Deploying a reproducible lean system using integrated mapping tools and the measurement of value

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Deploying a reproducible lean system using integrated mapping tools and the measurement of value

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Abstract

This dissertation focuses on lean transformations and the use of mapping tools. Since mapping the value chain is applied as a form of progress toward lean manufacturing and as a formula to guide improvement activities, it is a key area in this field of research. Mapping tools are often used as auxiliaries in continuous improvement activities and in Kaizen events while attempting lean transformations. Commonly, maps use only time as a unit to track progress and monitor improvements. Based on the gap found in the body of knowledge, this study focuses on three main research questions: 1) How can value be measured in an economical way, using mapping techniques to boost improvement acquisition? 2) How can a lean production system (LPS) be deployed while reaching target levels of performance? 3) How can a LPS and its organizational culture be transferred to or replicated across other plants in the same company?

This dissertation consists of seven chapters. Chapter one is dedicated to introducing the problem, the research questions, and the aim of this study. Chapter two presents an overview of lean manufacturing for organizational transformation, business excellence models utilized in lean transformation, mapping tools, metrics, and training people. It also defines the relationships between these elements and lean transformation.

Chapter three explains the research design for this project in detail. It presents the industry in which this study is conducted, namely, the automotive sector. It utilizes the qualitative case study as the primary method, following an explanatory multi-cases design. It relies on inductive logic. Cases were selected following the purposive sampling principle. The cases themselves represent collaborative work conducted by the author's research team and an automotive supplier in Japan (the organization). Semi-structured interviews were conducted with several key personnel within the organization. The data were triangulated with additional documents and publications provided by the organization, as well as the on-site observations recorded by the research team. For tool analysis and the creation of guidelines, practical testing employing secondary data was carried out.

Chapter four is dedicated to assessing the measure of value in an economical way, using case studies (treated as separated entities) as the main strategy and secondary data to test the tools to guarantee the suitability of the primary data collected in both cases. The functions of the selected lean mapping tools were compared, and the settings and environments in which each one would perform their best were determined. From thereon, the author established the core characteristics from a user's perspective, to compare value stream mapping (VSM), material and information flow chart (MIFC), and the system design diagram (SDD) and evaluated the findings to see whether the measure of economic value was present in reality or not. It also aimed at identifying the common elements and how they are tracked. This chapter introduces new elements to measure performance and shows the possibility of using economic assessment in mapping. It was found that companies may have been "doing it in their own way," exposing the possibility of integration of economic measures in mapping. This will certainly simplify a practitioner's work in the earlier stages and support a manager's decision making. The comparison led to the determination of guidelines and the creation of a tools-placement model that is directly linked to the deployment of a lean or a Toyota production system (TPS). It describes how value can be measured in economic terms and be used to boost improvements. The chapter also introduces new elements to measure performance, thereby indicating the possibility of using economic assessment in mapping.

Chapter five focuses on the deployment of a LPS. It presents the key components of a lean journey, which are illustrated in a gradual and cyclical deployment model linked to the placement of tools. The model intends to serve as a blueprint for organizations in the initial state of lean, to reduce their margin of error and to shorten their failure in the early stages. Empirical work was focused on the implementation process of improvement activities guided by mapping tools. Mapping, in both cases, with the appropriate internal tool version comprising the MIFC or SDD, is a means to an end. Both cases A and B have a solid belief in the effects that the use of the tool can trigger. The role of these tools differs from the role of traditional VSM and these findings are integrated in the proposed model. It includes guidelines for the placement of tools, and explains the connection they have with maturity levels. Finally, the chapter presents a logic value stream costing (VSC) introduction process to support lean efforts.

Chapter six investigates the interplant transference of a LPS. In this section, the supplier was treated as a whole, to examine the connections between the analyzed plants, in terms of lean or Toyota production system (TPS) introduction and transference. In the cases analyzed, no established protocol to transfer their production system step-by-step was found. However, this is not a diminishing aspect. Instead, the core knowledge and principles are passed on by a learn-by-doing approach. Internal adaptation came out as a critical factor for the implementation of the tools and lean model transference. It provides a rational structure for model transference that practitioners can use in real settings and can serve as a strong base to build a pragmatic model for companies to follow in lean transformations.

Chapter seven presents the general conclusions and directions for future research. The conclusions support studies where implementation per replication played a negative role. However, this study provides a new perspective on tools and systems adaptation and does not treat just-in-time (JIT) as a lean method but as an end to reach a system that is as close as possible to the one-piece flow. It contributes to the body of knowledge around mapping in lean for value creation. It includes an introduction of new elements in measuring performance and shows the possibility of economic assessment in mapping in a logical way. Internal adaptation came out as a critical factor for the implementation of tools and lean model transference. Previous studies do not include mapping tools, their protocols, and the roles they play in systems transference. Thus, this study sets a new path for adaptation studies.

Most previous studies involve the use of a single tool. This study illustrates how the different tools integrate and work together (if and when required). The author considers this is a milestone in the field, and believes that it would serve as a resource for future work that may aim to develop further the proposals and test them in real settings. The integration of the method (as described in chapter four) into mapping will simplify the practitioner’s work. This study aims to promote the true essence of lean and TPS which is deploying a system that can operate as closely as possible to the one-piece flow.

Acknowledgments

I would like to express my gratitude to my advisor, Professor Mokudai, for supporting me through my journey as a foreign student, for his guidance, patience, and kind advice, always. I consider myself extremely lucky to have someone who believed in my ideas and gave me insights, while helping me understand the new environment better. He certainly made my journey much easier. I highly respect him as a person, researcher, and professional, and I will always take his teachings with me wherever I go.

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I would also like to thank my mother, who has always been a great source of strength. Even from a distance, she managed to be a great source of support for me. I would like to extend my gratitude to my brother and sister, who I deeply missed these years. I thank them for bringing joy to my life whenever we shared time together. I am grateful to my father, for giving me the opportunity to succeed as a professional and for always being respectful of my decisions in life.

Finally, to all those I encountered during my stay in this beautiful country, whose presence, in some way or the other, has changed me and made me evolve as a human being. I have grown professionally, but most importantly, I have gained a lot of life lessons that have left intangible, immeasurable, and permanent impacts on me, which is the most valuable thing about this four-year journey.

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List of acronyms

% C & A	Percent complete and accurate
AC	Activity ratio
AME	Association for Manufacturing Excellence
CC	Current condition
CT	Cycle time
CTP	Cost-time profiling
DFA	Design for assembly
DFM	Design for manufacturing
DFO	Design for operation
DtD	Dock-to-dock time
FG	Finished goods
FTE	Full-time equivalent
GRAI	Graphs with results and actions interrelated
IDEFO	Integrated definition diagram
JI	Job Instruction
JIT	Just-in-time
JM	Job Methods
JR	Job Relations
KPIs	Key performance indicator
LEI	The Lean Enterprise Institute Inc.
LPS	Lean production system
LR	Lean rate
LT	Lead time
LTM	Lean Transformation Model
MBPM	Metrics-based process mapping
MFC	Material flow chart
MIFC	Material and information flow chart
PDCA	Plan, do, check, act
PIT	Process information table
QFD	Quality function deployment
SDD	System design diagram
SME	Society of Manufacturing Engineers
SMED	Single minute exchange of die
TC	Target condition
TPM	Total productive maintenance
TPS	Toyota production system
TQM	Total quality management
TWI	Training within Industry
VNM	Value network mapping
VSC	Value stream costing
VSM	Value stream mapping
VSMM	Value stream macro mapping
WIP	Work-in-process

Chapter 1: Introduction and problem statement

1-1. Introduction

Lean has been an interesting and a polemic topic of study since the early nineties. The term emerged to explain a desirable state in operations that allowed positive changes in the production floor. Lean is distinguished from mass production by its single-minded focus on eliminating waste in all aspects of the enterprise.

There have always been divergent opinions around lean. It can be stated that the majority falls on the positive end, as the term is often brought up while talking about world-class companies. However, when it comes to systematically explaining how it is achieved, the situation becomes ambiguous and vague.

According to Liker and Hoseus (2015), two broad categories emerged from the review of the literature on lean production, based on whether lean production and/or just-in-time philosophy has been implemented or not, and, if it has been implemented, then based on the degree to which it has been implemented.

Many companies have tried using tools applied by Toyota in their operations with some success, but have often failed to achieve the kind of remarkable results in quality, speed, and productivity that Toyota is known for (Toivonen, 2015). Toyota is an example of a learning organization that is real and successful. It starts with the assumption that people are the most important resource and need to be encouraged, developed, and challenged. Human resources management is one of the most visible and important functions in the company, because humans are the only competitive resource that cannot be copied (Liker and Hoseus, 2010).

Infrastructure practices developed for one market and cultural situation tend to be difficult to translate into a different market or culture, as many organizations have found, such as for example when they attempt to import Japanese practices into the United States (Tolich, Kennedy, & Biggart, 1999) . Aoki (2008) highlights the necessity to understand not only the details of the implementation of Kaizen activities in countries outside Japan, but also the nature of Japanese Kaizen activities themselves, in more depth.

By comparing both, the variety and extent of lean practices being implemented, Doolen and Hacker (2005) demonstrated that it is possible to empirically evaluate the applicability of lean practices to different manufacturing organizations.

Developing an organization's managerial system or model is not about copying the tools and techniques that another organization has come up with, which would be jumping to solutions. Each organization has its unique characteristics and exists in unique conditions (Rother & Aulinger, 2017). Organizational capabilities, which have been developed through their own history, and also consist of complex social relationships, are difficult to transfer to other plants (Aoki, 2008).

The classic two-pillar TPS representation tends toward influencing one to pick some tools out of the TPS, and might support a narrow-minded view. In every case, tool-picking enables the attainment of a certain improved, but non-optimal, and probably unstable level. Therefore it is important to present new representations of TPS that show the interactions between the tools and how they mutually require each other (Rüttimann & Stöckli, 2016).

Many researchers and practitioners are trying to better understand and explain what it means for an organization to be lean, and how to achieve it, ever since the term has been associated with the success of top organizations. The term is subject to interpretation and depends on the context, but even in that sense, it remains true that the reason for wanting to be lean is to achieve outstanding performance and profitable outcomes. When an organization reaches a certain level of demand where they need extra capacity, they may decide to expand their operations to satisfy the demand of existing or new customers, and accordingly, they may decide to open new facilities. A common drill that organizations carry out, is to try to repeat practices that once worked, in order to reproduce results. However, the problem arises when there is no clear idea of how to translate the know-how into tangible and methodical steps that can be converted into actions that have a high and quantifiable certainty of success.

Research has been previously devoted to the search for suitable frameworks that provide a complete integration of lean elements into a coherent whole or a detailed step-by-step method for the implementation of lean manufacturing (Marshall, 2015; Perez, 2014). Even after an extensive review of literature around lean, a framework that offers a logical explanation for lean in components or uses a step-by-step method that allows the transference and deployment of a lean transformation in an interplant automotive manufacturing environment, is missing. As on this date, there are a couple of studies that propose frameworks. However, they involve a particular approach and come with restrictions that suggest that the model cannot be freely extrapolated (Karim & Zaman, 2013).

1-2. Aims and scope of the study

Mapping is applied in the value chain as a form of progress toward lean manufacturing and as a formula to guide improvement activities. Mapping tools are often used as auxiliaries in continuous improvement activities and in Kaizen events while attempting lean transformations. In western countries, they are highly emphasized as a means to achieve improvements in the value stream, particularly in production processes. Despite being highly utilized, their role and their application may be misunderstood. Conceivably that could be a root cause for the poor results and disengagement in the long-term.

The author encountered three main gaps: 1) the deployment of lean in an organization is not aligned with the context and current state of the company, 2) it is not clear how the interplant transference of lean takes place, and 3) metrics to track the performance associated with an organization that calls itself lean are either complex or just consider the time frame in their assessment and are commonly treated separately from the tools utilized for improvement.

There are several studies on lean and mapping tools (Doolen & Hacker, 2005; Karim & Zaman, 2013; Kuhlang, Edtmayr, & Sihn, 2011; Seth & Gupta, 2005). However, a lot of the research has mostly been qualitative, including significant amounts of the researchers' perspectives and experiences specific to when their studies were carried out. By first performing exploratory research followed by using secondary data to test tools, this study aims at arriving at an objective perspective and an unbiased case study analysis. It aims to secure the correctness of primary data. Including value stream mapping (VSM), a tool that is already known by most practitioners and that has been highly studied, lends an advantage in understanding the knowledge and setting the field for the introduction of more novel tools such as metrics based process mapping (MBPM), cost-time profiling (CTP), and value stream costing (VSC). By examining lean in sites located in Japan, this study aims at reducing the ambiguity in the extant knowledge by re-learning some concepts and clarifying others that may have been misunderstood, based on what was found in papers from purely western sources. For this study, the terms, TPS and lean, are used interchangeably, despite possible differences in their practical applications, because that would have to do with the practitioner's understanding of the terms.

The aim of this study is to illustrate the process followed by companies that emerge in lean transformations and opt to deploy those methodologies across their subsidiaries or different plants while preserving the desired levels of performance, in a clear and systematic way. This study intends to link mapping tools and explain their positioning and the roles they play in lean transformation and problem-solving. This study also aims to provide a different perspective on performance measurement beyond the classical time-based metrics. This study intends for practitioners to grasp an understanding of the tools complementing TPS that can later on become lean in the western world. Hence, the drawbacks of the inclination that just the replication of tools generates can be reduced. This summarizes the three main objectives:

1. To improve and expand the understanding around the existing mapping tools, which visually represent value-creating processes in a production line.
2. To describe the current metrics used to measure the outcomes of the lean transformation, which also integrate an economic measure of value, and to examine their relationship with mapping tools.
3. To explain how organizations can transfer an interplant model that preserves an optimal performance level while pursuing lean or TPS.

