hired for operating the equipment had 5–15 years of manufacturing-based experience. Managers were heavy engaged in working with associates to establish practices and procedures for standardized work instructions. The work instructions were stored in an ERP system and required operators to have training from an internally certified trainer for the process. To develop cross-functionality, all personnel were trained to operate the equipment. The work groups were self-directed, but there was a sense that collaboration with the management team indirectly helped to develop some of the practices. The ERP system, which was purchased, allowed for quick feedback from the operators, as well. It was still in the early phases of development, but there were options for employees to capture items in an effort to create proactive planning of work or items to drive improvement. In numerous discussions, there was a common theme of trying to provide feedback both up and down the organization structure. Yet because both elements were in the early phases, the company received a mid-grade score. Associate development and training were key elements in starting the business. Even in the early aspects of the business proposal, when determining the location for developing the business, there were large training expenses and a focus on finding training grants to foster developmental planning for associates. Even within the training plans of associates, there are items identified that highlighted the belief in problem-solving training across the business as well as quality management training to teach associates how to use and understand key quality elements such as PFMEA and control plans of the APQP process.

Relative to assessing the quality management aspect, there was a heavy focus on an integrated system to control documentation in preparation for being IATF certified. There was not much auditing in place, such as formal audits, that would be used to sample conformance to quality procedure and protocols. The was a structured plan to have both internal auditors in effort to ensure strict adherence to policies and procedures. To this point in the operations, they were not required to be IATF compliant and were working through structured plans to meet this objective in the next 8 months. The company already had staff on hand who were certified as internal quality auditors. The reason the company scored lower is due to the facts that the work being done was designed to meet the requirements, but examples of structured documented audits were not given. In relation to documentation control, the ERP system had features that interlock many of the critical documents that required strict control for auditing purposes. The focus at this point, was for the company to finalize the system for controlling documentation. Since the system was not fully functional, the score fell in the mid-range until data could be provided to show the full integration and leveraging of these quality systems to drive improvement and not only remain compliant.

Conclusions

The objective of this research was to develop a framework for LRA to quantitatively measure key variables that are precursory constructs in order to provide insight prior to beginning lean implementation. This tool could be used in a multitude of applications and was illustrated in this work to demonstrate that point. This research primarily focused on manufacturing-based companies and organizations. In this research, the assessment was examined holistically from a single facility operation as well as at all the departments for consistency for conformance to the criteria. When reviewing examples during an assessment, consistency of practices and distribution of common within a business is a focus in determining a rating.

As for validation case studies, while the two businesses had different product portfolios and technologies used to operate and support each business, the LRA provided beneficial insight prior to starting a lean implementation. It very evident that with a high score, as calculated in the first assessment of the home décor company, the company has some practices that might conflict with the required discipline that is needed to function in the system and with the principles of LMS. There was already a strong indication that undertaking an aggressive LMS implementation plan might be a risky effort that would lead to less than anticipated results. When the LRA received a 2.8 overall score, in the case of the automotive company, the score does not provide a clear understanding of how the implementation might progress if attempted. However the LRA score of 2.8 provides evidence of better alignment with the enablers of lean in the automotive case than in the first assessment of the home décor business with a LRA of 4.5.

Next Steps for the Case Study Firms

Creating a better sense of work required in a deployment plan would provide more clarity of the risk of making changes or modifications to practices, procedures, and policies. It is necessary to use the LRM and understand why the LMS tools sort the complexity within the implementation plan. The results of this work will help determine how tools are selected to create a quantitative measure to allow a business to tailor the methodology to different aspects of implementing lean. This will be used to create a working level to understand if the lean implementation plan is too aggressive or has alignment that gives predictability to a successful implementation plan. These issues are addressed in the upcoming chapters of this dissertation.

CHAPTER 3:

STRUCTURED METHODOLOGY FOR TAILORING LMS

Since the mainstream introduction of lean manufacturing in the classic book *The Machine That Changed the World*, organizations in global manufacturing markets have attempted to harness the power of lean philosophies and tools as a composite (Womack & Jones, 1994). In a review of the literature in this area, Amin and Karim (2013) found that companies and organizations have tried to leverage those precepts to make performance improvements to help businesses become more competitive in their respective markets. A key part of utilizing lean tools to assist in delivering improved performance is the perception of proper tool selection. This chapter includes a review of academic publications and methodology for how manufacturing-based companies and organizations perform what they perceive as proper tool selection and proposes a structured framework for achieving the same.

Background of the Problem

Performance management systems have been a focus of systems research to help business organizations determine performance criteria to monitor business performance as a valuation of their respective strategies (Okwir, Nudurupati, Ginieis, & Angelis, 2018). Key aspects of evaluating the health and viability of a business include cost control and profitability, which are important high-level perspectives but do not provide the detailed, level monitoring of business vitals that collectively enhance business health (Bianchi, Winch, & Cosenz, 2018; Micheli & Mura, 2016; Sangwa & Sangwan, 2018). A key need of the system is the ability to utilize a Performance Measurement System (PMS) that is adequately comprehensive for operational businesses but flexible enough to meet the ever-changing topography of the highly competitive global manufacturing market (Bititci, Carrie, & McDevitt, 1997). Companies that manage performance with systems used to provide the visibility of the business performance with the best methods tend to increase viability and sustainability for the business (Bellisario & Pavlov, 2018; Turisová, Tkáč, & Pachta, 2018). Since the early focus on managing operational processes, there has been consistent lack of understanding how performance should be measured and how LMS influences it (Bellisario & Pavlov, 2018). In an effort to create the proper performance metrics for a business, there are both financial and non-financial elements that need to be considered. This research primarily focuses on the non-financial elements that control performance (Sandein, 2008). This research assumes that the commercial aspects of contract negotiations and profitability are not being addressed through performance management systems. The chapter focuses on understanding operations and tailoring systems to optimally control their performance at the sources with key influence.

While most research on this topic focuses on the ability of LMS to make and see operational improvement opportunities, LMS also offers the capacity to share information, understand, and control performance (Hernández Lamprea, Camargo Carreño, & Martínez Sánchez, 2015; Tek Aik, 2005). The proper choice of key performance variables to measure business health occurs by managing processes and by understanding required indicators while comparing them to actual business performance (Kennedy & Widener, 2008). The key element of PMS is to provide visibility to deviations between the plan and the reality of performance at specified times or in the relation to LMS in as close to a live state (Turisová et al., 2018). It is best if the measurement of performance can be standardized like a robust process (Bititci et al., 1997). Not only does PMS allow monitoring of performance, but it can be the catalyst for guiding improvement (Ferreira & Otley, 2009). Not having PMS could leave a business vulnerable and allow for degradation and gaps to performance that might lead to irrevocable changes within the company (Bianchi et al., 2018; Bisbe & Malagueño, 2012). Relative to LMS implementation, PMS has been related to the use of financial and non-financial performance measures to create structure and standardized procedures that better align with employee empowerment and the visual management of performance (Bellisario & Pavlov 2018; Fullerton et al, 2014; Kennedy & Widener, 2008). Research has shown that LMS operations-based PMS have provided a measurably heightened level of business/organizational performance in comparison to more prevalent accounting-based management systems (Bellisario & Pavlov, 2018). It is not currently known how key LMS operational components are selected and matched with PMS.

Statement of the Problem

Scholars have commonly found increased performance from lean implementation based on certain performance targets and tools related to the improvements of relative areas. However, the research varies slightly in perspectives on the reasoning behind lean implementation. While continuous improvement is a fundamental element of lean, reasons for requiring these tools over current practices differ (Kornfeld & Kara, 2013). In any form of business operation, there needs to be a control method in place to provide visibility and methods of redirection and correction if performance does not reach a required state (Jing, Niu, & Chang, 2015).

Purpose of the Study

The purpose of this research is to determine the best control method to match required business performance KPIs. The research is designed to build a methodology for proper lean tool selection prior to lean system implementation by understanding performance requirements. This research formulates an applications-based methodology to be used in an industrial or manufacturing application. Once the methodology for tool selection is defined, it is coupled with a quantitative tool to determine the interaction between systems and resources in order to provide the specified work content level of the required implementation.

Significance

The primary reason for developing this framework is to provide implementers with an understanding of the effort or work content that the implementation will encompass in order to tailor the plan to ensure that the finalized system state offers the required performance and system controls. Within LMS implementation, there is a need for a formal system control for each aspect of the business to support the required KPIs.

Literature Review

Incorporating PMS into LMS

LMS has become the leading process for a systematic approach to optimizing changes and measuring performance in manufacturing-based companies (Bellisario & Pavlov, 2018). Critical aspects of measuring and managing performance present a holistic vision of performance that transcend high (executive and strategic) needs to attain the ability to measure key tactical variables (Bititci et al., 1997).

Figure 1 defines key elements to be considered during the process of building, maintaining, and changing PMS to capture lean characteristics (Ferreira & Otley, 2009). Even in the early development of this framework, the authors found that each aspect of this framework is not required for every business but capturing key areas can aid in understanding which factors can or need to be applied.

One of the primary objectives of operating a business is profitability to maintain health. However, not all lean activities directly relate to aspects of profit and loss; in an effort to realize the synergies of LMS, traditional accounting practices are not ideal (Kennedy & Brewer, 2005).

Lean accounting practices that look at non-financial elements, such as those that cohere with the behavioral and social controls of LMS, use techniques that support the empowerment of employees and peer pressure to generate adherence to lean-based systems (Kennedy & Widener, 2008). A practitioner survey showed that in an isolated format, planning, cybernetic controls, reward, administration, and culture are aimed at controlling practices and developing behaviors to regulate performance, which is consistent with LMS but also relates to a synergistic perspective (Malmi & Brown, 2008).

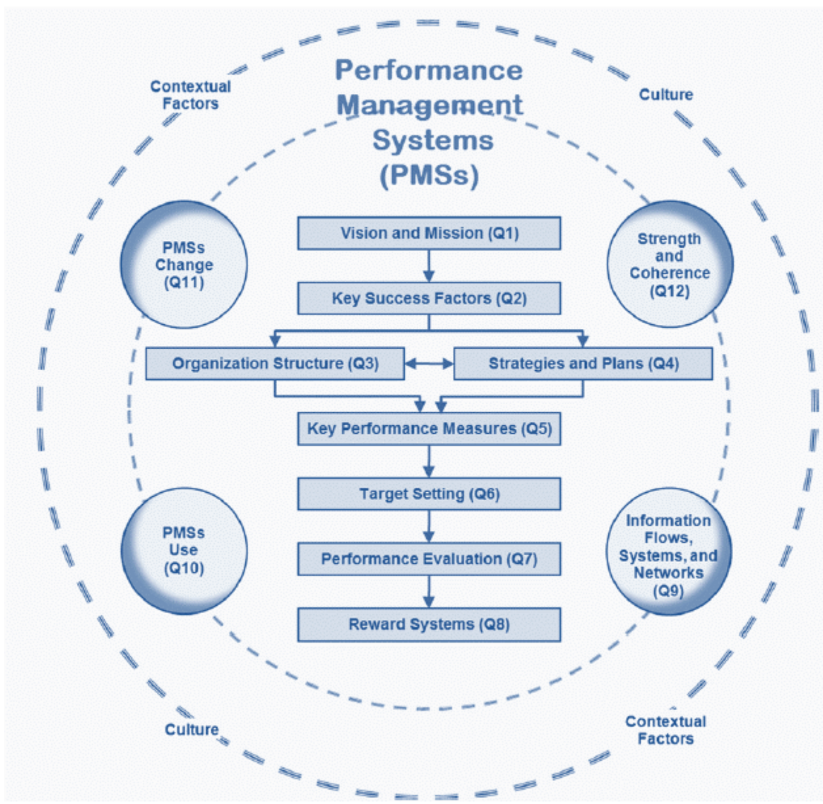

Figure 1. Key elements to be considered during the process of building, maintaining, and changing PMS to capture lean characteristics. From "The Design and Use of Performance Management Systems: An Extended Framework for Analysis," by A. Ferreira and D. Otley, 2009, *Management Accounting Research, 20*, p. 268.

An empirical case study provided evidence that management accounting systems alone do not provide adequate control and that there are direct benefits to properly fitting the PMS system to the design and complexity level of the business it supports (Sandein, 2008). In developing a proper measurement system, many variables have levels of interaction that influence performance and there is some level of subjectivity that must be incorporated to capture this effect (Richard, Devinney, & Johnson, 2009). The control aspects of a PMS should be used concurrently in a balanced and complementary management tool in order to maximize the control aspects of the system (Kristensena & Israelsen, 2014). The organizational structure design plays a key role in optimizing communication across different levels of the organization to support the PMS (Gollan, Kalfa, Agarwal, Green, & Randhawa, 2014). The understanding of the relationships between PMS requirements and the cultural aspects of an organization also play a key role in sustainability and in deviating from solely relying on traditional accounting-based reporting to give the required granular visibility (Passetti, Cinquini, Marelli, & Tenucci, 2014).

More comprehensive ERP/IT systems create strategic alignment among multiple constructs by creating control in the form of governance to have a constructive impact when multiple paradigms are controlled (Luftman, Lyytinen, & Zvi, 2015). A quantitative study revealed that KPIs need to be tailored during the development of business strategies to create optimal alignment (Micheli & Mura, 2016). Increasing the complexity of the measurement system can harm a strategy that was constructed to improve the objective, which also make defining and simplifying measurement variables more important for the sustainability of PMS (Okwir, Nudurupati, Ginieis & Angelis, 2018).

It is critical to realize that PMS requires maintenance that needs to be constantly monitored to ensure that the proper requirements of the business are reflected and captured to avoid conflicts within an LMS (Sangwa & Sangwan, 2018). The PMS needs to function as a "closed loop" by measuring the required performance, as well as monitoring and sharing information across a variety of levels and positions in an organization (Bititci et al., 1997). In developing PMS to control performance, it is important to understand the complexity and uncertainty of system maintenance (Franco-Santos & Otley, 2018). There still remains a large discrepancy in the area related to the practices of cost-leadership strategy versus controls based on non-financial financial gauges, which supports the tailoring aspect of PMS to fit one specific business requirement (Micheli & Mura, 2016).

Enterprise resource planner (ERP) is effective tool to support LMS, which could be more effective if implemented concurrently instead of being considered a separate system from PMS and LMS (Powell, 2013). After all, IT/ERP systems, by default, can create alignment between PMS and LMS (Luftman et al., 2015). Similar to implementing LMS and the need to tailor the systems to specific business requirements, the aspects considered for selecting performance indicators to monitor the heath of the business require the same type of philosophy (Franco-Santos & Otley, 2018). There is evidence that the concept of PMS is being used across businesses to leverage improvements and maintain or control required performance, but it is not exactly clear how the specific tools are being applied (Bellisario & Pavlov, 2018). The lack of appropriate performance measures has led to conflicting results of lean implementation (Sangwa & Sangwan, 2018).

Lean Tool Selection

The selection of tools to guide the required performance is an essential part of the implementation of varying lean tools (Jing et al., 2015). With the amount of global competition, optimizing a business operation in the most efficient and effective manner is paramount (Karim & Arif-Uz-Zaman, 2013). For instance, the lean tool designed for waste elimination creates a systematic approach for managing overproduction, inventory, waiting time, over-processing, transportation, motion, and defects (Ramesh & Kodali, 2012).

Research has offered various formats to optimize lean tool selection. Analytic hierarchy process (AHP) is used for lean tool and technique selection since it accurately evaluates the influence of criteria in terms of goals achievement (Vinodh, Shivraman, & Viswesh, 2011). AHP is a theory of measurement using pair-wise comparisons that relies on the judgment of experts to derive priority scales. Manufacturing companies tested this method using a broadly applicable case study with multi-criterion decision-making (MCDM) analysis because it involves several criteria. Vinodh et al. (2011) argued that an AHP is best suited for lean tool and technique selection because it can accurately evaluate the influence of criteria in terms of goals. The main reason for AHP adoption is dealing with inconsistencies associated with the subjective judgment of decision-makers. A method for dealing with these discrepancies can ensure that the judgments are consistent enough to lead to the selection of the best lean tools and techniques for the scenario. Using a case study, the authors concluded that utilizing AHP enables decision-makers to select the best lean tools and techniques for implementation, which leads to greater business prosperity. Ramesh and Kodali (2012) used a model that presents companies with the opportunity to compare the performance of value-stream management tools with lean material and information flow mapping and then to choose the best tool for waste identification and removal, based on company priorities.