Since this study was conducted in the automotive industry, the cooperation of the automotive suppliers was necessary. There was a need to access their sites as well as seek permission for the use of confidential information. Therefore, the sample became small, and for the same reason, the generalizations of the outcomes should be limited to this industry. However, they can be used as a reference for necessary testing and future research, to generalize the findings to other sectors.

1-3. Problem statement and research questions

The previous analysis of the context, literature, and exploration of the field, leads to the following problem statement:

The process of transferring or reproducing a system for achieving lean transformation from organization to organization remains undefined, and the way in which mapping tools integrate into lean transformation remains unclear. The impact of the current methods is not visible in a quantifiable and economic manner.

Therefore, the main research questions in the present study are:

1. How can value be measured in an economical way along with mapping techniques to boost the acquisition of improvements?
2. How can a lean production system (LPS) be deployed while reaching the targeted levels of performance?
3. How can a LPS and its organizational culture be transferred to or replicated in other plants of the same company?

1-4. Structure of this thesis

This document is organized into seven chapters that arrange the content in a logical order. The study begins with the introduction, and then presents the problem statement and research questions. Next, it addresses the literature that is related to the topics involved. The study reviews lean, business models, and lean transformation first, and then presents the mapping tools. This is followed by a presentation of the measurement systems and training. Once the related existing knowledge is explained, the research design is introduced. After introducing the method, the empirical cases are presented. Next, the study proceeds to answer the research questions and presents the discussions around them. The final part concludes the study and presents directions for future research.

a) Background overview (Chapter 2): This chapter presents a review of the literature on lean models, mapping tools, performance metrics, and training people.

b) Research design (Chapter 3): This chapter presents a description of the methodology, approaches, and perspectives in this study in detail. The details of how the research was performed and arguments relating to particular selections are presented. Exploratory research, secondary data to test tools, and empirical research processes are addressed in this section. Subsequently, the cases are described individually. The author presents an analysis of the different tools and compares them. This comparison facilitates the creation of guidelines for their use, and presents the proper context for their application.

c) Measure of value in an economical way (Chapter 4): This chapter analyzes the main characteristics of VSM and compares these characteristics with the mapping tool variants in cases A and B. It describes how performance is measured and how value is linked to an economic metric in each plant. The author provides suggestions after discussing the insights.

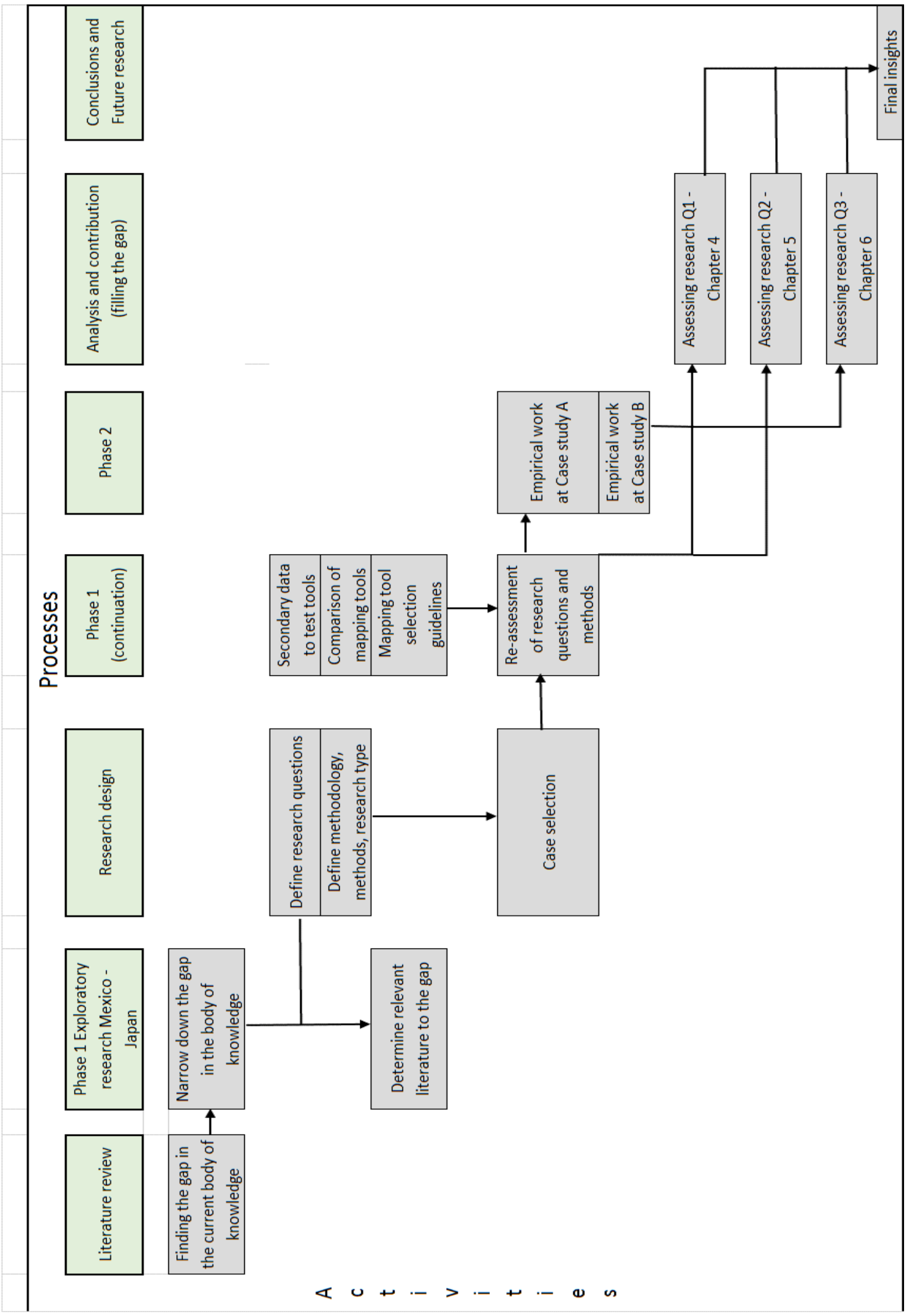
d) Deployment of a LPS (Chapter 5): This chapter addresses how a LPS can be deployed while reaching the targeted levels of performance. It describes the key components in a lean journey, and presents a model that represents lean in different blocks. This model is linked to tool selection and placement in a value stream.

e) Interplant transference of a LPS (Chapter 6): This chapter discusses the topic of production system transfer between plants of the same organization, through the insights gained from the case studies. It presents a structure for model transfer that practitioners can use in real settings.

f) Conclusion and directions for future research (Chapter 7): This chapter presents final thoughts and implications of the study. It concludes with a summary of the contributions made to the existing body of knowledge and presents directions for future studies.

The different stages of this project are described and linked together in figure 1.

Figure 1: Research stages



1-5. Publications included

In Chapters 3 to 6, the following publications are included:

1. Chavez, Z. and Mokudai, T. (2016) 'Mapping tools selection towards lean transformation in manufacturing environments,' in Euroma 23rd Conference, Norway, 17–22 June 2016. Norway, pp. 1–10.
2. Chavez, Z., Mokudai, T. and Uyama, M. (2018) 'Divergence between Value Stream Mapping Western Understanding and Material and Information Flow Chart Principles : A Japanese Automotive Supplier's Perspective,' Journal of Service Science and Management, 11, pp. 219–241.

Chapter 2: Overview

2-1. Lean in manufacturing for organizational transformation

The concept of "lean production" was first introduced in "The Machine That Changed The World" (Womack, Jones, & Ross, 1990). It referred to a new way of looking at the manufacturing enterprise. Lean is distinguished from mass production by its single-minded focus on eliminating waste in all aspects of the enterprise. At that time, they defined lean production as follows: a superior way for humans to make things, which provides a wider variety of better products at a lower cost. It provides more challenging and fulfilling work for employees at every level, from the factory to the headquarters. It follows that the entire world should adopt lean production and as quickly as possible. Soltero and Boutier (2012) describe lean in a contemporary way, as a set of practiced skills that facilitate the modification of organizational culture and the culture linked to it. They suggest that lean is not merely a set of tools to be implemented. It capitalizes on the entire workforce's involvement in creative problem-solving and continuous improvement, reaching beyond the competition by innovatively developing best practices.

Marshall (2015) presents an extended review of literature on the concept of lean which can serve as a guide to understand the history and path of research in lean over the past 20 years. The author concludes that lean production is not a singular concept. Rather, it is a combination of all waste elimination and components for continuous improvement. In essence, JIT production is contained in lean production among many other principles.

Krafcik (1988) coined the term "lean production" to describe TPS and was one of the first to demonstrate that a lean production method can lead to enhanced operational performance.

Liker and Hoseus (2010) explain that what is now called "lean" is intended to bring problems to surface, and that people perform the roles of problem detectors and problem solvers under necessary conditions for achievement. Achieving manufacturing leanness is a continuous improvement technique to generate optimum value from the process (Karim & Zaman, 2013).

Organizations of many kinds throughout the world have been borrowing specific methods from Toyota that have been turned into programs like lean manufacturing, lean enterprise, and lean six sigma. Underlying these programs is a fundamentally different assumption from what is seen in Toyota’s culture. These lean programs assume that expertly trained individuals applying the right tools to specific problems will dramatically improve business performance in a relatively short period (Liker & Hoseus, 2010). TPS aims to develop fragile systems that intentionally depend very heavily on people. Without highly capable and motivated people solving problems rigorously, the lean system will fail, and there is, by design, little back-up.

Sometimes, the implementation of an inappropriate lean strategy in a given situation can lead to an increase in waste, cost, and production time of a manufacturer. Owing to the inappropriate selection of lean strategies, changes may cause disruptions in the very process they are meant to improve. Therefore, it is crucial to have a systematic method to implement appropriate lean strategies based on identifying waste in manufacturing processes (Karim & Zaman, 2013). After analyzing the literature on the classification of lean tools by several authors, the author proposes the most commonly used lean tools. The author came out with a list containing the following: line balancing, concurrent engineering, cellular manufacturing, process layout, 5S, single minute exchange of die (SMED), total quality management (TQM), total productive maintenance (TPM), and autonomation. Each of these tools require a different level of maturity from the organization. For instance, concurrent engineering requires higher levels of lean assimilation and maturity, as it involves desing aspects and product development.

While existing lean evaluation tools do describe the lean status of an organization, they do not help in tracking and identifying improvement activities. Of the many companies implementing lean thinking today, very few companies can demonstrate the benefits of lean. This is partly because their performance measurement systems do not focus on doing so (Srinivasaraghavan & Allada, 2006).

2-1-1. Business excellence models

Different business excellence models have emerged since the end of the 1980s as a result of the rapid development of the quality movement. In the beginning, there were quality awards models or TQM models, but the terms "quality" and "TQM" were gradually replaced by the term "business excellence" (Toma & Naruo, 2017).

If we think about a model structure, if the model is universally valid, then it should be of use across all countries and situations. Evidence to date does not support this view. For example, research comparing different national quality awards leads to the conclusion that there is no one best worldwide award structure (Williams, Bertsch, Van Der Wiele, Van Iwaarden, & Dale, 2006).

The importance of the value given to a business by investors suggests that in assessing business excellence, more emphasis is needed on the way in which the management is increasing value and its constituent parts. This means that the business models that the management uses needs to be examined, specifically, with respect to how and why they may change over time, and how the strategy is extracted from these models (Williams et al., 2006).

Business excellence models were designed to help organizations focus their efforts in a more systematic and structured way to obtain superior performance (Toma & Naruo, 2017). Toyota Motor Company (TMC) represents one of the most interesting examples of corporations in which quality leads to business excellence. Toma and Naruo (2017) state that TPS constitutes an efficient production system that makes a decisive contribution to the success gained at a global scale by one of the most representative Japanese corporations from the automotive industry that, to eliminate waste, puts quality at the center of its concerns. In summary, the Toma and Naruo (2017) highlight two principal stages that are distinguished in the historical evolution of TPS. The pre-war stage is the one that bears the decisive imprint of the founder, Sakichi Toyoda, and is the one in which the term "production system" appears. The postwar stage marks the consecration of TPS together with the design, implementation, and continuous improvement of the system.

Doolen and Hacker (2005) review seven assessment tools and provide details of the lean aspects that each of them includes, providing a good blueprint of the most known assessments, thus enabling objective comparison.

Sousa and Voss (2002) have very ably summarized the large and complex body of literature concerning the closely related issue of the relationship between quality and the performance of organizations. Their major conclusions are: QM practices, as measured in the European Excellence Model, have a significant and strong impact on quality; quality performance (mainly conformance quality) has a significant and strong effect on operational performance; and quality performance has a weak and not always significant effect on business performance.

Williams et al. (2006) analyze and critique business excellence models, suggesting that the original models might still be a useful guide for improvement, but only for organizations whose conformance quality is poor. More advanced organizations should choose their relevant dimensions and weightings rather than use any standard one-size-fits-all model with more attention to the processes by which their business models and strategies are developed.

Shah (2007) avouches that to address the issue of identifying and employing skilled employees, certification in manufacturing by a third party can help show that an individual has kept up with new developments in the field. Certification also provides individuals with a documented credential of proficiency in their profession. This is one of the major benefits for organizations opting for the adoption of a business model. In his research, he gathered data for a role delineation study to validate and prioritize the areas of competence to be included in the database of knowledge and for the lean manufacturing certification programs administered in collaboration by the Society of Manufacturing Engineers (SME), the Association for Manufacturing Excellence (AME), and the Shingo Prize. In doing so, he used the Delphi technique.

Perez (2014) identifies and analyzes several lean frameworks, including the most well-known national quality award models for operational excellence, and the main architecture frameworks for enterprise integration. Concepts derived from this analysis contributed to the design and understanding of the enterprise architecture framework.

Toma and Naruo (2017) also explain the evolution of business excellence, starting with the concept of total quality management until what is currently known as business excellence models.

Such affirmations endorse the need for the adaptation of frameworks and assessments through the course of the evolution of lean knowledge along with the characteristics of the industry.

Infrastructure practices may well be necessary to support and enhance the effects of core practices on performance, but on their own, they might not be sufficient. What is difficult to imitate, and therefore, of real value, may not be the infrastructural practices per se, but rather, their integration with the core practices. It is something to which the models allude while failing to provide clear guidelines to potential users (Williams et al., 2006). No one knows whether achieving high points on the models will lead to excellent performance in the stakeholder marketplace or not. The overall goal of any successful framework, methodology or business excellence model, is developing the capabilities necessary to overcome challenges that arise along the journey of continuous improvement.

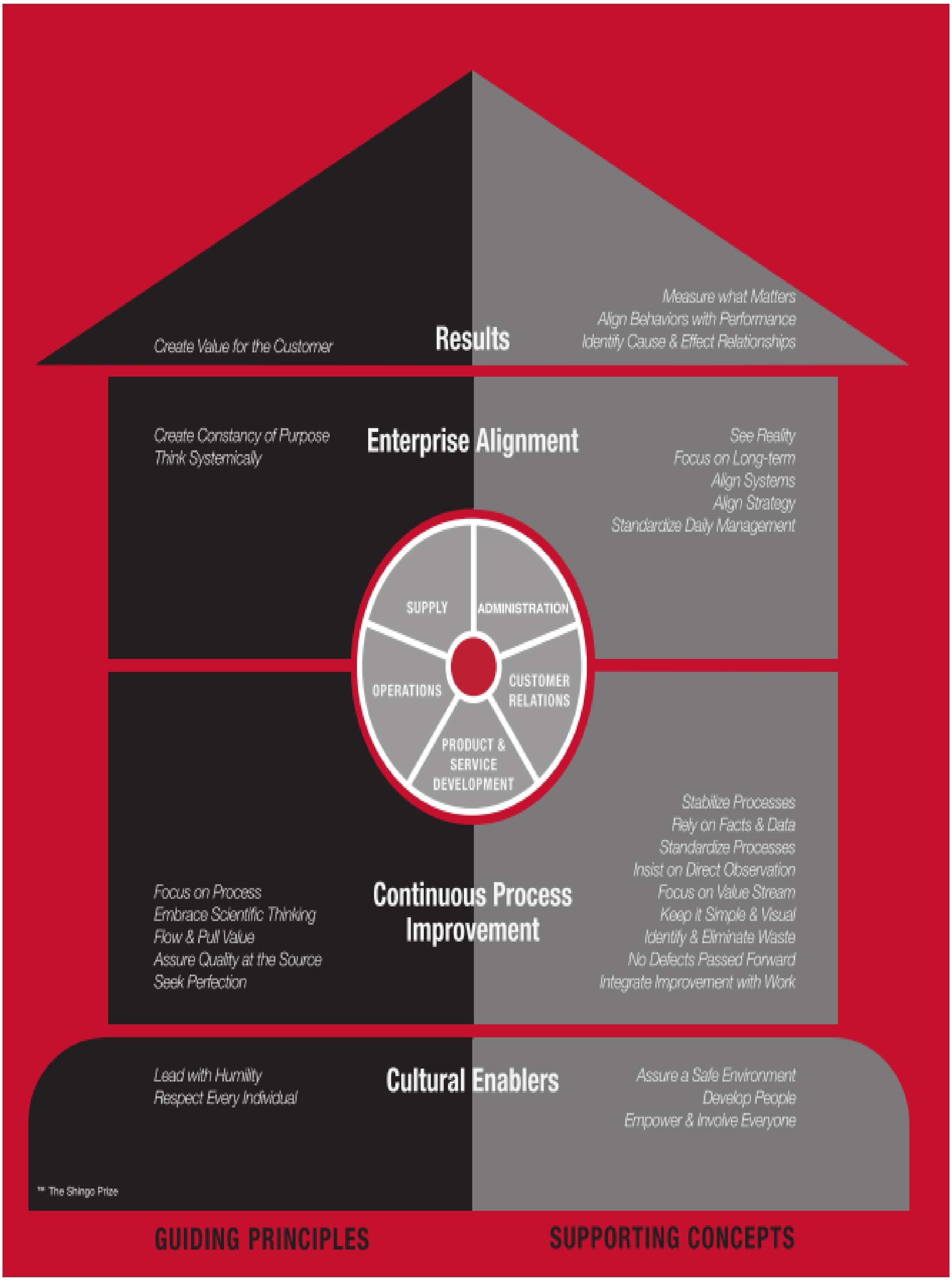
2-1-2. Shingo model

The Shingo Prize for Operational Excellence is a not-for-profit organization, located in the Utah State University premises, and named after the Japanese industrial engineer Shigeo Shingo. The Shingo Prize for Excellence in Manufacturing was instituted in 1988 to promote awareness of lean manufacturing concepts and to recognize companies in the United States, Canada, and Mexico that have achieved world-class manufacturing status. The Shingo Prize philosophy is that world-class business performance may be achieved through focused improvements in core manufacturing and business processes (Zainal, 2007). In 1988, Shingo received his honorary Doctorate in Management from Utah State University and, later that year, his ambitions were realized when The Shingo Prize for Excellence in Manufacturing was organized and incorporated as part of the university. In 2007, the organization was renamed The Shingo Prize for Operational Excellence due to its relevance to every industry, and not exclusively to manufacturing. The Shingo handbook highlights Dr. Shingo's most important contribution, as his understanding of the relationship between concepts (principles), systems, and tools. It also highlights how, unfortunately, over the years, most of us have gravitated toward the tools associated with effective operations and have paid too little attention to the power of the principles he articulated.

The mission of The Shingo Prize for Operational Excellence is to create excellence in organizations through the application of universally accepted principles of operational excellence, alignment of management systems, and the careful application of improvement techniques across the entire organizational enterprise. They do this by teaching correct principles and new paradigms that accelerate the flow of value, align and empower people, and transform organizational culture (Shingo, 2016). They operate with a vision to be the global standard of excellence in every industry. Figure 2 is the visual representation of their model, from bottom to top. The aforementioned core category elements are: guiding principles, supporting concepts, cultural enablers, continuous process improvement, enterprise alignment, and results.

The Shingo model consists of an organized collection of guiding principles (the house) and a transformation process (the diamond). The Shingo Prize claims to be the culture of operational excellence that comes from a disciplined application of the Shingo model in the organization. Every year, organizations apply to be assessed by the institute. Recognition is given each year to successful challengers from around the world at the Annual Shingo Prize International Conference and Awards Ceremony and Gala. Recipients may come from any industry, and any part of the world. Around ten to twenty companies are awarded either with a Shingo Bronze or Shingo Silver Medallions (Shingo, 2016).

Figure 2: Shingo model house



[Source] Shingo (2016). The Shingo handbook 2016

2-1-3. Association for Manufacturing Excellence (AME) model

The AME is a not-for-profit, practitioner-based organization dedicated to cultivating understanding, analysis, and exchange of productivity methods, and their successful application in the pursuit of excellence.[1]

The AME Excellence grants an award and recognizes North American manufacturing plants that have demonstrated excellence in manufacturing and business operations. The primary focus of the award is to acknowledge continuous improvement, best practices, creativity, and innovation. This award supports AME's mission of inspiring commitment to enterprise excellence through shared learning and access to best practices. The eligibility requirement is that the entity should be a single plant in the United States, or Canada, or Mexico. Applicants carrying out maintenance, repair, and overhaul activities in either the private or the public sector, are eligible. A record of companies applying for the award has been maintained since 2010.

In order to apply for the AME Excellence Award, companies must begin by completing the "Intent to Apply" and "Plant Profile." They must include information in the "Proof/gaps (evidence)" column to support each response. Final decisions regarding the recipients of the AME Excellence Award are made by the AME Awards Council. All members of the AME Awards Council and all AME assessors sign confidentiality and non-disclosure agreements. AME assessors visit the applicant's plants to evaluate the submission. A site visit generally lasts between 1.5 and 2 days. Recipients of the Excellence Award are selected based on the combined results of the achievement report review and site visit feedback. After this, the plant results are notified, and finally, AME presents the award at the applicant's site. Annual recognition is granted during their annual international conference.

The requested metrics focus on several sections of the Award Criteria. They include traditional metrics tracked by most organizations relative to safety, quality, cost, delivery, and profitability. Figure 3 is a representation of the dashboard summarizing the categories and results, and includes a radar chart. The key metrics provided are based on the plant, which may be considered a profit center

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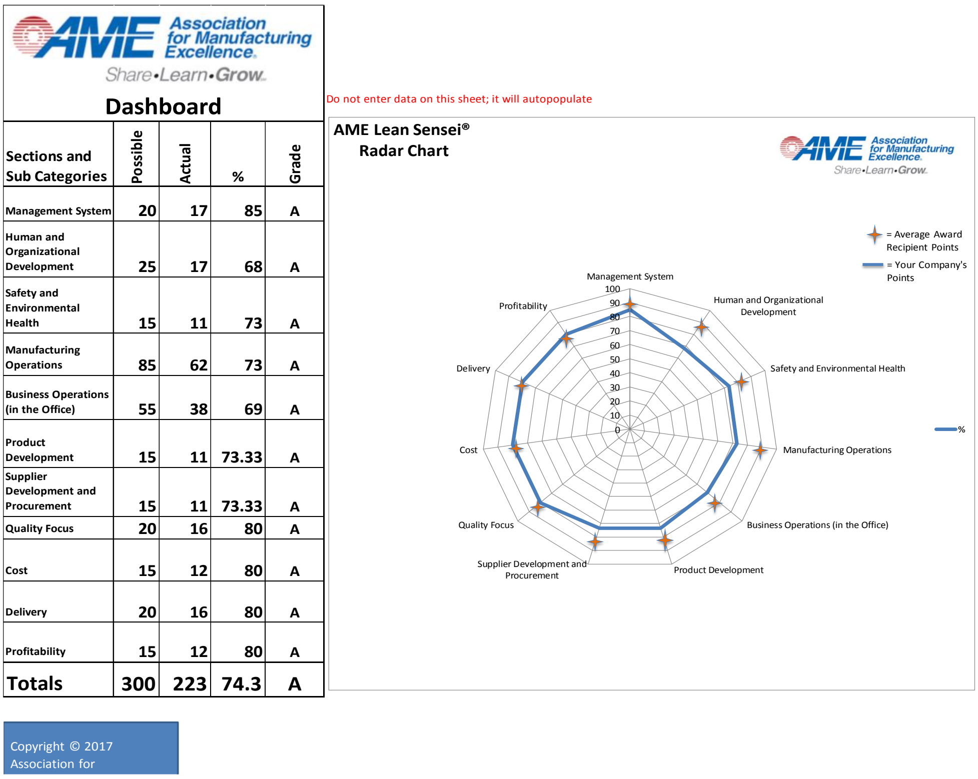
[1] Extracted from http://www.ame.org

or a budget center. Within most of the key metrics segments, specific result measures (or theoretically similar measures) are required[2].

Since 2010, no more than 8 applicants have been selected as award recipients each year. Applicants do not compete against other organizations. Success is measured in terms of how effectively the applicants stack-up against the criteria outlined in what they call "the Lean Sensei."

Figure 3: AME dashboard from Lean Sensei assessment AME award


AME Association for Manufacturing Excellence
Share•Learn•Grow.
Dashboard

Sections and Sub Categories	Possible	Actual	%	Grade
Management System	20	17	85	A
Human and Organizational Development	25	17	68	A
Safety and Environmental Health	15	11	73	A
Manufacturing Operations	85	62	73	A
Business Operations (in the Office)	55	38	69	A
Product Development	15	11	73.33	A
Supplier Development and Procurement	15	11	73.33	A
Quality Focus	20	16	80	A
Cost	15	12	80	A
Delivery	20	16	80	A
Profitability	15	12	80	A
Totals	300	223	74.3	A

[Source] www.ame.org , lean assessment example, accessed on May 1, 2018

2-1-4. Lean transformation model (LTM)

The LTM was developed by John Shook and others at Lean Enterprise Institute Inc., (LEI) after decades of working with organizations and individuals that have made attempts to transform themselves. LTM is a heuristic framework that should be used continuously as a guide for

[2] Extracted from metric supplement worksheet, http://www.ame.org

experimentation, problem-solving, and learning. Ultimately, it operates with the goal of helping organizations become lean enterprises[3].

LEI is a nonprofit organization based in Cambridge, MA. It works with a mission "to make things better through lean thinking and practice"[4]. It was founded in 1997 by management expert James P. Womack. LEI conducts research, teaches educational workshops, publishes books and eBooks, runs conferences, and shares practical information on lean thinking and practice. Their model has become a framework that organizations treat as a base to transform themselves and to improve their operations. The organizations and /or practitioners are free to choose from the tools and techniques aimed at problem-solving, as shared and taught by LEI.