In a case study of a medium-sized, original equipment manufacturer (OEM) for many automobile manufacturers located in the northern part of India, researchers developed a decision heuristic that Hines and Rich (1997) designed using a value stream analysis tool (VALSAT) approach to select value stream mapping techniques. This approach built on Hines and Rich’s

(1997) matrix that encompassed lean value stream mapping in the decision heuristic. This methodology was novel in its ability to integrate AHP-PGP modeling using an iterative algorithm to achieve prioritized goal optimization (Ramesh & Kodali, 2012). Amin and Karim (2013) developed a time-based quantitative approach for selecting lean strategies for manufacturing organizations. The authors summarized past issues with lean tool selection, discussed manufacturing-choice-strategy, and presented a structured method for quantitatively assessing the perceived value of lean strategies (Amin & Karim, 2013). Their method provided a quantitative evaluation method for selecting appropriate lean strategies to improve manufacturing performance within an organization's time and resource constraints (Amin & Karim, 2013). In this model, time of lean implementation is included in the form of time to plan for lean implementation, modify the exiting process, train personnel in the new system, and validate the new production processes. In addition, the reduction of any waste leads to an increase in the manufacturer-perceived effectiveness value index (Amin & Karim, 2013). Finally, their optimization technique has provided the maximized perceived value of reduction of manufacturing waste within given time constraints.

Kornfeld and Kara (2013) developed a methodology for the selection of lean and six sigma projects in the industry. The authors used 74 surveys from organizations that they identified for participation because of their involvement in continuous improvement groups (Kornfeld & Kara, 2013). The authors focused on the criteria and methods used to select and prioritize continuous improvement projects (Kornfeld & Kara, 2013). They determined that practitioners often do not make a connection between business strategy and project selection, which inhibits their ability to prioritize continuous improvement projects (Kornfeld & Kara, 2013). This methodology focuses on the ability to eliminate an organization's tendency to adopt tools for their project portfolios from popular media, rather than academic journals or universities (Kornfeld & Kara, 2013). In doing so, practitioners often select inappropriate tools, such as brainstorming (Kornfeld & Kara, 2013). The authors surmised that this is likely why organizations report a high rate of project failure and dissatisfaction with selection methods.

Karim and Arif-Uz-Zaman (2013) offer a methodology for the effective implementation of lean strategies and their performance evaluation in manufacturing organizations. Their research introduced continuous performance measurement (CPM) as an effective methodology for implementing lean manufacturing strategies and serving as a leanness evaluation metric (Karim & Arif-Uz-Zaman, 2013). This approach requires companies to establish a proper relationship between the closely related lean strategies and manufacturing wastes while developing an overall concept of how a company should ideally run as an important part of tool selection (Karim & Arif-Uz-Zaman, 2013). Their findings indicated that CPM matrices, in terms of efficiency and effectiveness, are appropriate methods for the continuous evaluation of lean performance (Karim & Arif-Uz-Zaman, 2013). Manufacturers now have a validated step-by-step methodology for successfully implementing lean strategies (Karim & Arif-Uz-Zaman, 2013).

Taylor, Taylor, and McSweeney (2013) proposed a methodology that aims at providing a greater understanding of the success and survival of lean systems. Their research focused on selecting lean tools and techniques in order to secure long-term success (Taylor et al., 2013). The authors were concerned less with how to choose lean tools and techniques and more about other factors to consider when choosing and implementing lean tools and techniques for successful implementation (Taylor et al., 2013). They synthesized the previous literature to develop a taxonomy of lean characteristics (Taylor et al., 2013). A case study on a successful UK-based automotive manufacturing company explored what made the company successful with its lean implementation. The multi-faceted nature of lean highlights the need for managers to focus attention on lean implementation to nurture and encourage the many interactions and relationships that make it work effectively. This research shows that managers can use the taxonomy as a checklist to ensure that they are attending to all the necessary facets of their lean system. To create a high level of success, managers need to concentrate on the perceptions of employees around the themes and sub-themes they identified to successfully implement lean systems.

Vinodh, Hiagarajan, and Mulanjur (2014) designed a case study of a valve manufacturing organization in India to test this model and found that the sequential implementation of lean tools and techniques enabled decision-makers to implement them in an effective manner during the early phases. This model provides a methodology for the selection of lean tools based on 12 criteria (Vinodh et al., 2014). Their methodology involves the evaluation of five lean tools or techniques that apply to any tools or techniques under consideration in an organization (Vinodh et al., 2014). Vinodh et al. (2014) applied the fuzzy TOPSIS model by asking decision-makers to rate the five tools and techniques in linguistic terms (e.g. “good,” “very good,” etc.) based on 12 criteria. The linguistic terms were then converted to fuzzy numbers, and the authors used a series of equations to determine the distance of each concept from the ideal and anti-ideal state to compute a closeness index (Vinodh et al., 2014). This closeness index provided a ranking of the appropriateness of each lean tool or technique for that organization (Vinodh et al., 2014). The quantitative analysis showed that when an implementation matured to a certain level, simultaneous implementation could become feasible (Vinodh et al., 2014). The researchers concluded that this methodology provided a useful technique for manufacturing organizations to quantitatively prioritize lean tools and techniques during the initial phases of implementation (Vinodh et al., 2014).

Anvari, Zulkifli, Sorooshian, and Boyerhassani (2014) developed a qualitative method based on an analytical hierarchy process (AHP) for assessing and ranking effective lean tools and techniques using an integrated and a quantitative data envelopment analysis (DEA) approach. The AHP-DEA analysis supported the conclusion that this model incorporates undesirable outputs, unlike previous models (Anvari et al., 2014). This model used three lean tools based on expert opinion to assess and draw conclusions about the level of efficiency (Anvari et al., 2014). The methodology ranked the lean tools of continuous flow, poka-yoke, standardized work, synchronize, TPM, level scheduling, six sigma, cellular design, setup reduction (SMED), Jidoka, pull system, multi-skill (empowerment), and 5S (Anvari et al., 2014).

Anvari et al. (2014) offered an integrated design methodology based on the use of the group AHP-DEA approach for measuring lean tool efficiency with undesirable output. Their proposed methodology applies to lean tools and techniques in general but does not account for the specifics of how the method may apply to different companies (Anvari et al., 2014). Due to the many tools and techniques available, this method has proven beneficial in highlighting the options manufacturing companies can consider (Anvari et al., 2014). Practitioners could then use a company-specific method of selecting lean tools that other researchers described.

Jing et al. (2015) applied the VIKOR method to lean management tool selection during the transition to lean enterprise to build a model that accounts for multiple key performance objectives combined with the weighted impact provided of the specified lean tool feature evaluation criteria of the alternatives (Jing et al., 2015). This VIKOR decision-making method to select lean management tools not only maximizes the group utility of the decision but also minimizes individual regret (Alaskari, Ahmad, & Pinedo-Cuenca, 2016). Alaskari et al. (2016) focused on this methodology to guide small manufacturing enterprises.

A lack of understanding about how to use lean tools has proven to be a limiting factor in the implementation and sustainability of building a lean enterprise (Kornfeld & Kara, 2013). Leaders do not always make the connection due to the difficulties and costs that SMEs encounter when adopting lean tools that subsequently do not deliver the expected benefits. It is essential to have a mechanism for selecting the most appropriate lean tool for the company in an effort to deliver the required level of business performance. While adopting lean principles gives the initial appearance of simplicity, successful implementation requires strong leadership, detailed planning, and staff who are trained in the philosophy, tools, and techniques of lean manufacturing (Alaskari et al., 2016). The authors blended the use of questionnaires to determine the importance weight (IW) of each factor that influences the KPIs of a company. This methodology again leverages experts in the field of lean manufacturing for their experience with and knowledge of lean tools to guide decision-making and to validate the relative strength of the relationship between KPIs and specific lean tools. The tested selection matrix utilizes information from both lean experts and business personnel to create the correlation between the different KPIs and the lean tools to determine whether the best lean tools for a particular SME were chosen.

Safety

LMS embraces the continuous improvement philosophies of Toyota's "Our Values," with its top value of safety (Liker & Houseus, 2011). Safety is a measure of performance within a company that, at times, can be taken for granted but is a foundational element of the lean systems. A business cannot move beyond safety if there are issues or serious risks to the employees.

In the literature, the most prevalent tools used in managing this metric are total productive maintenance (TPM), standardized work, visual management, 5s, value stream mapping, *kaizen* (continuous improvement), and single minute exchange of DIES (SMED). The work of both Suzuki (1994) and Shirose (1996) demonstrated that the implementation of total productive maintenance (TPM) provides evidence that visual management and the ability to concisely share information plays a key role in improving safety performance. The four basic principles of a learning organization indicate that the standardization of labels and signs within a visual factory provide an improved safety environment for a company's employees (Tek Aik, 2005). Some primary drivers and the simplest tools to improve risk levels for employee safety are visual management systems and the reinforcement of required standards to quickly share across all levels of facility or even an organization (Ortiz & Park, 2011). The visual management tool goes beyond controlling the shop floor to visually communicating information and performance charts using vibrant colors to identity risk, pinch point, and areas that require special skills or knowledge (Suarez, 2019).

Multiple visual management case studies have also correlated improvements in safety to the morale of employees by connecting safety to the employee's personal areas of responsibility (Murata & Katayama, 2013). A focus on waste reduction activities (kaizen), process improvements (kaizen), 5s, and standardized work involves proactive planning to address the safety aspects of adaptations by heavily engaging in the specified area of work (Lehtonen, 2018). When focusing on improving safety, value stream mapping (VSM), which typically focuses on value-added (VA) time and waste reduction, benefits from conjoining kaizen events and 5s

(Main, Taubitz, & Wood, 2008). Performance sustainability is the ultimate goal that safety, health, and environmental (SH&E) professionals must possess, which includes knowledge of 5s, VSM, standardized work, and visual management to deliver a systematic approach to driving a safe philosophy and culture (Taubitz, 2010). Efforts to expand the 5s methodology by adding a sixth "s" to improve safety systems incorporate standardized work and visual management to create an understanding of "who, what, where, when, and why" and enhance the organization and cleanliness of the workspaces (Anvari, Zulkifli, & Yusuff, 2011).

One case study applied 5s to a small manufacturing enterprise with a minimal number of safety incidents to look at non-incident scenarios through a measurement of risk reduction activities by leveraging this lean methodology (Hernández Lamprea et al., 2014). Leveraging employee-focused kaizen events focused on using the 5s workplace organizational tools and visual management controls to elevate employee focus and attentiveness by identifying areas of risk to reduce the frequency and severity rates of incidents (Singh & Ahuja, 2014). Using SMED directly increased worker safety by added a specific structure and sequence of operations to formalize the process and eliminate tacit practices among employees (Joshi & Nail, 2012). Another case study indicated that there is a relationship between the utilization of both TPM and 5s methodologies to increase the collective focus through employee engagement to improve safety performance (Singh, Gohil, Shah, & Desai, 2013). The most comprehensive use of lean tools incorporated visual management, standardized work, 5s, TPM, and *kanban* to improve product safety, which indicated that the tools could work cohesively to exclude all forms of waste by intensifying and stimulating continuous improvement (Baskiewicz & Orhan, 2019). However, while tools, such as standardized work, capture routine activities, safety processes are ever-evolving (Martínez-Córcoles, Schöbel, Gracia, Tomás, & Peiró, 2012). See Table A1 in the appendix for a summary of the literature on safety.

Quality Control

LMS, in a holistic form, is designed to meet customers' needs at the required quality level. As in the previous section, many tools can be used to control different aspects of quality and there is not a single fit that works for all applications. In the early literature, Suzuki (1994) and Shirose (1996) both guided practitioners to use visual management to provide control and improvements to quality performance. A case study based in a manufacturing machine shop provided evidence that the use of a TPM system, which began with a foundation of 5s, systematically improved the quality performance of the manufacturing equipment through improved and collaborative maintenance activities (Singh et al., 2013). Total quality management (TQM) and the usage of standardized production activities had the ability to provide more control and understanding of performance (Victor, Boynton, & Stephens-Jahng, 2000).

Several case studies have also shown that systematic kaizen activities, focusing on visual management controls, related to maintaining and improving quality (Murata & Katayama, 2013). For instance, the practices of manufacturing relative to standardized work have entered the health care industry to communize the treatment of pneumonia patients based on best practices (Mannon, 2014). Standardized work and kaizen are critical elements of establishing TPM systems, which aim at stabilizing processes and correlate with improved quality control through engaged and more cross functional employee maintenance activities (Victor et al., 2000). VSM exposes the performance of a manufacturing operation to ensure that items such as scrap, first-time quality, and customer value align with the practitioners work by increasing non-value-added

(NVA) time and the ability to see the waste (Voelkel & Chapman, 2003). Voelkel and Chapman (2003) showed that the VSM tool can help inform and guide the performance of a manufacturing operation relative to meeting customer quality requirements. In a study on a learning organization, TQM was the foundation for creating synergy, but 5s and visual management were also required for quality performance (Tek Aik, 2005). SMED is considered more of a productivity improvement activity, though, ideally, it should be utilized in the design of equipment to enhance quality control methods (Cakmakci, 2009). The SMED philosophy helps to improve the operators' quality of work during change-overs by creating a standard for error-proofing the process (Joshi & Naik, 2012).

The tools of standardized work—pull, single-piece flow, TPM, and kaizen—may be used in a first-time calculation of OEE (Wee & Wu, 2009). Studies on medium-to-large-sized companies (150+ associates) have adopted 5s as part of their quality systems and improved performance (Bayo-Moriones, Bello-Pintado, & Merino-D´ıaz de Cerio, 2010). As case study-based research demonstrates, the benefits of 5s on KPIs—such as wasted, reprocessed, and rejected material—have positively impacted soft metrics such as a sense of belonging, cooperation, and labor relationships (Hernández Lamprea et al., 2014). Through "High 5s" projects, hospitals have looked to leverage the characteristics that improve manufacturing quality performance to create standardized safety protocols through adherence to specified sequences and steps, which improve the quality of care and safety of patients (Leotsakos et al., 2014). Norwegian manufacturing case studies have shown through qualitative and explorative methodologies that a high level of process maturity is able to implement SMED, standardized work, and TPM systems to stabilize processes and reduce errors and deviations from the process (Ringena et al., 2014). The implementation of strategic 5s, kaizens, and standardized work procedures directly improved quality performance in customer complaints and in process rejections by focusing on the VA aspect of employees (Singh & Ahuja, 2014; Sundar, Balaji, & Kumar, 2014). Not only are visual controls important in shop floor activities but using visual management for displaying performance by creating visibility around where and what improvement opportunities exist can help meet customer requirements successfully (Bititci et al., 2016). However, the literature does not provide details about how the systems were implemented or, in many cases, if the systems focused on single specific elements, such as scrap reduction, first-time quality, PFMEA RPN reduction, or customer complaints that enhanced or improved quality performance overall. See Table A2 in the appendix for a summary of the literature on quality.

Productivity/OEE

This section covers some of the tools that correlate with improving and controlling the productivity and OEE aspects of performance. Productivity improvements and OEE are two of the foundational measurable aspects of LMS concerning waste elimination for continuous improvement. Some of the simplest techniques are sharing information, in which the methodology of visual management can improve information communication as well as aid in understanding required procedures and process steps or requirements for consistency and repeatability (Tek Aik, 2005). The use of ad hoc teams to deploy LMS through kaizen events, or workshops, provided quantitative evidence that the tools of SMED, standardized work, 5s, TPM, VSM, visual management, and error-proofing led to improvements in OEE among manufacturing companies (Marin-Garcia, Val, & Martin, 2006). Controlling OEE performance by implementing TPM methodology correlated to improved equipment uptime by preventing unplanned failures and maximizing the FTQ in the error-proofing the process (Wee & Wu, 2009). The framework that focused on controlling VA, NVA, and necessary but non-value-adding (NNVA) time using SMED, TPM, and VSM improved operational performance and helped to lower required inventories (Bayo-Moriones et al., 2010). A case study on an automotive machine shop showed that leveraging 5s and TPM created a synergy and directly led to the improvement of equipment output by eliminating unplanned downtime and improving the first-time throughput of parts produced in the system (Singh et al., 2013). Again, 5s is a diverse tool and can be directly related to improved productivity factors by enhancing communication and cooperation and by leveraging the standardized process aspect of procedures (Hernández Lamprea et al., 2014). Researchers applied 5s and kaizen practices to the manufacturing of steam boiler systems, which improved labor productivity and reduced machine breakdowns (Singh & Ahuja, 2014). The implementation of the LMS tools SMED, standardized work, and TPM have been applied to a qualitative and explorative methodology to show that they do contribute to improved OEE and productivity; however, the system implementation required maintenance as well as time to mature. See Table A3 in the appendix for a literature summary on productivity.

Systems do not become holistic spontaneously (Ringena et al., 2014). Visual performance management systems (VPMS) implementation have positively impacted productivity performance in multiple company case studies (Bititci, Cocca, & Aylin, 2016). The implementation of a SMED system for a food processing plant directly reduced the changeover time in three case studies but also led to the implementation of some TPM-based fundamentals of the changeover process, which improved the mean time between failures and repairs in the same cases (Lozano, Saenz-Díez, Martínez, Jiménez, & Blanco, 2017). The ability to detail a change-over methodology related to shorter change times and a reduction in errors made during the process (Joshi & Naik, 2012). SMED is not only proven as a method to tackle OEE downtime loss of setup and changeover procedures but also to address other losses as categorized under the "six big losses" of OEE (Benjamin, Murugaiah, & Marathamuthu, 2013). Error-proofing/Poka-yoke methods were also able to increase the controls system, as a case study revealed, when the minimization of errors in production directly reduced workload to the operator and improved the OEE of the system performance (Wang & Pan, 2011).

Inventory Control

Inventory is one aspect of waste reduction on which LMS is premised. A quantitative case study has shown that the interactions among TPM, 5s, VSM, pull system, level scheduling, and visual management systems impact the ability to control lead time (Abdulmaleka & Rajgopa, 2007). Wee and Wu (2009) used VSM to develop an implementation strategy for the LMS tools of visual management and TPM to reduce both NVA and VA time and to shorten lead time in order to supply requirements at a Taiwanese Ford manufacturing facility. A VSM and kanban-based pull system reduced WIP by 89.5% and finished goods by 18% (Singh, Garg, Sharma, & Grewal, 2010). The interactions among the LMS tools—pull system, level schedule, SMED, and TPM—drove each to contribute to stabilizing the process to lower inventory requirements as well as deliver financial performance (Hofer, Eroglu, & Hofer, 2012). Kaizen was the determining tool used to select TQM processes to improve process quality control in order to quantitatively reveal inventory reduction (Rahmana, Sharif, & Esa, 2013). The structured use of 5s and kaizen (the organizational tool) improved delivery attainment by 10% (Singh & Ahuja, 2014). One study bundled lean tools, such as SMED, pull, level, and TPM to reveal the configurations these provided to methodically reduce inventory while maintaining the ability to meet customer requirements (Marodin, Frank, Tortorella, & Fetterman, 2017). In another case study, SMED, 5s, and error-proofing stabilized and leveled the material flow of single-piece flow, standardized work, visual management, and TQM (Iranmanesh, Zailani, Hyun, Ali, & Kim, 2019). See Table A4 in the appendix for a literature summary on inventory control.

Gaps in Literature

These methodologies still rely on a form of subjective human interpretation or decision making as a key component of determining lean tool selection in supporting business needs. The critical item to understand through all the literature is comprehending where lean tools provide gains and control relative to performance and that they are very versatile and can be applied numerous ways. This versatility and power of the tools can be one of the issues driving complexity and mis-application of the tools for the business needs in regard to struggles in successful deployment. The importance of understanding one's business needs/requirements and then determining an optimal way to connect the LMS tools to the desired business performance control measures cannot be overstated. The human decision-making referenced earlier is focused on aligning the process of LMS tools selection to best fit the current business scenarios. It also needs to be a consideration in determining what will be more conducive to a successful deployment plan. The methodology in this research is aimed to bring more quantitative data to understand more granular needs to guide this decision-making process of deployment planning. The structured method for quantitatively assessing the perceived value of lean strategies has some benefits but could be more optimal in measuring the level of required work or action needed to implement and sustain the system. There are significant bodies of work all showing that lean tools provide successful systemization for stability and continuous improvement. The literature also shows that there is a competitive reason, or business viability concern, driving the need for these tools. A gap in the literature is the understanding of how a current business is managed with or without systems. The articles in the literature review provided a guide for selecting appropriate lean strategies to improve manufacturing performance do not offer insight into the current state of business infrastructure, which could highlight potential issues when trying to make a transition to the ultra-rigorous, systems-based lean tools and principles.

The proposed method of this research is designed to understand current business infrastructure combined with other methods to control the reach of KPIs. In typical manufacturing businesses, certain items such as the capital assets are degraded through excessive use and employees move or transition to different roles and responsibilities. The proposed methodology will identify specific lean tools to support each of the business KPIs. The next section covers the quantitative methodology for applying the LRA multiplier from the LRA framework discussed in the prior chapter to the required system to meet sustainable business performance indicators in order to understand the work effort and difficulty of the implementation.

Methodology for LMS Tailoring & Tool Selection

The methodology developed here is to be utilized in industrial manufacturing applications for ease of use for practitioners. The process assimilates PMS and LMS with interactive integration of the lean tools to focus on a specific performance variable for control and improvement planning. The process incorporates philosophies from Ferreria and Otley's (2009) PMS framework to determine KPI management. The framework offers a holistic system for business control and measurement. The research is primarily aimed at the non-financial operation portion of PMS and the incorporation of LMS tools to oversee and measure gaps in performance, share information, and maintain systems to optimize performance control. The performance characteristics may not have a positive impact on financial performance but help to control operational performance close to the sources.

The second part of the methodology leverages the tool selection process in a more interactive way to connect the correct tools to the targeted control that is expected. Setting a target for KPIs is not the purpose of this research, but the methodology does regulate the performance of the required areas to best control, maintain, and potentially improve performance. The third part of this methodology connects the KPIs/targets to lean tools and begins to quantify the amount of work that these activities/modifications will require to be implemented. This process also incorporates the LRM from LRA (Chapter 2) with the tools selection process to quantitatively predict the “effort” and “cost” of implementing the systems. The fourth step in the process determines the strategy of implementation based on the results of the aggregated data.

Step 1: Determining the KPIs and the Lean Tools to Select

The process starts with determining the requirements to be measured and controlled. The method is based on the areas of safety, quality, productivity, and inventory control illustrated in Table 5. Within each classification there can be multiple specifications that require control. The selection process is based on identifying the tools that best fit the specific requirement of the desired control or improvement. For example, quality can pertain to customer satisfaction, customer complaints, shipment of non-conforming material to the customer, first time quality, and scrap. While each of these classifications fall within quality, they could potential require different systems to optimally manage the performance. The methodology is capable of handling single areas of focus or more complex levels where multiple areas drive systems to improve performance. Ultimately, this research is focused on the internal aspects of an area such as quality because, in theory, if the system does not allow for the production of defects, it is not possible to have non-conforming materials delivered to a customer.

Table 5

Lean Tool Selection

	Requirements	SMED	Pull	Level Schedule	Single Piece Flow	Standardized Work	5s	TPM	VSM	Visual Management	Cellular Manufacturing	TQM	Kiazen	Poka-yoke
Safety	S1						X			X				
Quality	Q1											X	X	X
Throughput/OEE	OEE1	X				X		X						
Inventory Control	IC1		X											

Step 2: Estimation of Resource Requirement

Once the requirements and the tools for monitoring and measuring performance are selected, the methodology focuses on the planning aspect of how to use the tools. This process starts to look at the resources to support planning through implementation by transforming the requirements from the lean tool selection process and building the resource utilization matrix (RUM) (see Table 6). From this point, the resources or functional groups to support the planning and implementation will be determined. The resources are based on the functional departments that partake in the planning and implementations process. These resources were weighted based on whether they were the primary owners of the system, which meant that they became the coordinator of the key task to accomplish the proper implementation. The primary owner role was weighted higher to signify that there was more work required or complexity essential to increase the utilization of the resource. The secondary owner was weighted less, which implied that they had a lower or same level of expected work content, which correlated with lower utilization.

Table 6

Resource Utilization Matrix

Requirements	Resource/Functional Group									
	A	B	C	D	E	F	G	H	I	J
S1 5s	P	S								P
S1 Visual Management	S	S	P				S			P
Q1 TQM					S					P
Q1 Kaizen			S							S
Q1 Poka-yoke	P						P			S
OEE1 SMED					P					S
OEE1 Standardized Work										S
OEE1 TPM				P				P		
IC Pull		P								

Note. P = Primary system responsibility; S = Secondary system responsibility.

The effort ratio in Table 6 derived from the planned estimate work differential between the primary and secondary levels. This methodology is singular in that it shows that the interactions among the lean tools can offer a more optimal process for controlling the performance requirements, as shown in the literature on how lean tools are used.

Step 3: Determining the Effort Requirements for the Complexity of Implementation

The generation of the RUM and the incorporation of planning work content differences informed the scoring value to quantify the delta in the effort requirements. The work content in this portion of the methodology is the planning of activities but can be changed based on how the work is distributed among the team members. In designing the systems to fit the business requirements, cross-functional engagement is key in the design so that all the parties that use and have expectations about the system partake in the development process. By structuring the implementation and design planning, the effort scores can be set for the primary owners and secondary owners. In Table 7 the scores designated with a *P* for primary owners and *S* for the secondary owners have the relative weights applied.

Table 7

Lean Deployment Setup Matrix

Requirements	Resource/Functional Group										Lean Readiness Multiplier
	A	B	C	D	E	F	G	H	I	J	
S1 5s	2	1								2	1
S1 Visual Management	1	1	2				1			2	1
Q1 TQM					1					2	1.2
Q1 Kaizen			1							1	1.2
Q1 Poka-yoke	2						2			1	1.2
OEE1 SMED					2					1	1.5
OEE1 Standardized Work										1	1.5
OEE1 TPM				2				2			1.5
IC Pull		2									1

Note. The effort ratio is P = 2 and S = 1.

Step 4: Incorporating the Lean Readiness Multiplier

The implementation effort can vary by the area that is being implemented and the established habits of a business. The LRM as calculated from LRA (Chapter 2) is integrated into the lean deployment set-up matrix. Scaling the effort properly must account for the quantity of activities required, the implementation, and the resource effort to successfully implement the lean systems. The LRA for determining the multiplier can be calculated for specific areas or the overall aspect of a business. As with this selection process, the assessment needs to be applied as it best represents the true state of the business. The methodology is not about achieving the score but using the quantitative tools to best plan the deployment of tools in order to most effectively monitor and measure the performance of the business and for control to be set individually for each area if there are differences in the systems and the processes based on size of the areas.

The application of the LRM can vary by how it is being applied to a business. More complex applications of the LRA could benefit from performing multiple assessments in respective areas to provide multiple LRMs. The need for multiple assessments needs to be driven from business requirements as well as seeing differences that could relate to alignment to the enablers which are being measured between areas in which the LRA is being applied. The illustrative model in Table 7 provides an example of multiple LRMs in the Lean Deployment Set-up Matrix. As discussed in the literature on developing the pre-assessment methodology, the objective is to leverage the LRA to understand alignment or lack of to the enablers for providing quantitative measure to the strategy aspect of the deployment. It is important to understand if the areas where the LRA is being applied would provide more clarity by taking the extra steps to perform multiple LRAs. The need to create this requirement could be generated from the application being in a very large facility, multiple departments in which they function, and line independent businesses.

Table 8

Lean Deployment Resource Effort Matrix (LDREM)

Requirements	Resource/Functional Group									
	A	B	C	D	E	F	G	H	I	J
S1 5S	2	1								2
S1 Visual Management	1	1	2				1			2
Q1 TQM					1.2					2.4
Q1 Kaizen			1.2							1.2
Q1 Poka-yoke	2.4						2.4			1.2
OEE1 SMED					3					1.5
OEE1 Standardized Work										1.5
OEE1 TPM				3				3		
IC Pull		2								
Total Requirements	5.4	4	3.2	3	4.2	0	3.4	3	0	11.8
Ranking	2	4	5	7	3	9	5	8	10	1

The application of the multiplier is illustrated in Table 8, which can impact the values in the resource columns LDREM. The multiple tailors the implementation process by looking at systemic practices and using them to increase the effort to implement through the evaluation of the adherence and practices of other systemic processes in the business.

Step 5: Creating a Deployment Plan from the Resource Effort Requirements

This quantitative methodology provides a measurement of the estimated effort to perform the required deployment by function groups and identifies what groups have the largest work expectation. It allows for another aspect of tailoring in which one might determine that the amount of effort to conduct the implementation might exceed the capabilities of the current resource. It might also redistribute the division of work to a more proportional level to ensure the desirable outcome is achieved relative to the implementation. It also has the potential to reveal whether there are adequate resources available to perform the deployment. The estimated hours to perform the example implementation appear in Table 9.

Table 9

Deployment Planned Effort and Ranking

	A	B	C	D	E	F	G	H	I	J	
Requirements	**5.4**	**4**	**3.2**	**3**	**4.2**	**0**	**3.4**	**3**	**0**	**11.8**	38
Effort Ranking	**2**	**4**	**5**	**7**	**3**	**9**	**5**	**8**	**10**	**1**	
% of Effort Req.	14%	11%	8%	8%	11%	0%	9%	8%	0%	31%	100%
Effort Hours (5 Hours per Effort Requirement Unit)	27	20	16	15	21	0	17	15	0	59	190

Validation Case Study

A demonstration of the methodology occurred in a 60-year-old automotive company. The identity of the company cannot be disclosed due to the confidentiality requirements of the business. The company had grown organically and was technically advanced in engineering competency but had not focused on or understood the benefits of a systemic approach to LMS. The main performance measurement tool had been the profit and loss statements as compiled at the close of each month. The company was also expanding the manufacturing segment of the business for diversification and growth.

The business, with a rich heritage of automotive engineering and limited experience in Tier 1 automotive manufacturing, determined that it was imperative to build a performance management system to track areas that had not been critical for success in the past. In LMS, the focus is less on the cost of implementation than on the success or impact of the tools in providing the needed performance visibility and control over requirements. This methodology will provide visibility and a quantitative method to reveal the resources used to design and structure the performance management system requirements.

The first area of performance control is protecting the safety of the people and ensuring that planning determines material handle, personal protective equipment (PPE), and interactions with equipment in a steadier state of productive operation instead of facilitating a crafts-style of operation. In doing so, the work content can become more repetitive and repeatable. The process to select the lean tools for this application involved the creation of a team-focused collaborative state. The process also involved capturing where and how material would be moved or handled by operators to determine the proper protocols such as PPE (gloves, eye protection, lifting requirements, frequency of lifts, duration, etc.). The business had no recordables since 2016, so this type of work was new to the company and involved a much more labor-intensive process. The team had to identify the proper PPE and build it into standardized work instructions.

The next portion of the control of this KPI incorporated visual management to identify whether the proper tools were being used to handle the sequence of moving the parts, factoring in the sharp edges of the parts, print requirements, and whether lift assists were required to protect the operators using the product. To sustain the workplace organization, a 5s system was added to structure the reviewing process and the proper tools. The 5s methodology structured the process to ensure that the specified work content remained in place or could identify missing items.