The LTM (figure 4) asks organizations to pursue a lean transformation guided by the following five questions:

1) What is the purpose of the change? What true north and value are we providing? In simpler terms, what problem are we trying to solve?

2) How are we improving the actual work?

3) How are we building capability?

4) What forms of leadership behavior and management systems are required to support this new way of working?

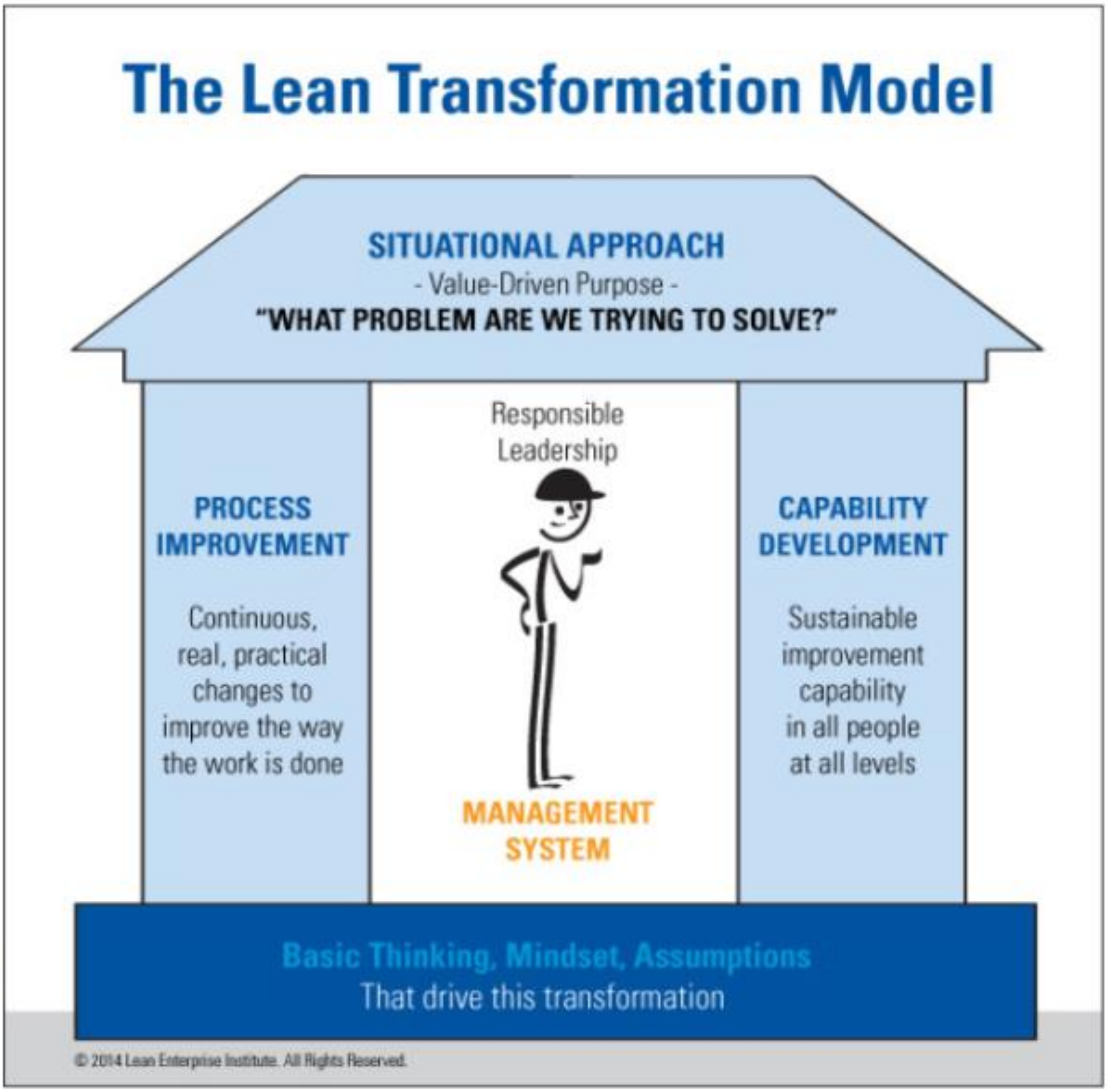
5) What basic thinking, mindset, or assumptions comprise the existing culture, and are driving this transformation?

[3] Extracted from http://www.lean.org
[4] Extracted from http://www.lean.org

LEI founders, Womack and Jones, recommend that managers and executives who have embarked on lean transformations think about three fundamental business issues that should guide the transformation of the entire organization:

- Purpose: What customer problems will the enterprise solve to achieve its own purpose of prospering?
- Process: How will the organization assess each major value stream to make sure that each step is valuable, capable, available, adequate, flexible, and that all the steps are linked by flow, pull, and leveling?
- People: How can the organization ensure that every important process has someone responsible for continually evaluating that value stream in terms of business purpose and lean process? How can everyone touching the value stream be actively engaged in operating it correctly and continually improving it?

Figure 4: Lean transformation model



[Source] www.lean.org, lean organization website, accessed on April 16, 2018

The model claims to have been developed after observing efforts in the community over several years. LEI states that a successful transformation calls for a situational approach that is based on innovating key dimensions of any organization by addressing the five questions. They call the questions "fractal," meaning that the same questions apply irrespective of whether one is working at the macro enterprise level or at the level of individual responsibility. However, while the transformation model that has emerged through years of experience is situational, the nature of the questions remains clear. If an organization fails to address each question entirely, or addresses the questions without a sense of how each relates to the others, the transformation will struggle to sustain its momentum[5].

In the LTM, the process of successful lean transformation lies in applying the "plan, do, check act" (PDCA) cycles of experimentation at every level, everywhere, all the time.

Being situational implies that each situation has a different aim or purpose. Being grounded in a common set of principles, yet being situational in the application, provides a rich opportunity for the development of truly profound philosophy. Lean thinking and practice also propose a specific point of view around each question. The core belief is that there are certain approaches to answering each of the five questions that will yield greater success in the lean journey of any organization[6].

2-1-5. Differences between the models

In the search for excellence, organizations keep looking for a benchmark model to follow. Even though the models operate in environments that are similar to manufacturing environments, in reality their application and impact will depend on the organization, its resources, and style. For instance, a model like Shingo will not be pursued by a small company that is just starting out on its lean transformation. Similarly, a corporation working under one-piece flow and looking to attack bigger customers may not opt for the LEI model to start with. However, the three of them, AME, LEI and Shingo model share a common aim when it comes to what they want to achieve: the aim of being profitable while

[5] Extracted from the lean transformation framework http://www.lean.org
[6] Extracted from the lean transformation framework http://www.lean.org

creating value. The three models, regardless of whether they state it directly or not, aim to achieve one-piece flow.

The three of them use Japanese terms such as Muda, Mura, Muri, Sensei, and Kaizen, in their guidelines and principles. AME does not state the connection to TPS directly. However, we observe some connection among them in the blueprint for organizations. This blueprint includes different categories guided by principles that will grant the organizations a different number of points in each category, if upon meeting the principles, the points are granted. The categories are predetermined and the number of points in each one are already stablished by AME. AME suggests lean techniques, tools, and principles that are generally accepted to eliminate unevenness and variations including (but not limited to): standard work, Jidoka, Poka-yoke, Heijunka, Kanban, horizontal deployment (Yokoten), and VSM.

Shook, the Senior Advisor and Executive Chairman of LEI, spent a considerable amount of time studying and working with Toyota. From thereon, concepts like VSM and Gemba walks, among others, emerged as terms that the lean western world has now become familiar with.

The lean model by LEI operates in an open access mode, and there is no specific roadmap for organizations to follow (i.e., what tools to use and what methods or techniques to follow, among other similar things). However, a lot of content around it has been made freely available on their website. The courses, training sessions, webinars, lectures, etc., offered to practitioners, center round similar techniques that the AME and Shingo models suggest (VSM, 5S, standard work, etc.).

The AME excellence model significantly emphasizes on metrics and measures, which can lead to practitioners striving for numbers and losing the meaning behind them. The Shingo model criticizes this tendency toward tool orientation.

The Shingo model, on the other hand, tries to make organizations conscious of the meaning of operational excellence, stating that it cannot be a program, another new set of tools, or a new management fad. Dr. Shingo understood that operational excellence is not achieved by the superficial use of tools and techniques. Instead, achieving operational excellence requires people to “know why” (i.e., an understanding of underlying principles). Programs, names, tools, projects, and personalities are insufficient to create lasting change.

Table 1 summarizes key characteristics of the models, allowing to make a comparison between the models. A major aspect to highlight is the point of emphasis on each one of the models, which can be considered the main differentiating point between them: TPS principles, Metrics and measurement and problem-solving for Shingo, AME and LEI model respectively. The field related to open access, Y/L (yes with limitations) has to do with the fact that even though most of the information is available online, there are some segments that require to be a member in the organizations (i.e., Shingo, AME or LEI) or pay certain fees such as workshops, specialized courses with a trainer or direct consultation from an specialist.

Table 1: Business Excellence models comparison

Characteristics (Y: yes , N: no, Y/L: Yes with limitations)	**Shingo**	**AME**	**LEI**
Japanese terminology usage	Y	Y	Y
Oriented to achieve one piece flow as main goal	Y	Y	Y
Offers a pragmatic road map	Y	Y	N
Awards certifications	Y	Y	N
Contains an auto-evaluation (self-assessment) for the organization	Y	Y	N
Open access	Y/L	Y/L	Y/L
Point of emphasis	TPS principles	Metrics and measurement	Problem solving
Visual model representation	Y	Y	Y

2-2. Mapping tools in lean transformation

In lean thinking, it is common to use value mapping techniques that support strategies preceding any specific efforts of mapping linked to tools such as one-piece flow, visual control, Kaizen, cellular manufacturing, inventory management, Poka-yoke, standardized work, and workplace organization, among others. Such strategies share the same purpose: to deploy a production system that is as close as possible to an agile system that makes appropriate use of the resources available.

Lau and Mak (2004) underline the need for an effective tool to develop a manufacturing system or to modify an existing system for a specific requirement within a reasonable time frame and cost. Several tools are presumed to support these actions, such as process mapping based on flow maps, integrated definition diagram (IDEFO), graphs with results and actions interrelated (GRAI), material and flow-modeling and simulation software, and mapping techniques based on TPS and VSM.

According to Álvarez, Calvo, and Peña (2009), the implementation of a lean manufacturing strategy allows strengthening the phase sequence, thereby carrying the operational and continuous improvement activities to excellence, and the removal of worthless activities. The influence of lean manufacturing practices contributes to the operating performance of the plants substantially. Further, the use of these tools enables the improvement of the results. Value chain mapping is applied as a form of progress toward lean manufacturing and as a formula to guide improvement activities. Following a benchmarking perspective and making use of a contrast tool, it facilitates improvements in a production environment.

Serrano, Ochoa, and de Castro Vila (2008) summarize the main elements that a tool should have to be efficient in the redesign of a production system[7]:

- Use a common language so that the people involved in the process can discuss the decisions.
- Achieve efficiency in use. Results are worth the time and effort required by the team.
- Employ a graphic and standardized language to help to make the application process easier.
- Utilize quantitative analysis. The decisions should be based on objective and scientific data analysis.

[7] When we talk about the redesign, we are referring to the improved design.

- Emphasize the initial problem situations and at the same time, provide clear guidelines and innovative concepts to improve the operational performance of the system.

- Reflect a systematic vision. The study should not lose perspective of the system to be analyzed and improved. The optimization of a point in the process is evaluated for its effect on the system.

- See redefinition and redesign as a starting point for the strategic planning of the improvement of the system.

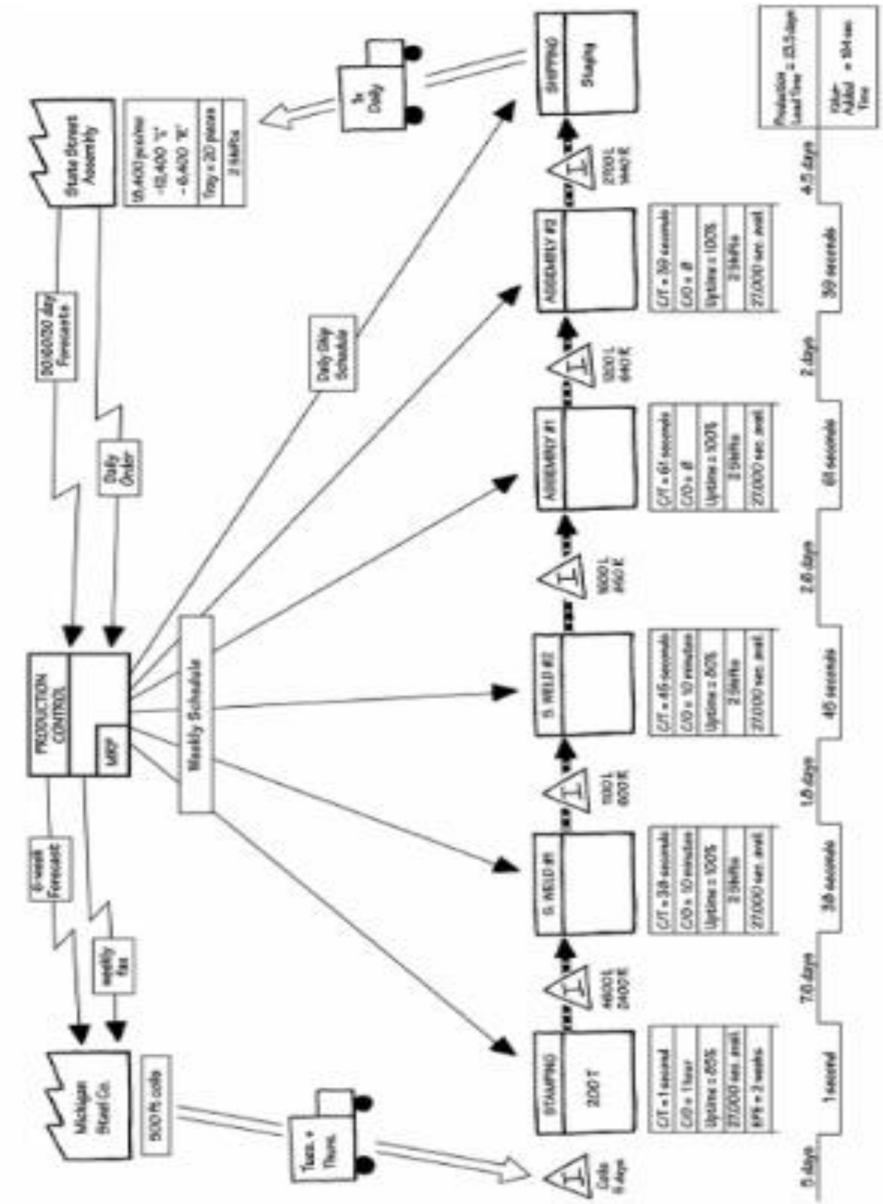
The success of mapping lies in the fact that it allows obtaining a diagnosis, but does not finish until a plan of action is generated. This plan enables taking a step toward change, once the weak points are detected, directly in all found variants of mapping methods, forces to the creation of an action plan for the achievement of the improvement or what is known as the future state (Chavez, 2012). Past literature has tended to overlook the choice of a suitable tool to address the problem we are trying to solve (Chavez & Mokudai, 2016).

2-2-1. Value stream mapping and variants

VSM is a tool to visualize the flow of material and information in a manufacturing plant. VSM initially focused on the analysis and improvement of the environments of manufacturing lines with a disconnected flow. They consume shared resources (equipment, materials, and personnel), but they work at the same time, without a sequencing of efficiency in the use of these resources (Rother & Shook, 1998).

Rother and Shook (1998) define VSM as a useful tool that not only highlights process inefficiencies, and transactional and communication mismatches, but also guides the improvement and redesign of manufacturing environments. Such useful tools have been evolving through different applications in many cases, in different environments and contexts. A visual representation of VSM is presented below in figure 5, from the didactic case in Rother and Shook (1998).

Figure 5: Value stream mapping



[Source] Rother, M., & Shook, J. (1998). Learning to see: value stream mapping to create value and eliminate Muda. Lean Enterprise Institute Brookline. Cambridge, MA. Lean Enterprise Institute. https://doi.org/10.1109/6.490058

Based on the application process, VSM is formed through five steps or phases (Rother & Shook, 1998):

1. Selection of a product family.
2. Creation of the map of the current status.
3. Creation of the future state map.
4. Definition of a work plan.
5. Compliance with the defined work plan.

Several arguments are presented in favor of VSM, claiming that it has the potential to improve production systems. Some of these are: (1) the analysis of the initial situation is based on data acquisition, (2) the treatment of numerical data and a graphical interface makes it easy to see the relationship between material and information flows, (3) the systematic vision provides each family of products with the ability to reflect the inefficiencies in the manufacturing system, (4) it provides a common language to unify the concepts and techniques in a single body, and (5) there is the possibility that this is a starting point for a strategic plan for improvement.

It is important to denote that generating “a current state map” and the effort required to create it, are pure “Muda” and non-value-adding activities unless the map is used to create and implement a “future state map” which eliminates sources of waste and increases value for the customer (Chavez & Mokudai, 2016).

The focus of VSM is on a product “value stream” (all actions required to transform raw materials into a finished product) for a given “product family” (products that follow the same overall production steps). In applying VSM, waste is identified at a high level along the value stream in the form of all elements that prohibit or hamper the flow of materials and information and in the form of inventory (raw materials, work-in-process (WIP) and finished goods (FG)). In future state design, major issues that create waste during production are addressed. The future state map forms the base for the implementation plan. It also helps in implementing focused improvement initiatives, such as set-up reduction (Goubergen, Landeghem, Aken, & Letens, 2003).

The discovery that it takes a product much longer than it should to flow through the process is a major finding (Manotas & Rivera, 2010).

Serrano (2007) evaluated the applicability of the VSM in production environments with disconnected flow lines. The results confirm the practical validity of the VSM in redesigning production systems. The approach adopted in Serrano (2017) consisted of the multiple case study method, where six companies were examined. These companies perceived VSM as a practical tool for redesigning and creating flexible and efficient production systems. VSM is valid as a standalone tool in justifying the redesign process. It makes improvements to the system at the productive performance level. Serrano (2007) tests the hypothesis that VSM is the reference for redesigning the production system according to the plans of action based on the future state and strengths recognized by the teams, in each of the case studies analyzed. Kuhlang et al. (2011) introduced a methodical approach which connected VSM and methods-time measurement (MTM). They offered a new approach to reduce lead time and to measure productivity based on lean principles and standardized processes.

VSM has proved effective in identifying and eliminating waste in a facility with similar or identical product routes, such as in assembly facilities (Seth & Gupta, 2005). In their work, Seth and Gupta (2005) attempted to use VSM as a technique to achieve productivity improvement at the supplier’s end in the automotive industry.

Romero and Arce (2017) performed a literature review on VSM. They selected 120 studies in the manufacturing industry and analyzed the evolution, application, and performance of the tool. They found that in previous research, authors had utilized both, lean and non-lean tools. As for the subject of performance, available literature has indicated that the reduction of lead time is a key performance indicator that most researchers have targeted in their papers, where the average improvement is 52.26 percent when applied. Research shows that Europe is the area where more research on VSM has been conducted. However, Asia has made notable contributions to the development of knowledge in this field as well, especially in recent years. These efforts have advocated modeling and simulation works primarily.

Most efforts in the development of VSM variants have been recent. This could be due to many reasons, such as new challenges in the market, the weaknesses of the traditional VSM, and the ease of adaptation of VSM to the different characteristics of different production environments (Romero & Arce, 2017).

While analyzing the applicability of VSM, the following weaknesses have been highlighted (Khaswala and Irani, 2001; Braglia, Carmignani, and Zammori, 2006):

- It fails to map multiple products that do not have identical material flows.
- It fails to link delays caused by queues and unnecessary transportation, as well as changes in transfer due to poor plant layout design, handling of materials, and operational parameters, (e.g., machines cycle time and performance measures).
- It does not consider economic "value" measures, such as utilities, operating costs, and inventory costs.
- It fails to show the impact that plant distribution has on delays owing to the handling of inefficient materials and batch sequences in each process in the flow. At the same time, it also omits container size, trip frequency between operations, and other similar factors.
- It is based on the manufacturing of low range and high volume systems.
- There is no visibility of the impact of inefficiencies, such as, the creation of larger amounts of WIP, cost of operation, downtimes, and leisure. This is because the products travel long distances and are part of non-integrated workflows. The lack of independence in the process and nonexistent protocols add to this.

There are two technical variants of VSM: value stream macro mapping (VSMM) and value network mapping (VNM). Both of them have emerged in industries that are different from the automotive industry. However, their guiding principles can be of help. They are worth exploring for future research applications.

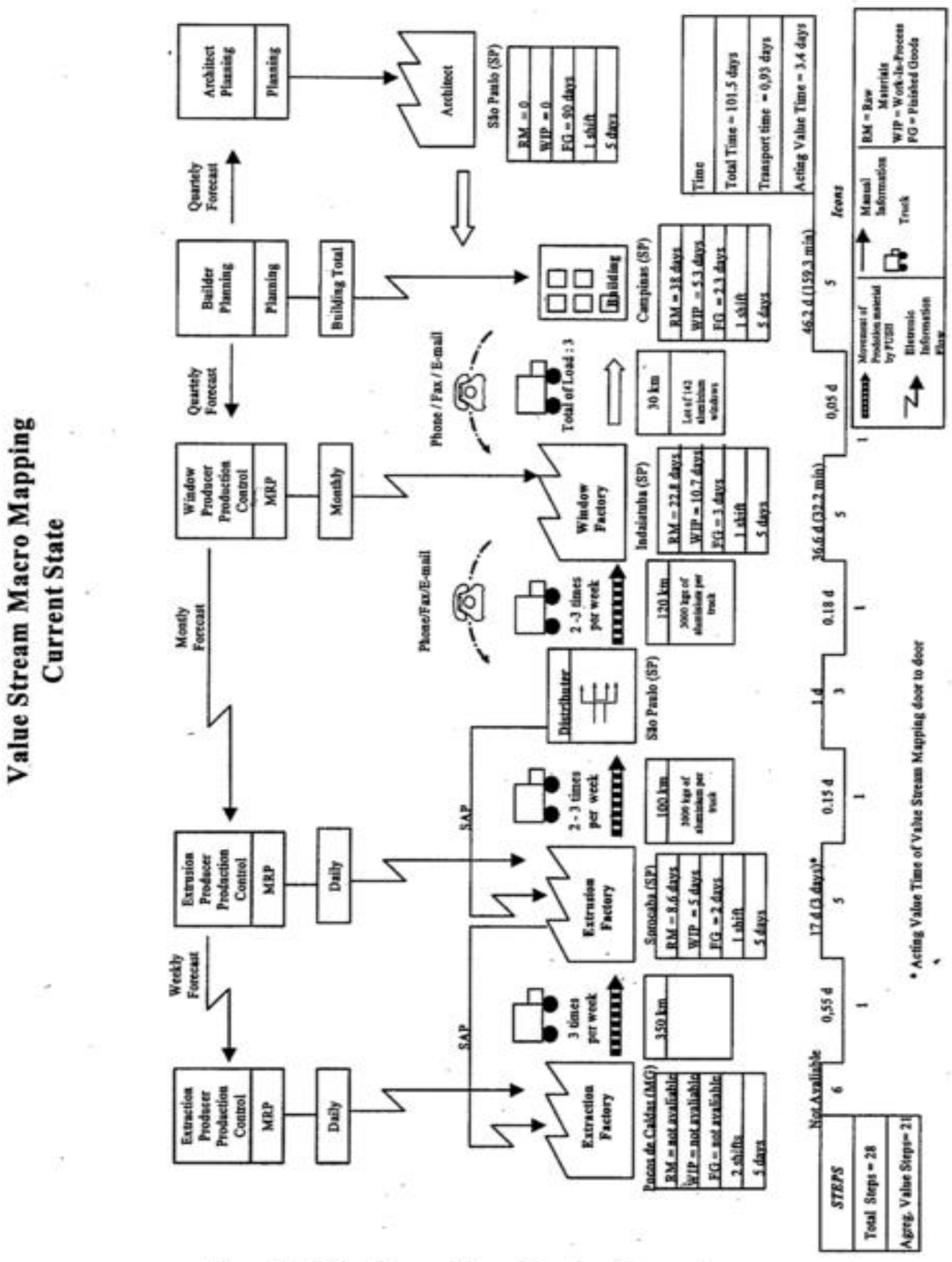
VSMM is an extension of VSM. It not only shows the waste and flow within a company throughout the supply chain, but also shows the waste and flow within several companies throughout the supply chain. It provides a complete view of the value chain processes of a specific product family (see figure 6) as well as the identification of suppliers and their production processes. Further, it allows the identification of waste that is inherent in the value chain of the selected product family in order to map it (Fontanini & Picchi, 2004; Jones, Womack, & Brunt, 2011).

VSMM makes it possible to apply concepts and techniques of lean into all macro manufacturing since the display of the value of the product flow promotes the application of these techniques as a whole, and not individually, (i.e., along with the supply chain). The main objective of value chain mapping of macro manufacturing is to allow agents of the supply chain to identify waste and focus on flow together to create the ideal state. Thus, VSMM enables the analysis of the necessary interfaces for the composition of the future state, by incorporating improvements (Fontanini & Picchi, 2004).

VNM was developed to eliminate the limitations imposed on the traditional methodology when many value streams have multiple flows that merge (Khaswala & Irani, 2001). It can map the complete network of the flows in a value chain of a complex product, with a complex bill of material and several levels of assembly. VNM uses an approach that is more suited to the prevailing state of affairs in companies, based on their structures and production strategies. This approach works in complex environments where the processes required to manufacture products involve several subassemblies and a complex bill of materials. They work under a make order or an engineer to order a scheme. The volume is low, but the variety is high. The lead times must be low and at a reasonable cost and budget as the application of the tool is limited (Chavez, 2012).

Khaswala and Irani (2001) developed and demonstrated the benefits of this approach using the results of a pilot study done in a functional workshop under scheme production for orders. VNM was developed to eliminate the limitations of the traditional VSM methodology, when we have multiple products with complex lists of materials flows and multilevel assembly. It uses algorithms to group similar distributions of plant design and manufacturing routes, which helps identify families of similar routes, in order to then be able to develop a map of the current state.