Table 10 displays the lean tool selection used to determine which tools apply internally to control safety. These tool selections for controlling safety are aligned with the literature reviewed earlier in this chapter. Tool selection entered the ERP system, enabling the operators to confirm that they had proper tools to perform the work at the work stations, which they logged for the purpose of part traceability.

Table 10

Safety Management Selection Process

	SMED	Pull	Level Schedule	Single Piece Flow	Standardized Work	5s	TPM	VSM	Visual Management	Cellular Manufacturing	TQM	Kiazen	Poka-yoke
On Time Delivery (%)													
Materials/ Inventory DOH													
Labor Productivity/ Throughput (OEE)													
Quality (%)													
Safety (0 Recordables)					X	X			X				

The next area of control was quality control, which involves protecting the customer from receiving material that did not meet the specified requirements. Shipping nonconforming items can damage the perception of a business that may have taken years to cultivate. A company with quality control problems may not track customer complaints or have a process to track scrap as measure of performance. Even in a crafts-type performance model, quality control would only become an issue if there was an adverse impact on the P&L statement. The parts that were being produced for this customer were premium in nature, which carried a selling price of nearly $3000/unit. This premium cost product brought forth a belief that managing performance and controlling the tool setup were vital to preventing or minimizing the number defective parts made during required tool changes.

The selection process involved an analysis of the holistic quality system to control performance. The selection of the items in Table 11 occurred to best fit the high precision product and minimize the ability of the operators to default to past practices.

Table 11

Quality Management Selection Process-Scrap Control

	SMED	Pull	Level Schedule	Single Piece Flow	Standardized work	5s	TPM	VSM	Visual Management	Cellular Manufacturing	TQM	Kiazen	Poka-yoke
On Time Delivery (%)													
Materials/ Inventory (Inventory Turns) DOH													
Workforce													
Productivity/ Throughput (OEE)													
Quality (%)					X	X	X				X	X	X
Safety													

In much of the literature, 5s and standardized work are diverse tools with elements that reach across and help connect levels of management to floor level operators in order to maintain priorities among key items that are visible and practiced continuously. The next tool, TQM, embraces many of the characteristics of LMS but initially remained separate. Again, the employee-centered nature of the system was important as well as the ability to focus the resources on understanding the predictive nature of the process in an effort to document and error proof the system. The systems-focused portion used the fundamental tools of process failure modes effect analysis and control plans to reduce risks to the system and leverage standardized activities to help make key activities repeatable and reproducible. This process also used the kaizen concept to actively engage error proofing in order to minimize the possibility of making mistakes. The ability to maintain equipment performance was also key for managing the scrap aspect of performance.

Total productive maintenance (TPM) served as a broad engagement strategy with a focus on predictive, preventative, planned, and unplanned emergency issues, which could create larger quantities of defective parts. The collective mindset of the systems was tailored to eliminate the no cost and lower cost aspects of implementation in order to avoid scrap production through easy error proofing. The ERP system also allowed for the simple interlocking of required checks, maintenance items, communication of standards, and reminders to continuously reinforce the implemented ideas.

Table 12

Quality Management Selection Process: Tool Setup Scrap Control

	SMED	Pull	Level Schedule	Single Piece Flow	Standardized work	5s	TPM	VSM	Visual Management	Cellular Manufacturing	TQM	Kiazen	Poka-yoke
On Time Delivery (%)													
Materials/ Inventory (Inventory Turns) DOH													
Labor													
Productivity/ Throughput (OEE)	X	X							X				X
Quality (%)													
Safety													

Within the scrap control process, the tooling setup posed the largest risk, as the process to machine the products involved advanced tools. In this case, unplanned failures and improper setup could easily become uncontrollable. One piece of scrap per day would exceed the 3% allocated in the financial budgets for the project. In most manufacturing cases and lean systems, this area provides a standard opportunity to make continuous improvement activities. It is also part of the big six OEE losses and the seven forms of waste in the LMS process. To control this portion of the scrap KPI, SMED, visual management, error proofing, and pull systems for tooling provided the ideal interactions among tools to best control this performance (see Table 12).

Since there is potential for tool changes to occur at least one time per shift, there could not be any allowance for a single piece of scrap for this type of planned activity. Proper LMS tool selection could control this SMED to optimize tool changes and change-over between the products. A specific pull system ensured that, as tools were analyzed and utilized, inventory was available to meet customer demands. Visual supermarkets were established to demonstrate that the desired inventory levels of tools were available. Due to the precision of the product, the tools were setup and there were required inputs to the CNC machines to bring the part to a nominal position, or the most desired position to minimize defect potential. The tool setup machine had the ability to determine offsets and directly input them into the machines through the ERP system. The ERP system was critical in monitoring life, flagging, and notifying personnel when tool changes were pending to prevent the manufacture of nonconforming material.

As the systems were being built, the stability of the process throughput became the central focus. To control the productivity or OEE of the equipment, the LMS tools used were SMED, standardized work, 5s, value stream mapping (VSM), TPM, TQM, Poka-yoke (error proofing) and the kaizen/continuous improvement mindset (See Table 13 for the lean tool selection process for PMS of productivity/OEE). The process was based on running the parts concurrently since they were involved in the same final product. While some of the visible systems were used to control different aspect of performance, such as safety and quality, these tools were then reviewed and expanded to cover the additional needs and elements that specifically pertained to the variable of control.

Table 13

Productivity/OEE Control Selection Process

	SMED	Pull	Level Schedule	Single Piece Flow	Standardized work	5s	TPM	VSM	Visual Management	Cellular Manufacturing	TQM	Kiazen	Poka-yoke
On Time Delivery (%)													
Materials/ Inventory (Inventory Turns) DOH													
Labor													
Productivity/ Throughput (OEE)	X				X	X	X		X		X	X	X
Quality (%)													
Safety													

In the process of building PMS for controlling the productivity of the manufacturing process, the VSM was incorporated to begin analyzing the system performance interactions in preparation for the influence of the future work on inventory control work. The VSM is prescribed as a key visual tool that calculates lead, VA and NVA time, though, in this case, it was not mandatory in connection with the other tools to control productivity. In the process of defining the TPM system, it became important to ensure that the equipment was consistently being observed, inspected, and measured with predictive tools. The manufacturing process had substantial automation, which blended traditional skilled and productive-based maintenance activities to manage and monitor the equipment in order to prevent issues that could lead to long instances of unplanned downtime. This kaizen/continuous improvement process became a key part of the PMS of the productivity by identifying optimal ways to control items in the PLC, which provided interlocked integration of the ERP system to optimize assembly processes. This data from the process of interlocking and traceability could lead to control improvements and determine optimal process flows through shared equipment. The selection of the 5s process was identified to maintain equipment health to a new like standard. 5s ensured that equipment coolant, hydraulic, and pneumatic systems were functioning in state of control and reduced risk of failure.

Material inventory was the final aspect under consideration (see Table 14). Part of the strategy behind material control falling last was that much of the supply base was directed by the final customer. Also, quality performance and productivity influenced the calculation to build each type of material scheduling system. Many of the tools used in this part of the LMS were already identified as key systems to manage the performance. The one system that had not been intended earlier was single piece flow since much of the process had been established to run any part at any time without the need to purge the system and recharge with new material of an alternate part number.

Aggregating the Tool Selections

See Table 15 for the aggregated selection of the LMS tools for deployment. While each of the specific requirements were individually analyzed to determine the best fit for tailoring the processes to fit the business needs, the entire deployment was quantitatively measured to understand the effort. Also, each tool will provide a tailored aspect of control, but the interactions among the LMS tools will provide the best form of control for the PMS of the business.

Table 14

Inventory Control/On-Time Delivery

	SMED	Pull	Level Schedule	Single Piece Flow	Standardized work	5s	TPM	VSM	Visual Management	Cellular Manufacturing	TQM	Kiazen	Poka-yoke
On Time Delivery (%)													
Materials/ Inventory (Inventory Turns) DOH	X			X	X			X			X	X	
Labor													
Productivity/ Throughput (OEE)													
Quality (%)													
Safety													

Table 15

Aggregated Tool Selection

	SMED	Pull	Level Schedule	Single Piece Flow	Standardized work	5s	TPM	VSM	Visual Management	Cellular Manufacturing	TQM	Kiazen	Poka-yoke
Safety (S1)					X	X			X				
On Time Delivery (IC)	X			X	X			X			X	X	
Quality (Q1) Scrap					X	X	X				X	X	X
Quality (Q2) tooling	X	X							X				X
Productivity/ Throughput (OEE)	X				X	X	X	X			X	X	X

Table 16

Resource Utilization Matrix (RUM)

Requirements	Resource									
	Maintenance	Manufacturing	Quality	Purchasing	Finance	Process Engineering	HR	IT	IE	Materials
S1 Standardized Work	S	P				S			P	S
S1 5s	S	P	S			S		S	P	P
S1 Visual Management	S	P	S			S	S	S	S	P
IT Single Piece Flow			S			P		S	P	P
IT SMED	P	P	S	S	S	S		S	P	S
IT Standardized Work		S	P			S			P	
IT TPM	P	S		S		P	S	S		
IT VSM				P	P					P
IT TQM	S	S	P	S	S	S	S	S	S	S
IT Kaizen	S	S	S	S	P	S	S	S	S	S
TO SMED	P	S	S	P		P		S	S	
TO Visual Management Floor		S	S			S	S	P	S	
TO Pull				P	S	P		S	S	
TO Poka-yoke			P			P				
Scrap Standardized Work		P	P			S		S	S	
Scrap 5s		S	P			S				S
Scrap TPM	P	P	S			S		P		
Scrap TQM	S	S	P		S			S		S
Scrap Kaizen	S	P	P							
Scrap Poka-yoke		S	P			P				
OEE SMED	S	P	S						S	
OEE 5s	S	P							S	
OEE Standardized Work	S	P	S						S	
OEE TPM	P	P	S			S		S	S	
OEE Visual Management		S	S		S				S	P
OEE TQM	P	P	P		S	P		S	S	
OEE Kaizen	S	P	P	S	P		S	S	P	P
OEE Poka-yoke			P			P				

Note. P- Primary system responsibility. S- Secondary system responsibility.
HR- Human Resources; IE- Industrial Engineering; IT-Information Technology

Because the different selections above were all made independently to focus on the specific, the aggregated selection was consolidated to a single table in which the process begins to determine the effort of the deployment requirements. The process begins with building the requirements utilization matrix (RUM). Table 16 shows the tool selection being transformed into RUM and the resource designation of the primary and secondary role responsibilities.

Table 17

Lean Deployment Utilization Setup Matrix

Requirements	Resource									
	Maintenance	Manufacturing	Quality	Purchasing	Finance	Process Engineering	HR	IT	IE	Materials
S1 Standardized Work	1	2				1			2	1
S1 5s	1	2	1			1		1	2	2
S1 Visual Management	1	2	1			1	1	1	1	2
IT Single Piece Flow			1			2		1	2	2
IT SMED	2	2	1	1	1	1		1	2	1
IT Standardized Work		1	2			1			2	
IT TPM	2	1		1		2	1	1		
IT VSM				2	2					2
IT TQM	1	1	2	1	1	1	1	1	1	1
IT Kaizen	1	1	1	1	2	1	1	1	1	1
TO SMED	2	1		2		2		1	1	
TO Visual Management Floor		1	1			1	1	2	1	
TO Pull				2	1	2		1	1	
TO Poka-yoke			2			2				
Scrap Standardized Work		2	2			1		1	1	
Scrap 5s		1	2			1				1
Scrap TPM	2	2	1			1		2		
Scrap TQM	1	1	2		1			1		1
Scrap Kaizen	1	2	2							
Scrap Poka-yoke		1	2			2				
OEE SMED	1	2	1						1	
OEE 5s	1	2							1	
OEE Standardized Work	1	2	1						1	
OEE TPM	2	2	1			1		1	1	
OEE Visual Management		1	1		1	2			1	2
OEE TQM	2	2	2		1	2		1	1	
OEE Kaizen	1	2	2	1	2		1	1	2	2
OEE Poka-yoke			2			2				

Note. P- Primary system responsibility = 2. S- Secondary system responsibility = 1.
HR- Human Resources; IE- Industrial Engineering; IT-Information Technology; PE-Process Engineering

The primary roles have two times the responsibility in this case scenario. The RUM expands by changing the coefficient to the designated number based on the roles and responsibility level, thus creating the lean deployment utilization setup matrix in Table 17.

Table 18

Lean Deployment Utilization Set-Up Matrix with LRM: Case Study

Requirements	Resource										Lean Readiness Multiplier
	Maintenance	Manufacturing	Quality	Purchasing	Finance	Process Engineering	HR	IT	IE	Materials	
S1 Standardized Work	1	2				1			2	1	2.8
S1 5s	1	2	1			1		1	2	2	2.8
S1 Visual Management	1	2	1			1	1	1	1	2	2.8
IT Single Piece Flow			1			2		1	2	2	2.8
IT SMED	2	2	1	1	1	1		1	2	1	2.8
IT Standardized Work		1	2			1			2		2.8
IT TPM	2	1		1		2	1	1			2.8
IT VSM				2	2					2	2.8
IT TQM	1	1	2	1	1	1	1	1	1	1	2.8
IT Kaizen	1	1	1	1	2	1	1	1	1	1	2.8
TO SMED	2	1		2		2		1	1		2.8
TO Visual Management Floor		1	1			1	1	2	1		2.8
TO Pull				2	1	2		1	1		2.8
TO Poka-yoke			2			2					2.8
Scrap Standardized Work		2	2			1		1	1		2.8
Scrap 5s		1	2			1				1	2.8
Scrap TPM	2	2	1			1		2			2.8
Scrap TQM	1	1	2		1			1		1	2.8
Scrap Kaizen	1	2	2								2.8
Scrap Poka-yoke		1	2			2					2.8
OEE SMED	1	2	1						1		2.8
OEE 5s	1	2							1		2.8
OEE Standardized Work	1	2	1						1		2.8
OEE TPM	2	2	1			1		1	1		2.8
OEE Visual Management		1	1		1	2			1	2	2.8
OEE TQM	2	2	2		1	2		1	1		2.8
OEE Kaizen	1	2	2	1	2		1	1	2	2	2.8
OEE Poka-yoke			2			2					2.8

Note. P- Primary system responsibility = 2; S- Secondary system responsibility = 1.

Table 19

Final Lean Deployment Utilization Matrix: Case Study

Requirements	Resource										Long- / Short-Term
	Maintenance	Manufacturing	Quality	Purchasing	Finance	Process Engineering	HR	IT	IE	Materials	
S1 Standardized Work	2.8	5.6				2.8			5.6	2.8	
S1 5s	2.8	5.6	2.8			2.8		2.8	5.6	2.8	70.0
S1 Visual Management	2.8	5.6	2.8			2.8	2.8	2.8	2.8	2.8	
IT Single Piece Flow			2.8			5.6		2.8	5.6	5.6	
IT SMED	5.6	5.6	2.8	2.8	2.8	2.8		2.8	5.6	2.8	
IT Standardized Work		2.8	5.6			2.8			5.6		
IT TPM	5.6	2.8		2.8		5.6	2.8	2.8			173.6
IT VSM				5.6	5.6					5.6	
IT TQM	2.8	2.8	5.6	2.8	2.8	2.8	2.8	2.8	2.8	2.8	
IT Kaizen	2.8	2.8	2.8	2.8	5.6	2.8	2.8	2.8	2.8	2.8	
TO SMED	5.6	2.8	2.8	5.6	2.8	5.6		2.8	2.8		
TO Visual Management Floor		2.8	2.8		5.6	2.8	2.8	5.6	2.8		86.8
TO Pull				5.6	2.8	5.6		2.8	2.8		
TO Poka-yoke			5.6			5.6					
Scrap Standardized Work		5.6	5.6			2.8		2.8	2.8		
Scrap 5s		2.8	5.6			2.8				2.8	
Scrap TPM	5.6	5.6	2.8			2.8		5.6			103.6
Scrap TQM	2.8	2.8	5.6		2.8			2.8		2.8	
Scrap Kaizen	2.8	5.6	5.6								
Scrap Poka-yoke		2.8	5.6			5.6					
OEE SMED	2.8	5.6	2.8						2.8		
OEE 5s	2.8	5.6							2.8		
OEE Standardized Work	2.8	5.6	2.8						2.8		
OEE TPM	5.6	5.6	2.8			2.8		2.8	2.8		
OEE Visual Management		2.8	2.8			5.6			2.8	5.6	156.8
OEE TQM	5.6	5.6	5.6		2.8	5.6		2.8	2.8	0.0	
OEE Kaizen	2.8	5.6	5.6	2.8			2.8	2.8	5.6	5.6	
OEE Poka-yoke			5.6			5.6					
Requirements Effort	64.4	100.8	95.2	30.8	33.6	84	16.8	50.4	70	44.8	
Effort Ranking (RBR)	5	1	2	9	8	3	10	6	4	7	

Table 18 applies the LRM from the Chapter 2 case study of the automotive engineering company. The LRM increases the effort requirements by taking the gap of the lean readiness assessment to a more mature state and bolstering the required based on the LRM.