Figure 6: Value stream macro mapping



[Source] Fontanini, P., & Picchi, F. a. (2004). Value stream macro mapping—a case study of aluminum windows for construction supply chain. In Proceedings of the 12th Annual Conference of the International Group for Lean Construction (IGLC-12) (pp. 576–587). Elsinore, Denmark. Retrieved from http://www.iglc2004.dk/_root/media/13104_110-fontanini-picchi-final.pdf

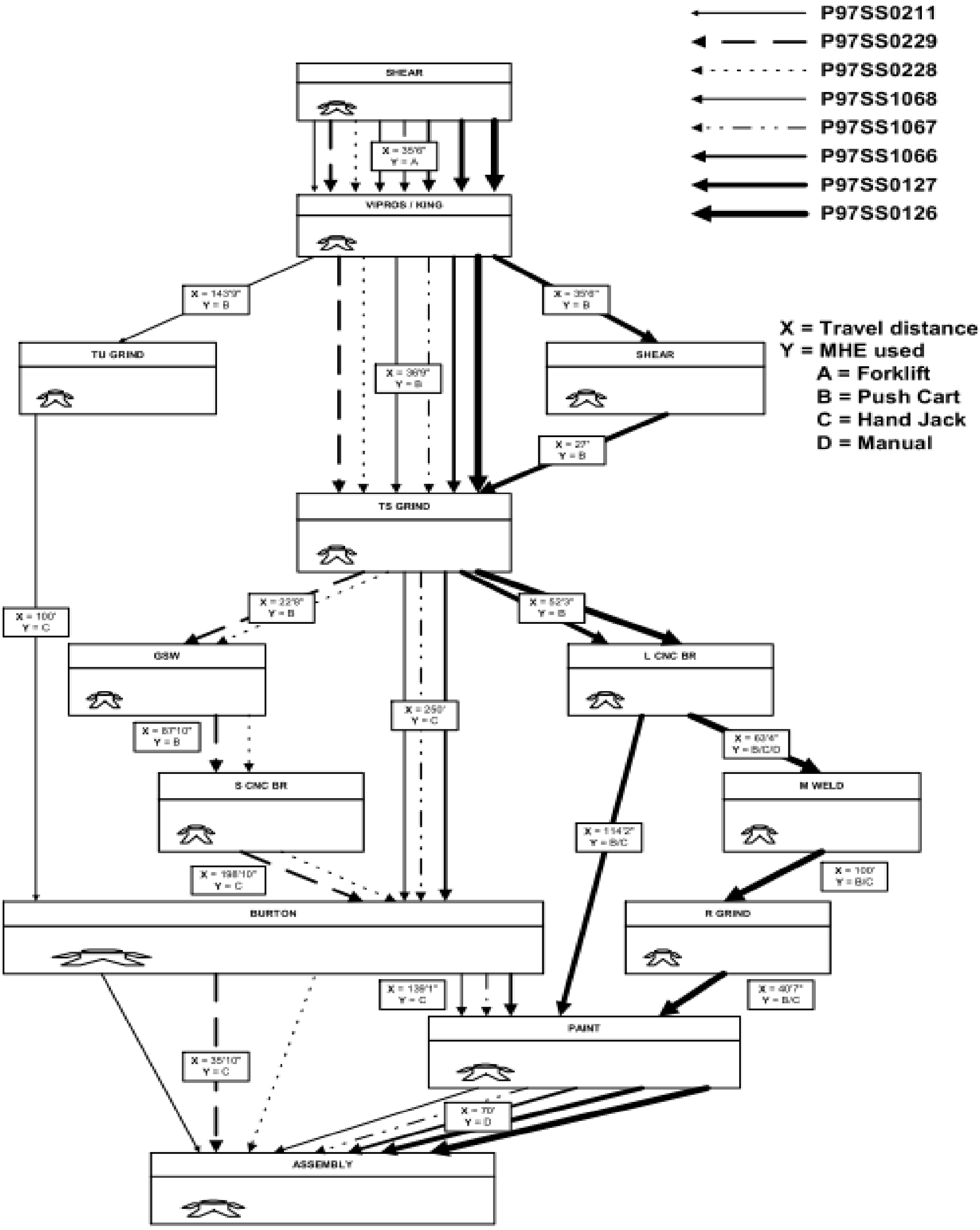
Figure 7 displays an example of a VNM at level 2, which is the last step in creating a current state using the VNM methodology. Despite the improvements that VNM brings to VSM, in the application of the tool to contexts that are more like a project environment than a serial production scheme, it is still deficient, which suggests that there is a lot of research to be carried out. Among the deficiencies, the following can be highlighted:

- It lacks information on lot sizing, cycle time, job sequencing, and WIP buildup in each process, as a result of queuing delays.
- It does not consider the capacity limitations of the system when multiple assemblies require sharing a process.
- It lacks a detailed analysis of the material handling systems and processes connecting different pairs of process boxes.

According to the literature analyzed, before mapping and choosing a specific tool, practitioners need to know the following characteristics: the complexity of the bill of materials, levels of assembly, number of processes, production strategy or scheme (job shop, project or serial), business type, and demand. Being aware of those characteristics will prevent from truncating efforts.

Even though VSM and its variants demonstrate great tangible improvements in manufacturing environments, current enterprises opting for lean manufacturing show the need for a more detailed output and a more problem orientated tool.

Figure 7: Value network mapping at level 2

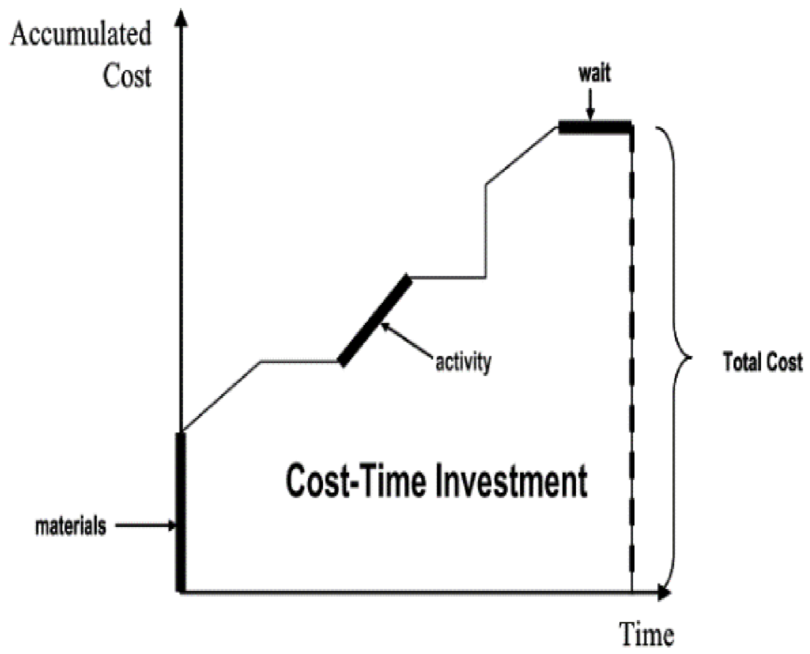


[Source] Khaswala, Z. N., & Irani, S. a. (2001). Value network mapping (VNM): Visualization and analysis of multiple flows in value stream maps. In Proceedings of the Lean Management Solutions Conference, St. Louis, MO. Retrieved from http://www.lean-manufacturing-japan.com/Value Network Mapping (VNM).pdf

2-2-2. Cost-time profiling (CTP)

The trendiness of VSM shows that many companies are interested in tools to compress their processes in the time dimension. It is also evidence of the fact that the awareness that the smooth and quick flow of the product through the process are desirable characteristics, is stronger than ever (Rivera, 2006). CTP is a tool that offers valuable insights into process performance and process improvement. An important feature of CTP is that it requires real-time information to be accurate. Basic concepts were developed at Westing House Corporation in the 70s (Fooks, 1993) only for internal use with no further diffusion. However, later on, the concepts and basic applications were introduced by Fooks (1993). Currently, the more meaningful and explicit literature found on this tool was crafted by Rivera (2006) who defines the components of CTP (figure 8) clearly: materials, waits (waiting time or idle time), total cost, and cost-time investment.

Figure 8: A Cost time profile



[Source] Rivera, L. (2006) Inter-Enterprise Cost-Time Profiling. Virginia Polytechnic Institute and State University

In simple words, CTP measures how much money is invested in the manufacturing process of a product and for how long (time). It creates a graph that presents the accumulated cost at every point in time, measuring the area under this curve (total cost-time investment), and then uses this quantification to measure the impact. The graphs are performed in a software tool developed by the Center for High-Performance Manufacturing (CHPM) at Virginia Tech on 2006, parallel to the research performed by Rivera (2006). Manotas and Rivera (2010) followed an example with a simple project network with seven activities, showing in detail the phases of application. This case offers a practical view and a numerical representation of the concepts that were previously introduced by Rivera (2006).

Gracanin et al. (2014) present an application on CTP, starting with the data gathered from a real assembling company based on VSM and VSC rules. There is not much explanation for or information on the company that was taken as one of the case studies. However, there is a graphic representation. Results suggest that the tool emphasizes the importance of the relationship between money and time and provides a framework for value stream optimization.

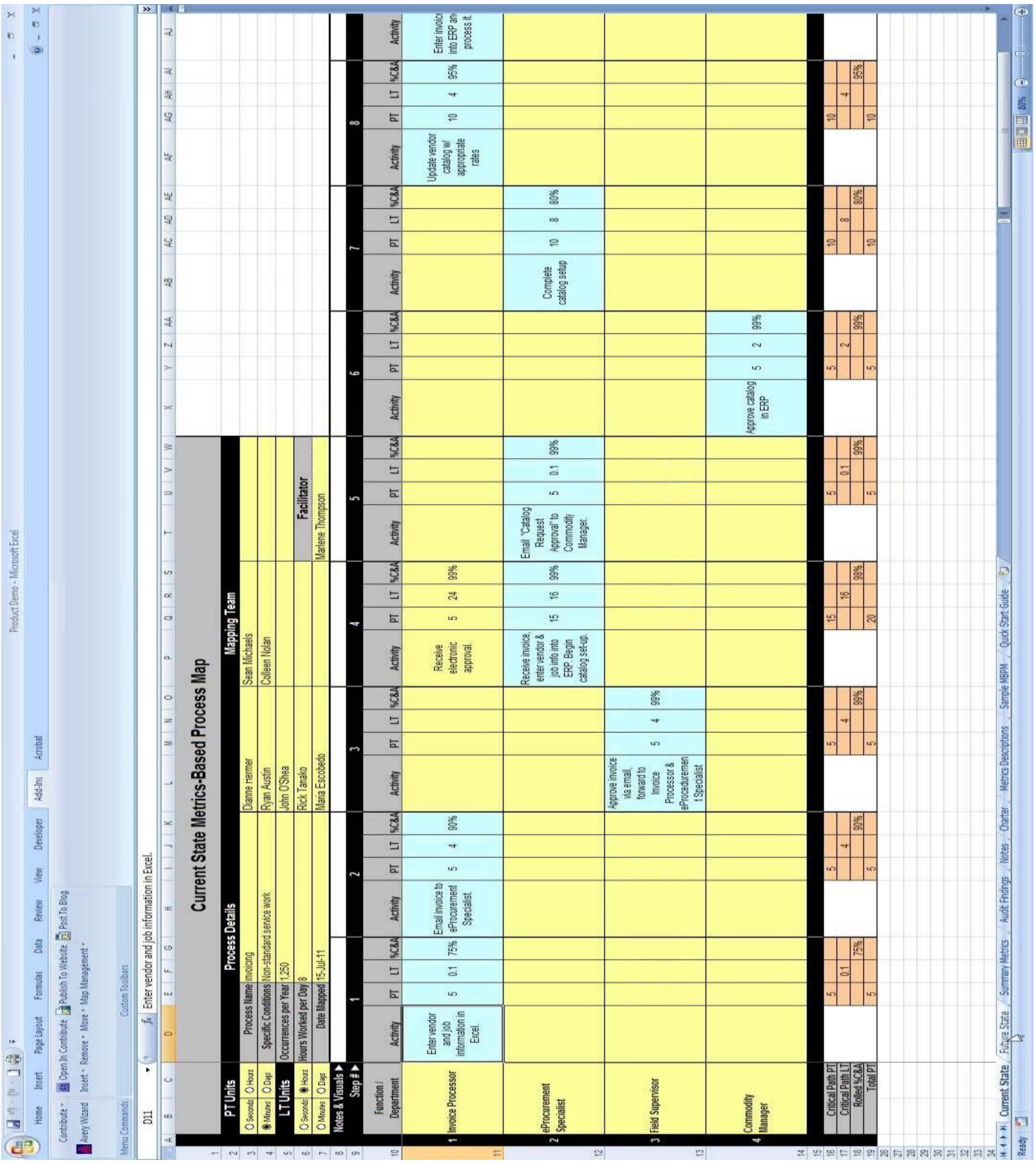
The simultaneous attention to cost and time have made possible the identification of the measurable monetary impact that the timing of costs, activities, waiting time, and material releases have on the direct cost of a product. These considerations make CTP an important tool that can be used to complement VSM while characterizing a production process (Rivera, 2006).

2-2-3. Metrics-based process mapping (MBPM)

MBPM was developed by Karen Martin. Mike Osterling first presented it in 2007, in a book titled "The Kaizen Planner." Later on, they affirmed that the proficiency in process measurement and analysis remained low (Martin and Osterling, 2013), thus slowing down improvement and creating significant risk while attempting to solve problems due to the lack of relevant metrics. This led them to introduce MBPM as a standalone improvement tool that can be used by itself and not as part of a Kaizen event. At this point, no application cases have been found, and there is no other study or literature on the tool other than the one presented by the creators.