The final combination of lean deployment utilization setup matrix from Table 18 with the LRM nets the final lean deployment utilization matrix in Table 19 where the columns can be added to look at the requirements for the individual departments. What this table provides is a quantitative measure of the effort by the respective departments. Table 19 can also provide insight into whether there would seem to be an overload or underutilization situation. This quantitative analysis gives visibility to effort, which past models had not considered and which can be key in identifying the problems that have caused LMS implementation failure rates as high as 95%. The simple nature of LMS can lead to an underestimation of the work and effort requirements necessary for implementation and the ability to leverage quantitative analysis to provide insight about the effort to increase the success rate of the implementation. The estimated effort to implement are shown in Table 20. The effort summary considers the level of effort, ranking the areas and detailing more comprehensively the actual deployment plan to increase the ability to meet the deployment expectations.

Table 20

LMS Tailoring Effort Summary

	Maintenance	Manufacturing	Quality	Purchasing	Finance	Process Engineering	HR	IT	IE	Materials	
Requirements Effort	64.4	100.8	95.2	30.8	33.6	84	16.8	50.4	70	44.8	590.8
Effort Ranking	5	1	2	9	8	3	10	6	4	7	
% of Effort	11%	17%	16%	5%	6%	14%	3%	9%	12%	8%	100%
Effort Hours	322	504	476	154	168	420	84	252	350	224	2954

The effort summary also creates and estimates the hours required to perform the deployment and provide visibility to working requirements. In this case, it should take 5 hours to support each effort requirement. This understanding allows for structuring the deployment and creating better communication, collaboration, and buy-in between the different owners.

Conclusions

The objective of the proposed LMS tailoring methodology was to create a quantitative approach to understanding the effort to deploy LMS by understanding of how companies are using PMS to control KPIs. This understanding is used to guide the tool selection process to manage, maintain, and control the variables at the closest point of influence through the LMS approach. The PMS and LMS requirements in this research represent a continuation from the LRA of Chapter 2 and are concerned with promoting the visibility and objectivity of requirements and tools analysis to tailor them in order to deliver the optimal performance control for a manufacturing company. The understanding of the effort and the hours estimated for the deployment allowed for structure planning of the deployment strategy as well interactions among groups to make this successful and ultimately meet the requirements to keep the business operator in a planned state or to realize improvement opportunities with more confidence and reaching an expected outcome.

Next Steps

This chapter proposes an objective methodology for tailoring and analyzing LMS. The effort summary should reduce the level of complexity in relation to the deployment by placing the focus on the planning and coordination between functional groups by understanding hours and their interactions.

CHAPTER 4:

FRAMEWORK FOR TAILORING LMS DEPLOYMENT

In the framework for implementing LMS, there are planning phases, which include understanding the performance needs of a company, the tools that optimally fit the control of the area, the existing practices of the business, as well as how those relate. The final step is the actual deployment process that encompasses the cultural practices of the company and how the tools and systems fit the required resources to support the implementation. Deployment is the "action of bringing resources to effective action" (Google, 2019). The deployment process begins with the critical areas of focus discussed in the previous chapter. The second phase in the structured tailoring methodology focuses on planning the resources to execute the deployment. The third phase involves considering the factors that affect the deployment strategy. The final phase concerns monitoring the performance of the company for continuous improvement. This process creates a sense of alignment between the actions necessary to meet performance requirements while also helping to identify sources of risk and opportunities for improvement (Dennis, 2006).

Deployment of Lean Manufacturing Systems

The order of deployment should generally begin with priority on safety to protect the most valuable resource, employees. The structured approach involves minimizing both regulated and unregulated risks as well as improving energy usage through work structures designed for conservation and efficiency (Anvari et al., 2011). Priority is generally given to quality, which is key to establishing a reputation among customers and involves the adherence to systems that repeat and reproduce well-made products. The third priority is productivity, or overall equipment effectiveness. The final priority is inventory turns and inventory management performance. This sequential process stems from the philosophy of showing that employees reside at the foundation of the process and are considered an investment (Mikami, 2005).

Prioritization of Deployment

Safety. Lean tends to focus on continuous improvement to establish a competitive advantage; however, reducing risks to employees and creating additional structures to manage safety should also be central to lean (Main et al., 2008). It is necessary to prioritize safety first because accidents are not random occurrences but derive from behavior, actions, and the culture of an organization across multiple levels (Ansari & Modarress, 1997). This priority brings benefits to lean manufacturing systems not only in the application of the tools but in the communication and focus on the people using the systems (Mikami, 2005). If the priority of reducing industrial hazards is not consistently reinforced, there is a risk that safety may be neglected (Jilcha & Kitaw, 2016). The objective of prioritizing safety is to maintain awareness of hazards, especially in scenarios in which there are significant changes or turnover in the labor force (Brown & O'Rourke, 2007).

The successful deployment of safety strategies not only decreases risk and hazard levels but also correlates with improved profitability and competitiveness. In many cases, when the concept of LMS deployment is absent from planning or deprioritized, issues arise relative to this devaluation. Worker compensation based on work-related accidents and missed time on the job are forms of waste that do not appear in the six big OEE losses or the seven types of waste in lean but negatively impact performance as well as human resources. For successful implementation, it is necessary to link the system deployment to and create a reinforcement of safety that offers a flow of information to adhere to expected practices and protocols (Becker, 2001). Also, reinforcing the importance of safety through a systematic approach makes it more effective by sharing and reviewing the information within an organization to inspire performance as well as align the expectations of all employees (Main et al., 2008).

Quality. Once there is a systematic approach to controlling employee safety, the next priority is quality performance. Quality performance affects multiple aspects of a business, ranging from external perceptions to variable cost control on the P&L. This deployment activity is set as the second priority if there are issues across multiple fronts in the business that need to be addressed. Quality is vital since it appears in annual reports at a high level, from a supply-side perspective, and concerns the expectations that customers set. External quality performance develops a company's reputation as stories of success to share in outward-facing annual company reports. The internal aspect of quality concerns the process capability of holding tolerances and manufacturing parts through the print and process the first time instead of contributing defective pieces that could be delivered to the customer while increasing the variable costs of manufacturing. If an unplanned issue cannot be handled concurrently within the designed system, modifications should be made to the quality system, protocols, or practices in an effort to provide control and structure to make improvements.

Productivity/OEE. The method is to build on characteristics from the previous section (i.e., safety and quality) to develop performance calculations for various lean systems. Productivity and items that relate to OEE serve as the next area of focus. For example, the productivity calculation for OEE is $A_t * P_t * Q_s$.

Available time = A_t = actual productive time (APT) / planned productive time

Performance = P_t = (total parts produced * ideal cycle time) / APT

Quality = Q_s = (total parts produced - scrap) / total parts produced

Where negative safety performance will affect the productivity of a business in the workforce, the APT and the unplanned effect of personnel can impact the equipment (Main et al., 2008). The calculation above provides insight about the variables in the productive state that influence the productivity and performance of the equipment.

The safety aspect of deployment also impacts employee morale, which from a quantifiable metric is challenging to correlate but has been shown to influence productivity (Ansari & Modarress, 1997). The quality aspect of deployment can be calculated more overtly based on the impact it has on the throughput of a production environment as the number of gross parts minus the defect scrap part net the quantity of parts capable of meeting customer requirements.

Inventory management. As with the three previous variables, there is a sequential process to have variables under control, which involves a process to understand the control aspects of the deployment and their influence on the inefficiencies of the various systems. In regard to finished inventory, the variables used to calculate the product levels derive from three aspects of the finished goods inventory (FGI). The FGI stems from the aggregate of cycle stock, buffer stock, and safety stock (Smalley, 2009).

Cycle stock: C_s= customer average daily demand * lead time in days to replenish.

Buffer stock: B_s = Customer demand variation % of cycle stock

Safety stock: S_s = based on a safety factor of the buffer stock and cycle stock. (Smalley, 2009, p. 22)

Similar to the previous section on productivity, the sequential effect of control can surface in how it affects the metrics of inventory control and how inefficiencies in safety, quality, and productivity increase the FGI and other inventory levels in order to protect the supply of customer requirements on time. If it is critical to lower inventory, then it is necessary to implement a comprehensive control across the different variables to develop a quantitative method for controlling the individual variables for robust inventory level control. This method will build a deeper understanding of influential variables and a more comprehensive and systemic approach to performance.

Considerations for Deployment Strategy

This research builds an understanding that certain aspects of a business motivate the effort to implement LMS. In many scenarios, the attempt to deploy LMS is rooted in struggles with performance and the need for significant change to substantially lower-than-expected performance. In determining what interventions need to be performed, the state of the business and the type of urgency that is required to meet the business concerns must be considered. In other words, priorities must be based on the specific business or case scenario. In a chaotic state or state of duress, the deployment planning process can accentuate the importance of communication and collaboration by connecting the work to a solution to numerous issues. The priorities discussed in this chapter concern a strategic and controlled change to a stable business that does not need immediate improvements to save the enterprise.

Various considerations were involved in developing the "Deployment Planned Effort Summary" in Chapter 3. The effort summary provides insight about the effort to deploy specific LMS strategies in conjunction with all other business requirements. Ultimately, greater knowledge of the required effort will allow practitioners to process more quantitatively and plan for the deployment strategy.

The facility size is one part of the deployment strategy. The number of processes under consideration is important as well as the size of the facility, but the size of the facility does not dictate the success of lean deployment (Abolhassani, Layfield, & Gopalakrishnan, 2016). The amount of deployment also correlates with expertise and level of lean experience, which Abolhassani et al. (2016) have found more prominently developed in larger organizations. Small and mid-sized enterprises (SMEs) have had the capacity to mobilize faster and deploy LMS with greater flexibility (Krishnamurthy & Yauch, 2007). SMEs have also had more difficulties implementing 5s, waste elimination, TPM, pull systems, and inventory control tools than larger organizations with more than 250 employees (Abolhassani et al., 2016). SMEs tend to implement LMS more reluctantly because of concerns about costs and a lack of understanding about the benefits of the deployment (Rose, Deros, Rahman, & . & Nordin, 2011). Empirical data have shown that the firm size, country of business, and GDP per capita influence the level of LMS deployment (Yang, Hong, & Modi, 2011). The consistent message from the literature is that SMEs are flexible, but larger organizations realize better performance from LMS (Abolhassani et al., 2016; Krishnamurthy & Yauch, 2007). This information highlights the benefits of understanding how effort and size impact the need to create a comprehensive system to fit a business environment.

The resources to support deployment are also key to a successful plan. Resource constraints to support LMS have created a barrier to the deployment process among SME manufacturing organizations (Rose et al., 2011). Large organizations might have more resources, but they also tend to have higher levels of expertise and experience (Abolhassani et al., 2016). Where SMEs tend to embrace more entrepreneurial motifs with quicker adoption and agility to make more abrupt changes, their smaller scale of resources can complicate overseeing and maintaining adopted techniques and processes (Bennis & O Toole, 1993).

Firm size impacts the LMS effect on performance. Smaller firms do not realize the same magnitude of market performance and financial gains as firms with resources on the larger side, (greater than 250 associates) (Yang et al., 2011). The resources of SMEs tend to have less confrontation during the change process and more simplified organizational structures (Krishnamurthy & Yauch, 2007). While SMEs tend to have greater flexibility and less resistance to change, they have other deficits in comparison to larger organizations relative to knowledge diversity, expertise, and ability to leverage external resources. In SMEs, resource limitation when implementing multiple lean systems can be a disadvantage (Djassemi, 2014). For the resource aspect of the deployment, one must understand whether the same associates are supporting multiple deployments in the planning process. This is premised in understanding the utilization of the resources that are focused on understanding work elements with the LMS design and protocol development to not inadvertently overload the associates involved.

The geographic location of the organization is another characteristic that needs to be considered and understood regarding how it will affect the deployment strategy. There are numerous academic studies that focus on LMS in different country regions, and while many of the tools are the same, culture does impact how and what systems influence performance (Cagliano, Blackmon, & Voss, 2001). Location and the demographics of the personnel affect how the systems are deployed (Tortorella, Piorando, & Tlapa, 2017).

The process defined in this research combines the considerations discussed previously along with an LRA to capture systems characteristics, organizational understanding, and aggregates of the tool selection process to understand the effort to define a deployment strategy for success. Understanding the considerations of facility size, quantity of human resources, and geographical context aid in defining deployment planning and understanding some contextual effects that can either be constructive or detrimental to the success of the deployment planning.

PDCA for Managing and Maintaining Systems

Toyota culture and the process of continuous improvement are built around the plan, do, check, act cycle (PDCA) that Edward Deming developed, which has formed the foundation of problem-solving as well as an LMS (Liker & Meier, 2006). The ultimate goal of utilizing LMS is the ability to move beyond solving problems in the short term to consistently focus on improving systems through planning (Sobek & Smalley, 2008). To leverage the PDCA process and continuously check systems to control and improve performance, there needs to be a structure in place to align performance control opportunities with improvement (Dennis, 2006).

The goal of this study is to develop an efficient way to communicate performance and adhere to these required systems. Matsuoa and Nakahara (2013) identified communication as important in planning and deployment. The developed systems and processes are aimed at continuous monitoring, along with the ability to modify and adopt practices that create visibility and improve performance opportunism (C. Johnson, 2016). While a straightforward process, the PDCA has proven to be effective and should not end with the deployment but become a reoccurring part of verifying the robustness of LMS (Sobek & Smalley, 2008).

Deployment Validation Case Study

The validation of the deployment process began with analyzing the effort summary from Chapter 3. Subsequently, the effort summary was combined with the logical sequencing that leveraged the cascading performance benefits to determine the deployment strategy. Based on that defined process, deployment progressed in the chronological order of employee safety, quality performance systems, productivity, and inventory control. This is also part of the process of tailoring the deployment plan to fit the specific business protocols and procedures required to control or improve systems.

Certain considerations must be applied and understood to craft a deployment strategy that ultimately leads to success relative to performance management. It is also essential to understand that monitoring and maintenance of the systems are required to ensure that they continue to fit the business needs after the deployment. Any changes in customer requirements can produce maintenance issues or modifications to provide the needed performance. Ideally, the system design would best meet this requirement and incorporate ways to monitor for adjustments in requirements, changes, and system calculations. For example, the calculations for inventory control include multiple components, such as scrap percentages and productivity calculations relative to equipment efficiency and unplanned downtime (Smalley, 2009). The input for calculating the variables can affect the areas in which performance metrics are measured. These changes can ultimately affect the ability of a company to meet safety, quality, and delivery requirements to a set customer.

The landscape for this example is consistent with the testing methodologies in this research, which focused on a 60-year-old automotive engineering company that was entering into the Tier-1 supply in the North American market. The deployment strategy the business needed for LMS derived from the aim of developing a robust control for managing performance and avoiding issues that could jeopardize the ability of the new Tier-1 to meet customer requirements.

The sequence of the deployment initially started with the “Deployment Effort Summary” in Table 21 and the “Final Deployment Effort Matrix” in Table 22 to examine the expected requirements for developing the systems deployment plan.