MBPM is directly controlled by the people who actually carry out the work. It is defined by the authors as a method that enables improvement teams to perform the type of detailed current state analyses that are often required to design process-level improvements. In organizations where VSM is used as a strategic tool to depict how work is done at a macro level, MBPM is used to understand the current performance at a micro level and to design tactical level improvements. MBPM directs actions and activities that restrict the flow, specific steps or tasks in a process. In figure 9, the process is broken down into the activities provided under MBPM, which integrates two strong analytical tools: line process maps and time and quality metrics.

Figure 9: Metrics-based process mapping



[Source] Martin, K., & Osterling, M. (2013). Metrics-based process mapping: identifying and eliminating waste in office and service processes. (2nd Edition). Florida, United States. CRC Press, a Productivity Press Group.

If people involved in the process do not see the improvements, they will resist, and as a result, sustainable improvement will be hard to achieve. This is why it is important to highlight MBPM as an effective tool in defining, improving, and managing processes. It does not include detailed content on how to build organizational culture where metrics-based process mapping is used as the means to build the organizational discipline that is necessary for continuous improvement (Martin and Osterling, 2013).

2-3. Assessing performance: metrics

2-3-1. Metric determination

Firms often fail to maximize the benefits of lean at a macro level because they fail to develop the performance metrics required to evaluate improvements in effectiveness and efficiency. There are different methods to measure system leanness. One of the most prolific approaches has been to observe how many lean tools, techniques, or principles a company has implemented (Rivera, 2006). This derives from the classic “temple” representation of the TPS, often leading to the interpretation that lean is a toolbox from which one can select independent tools. By picking just some tools, however, the full potential of the TPS certainly cannot be exploited, and in the worst case, it may even cause a disruption in production (Rüttimann & Stöckli, 2016).

Given the inherent complexity of manufacturing processes, a measurement method to deal with these complications is particularly critical. Moreover, Gunasekaran and Kobu (2007) state that conventional measures mainly measure only financial metrics such as the rate of return on investment, cash flow, and profit margins. This is a disadvantage because it tends toward an inward-looking focus that fails to include intangibles and lagging indicators.

The effectiveness of an organization increasingly depends on investments by suppliers and customers. Thus, the relationship will move from being dominated by customer purchasing power, short-term product cost, and quality considerations, which can be measured by traditional metrics, to a relationship involving a long-term commitment by all parties involved, for which new metrics must be developed (Williams et al., 2006).

The collection of information on manufacturing processes is mainly adapted for mass production. Product cost represents crucial management information. In the modern economy, however, customer value and measuring the cost of resource use are priorities. Many companies are not able to identify and recognize complete value streams (Gracanin, Buchmeister, & Lalic, 2014) and as a result, fail to recognize situations when it is necessary to take proper action promptly.

Lean rate (LR) and activity ratio (AR) are the most well-known numerical indexes used to represent how lean an organization is. The concepts underlying both are very similar, even though the names of their components are slightly different. Both support mapping tools such as VSM and MBPM, and the indexes are recalculated and analyzed to control improvements.

2-3-2. Lean rate (LR)

LR is useful in finding and tallying inventory accumulation where the flow of value had to be interrupted due to process problems (Álvarez et al., 2009).

Equation 1: Lean rate formula

$$Lean\ rate = \frac{Time\ that\ add\ value}{Total\ of\ invested\ time}$$

[Source] Álvarez, R., Calvo, R., and Peña, M. M. (2009) 'Redesigning an assembly line through lean manufacturing tools,' International Journal of Advanced Manufacturing Technology, 43, pp. 949–958. doi: 10.1007/s00170-008-1772-2

Álvarez et al. (2009) focuses on the analysis and the use of VSM to attain improvements by implementing Kanban and milk run efficiently. Their strategic influence is measured by means of two lean metrics: lean rate (LR) and dock-to-dock time (DtD). These metrics are important to establish gains and identify areas for further improvement. The improvement objectives center round reducing stocks while avoiding idle time, and the movements of workers due to accumulated material. Both metrics, LR and DtD improved. In general, LR represents the percentage of the time that adds value to a production system (see equation 1). The aim is to increase it as much as possible.

2-3-3. Activity ratio (AR)

AR also represents a percentage, used as a metric and it is referred to as percent activity (% activity). It is already set up while performing a MBPM analysis (Martin & Osterling, 2013). The percentage is the fraction of the time of the total performed work, as seen in equation 2. The percentage of waiting time can be easily obtained by simply reducing the AR from 100 percent (i.e., the total amount of time available).

Equation 2: Activity ratio formulas

1) $Activity\ ratio = 100 \times \frac{Critical\ path\ PT\ Sum^{\ 1}}{Critical\ path\ LT\ Sum^{\ 2}}$

2) $\%\ \text{waiting time} = 100\% - Actitivity\ Ratio$

[1] $Critical\ Path\ PT\ Sum$: $The\ cumulative\ total\ of\ the\ Critical\ Path\ PTs\ for\ each\ step.$ $It\ is\ calculated\ just\ as\ a\ sum\ of\ the\ critical\ Path\ PT\ (processing\ time) for\ all\ process\ steps.$

[2] Critical Path LT Sum: The total of the individual lead times (LTs)along the critical path. Besides being used to calculate the AR, it helps determine the actual throughput time. It is determined as a sum of the critical path LTs for all process steps.

[Source] Author version from (Martin & Osterling, 2013)

This metric indicates the magnitude of the opportunity for improvement in the flow of work through a process (Martin & Osterling, 2013). Often, initial calculations of AR present a very low outcome. However, the author recommends focusing on the fact that this is a ratio, although the AR may be low or may have decreased the LT and PT as improved by team efforts. Leaders must motivate and guide the team to keep the efforts going.

2-3-4. Value stream costing (VSC)

VSC is defined as a technique under the lean accounting canopy, introduced around 2000. It is based on the value stream concept and is intended to avoid the drawbacks of traditional costing. VSC aims at capturing the cost of materials, labor, and every resource directly within the value stream with little or no allocation of overhead costs. Inside a value-stream-based lean manufacturing system, it allows the costing of a product family (at an intermediate level of detail) in an understandable and timely way, and drives continuous improvement and decision making in combination with non-financial performance measures (Ruiz et al., 2013).

There is very little research on methods to be used in applying VSC. Thus far, López and Uraga (2008) presented the most basic and explicit application found. The authors noticed the lack of methodology to be used in applying VSC. Accordingly, thus, they have proposed a scheme to apply this tool based on the main concept framed by the pioneers and creators of lean accounting, namely, Maskell and Baggaley (2003). Maskell and Baggaley (2003) also recommend VSC as a means for the simplification of the calculation of production cost when the lean maturity level is in a higher state. Saying that an organization has achieved a higher level of maturity means that it has achieved short lead times, low and stable inventory levels, and flexible value chain lines. This is why VSC has been found to work well with other tools such as VSM (Ruiz et al., 2013) and CTP (Gracanin et al., 2014) among others.

Differences between direct and indirect costs disappear when VSC is applied. Al costs within the value stream become direct, and costs outside of the value stream map are not included (Gracanin et al., 2014). One of the benefits that should be highlighted is that besides modeling the processes, it simplifies the accounting process when compared to traditional costing and ABC. Similarly, it encourages continuous improvement since it reflects operational improvements. Cost reduction is tackled by reducing Muda, and not by increasing the production volume which leads to avoiding excessive production.

Metrics and future states presented by López and Uraga (2008) and Ruiz et al. (2013) show the improvements achieved after using VSC. It is not that the tool itself will promote improvement, but rather that it will allow the organization to see where the waste is hidden clearly in terms of money. This can translate to money that can be recovered. Since the organization is already working under a value stream scheme, gathering the information required becomes just a matter of displaying and organizing the data, in order to see the gaps and identify room for improvement. One drawback of VSC is that it is a method that treats all items as equal. It might work well for short-term performance measurement and short-term decisions, but will not work as well while considering the long-term (Ruiz et al., 2013). Traditional accounting or costing management may not indicate if progress is achieved or if improvements have been made with lean initiatives. However, VSC analysis allows production personnel to see how their lean initiatives are benefiting the organization. It also allows the introduction of improvements to the value stream, because it makes visible the processes where we have idle, waiting time or excess capacity. Improvement can be seen as an improvement of an economic type. An economic improvement can be a high trigger for decision making under the watchful eye of the management when it comes to launching projects, assigning resources or choosing investments. Therefore, having an analysis of this type can be extremely helpful for making successful choices.

2-3-5. Metrics in mapping tools

Metrics complement the mapping tools that track the various stages of an organization's lean journey. While the time dimension is predominant in the metrics used to measure performance in lean environments, the economic factor is not directly linked to improvement.

The time dimension, that is, lead time (LT), cycle time (CT), and processing time, can serve as a basis for tracking improvements. However, we can also associate other data (WIP, man-hours, and inventory), the specific details of which facilitate better direction in designing improvement projects and in rapid decision making. Organizations often omit the adaptation of metrics. However, using proper metrics can benefit performance as well as utility.

2-4. Training people

How can a culture that empowers workers be created? The answer inferred from the existing knowledge suggests that the way to do so is training. Accordingly, the following two subsections describe the two major paths that maybe relied on to facilitate the development of workers in a continuous improvement mindset and environment that have contributed to shaping both, TPS and its western version, lean.

2-4-1. Training within Industry (TWI)

Training within Industry (TWI) has been directly influential in developing what we call today as lean. It was developed by the United States during World War II. At that time, it was necessary to assign simpler tasks to unskilled workers for anticipated wartime. In 1951, Edgar McVoy brought Lowell Mellen to Japan to install the TWI program. When the program was created, the goal was to train people using a standard method and then train groups of people with no industry distinction. Thus, young trainers might be teaching older and more experienced supervisors (Warren, 2010). However, later on, the same methods were transferred to the New United Motor Manufacturing, Inc. (NUMMI) plant in the USA by Toyota. This was what the Americans had taught the Japanese decades earlier (Dinero, 2005). Through NUMMI, Toyota began the repatriation of this expatriated technology. TWI was developed over time through practice and implementation. The programs were standardized but not static, as stated by John Shook in the foreword in Dinero (2005).

The TWI program comprises three segments, known commonly as the three “Js”:

- Job Instruction (JI) is the foundation of standardized work and allows employees to quickly establish the one best way to perform a job.
- Job Relations (JR) gives employees a set of skills that encourage positive relations, increases cooperation and motivation, and helps them effectively deal with conflict.
- Job Methods (JM) provides employees with a process to put their ideas for improvement to test, and then, in place, if the new method yields better results.

Currently, TWI as an organization, keeps training instructors and certifies them. They have created training know-how and various teaching materials since their inception over 60 years ago. They support the development of human resources in organizations. Meanwhile, according to Dinero (2005), in Toyota, JI is still used as the key factor in their training efforts. For other courses or segments, Toyota has replaced the three Js but follows the same format in entirety and the same principles to some extent. Modifications were made because of the production system experimentations that Ohno was performing in the 1950s.

TWI is seen as a foundation for lean thinking and a catalyst that changes the culture from mass production to lean production. For some practitioners (Alan & Dean, 1993) it is seen as an instrument for implementing lean and for some others, it is considered as the “missing link” that can help an organization make the necessary cultural changes to solve problems and sustain lean transformation (Dinero, 2005).

2-4-2. Toyota Kata: habits and routines

Toyota can be synonymous with business excellence, attaining both, the visible part comprising practices, tools, principles, and the invisible parts comprising management thinking and Kata- routines (Toma & Naruo, 2017). Toma and Naruo (2017) provide an analysis of TPS. The main results show that the best practices of TMC related to total quality management and business excellence are derived from TPS. These practices are found in the attributes of business excellence. The postwar period brought to fore new aspects of TPS, that were confirmed when put into practice:

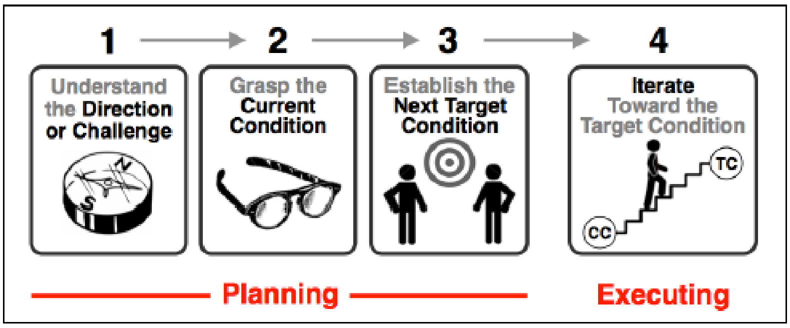
- The fight against Muda.
- Emphasis on quality and the use of specific techniques (e.g., PDCA cycle, statistical quality control methods, quality circles).
- Learning-by-doing.
- The implementation of the pull system.
- Focusing on streamlining production.
- JIT.

Toyota Kata (TK), developed by Rother and Aulinger (2017), is a holistic method to carry out improvement efforts that contains processes and behavioral patterns for strategically aligned goal setting, problem-solving, coaching, management, and training. It is a simple and teachable approach which also covers the management of improvement efforts.

The central message of TK is to describe and explain Toyota's process for managing people. Johnson, in the foreword in Rother's book, sets forth with clarity and detail the improvement and leadership routines at Toyota, or Kata, by which Toyota achieved sustained competitive advantage. Rother differentiates Toyota´s practices from those observed in western companies in their focus: "managing by means" instead of "managing by results." It replaces traditional financial-results-driven management thinking with an understanding that outstanding financial results and long-term organizational survival follow best from continuous and robust process improvement and adaptation, and not from pushing people to achieve financial targets without caring first about how their actions affect processes (Rother, 2004).