Table 21

Deployment Effort Summary

	Maintenance	Manufacturing	Quality	Purchasing	Finance	Process Engineering	HR	IT	IE	Materials	
Requirements Effort	64.4	100.8	95.2	30.8	33.6	84	16.8	50.4	70	44.8	590.8
Effort Ranking	5	1	2	9	8	3	10	6	4	7	
% of Effort	11%	17%	16%	5%	6%	14%	3%	9%	12%	8%	100%
Effort Hours	322	504	476	154	168	420	84	252	350	224	2954

The deployment plan includes the development of specific system requirements as well as the implementation rankings. Researchers could look at the deployments and attempt the entire LMS plan if all the required systems could be handled concurrently. Since this case study had a much smaller team and worker structure, the deployment of all the systems simultaneously would have been a significant and potentially overwhelming task. The system deployment had the flexibility to tier the areas where the systems for controls would be deployed based on the logical sequence of the implementation. To be successful and comprehensive, it is estimated that deployment would require about 1.5 years for a full-time employees (FTE) to implement all the systems and leverage the cascading effect of building the system successively. Assuming 40 work hours per week and 52 working weeks per year, each FTE translates to 2,080 hours per year. For 1.5 years, this translates to 3,120 hours. As for allocating these hours, given that we have estimated the requirement effort to be 590.8 units, it translates to 3,120 / 590.8 or 5.28 hours / effort unit.

Table 22

Final Deployment Effort Matrix

Requirements	Resource										
	Maintenance	Manufacturing	Quality	Purchasing	Finance	Process Engineering	HR	IT	IE	Materials	
S1 Standardized Work	2.8	5.6				2.8			5.6	2.8	70.0
S1 5s	2.8	5.6	2.8			2.8		2.8	5.6	2.8	
S1 Visual Management	2.8	5.6	2.8			2.8	2.8	2.8	2.8	2.8	
IT Single Piece Flow			2.8			5.6		2.8	5.6	5.6	173.6
IT SMED	5.6	5.6	2.8	2.8	2.8	2.8		2.8	5.6	2.8	
IT Standardized Work		2.8	5.6			2.8			5.6		
IT TPM	5.6	2.8		2.8		5.6	2.8	2.8			
IT VSM				5.6	5.6					5.6	
IT TQM	2.8	2.8	5.6	2.8	2.8	2.8	2.8	2.8	2.8	2.8	
IT Kaizen	2.8	2.8	2.8	2.8	5.6	2.8	2.8	2.8	2.8	2.8	
TO SMED	5.6	2.8	2.8	5.6	2.8	5.6		2.8	2.8		86.8
TO Visual Management Floor		2.8	2.8		5.6	2.8	2.8	5.6	2.8		
TO Pull				5.6	2.8	5.6		2.8	2.8		
TO Poka-yoke			5.6			5.6					
Scrap Standardized Work		5.6	5.6			2.8		2.8	2.8		103.6
Scrap 5s		2.8	5.6			2.8				2.8	
Scrap TPM	5.6	5.6	2.8			2.8		5.6			
Scrap TQM	2.8	2.8	5.6		2.8			2.8		2.8	
Scrap Kaizen	2.8	5.6	5.6								
Scrap Poka-yoke		2.8	5.6			5.6					
OEE SMED	2.8	5.6	2.8						2.8		
OEE 5s	2.8	5.6							2.8		
OEE Standardized Work	2.8	5.6	2.8						2.8		
OEE TPM	5.6	5.6	2.8			2.8		2.8	2.8		
OEE Visual Management		2.8	2.8			5.6			2.8	5.6	
OEE TQM	5.6	5.6	5.6		2.8	5.6		2.8	2.8	0.0	
OEE Kaizen	2.8	5.6	5.6	2.8			2.8	2.8	5.6	5.6	
OEE Poka-yoke			5.6			5.6					156.8
Requirements Effort	64.4	100.8	95.2	30.8	33.6	84	16.8	50.4	70	44.8	
Effort Ranking (RBR)	5	1	2	9	8	3	10	6	4	7	

The combination of the estimation for the time implementation and the effort summary provided a basis to create a multiplier to turn the effort summary number into a metric in planning the deployment. The multiplier of 5.28 hours per effort unit was rounded to a whole number of 5 and was multiplied by the effort requirement to determine the planning hours based upon 2,954 hours to deploy all the systems determined in the selection process methodology (see Chapter 3) and used in the case study analysis. This estimate of hours informed the planning aspect of the systems through the deployment and usage of controlling performance. The effort matrix helps to provide key lines of communication and interaction to create a collaborative system of development. The effort summary gives an indication of planning time as well as vetting to gut-check the principles inside the systems that control performance. The primary element of the deployment focused on collaborative planning and normalizing the planning effort through implementation, which is not an event as much as the principle for managing businesses. The systems are not forced and have repeatable communication of functionality as well as adherence to procedures and protocols.

Cascading the first LMS over 4-month intervals allowed for a logical progression to focus on planning and thoroughness instead of forcing the design and deployment. The second reason for selecting the 4-month intervals was that the same personnel leading the deployments were supporting most of the system development work. The sequential process built unfragmented focus and supplied resources to match the system under development while taking into consideration the fact that each team member had other responsibilities in addition to LMS deployment. While individual members of the team were experienced in lean systems, this project offered them the first opportunity to become champions of the deployment strategy.

The next part of deployment planning determined the method for dividing the systems into smaller increments. The original idea was to look at the functional departments in Table 21 to understand the effort requirements as a total and tailor the deployment based on resources available. However, in this deployment, the effort across the function relative to a specific variable appeared to be the more effective way of tailoring the deployment to focus on the area of performance control rather than the total functional group effort. As discussed earlier, the deployment prioritized the sequence by cascading the effect variables for performance control as related to each area. The lean deployment system's complexity lessened by isolating the variables that were independent and building the system around those determined variables.

Table 23

Lean Tool Selection: Safety

	SMED	Pull	Level Schedule	Single Piece Flow	Standardized work	5s	TPM	VSM	Visual Management	Cellular Manufacturing	TQM	Kiazen	Poka-yoke
On Time Delivery (%)													
Materials/													
Inventory DOH													
Labor													
Productivity/ Throughput (OEE)													
Quality (%)													
Safety (recordables)					X	X			X				

The logical sequencing held that safety performance control deployment would be the starting area. According to this strategy, the systems deriving from the tool selection process in Chapter 3 would be isolated and studied for the 4-month deployment planning time. As seen in Table 23, the safety system tool section has primary and secondary areas of support. The table highlights the systems required to support, manage, and control performance around safety. The lean systems in relation to the control of safety performance focused on the lean tools of standardized work instruction, 5s, work place organization, and visual management to help associates safeguard and organize the work environment. These areas stretched over 4-months, and hours were scheduled based on the effort matrix and the functional department that had obligations work on deployment planning to support the variable of safety.

Tables 24–27 reveal how the systems were divided into categories and rebuilt to create a quantitative picture of work planning. The main point here is less about understanding the number of hours required but about displaying a method to create the planning and communication aspects of the system. This case was developed by planning effort so that 80%–90% or more goes into planning and collaboration to ensure that performance control is effective. The process for determining the primary and secondary planning and deployment roles is shown in the resource utilization matrix (Table 24).

Table 24

Safety: Resource Utilization Matrix

Requirements	Resource									
	Maintenance	Manufacturing	Quality	Purchasing	Finance	Process Engineering	HR	IT	IE	Materials
S1 Standardized Work	S	P				S			P	S
S1 5s	S	P	S			S		S	P	P
S1 Visual Management	S	P	S			S	S	S	S	P

Note. P- Primary system responsibility; S- Secondary system responsibility.

Table 25 shows the next step in analyzing the individual safety-related systems to support the deployment by starting to incorporate the values for the primary and secondary roles.

Table 25

Safety: Lean Deployment Setup Matrix

Requirements	Resource										
	Maintenance	Manufacturing	Quality	Purchasing	Finance	Process Engineering	HR	IT	IE	Materials	Lean Readiness Multiplier
S1 Standardized Work	1	2				1			2	1	2.8
S1 5s	1	2	1			1		1	2	1	2.8
S1 Visual Management	1	2	1			1	1	1	1	1	2.8

Note. P- Primary system responsibility = 2; S- Secondary system responsibility = 1.

The next step in the modeling (Table 26) covers utilizing the LRM in different functional groups as well as summarizing the effort to identify which groups have the greatest workloads.

Table 26

Safety: Final Lean Deployment Matrix

Requirements	Resource									
	Maintenance	Manufacturing	Quality	Purchasing	Finance	Process Engineering	HR	IT	IE	Materials
S1 Standardized Work	2.8	5.6				2.8			5.6	2.8
S1 5s	2.8	5.6	2.8			2.8		2.8	5.6	2.8
S1 Visual Management	2.8	5.6	2.8			2.8	2.8	2.8	2.8	2.8
Requirements Effort	8.4	16.8	5.6	0	0	8.4	2.8	5.6	14	8.4
Effort Ranking (RBR)	3	1	4	6	6	3	5	4	2	3

The methodology divides each element into smaller groups and generates a greater understanding of who will take ownership of each aspect of the deployment. Understanding the manufacturing process, the complicated measurements involved in gauging requirements, and the weight of the products requires abundant input from the specified functional groups that interact with the product, the engineering group that designed the process and set the print requirements for manufacturing, and the department that will be running the operations and leading most of the quality checks. The material storage, movement of material, and loading and unloading of shipments require detailing and standardized processes. Understanding how to de-energize equipment and leverage visual tools ensures that the area of hazard has some form of precautionary visibility when any associates are working or entering equipment; it must be clear, at a glance, that proper precautions are taking place. Table 26 and the effort summary in Table 27 create structures surrounding the interactions and collaboration that aid in the deployment planning and execution.

Table 27

Safety: Deployment Effort Summary

Requirements	Resource										
	Maintenance	Manufacturing	Quality	Purchasing	Finance	Process Engineering	HR	IT	IE	Materials	
Requirements Effort	8.4	16.8	5.6	0	0	8.4	2.8	5.6	14	8.4	
Effort Ranking	3	1	4	6	6	3	5	4	2	3	
% of Effort	12%	24%	8%	0%	0%	12%	4%	8%	20%	12%	100%
Effort Hours	42	84	28	-	-	42	14	28	70	42	350

The deployment covers the planning and implementation of the procedures and protocols. It is used as a guide to ensure that the proper interactions are happening. In this case, the idea was to level the work load as much as possible with a slight increase towards the end when the processes from the deployment were utilized and being verified for functionality.

The hours from the Table 27 are not meant to be a guide to facilitate communication between the departmental groups. The hours serve as an estimate to design and deploy the systems. Since the process occurs over a length of time, it allows for increased vetting. In Table 28, the actual planning and deployment time slightly increased from the effort summary in Table 27 to 360 hours to foster the inner communication between groups to deliver functional base systems. The hours serve as communication and collaboration meter with the goal of implementing systems that support PMS control as well as capturing a starting point from whence changes occur. The data from modeling the tool selection in the final deployment matrix and the effort summary benefit communication to leadership and offer support in the form of quantitative measures.

Table 28

Safety: Actual Deployment Effort Planning

Functional Group	Dec	Jan	Feb	Mar	Total
Maintenance	12.0	8.0	8.0	16.0	44.0
Manufacturing	4.0	4.0	24.0	52.0	84.0
Process Engineering	8.0	8.0	16.0	16.0	48.0
Quality	4.0	8.0	12.0	12.0	36.0
IT & Materials (combined functional group during this part of the deployment)	16.0	16.0	16.0	16.0	64.0
Human Resources (HR)	4.0	4.0	8.0	4.0	20.0
Industrial Engineering (IE)	16.0	16.0	16.0	16.0	64.0
Total	64.0	64.0	100.0	132.0	360.0

The next aspect of performance control was the area of quality, which ensures that the shipped parts meet customer requirements. The focus on verifying that all shipped parts meet customer requirements drove the manufacturing philosophy to reduce the risk to produce defective manufactured parts. Table 29 shows the systems were analyzed to focus specifically on making parts correctly the first time. Since the cost of each piece is high, losses can damage the performance budget. The key LMS tools for focusing on the quality systems performance were standardized work, 5s, TPM, TQM, kaizen, and Poka-yoke.

Table 29

Scrap: Lean Tool Selection

	SMED	Pull	Level Schedule	Single Piece Flow	Standardized work	5s	TPM	VSM	Visual Management	Cellular Manufacturing	TQM	Kiazen	Poka-yoke
On Time Delivery (%)													
Materials/Inventory (Inventory Turns) DOH													
Labor													
Productivity/Throughput (OEE)													
Quality (%)					X	X	X				X	X	X
Safety													

Tables 30 represents the initiation of the modeling process and determines the primary and secondary roles for the deployment planning.

Table 30

Scrap: Resource Utilization Matrix

Requirements	Resource									
	Maintenance	Manufacturing	Quality	Purchasing	Finance	Process Engineering	HR	IT	IE	Materials
Scrap Standardized Work		P	P			S		S	S	
Scrap 5s		S	P			S				S
Scrap TPM	P	P	S			S		P		
Scrap TQM	S	S	P		S			S		S
Scrap Kaizen	S	P	P							
Scrap Poka-yoke		S	P			P				

Note. P- Primary system responsibility; S- Secondary system responsibility.

The modeling process is continued as the lean deployment setup matrix, which is populated with values for the primary and secondary users (see Table 31)

Table 31

Scrap: Lean Deployment Setup Matrix

Requirements	Resource										Lean Readiness Multiplier
	Maintenance	Manufacturing	Quality	Purchasing	Finance	Process Engineering	HR	IT	IE	Materials	
Scrap Standardized Work		2	2			1		1	1		2.8
Scrap 5s		1	2			1				1	2.8
Scrap TPM	2	2	1			1		2			2.8
Scrap TQM	1	1	2		1			1		1	2.8
Scrap Kaizen	1	2	2								2.8
Scrap Poka-yoke		1	2			2					2.8

Note. P = Primary system responsibility; S = Secondary system responsibility.

The final lean deployment model in Table 32 includes the applied difficulty multiplier and summarizes the level of effort.

The *Effort Summary* in Table 33 indicates that manufacturing quality and process engineering required the most significant level of support in developing the systems related to controlling scrap. Those systems required significantly more effort in planning the deployment.

Table 32

Scrap: Final Lean Deployment Matrix

Requirements	Resource										Lean Readiness Multiplier
	Maintenance	Manufacturing	Quality	Purchasing	Finance	Process Engineering	HR	IT	IE	Materials	
Scrap Standardized Work		5.6	5.6			2.8		2.8	2.8		2.8
Scrap 5s		2.8	5.6			2.8				2.8	2.8
Scrap TPM	5.6	5.6	2.8			2.8		5.6			2.8
Scrap TQM	2.8	2.8	5.6		2.8			2.8		2.8	2.8
Scrap Kaizen	2.8	5.6	5.6								2.8
Scrap Poka-yoke		2.8	5.6			5.6					2.8
Requirements Effort	11.2	25.2	30.8	0	2.8	14.0	0	11.2	2.8	5.6	

Table 33

Scrap: Deployment Effort Summary

	Maintenance	Manufacturing	Quality	Purchasing	Finance	Process Engineering	HR	IT	IE	Materials	
Requirements Effort	11.2	25.2	30.8	0	2.8	14.0	0	11.2	2.8	5.6	
Effort Ranking	4	2	1	7	6	3	7	4	6	5	
% of Effort	11%	24%	30%	0%	3%	14%	0%	11%	3%	5%	100%
Effort Hours	56	126	154	-	14	70	-	56	14	28	518

The quality systems control with the LMS modification used planning hours to structure the planning and deployment of time management. The interactions occurred by dedicating the time for planning, and collaboration was used to control the deployment so that the process would not be rushed. Cascading the process helps to foster long-term thinking about building thorough and optimal systems structures while not minimizing the deployment time during the micro-level focused aspects of the LMS. Again, it took slightly more hours to develop and deploy the system than expected. The *Final Lean Deployment Matrix* in Table 32 and the *Effort Summary* in Table 33 estimated the hours at 518. The actual time spent on planning was 532 hours, as seen in Table 34.

Table 34

Scrap: Deployment of Hourly Planning

Functional Group	Apr	May	Jun	Jul	Total
Maintenance	10	10	18	18	56
Manufacturing	40	24	28	32	124
Quality	48	44	32	32	156
Purchasing	0	0	0	0	0
Finance	4	4	4	4	16
Process Engineering	24	16	16	16	72
IT	16	16	16	16	64
IE	0	0	4	12	16
Materials	4	4	10	10	28
Totals	146	118	128	140	532

The tooling control was as a specific area of focus that related directly to the control of scrap. This aspect of deployment became critical because tools undoubtedly wear and need to be changed. The process cannot afford to remake defective parts, so the first part must fall within specifications. This process in the deployment lands within the logically sequencing to develop controls that have a cascading effect and progress through the LMS deployment process. The key strategies for controlling the tooling needs and preparation for tooling changes were visual management for tooling, error proofing to prevent installations of incorrect tools, and quick-change processes to minimize the need to offset the pull system to replenish tools upon usage.

As part of the tailoring process and the considerations discussed in the previous chapter, modifications can be made to optimize the deployment. Through learning based on previous deployments it is feasible to modify the Primary and Secondary work efforts for this deployment because it became a much simpler deployment. It can be seen that the primary and secondary responsibilities were reduced, which essentially lowered the effort requirements to manage this deployment. This is an example of the benefits of the framework to communicate interactions and understand if the deployment strategy needs to be modified to meet requirements. Due to following the logical sequencing it provides the visibility to reevaluate each deployment in an individual state. Also, the Quality-Scrap aspect of the deployment had considerable overlap to this specific focus.

Table 35

Tooling: Lean Tool Selection

	SMED	Pull	Level Schedule	Single Piece Flow	Standardized Work	5s	TPM	VSM	Visual Management	Cellular Manufacturing	TQM	Kiazen	Poka-yoke
On Time Delivery (%)													
Materials/ Inventory (Inventory Turns) DOH													
Manpower													
Productivity/ Throughput (OEE)	X	X							X				X
Quality (%)													
Safety													

The modeling of the primary and secondary responsibilities for controlling machine tool selection is displayed in Table 36.

Table 36

Tooling: Resource Utilization Matrix

Requirements	Resource									
	Maintenance	Manufacturing	Quality	Purchasing	Finance	Process Engineering	HR	IT	IE	Materials
TO SMED		S		S		P			S	
TO Visual Management Floor		S	S			S			S	
TO Pull				S	S	P		S	S	
TO Poka-yoke			S			P				

Note. P = Primary system responsibility; S = Secondary system responsibility.

The next step in the model is shown in Table 37 where the values are entered in the Resource Utilization Matrix to proceed with the modeling process and account for LRM.

Table 37

Tooling: Lean Deployment Setup Matrix

Requirements	Resource										Lean Readiness Multiplier
	Maintenance	Manufacturing	Quality	Purchasing	Finance	Process Engineering	HR	IT	IE	Materials	
TO SMED		1		1		2			1		2.8
TO Visual Management Floor		1	1			1			2		2.8
TO Pull				1	1	2		1	1		2.8
TO Poka-yoke			1			2					2.8

Note. P = Primary system responsibility; S = Secondary system responsibility.

Multiplying the LRM against the Lean Deployment Setup Matrix creates the Final Lean Deployment Matrix (see Table 38). This chart established the first understanding of the effort and work to deploy the systems to control tooling from a scrap control perspective. The tailoring that occurred in between the initial tool selection and the deployment allowed the effort requirement to be lowered through the reduction of primary and secondary responsibilities to support this aspect of the deployment. The deployment strategy was reduced from effort of 86.6 from new effort of 53.2. This reduction just provides a modified plan based on data more close to actual timing of the deployment.

Table 38

Tooling: Final Lean Deployment Matrix

Requirements	Resource										
	Maintenance	Manufacturing	Quality	Purchasing	Finance	Process Engineering	HR	IT	IE	Materials	
TO SMED		2.8		2.8		5.6			2.8		
TO Visual Management Floor		2.8	2.8			2.8			5.6		
TO Pull				2.8	2.8	5.6		2.8	2.8		
TO Poka-yoke			2.8			5.6					53.2
Requirements Effort	0	5.6	5.6	5.6	2.8	19.6	0	2.8	11.2	0	0
Effort Ranking (RBR)	-	3	3	3	4	1	-	4	2	-	-

The deployment of the system to control the tooling was estimated at 266 hours of work, which relates to planning in Table 39. The *Final Lean Deployment Matrix* shows that the primary work content revolves around the manufacturing engineering group while the other departments were secondary support functions. This deployment appears to be less complex but still requires numerous interactions between functional groups.

Table 39

Tooling: Deployment Effort Summary

	Maintenance	Manufacturing	Quality	Purchasing	Finance	Process Engineering	HR	IT	IE	Materials	
Requirements Effort	0	5.6	5.6	5.6	2.8	19.6	0	2.8	11.2	0	
Effort Ranking	-	3	3	3	4	1	-	4	2	-	
% of Effort	0%	11%	11%	11%	5%	37%	0%	5%	21%	0%	100%
Effort Hours	-	28	28	28	14	98	-	14.00	56.0	-	266

The LMS tooling deployment was simpler than the safety and quality control deployments, which is why it occurred over a shorter duration. The actual hours used for the tooling deployment was 272 as shown in Table 40, in comparison to 266 hours predicted in the modeling of the LMS for the tooling process.

Table 40

Tooling: Deployment Hourly Planning

Functional Group	Sep	Oct	Total
Maintenance	0	0	0
Manufacturing	16	16	32
Quality	12	12	24
Purchasing	12	16	28
Finance	0	8	8
Human Resources (HR)	0	0	0
Process Engineering	48	64	112
IT	8	12	20
IE	24	24	48
Total	120	152	272

With systems in place to control for safety and scrap, the next aspect of the system was productivity, or the ability to meet customer demands. The customer demand for the first 5 years of the program was set at 32/day. The internal budgets had been set on manufacturing the parts during one shift. The manufacturing process had multiple pieces of shared equipment and had a non-linear approach to the manufacturing process due to the lower production volumes for standard OEM production volumes. The tools selection to support these business requirements can be seen in Table 41.

Table 41

Productivity: Lean Tool Selection

	SMED	Pull	Level Schedule	Single Piece Flow	Standardized work	5s	TPM	VSM	Visual Management	Cellular Manufacturing	TQM	Kiazen	Poka-yoke
On Time Delivery (%)													
Materials/ Inventory (Inventory Turns) DOH													
Manpower													
Productivity/ Throughput (OEE)	X				X	X	X		X		X	X	X
Quality (%)													
Safety													

As the deployment process planning took place, the tool selection was modeled in the *Resource Utilization Matrix*. The primary and secondary planning responsibilities appear in Table 42.

As a continuation of the deployment planning methodology, the *Lean Deployment Setup Matrix* is populated with the values for the difference between primary and secondary effort responsibilities (see Table 43).

Table 42

Productivity: Resource Utilization Matrix

	Maintenance	Manufacturing	Quality	Purchasing	Finance	Process Engineering	HR	IT	IE	Materials
OEE SMED	S	P	S						S	
OEE 5s	S	P							S	
OEE Standardized Work	S	P	S						S	
OEE TPM	P	P	S			S		S	S	
OEE Visual Management		S	S		S				S	P
OEE TQM	P	P	P		S	P		S	S	
OEE Kaizen	S	P	P	S	P		S	S	P	P
OEE Poka-yoke			P			P				

Note. P = Primary system responsibility; S = Secondary system responsibility.

Table 43

Productivity: Lean Deployment Setup Matrix

Requirements	Resource										Lean Readiness Multiplier
	Maintenance	Manufacturing	Quality	Purchasing	Finance	Process Engineering	HR	IT	IE	Materials	
OEE SMED	1	2	1						1		2.8
OEE 5s	1	2							1		2.8
OEE Standardized Work	1	2	1						1		2.8
OEE TPM	2	2	1			1		1	1		2.8
OEE Visual Management		1	1			2			1	2	2.8
OEE TQM	2	2	2		1	2		1	1		2.8
OEE Kaizen	1	2	2	1			1	1	2	2	2.8
OEE Poka-yoke			2			2					2.8

Note. P = Primary system responsibility; S = Secondary system responsibility.

The methodology incorporated the LRM in Table 44. The productivity requirements were different from a deployment perspective, as the manufacturing system had to be optimized to meet the requirements. This optimization relied on kaizen to operate the system. That said, the previous systems were deployed in a proactive manner to guide and control performance. The deployment was consistent with the selection process and the modeling in Table 44, which indicated that kaizen would require the most effort. Many of the other systems being deployed developed areas that had already been addressed in previous deployments but not specifically aimed at optimizing the throughput of the systems. Table 46 indicates that the productivity deployment took 816 hours, which is 32 more than what was modeled in the *Effort Summary* in Table 45 for the productivity.

Table 44

Productivity: Final Lean Deployment Matrix

Requirements	Resource										
	Maintenance	Manufacturing	Quality	Purchasing	Finance	Process Engineering	HR	IT	IE	Materials	
OEE SMED	2.8	5.6	2.8						2.8		
OEE 5s	2.8	5.6							2.8		
OEE Standardized Work	2.8	5.6	2.8						2.8		
OEE TPM	5.6	5.6	2.8			2.8		2.8	2.8		
OEE Visual Management		2.8	2.8			5.6			2.8	5.6	
OEE TQM	5.6	5.6	5.6		2.8	5.6		2.8	2.8	0.0	
OEE Kaizen	2.8	5.6	5.6	2.8			2.8	2.8	5.6	5.6	
OEE Poka-yoke			5.6			5.6					156.8
Requirements Effort	22.4	36.4	28	2.8	2.8	19.6	2.8	8.4	22.4	11.2	
Effort Ranking (RBR)	3	1	2	7	7	4	7	6	3	5	

Table 45

Productivity: Deployment Effort Summary

	Maintenance	Manufacturing	Quality	Purchasing	Finance	Process Engineering	HR	IT	IE	Materials	
Requirements	22.4	36.4	28	2.8	2.8	19.6	2.8	8.4	22.4	11.2	
Effort Ranking	3	1	2	7	7	4	7	6	3	5	
% of Effort	14%	23%	18%	2%	2%	13%	2%	5%	14%	7%	100%
Effort Hours	112	182	140	14	14	98	14	42	112	56	784

Table 46

Productivity: Deployment Hourly Planning

Functional Group	Dec	Jan	Feb	Mar	Total
Maintenance	20	36	28	28	112
Manufacturing	36	56	56	64	212
Quality	44	32	40	40	156
Purchasing	0	0	8	8	16
Finance	4	4	4	4	16
Human Resources (HR)	12	12	8	8	40
Process Engineering	24	24	24	24	96
IT	10	10	10	10	40
IE	28	28	28	28	112
Materials	4	4	4	4	16
Totals	182	206	210	218	816

The final part of the deployment concerned inventory as a facet of lean deployment. To reduce and quickly turnover inventory, a company must minimize lead time by developing processes and information flow to receive a request, respond, and deliver a product to the customer in a minimal amount of time. However, this work was not designed to save a weak business or eliminate errors in business development across the commercial agreement spectrum.

The current customer for the product made an abrupt change in strategy for future supply and discounted the vehicle platform in which the parts were supplied. Because of this change, the ability to create the final aspect of the LMS deployment was negated. While the next phase of deployment was inventory control and the ability to meet customer demands, holding the proper amount of inventory for a supporting productive state was not required due to the strategic direction change of the OEM.

Results

The results from the systems correlated with performance control. From a safety perspective, the work done to the system provided standards and expectations that served as a constant reminder of the importance of adhering to requirements. Tables 47 and 48 indicate that there is consistency with safety performance and that there is a purposeful system available to support that area. The goal for safety should always be zero recordables and first aids since the objective is *never* to have employees injured while performing work activities. The next priority is to have methods in place to control and understand performance itself.

Table 47

Safety: Recordables

Safety- Recordables	Incidents
Nov-18	0
Dec-18	0
Jan-19	0
Feb-19	0
Mar-19	0
Apr-19	0
May-19	0
Jun-19	0
Jul-19	0
Aug-19	0
Sep-19	0

Table 48

Safety: Employee First Aids

Safety- First Aids	Incidents
Nov-18	0
Dec-18	0
Jan-19	0
Feb-19	0
Mar-19	0
Apr-19	0
May-19	0
Jun-19	0
Jul-19	0
Aug-19	0
Sep-19	0

In many cases, safety metrics are not well-publicized in regard to performance, but in the prioritization of deployment, they cascade to other areas to negatively affect performance. The goal of this dissertation was to develop a methodology using lean systems to control performance. The quality performance metric gets significant attention and is typically leveraged in companies' annual reports to highlight their success. In this case, the quality of performance overall was stable and in control. The metrics in Tables 48 and 49 indicate that there were no complaints from the customer during the start of production as a new Tier 1 supplier.

A second metric concerning supplier quality performance is the number of defects measured in parts per million. This metric was also at zero nearly one year into production, which established a sense of confidence at the OEM (see Table 50).

Table 49

Quality: Customer Complaints

Customer Complaints	#
Nov-18	0
Dec-18	0
Jan-19	0
Feb-19	0
Mar-19	0
Apr-19	0
May-19	0
Jun-19	0
Jul-19	0
Aug-19	0
Sep-19	0

Table 50

Quality: Part Per Million Defects to Customer

PPM Defects	PPM
Nov-18	0
Dec-18	0
Jan-19	0
Feb-19	0
Mar-19	0
Apr-19	0
May-19	0
Jun-19	0
Jul-19	0
Aug-19	0
Sep-19	0

A third metric concerned scrap generated during the manufacturing process. The internal budgets for scrap fell at 10% for calendar year 1, 6% for years 2 and 3, and 3% in years 4 and 5. As can be seen in Table 51, the LMS quickly brought the internal scrap performance below the budget performance for year 1 and to the expected level for advanced stages.

Table 51

Quality: Internal Scrap

SCRAP	% Pcs Msg
Jan-19	21.6
Feb-19	4.4
Mar-19	3.7
Apr-19	3.3
May-19	1.6
Jun-19	3.6
Jul-19	1.9
Aug-19	2.2
Sep-19	0.3

The next part of the sequence concerned productivity and the effectiveness of the equipment as well as its ability to meet the TAKT time of the customer. This part of the deployment process was required for improvement because the manufacturing process in its current state, based on many test runs, was not capable of meeting the demands of the customer without using significant overtime or resources. The data in Figure 2 indicate that the effectiveness of the equipment significantly increased because the LMS deployment brought the process to a state in which the ability to supply products to the customer became attainable and so would not start the process struggling to meet the demands of the customer.

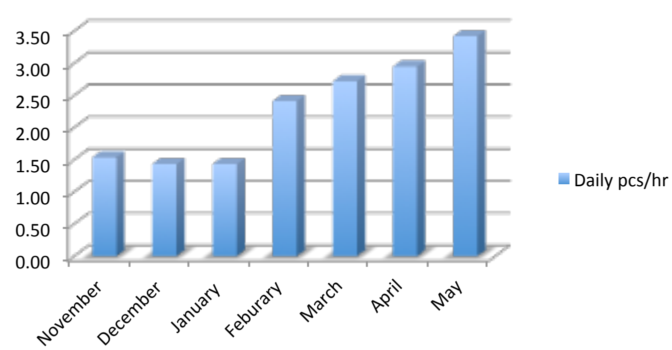

Figure 2. Productivity: System throughput (parts/hour).

With the improvement to productivity, the ability to meet customer demands was soundly established. The throughput of the system was validated to meet the demands of the customer, which appears in the customer track metric of on-time delivery in Table 52.

Table 52

Productivity: Ontime Delivery to Customer

Ontime Delivery	%
Dec-18	100%
Jan-19	100%
Feb-19	100%
Mar-19	100%
Apr-19	100%
May-19	100%
Jun-19	100%
Jul-19	100%
Aug-19	100%
Sep-19	100%

Conclusion

The inconsistent ability to deploy lean manufacturing systems has been a struggle since its introduction in North America (Davies, 2005). This process creates more of an evolutionary approach to building, controlling, and improving system infrastructure. It is important to note that Toyota built their infrastructure organically to serve their specific business needs following the effects of World War II (Wilson, 2013). The complexity of products in development will continue to increase, which will require enhanced precision, further complicating the ability of companies to manufacture goods (Williams, 2013). The strategic selection of control methods using LMS and the engagement of employees enhances performance (Bellsario & Pavlov, 2018). This work also extends the research validating the interaction (bundles) of LMS tools to provide improved performance and comprehensive control in focused areas (Shah & Ward, 2003).

CHAPTER 5:

SUMMARY, IMPLICATIONS, AND CONCLUSIONS

Summary of Results

Most scholarly work on deploying Lean Manufacturing Systems (LMS) was designed to improve the value-added time and reduce non-value-added time to increase stability and improve performance. However, the research in this dissertation provides methods for an LMS deployment from a planning and readiness perspective. The methods show that, through the application of the methodologies in an automotive setting, understanding readiness and tailoring the tools of LMS to the specific business creates robust planning and deployment systems. The deployment also considered the interactions among the LMS tools to better control performance in specified areas of focus. The process incorporated an assessment of the readiness of a facility or company to enact the key characteristics of LMS to determine the inconsistencies or gaps that could hurt the deployment performance. This method created a quantitative and objective approach to understand, from the cultural perspective of the change, the ability to tailor the plan through in the areas of: (a) problem-solving practices, (b) the level of employee empowerment, (c) training and employee development practices, and (d) quality system management practices and philosophies used prior to an LMS deployment.

The next part of the research utilized LMS as a Performance Management System (PMS) rather than solely as an array of continuous improvement practices. This process extended the work of Shah and Ward (2002, 2007) to leverage the interactions of multiple lean tools to control performance in key areas of: (a) safety, (b) quality, (c) productivity, and (d) inventory control to show that multiple tools provide robust control if selected and tailored to a business at a granular level. The methods in the dissertation research provided a quantitative and objective approach to add a tailoring aspect to the planning and deployment of LMS but also utilized effort requirements as support resources. This process could require additional employees to support the effort or, as in the example, cascade the deployment over a lengthier time by focusing on planning and vetting the system needs, which are requirements for both PMS and LMS to support the business performance.

Discussion of the Results

The methodology in this dissertation was designed to begin before work was completed and prior to deploying LMS, or, if a previous attempt was not successful, to reattempt LMS with a more structured approach based on the idea that planning the deployment using a quantitative tool is the most critical step in implementation. The process is aimed at determining the proper business requirements and tailoring the system for an optimized process to control and monitor performance. The dissertation presents a methodology that was tested on a single U.S. based manufacturing business and can be applied to international corporations with multiple business units or facilities.

Leveraging the readiness assessment prior to deployment and selecting tools to control a specific measurable had a high level of precision in determining performance. This methodology, as shown in the example cases, also considered the effort to deploy LMS based on the interactions among the systems to control the desired areas of performance. This research extended the work of the deployment process by taking a more granular look at PMS requirements as well as coupling the effects of current systems with a tailored approach to using LMS in the business.

Implications for Practice

This paper is aimed at extending the research on the limited success of lean deployments. These methods and processes were also designed for practitioners to apply the methodology to help understand, design, and plan the deployment of LMS through the creation of scoring systems and weighting processes to help communicate the work requirements to change, modify, or complete systems.

The most important part of the deployment process is understanding that the process cannot be delegated to a single person but needs to be a part of a collaborative planning and vetting process. After all, collaboration creates continuity and alignment with a vision of expectations. The other aspect of deployment is to look at the LMS as a method for control of performance in comparison to a mass of tools and philosophies designed for continuous improvement. With proper leverage, continuous improvement and a focus on the value-added aspects of LMS have an immense power to control and predict performance. Relative to managing and overseeing a business, the predictability of performance is important in communicating, forecasting, and delivering confidently. In most cases, positive or negative surprises create a sense of concern related to a difficulty understanding how a business performs and is operating.

The proposed Lean Readiness Assessment (LRA) approach is the basis for leveraging an objective and data driven approach to determine whether key enablers for successful LMS deployment are present. Even if the assessment concludes that there is a significant disparity between current practices and the areas of the assessment, the information can guide the deployment process. The data provide options to address areas of the assessment to improve the business and determine how modifications to current practice are received. The data also allow the process to move forward to determine PMS requirements and the best tools to control or improve those specific areas. Combining the Lean Readiness Multiplier (LRM) with the different lean deployment matrices used in Chapter 4 create an effort summary to determine an estimation for planning a deployment.

Creating and understanding of the communication benefits of designing systems-based performance control are essential. The planning effort is recommended as a primary focus since it exposes the systems to users and helps them to understand their needs within the process. Also, previewing the effort required for implementation helps in adjusting variables that are key to the deployment. As seen in the example deployment of the dissertation, the systems can be cascaded over longer periods of time. If time is too limited for the cascade, the process allows for adjustments to add more resources or modify current employee roles and responsibilities based on data, which serves as another example of how the deployment process can be tailored to best meet the business needs.

The ability to leverage an Enterprise Resource Planning (ERP) system is another factor that can assist is creating communication paths, such as reminders to error-proof the modified processes in order to keep key users aware of present activities. The ERP can also serve as a call for help if certain items are not completed on time, and there is a risk of impacting the performance variable negatively. In such a situation, the recommendation is to leverage the PDCA process to ensure that the issues that created the potential misses or overabundance of work have corrective measures developed to prevent them from reoccurring.

Recommendations for Future Research

This first example of the methodology was applied in a smaller manufacturing facility of fewer than 100 people; an enterprise of this size tends to accept changes more readily. However, there are significant opportunities to leverage the methodologies of this body of work in large-scale organizations. The assessment could be applied to an individual department or in functional groups to narrow their focus, which should increase manageability and the likelihood of success. The research will also help in understanding how to blend the requirements of planning a lean deployment with employee work schedules if it appears that planning does not occur at the expected time durations. As an extension of this research, unionized environments could utilize the methodologies to see if they facilitate communication and engagement to reduce anxiety about the changes.

The tool selection process was also limited to the application of this research. As the literature provided evidence and flexibility for the applications of lean tools in multiple areas of performance management, there is still a need to have more applications of this methodology with increased complexity to extend this body of work. The tool selection was identified as a key item to support the business requirements and in achieving specified levels of performance, as well as support a successful deployment strategy. The continuation of this work will build more quantitative data to further develop the process for a tailored tool selection and build data for the effort to deploy. Due to the diversity of the lean tools the extension of this element of the research will be a benefit to both academia and industrial practitioners to help support success in the deployment of LMS.

This application occurred in a well-established company with a heritage of deep engineering and problem-solving skills that was transitioning to become a Tier-1 manufacturing supply organization for diversification purposes. Applying the techniques developed in this dissertation to a deeply established brownfield manufacturing business would be another extension of the work and further development of this research. It is apparent from this dissertation research that the methodology provided improvement to understanding the interactions between functional groups/departments to improve vetting and collaboration in the deployment process. To better understand the influence of this structured methodology, it will be beneficial to have more long-term historic data to identify the influence of the framework based on having specified points where the change occurred to create identifiable starting points for trends in performance influenced by the modified systems. Similar to the recommendations relative to extending the research of lean tool sections, these future applications of this tailoring methodology within the different functional groups and more complicated business applications will help establish more quantitative data for the work effort vs. effort hours requirements as used in the Lean Deployment Matrices. The future applications of this tailoring framework will develop more precision and derivations of the efforts required to make deployments for guiding future practitioners. The experience gained through the future research and applications could extend to the area of advanced modeling capabilities for the tailoring of lean deployments for increased complexity. As the maturity of this structured framework increases the accuracy to plan required deployment efforts and strategy optimization in much larger and complex organizations.

The research on the maintenance of lean systems after deployment to guide companies should continue to focus on adjusting the systems based on durations of time. Since lean depends on customer requirements, adjustments would need to be made to the system as those requirements change. As on the product development front, requirements and technologies are constantly changing, which creates the need to modify the system on the manufacturing and operational fronts based on those new or updated requirements. Connecting the maintenance of

PMS to product development activities would also be an area of extension and create more continuity, as the product changes to match final customer needs.

Non-manufacturing-based applications for lean deployment could extend this work, as well. While the key areas of performance may differ, the systems-based approach to control safety, quality, productivity, and inventory are present in the medical and patient-care industries, where misdiagnoses and errors among physicians and medical staff have significant risks. The concepts of lean have been entering this arena, but it is still in its infancy and could have a positive impact. The medical field also has a reactive focus on patient needs but could benefit from the proactive and predictive portions of lean philosophies, which have demonstrated benefits on manufacturing.

APPENDIX A:

Literature Summary Tables

Table A1

Literature Summary for Lean Systems Supporting Safety

Sources:	SMED	Pull	Level Schedule	Single Piece Flow	Standardized work	5s	TPM	VSM	Visual Management	Cellular Manufacturing	TQM	Kiazen	Poka-yoke
1994 (Suzuki)									X				
1996 (Shirose)									X				
2005 (Tek Aik)									X				
2008 (Main, Taibitz & Wood)						X						X	
2010 (Taubitz)					X	X		X					
2010 (Ortiz & Park)													
2011(Anvari, Yusulff, & Zuikifil)					X	X			X				
2011 (Suarez)									X				
2012 (Joshi & Naik)	X												
2012 (Martinez-Corcoles et al.)					X								
2013 (Murata & Katayama)									X				
2013 (Singh, Gohil, Shah, & Desai)							X						
2014 (Lamprea, Carreno, Sanchez)						X							
2014 (Singh & Ahuja)						X						X	
2018 (Lehtonen)					X				X				
2019 (Czeto)					X	X	X		X				

Table A2

Literature Summary for Lean Systems Supporting Quality

Sources:	SMED	Pull	Level Schedule	Single Piece Flow	Standardized Work	5s	TPM	VSM	Visual Management	Cellular Manufacturing	TQM	Kiazen	Poka-yoke
1994 (Suzuki)									X				
1996 (Shirose)									X				
2000 (Victor, Boyton, & Stephens-Jahng)					X						X	X	
2003 (Voelkel and Chapman)								X					
2005 (Tek Aik)						X			X		X		
2009 (Cakmakci)	X												
2009 (Wee & Wu)		X		X			X						X
2012 (Joshi & Naik)	X												
2010 (Bayo-Moriones et al.)						X							
2012 (Kumar and Kumar)						X							
2013 (Murata & Katayama)									X			X	
2013 (Singh, Gohil, Shah, & Desai)						X	X						
2014 (Mannon)					X								
2014 (Lamprea, Carreno, Sanchez)						X							
2014 (Leotsakos et al.)					X	X							
2014 (Ringen et al.)	X				X		X						
2014 (Singh & Ahuja)					X	X						X	
2014 (Sundar, Balaji & Kumar)					X	X						X	
2016 (Bititci, Cocca, & Aylin)									X				
2017 (Lozano et al.)	X												
2018 (Lehtonen)					X				X				

Table A3

Literature Summary for Lean Systems Supporting Productivity

Sources:	SMED	Pull	Level Schedule	Single Piece Flow	Standardized work	5s	TPM	VSM	Visual Management	Cellular Manufacturing	TQM	Kiazen	Poka-yoke
1994 (Suzuki)									X				
1996 (Shirose)									X				
2005 (Tek Aik)									X				
2006 (Marin-Garcia, Val & Martin)	X				X	X	X	X	X				X
2009 (Wee & Wu)							X						X
2010 (Gibbons & Burgess)	X						X	X					
2010 (Bayo-Moriones et al.)						X							
2011 (Wang & Pan)													X
2012 (Joshi & Naik)	X												
2013 (Benjamin et al.)	X												
2013 (Singh, Gohil, Shah, & Desai)						X	X					X	
2014 (Lamprea, Carreno, Sanchez)						X							
2014 (Singh & Ahuja)						X						X	
2014 (Ringen et al.)	X				X		X						
2014 (Sundar, Balaji & Kumar)					X								
2016 (Bititci, Cocca, & Aylin)									X				
2017 (Lozano et al.)	X						X						
2019 (Kumar)	X	X			X	X	X	X	X	X	X	X	

Table A4

Literature Summary for Lean Systems Supporting Inventory Control

Sources:	SMED	Pull	Level Schedule	Single Piece Flow	Standardized work	5s	TPM	VSM	Visual Management	Cellular Manufacturing	TQM	Kiazen	Poka-yoke
2007 (Abdulmalek & Rajgopal)	X	X	X				X	X	X				
2009 (Wee & Wu)		X		X			X	X	X				X
2010 (Singh, Garg & Sharma)							X	X					
2012 (Hofer, Eroglu & Hofer)	X	X	X				X						
2013 (Rahmana, Sharif & Esac)											X	X	
2014 (Singh & Ahuja)						X						X	
2019 (Marodin, Frank, Tortorella & Fetterman)	X	X	X				X						
2019 (Iranmanesh, Zailani, Hyun, Ali & Kim)	X	X				X		X	X	X			X
2019 (Marodin, Frank, Tortorella & Fetterman)				X	X				X		X		

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ABSTRACT

A STRUCTURED METHODOLOGY FOR TAILORING AND DEPLOYING LEAN MANUFACTURING SYSTEMS

by

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The seminal works of Peter Drucker and James Womack in the 1990's outlined the lean manufacturing practices of Toyota Motor Corporation (TMC) to become a world leader in manufacturing. These philosophies have since become the springboard for a significant paradigm shift in approaching manufacturing systems and how to leverage them to optimize operational practices and gain competitive advantage. While there is no shortage of literature touting the benefits of Lean Manufacturing Systems (LMS), there has been significant difficulty in effectively deploying them to obtain and sustain the performance that TMC has achieved.

This body of work provides a novel methodology to break the deployment process into different elements by assessing the current business practices/interests and relating them to variables that support the philosophies of LMS. It also associates the key areas of lean from an operational perspective and connects the tools to business requirements by guiding the selection process to more effectively choose tools/processes that best fit the business needs. Finally, this methodology looks at different aspects of the deployment variables to provide a structured approach to tailoring the deployment planning strategy based on better understanding of the different interactions/requirements of LMS.

The research also provides a validation of the proposed structured methodology to help practitioners leverage the resulting objective/quantitative information from assessing the current business to help coordinate deployment planning effort. The framework considers aspects prior to deployment planning by providing an approach for pre-deployment assessment to provide critical input for tailoring the LMS deployment.

AUTOBIOGRAPHICAL STATEMENT

Kenneth J. Gembel II has spent 20 years of his 23 professional years in the automotive industry. Ken's early years were shaped as an enthusiast and competitor in the sport of motocross. This desire for competition helped create a passion for horsepower and a level of intrigue about how mechanical things work. This hobbyist interest is what shaped his desire to become an engineer.

His early academic life started at Western Michigan University where he pursued a degree in Materials Engineering (Metallurgical Focus). This is also when his professional career began at American Axle and Manufacturing (AAM) as a Metallurgical Engineer (1997). The AAM experience was instrumental in his professional development. Ken spent 17 years transforming manufacturing facilities through deploying lean manufacturing as the primary method for optimization of businesses. In his time at AAM, he progressed from a Metallurgical Engineer to a Plant Manager of multiple facilities. During his tenure at AAM he also earned a Master's Degree in Manufacturing Engineering from the University of Michigan - Ann Arbor in 2007. Immediately following this accomplishment, he entered the Wayne State University's 1st Ph.D. cohort for the Global Executive Track (GET) Program in 2008.

In 2013 Ken joined American Standard and was a Plant Manager for them in Alpena, Michigan for 3 years. This career step was then followed by joining the historic F1 Company Cosworth in 2016where he was responsible for their North American Business as the General Manager for North America.