Rother depicted this pattern of thinking and behavior with a four-step model as seen in figure 10. He named it the "Improvement Kata," after noticing the connection between Toyota's management approach and the concept of Kata (practice routines and "way of doing things") in Japanese culture.

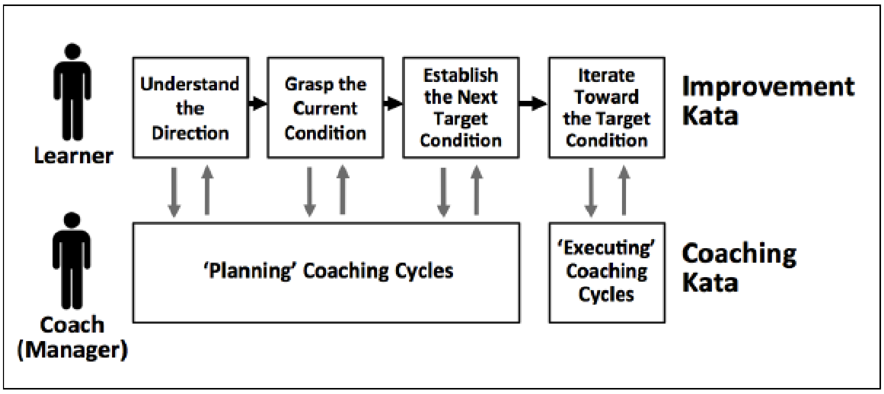
Figure 10: The Improvement Kata model



[Source] Rother, M. (2004) Toyota Kata: Managing People for Improvement, Adaptiveness and Superior Results. 1st edn. United States of America: Mc Graw Hill.

Toyota's management approach involves inculcating a scientific mindset in people that can be applied to an infinite number of objectives, thereby creating a deliberate and shared way of working throughout the organization (Rother, 2004). According to Rother, what Toyota managers are doing by combining the Improvement Kata pattern and Toyota's traditional Master-Apprentice teaching approach (which he calls the "Coaching Kata" because it resembles training in sports) in their daily work, is teaching a universal human means of improving, adapting, and innovating. Figure 11 depicts both, the Improvement Kata and Coaching Kata, and links them together to create the system of management.

Figure 11: System of management in Toyota Kata approach



[Source] Rother, M. (2004) Toyota Kata: Managing People for Improvement, Adaptiveness and Superior Results. 1st edn. United States of America: Mc Graw Hill.

The downside of the approach is its focus on incremental improvement instead of on breakthrough innovation (Toivonen, 2015). TK aims to create scientific thinking capabilities that can be applied to any challenging objective (Rother & Aulinger, 2017). The first step in TK is the planning phase of the Improvement Kata pattern, which involves three steps:

1. Getting clarity about the challenge that is coming from above, and what it means to your level.

2. Digging deep into your level or focus process, with facts and data to understand its current condition better.

3. Establishing your next target condition (TC), based on the current condition (CC) and in the direction of the challenge.

A vision is a long-range “ideal state,” as stated by the organization’s leadership, while speaking of value that flows to the customer. However, for day to day improvement, specific challenges defined as measurable descriptions of success for 1 to 3 years in the future may be given. Rother and Aulinger (2017) highly emphasize a vision, in the same way as the future state in a VSM. Having an organization or value stream-level challenge is important, so each learner's target condition is seen as connected and meaningful. It is difficult for people to stay engaged with something that does not have a purpose. The upward flow of information is a vital element in a policy deployment system, along with the distribution of a strategic challenge down into an organization. Adaptiveness comes from building on the lessons learned from an incrementally unfolding reality. The Toyota way provides a means to achieve our mission and vision, and provides a way of thinking and acting for employees globally that can be applied to different cultures where they do businesses.

Liker and Hoseus (2010) highlight the obligation of human resources in taking responsibility for continuous improvement in programs and operations. Improvement Kata (IK) and coaching Kata (CK) are about teaching a systematic and scientific way of working throughout an organization, to get better at reaching difficult goals. It is a culture modification process that involves developing new skills and a new mindset through deliberate and coached practice. The more capability is developed by the teams, the more the organization can empower and count on them.

Instead of pushing, they will pull as they strive to achieve target conditions scientifically and meet challenges that may have been considered as impossible (Rother & Aulinger, 2017). Although the scope of improvement efforts differ from level to level, the patterns of the IK and CK are content-neutral and get repeated at each level.

Toivonen (2015) presents the practice of TK and states that using real work-related problems and challenges (that are increasingly difficult), makes it economically viable to practice to the extent that TK becomes second nature.

2-4-3. Impact on the application of tools

Both TWI and TK principles rely on the scientific method. They use scientific thinking to develop behaviors, habits, and routines on the production floor. Organizations which, besides having tools in place, adopt one or the other will aid the elimination of barriers to the adoption of a lean scheme, which are caused by workforce particularities such as national culture, customs, or individual thinking.

Tools help develop solutions, but there is always a thinking process involved in their use. With TWI and TK, we can teach a way of thinking. Both methodologies follow a logical approach and do not assume that everyone thinks this way. Everyone who is unfamiliar with a job needs training. This does not mean that it can be assumed that every worker is familiar with the scientific method and will come out with solutions. In this sense, by training under TWI and TK, workers learn a variety of skills to solve problems that can be applied everywhere. They help personnel understand what the medium does (e.g., tools) and then select the simplest form to accomplish one's objectives.

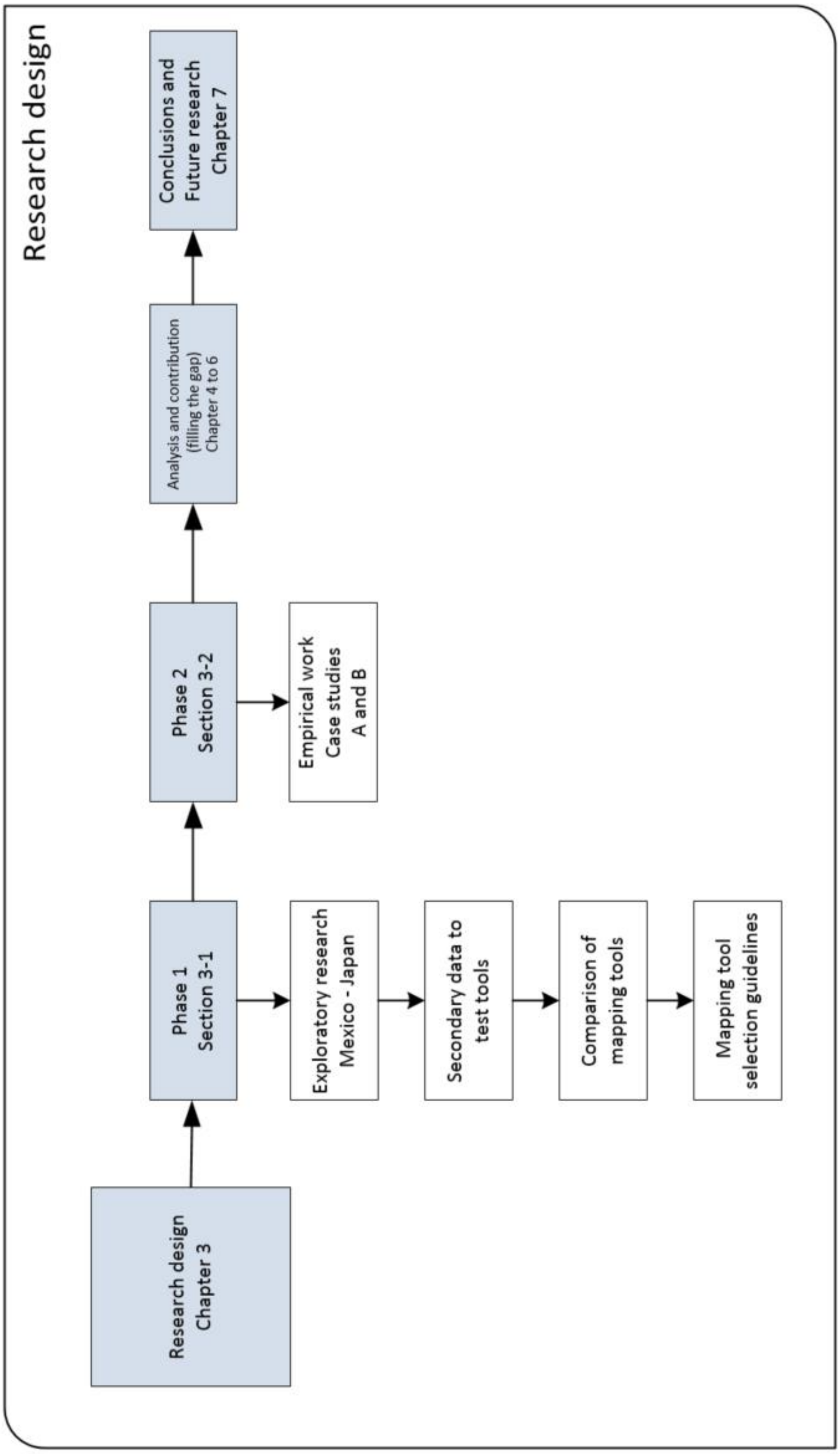
Standardized work can be overseen in TPS when it actually plays a central role. A common misconception about standardization is the assumption that it is simply regimentation, when in fact, its true value is to serve as the basis of experimentation (Dinero, 2005). Standards are set as baselines for comparison and are later used as baselines for improvement. In this sense, standard work serves as an enabler for individual innovation. As stated by John Shook in Dinero (2005) this sets the process that we have come to call as “continuous improvement” under lean thinking and PDCA by Deming.

Chapter 3: Research design

This chapter describes the research methodology, design, and strategy employed to collect and analyze the primary and secondary data. Phase 1 comprises exploratory research, the use of practical tools to test the secondary data, and a validation of the approach used in this study, as well as the logic behind the selection of the qualitative case studies. Phase 2 presents the empirical research, including an overview of the cases chosen. Finally the gap is described. The selected research questions that this project aims to address are laid out. Figure 12 is a visual representation of the outline of the following chapters.

Sections 3-1-2 to 3-1-4 are based on Chavez and Mokudai (2016) while section 3-2-2 is based on Chavez, Mokudai, and Uyama (2018).

Figure 12: Research design flow



3-1. Phase 1: Exploratory research and testing of tools

3-1-1. Exploratory research

The author in collaboration with other researchers conducted exploratory research from June 2015 until the first quarter of 2017. The author and one researcher were the constant participants in the entire exploratory phase. In September 2015, the author and the researcher traveled to Baijo, Mexico, for research. This region is a recognized automotive cluster with high economic activity due to the localization and concentration of automakers and suppliers. In this region, the author visited car manufacturers and suppliers. This trip gave the author and the researcher a good insight into the operations of these companies and their current situation with respect to tools and business development. In 2016, the team visited a few suppliers and OEMs in Japan, bearing in mind the observations noted in Mexico and the questions that were leading to the establishment of the problem statement for this study. By the end of 2016, the author and the researcher attended "The forum of the automobile industry: think about the global strategy of regional suppliers" (in Japanese: Jidōsha sangyō kanren fōramu: Chiiki sapuraiyā no gurōbaru senryaku o kangaeru) in Hiroshima, Japan. The forum allowed the author and the researcher to observe and understand the way in which interactions between local suppliers and researchers took place. While organizations raised concerns and presented their problems, the researchers spoke about their areas of research and presented ways in which they could contribute to the companies in their development projects and in their current operations. In February 2017, the author, the researcher and a research team from Japan, visited a couple of suppliers and local OEMs in Hiroshima. Based on the insights gained during the exploratory research, it was possible to narrow down the research questions and redirect the next phases of research.

3-1-2. Secondary data to test tools

The tools examined in this study are the latest mapping tools. They comply with lean thinking and have been developed for and under lean production characteristics. The common benefits of the tools presented in this study represent the common objective: decrease cost and lead time, and increase customer value. Feasibility, practicality, and attainability from the user's perspective need to coexist in a tool. This section describes the process followed in testing and studying the mapping tools in theoretical and practical settings, based on which we established guidelines for organizations starting out on or already in their lean journeys.

A period of around 8-9 months was dedicated to software exploration, followed by a three month period of comparison and creation of guidelines for tools. The activities included practical testing and case studies of the tools as used by other practitioners. The software and tools incorporated here were: CTP, MBPM, VSM, and VSC. The author used the original base case described by Chavez (2012) as a starting point for the experiment. The case provided the data necessary for the fields that shared properties with VSM and for the fields where that was not possible. The author set up hypothetical data to perform these simulations, in order to be able to analyze the same case using different tools. A comparison between the tools mentioned and an analysis of the tool selection process was carried out, and the findings were presented at the Euroma conference 2016, as well as in the proceedings by Chavez and Mokudai (2016).

In the case of VSC, an actual run was not performed for two reasons. The development of the tool was still at a premature stage, and the author did not have access to the income statements of the company in the original base case. Each of the tools performs a unique analysis, requiring the input of different data. Some of the parameters may be shared among them, but some other parameters are unique to each tool. Thus, the data had been set and adjusted for each tool, so that each would run properly and smoothly in each round of testing.

The main objective of testing the tools was to identify the conditions and the type of production process or manufacturing environment in which each of the tools worked best. Further, through the testing process, there was a better understanding of the capabilities of the tools, which enabled an objective comparison. Practical testing was conducted using both actual and hypothetical data.

3-1-3. Comparison of the tools

The basic data required to perform the test are summarized in the tables presented below. More details on the secondary data can be found in Chavez (2012). This company designs and manufactures connectors and cable assemblies for medical instruments. The production system, however, did not adapt to new production necessities. This led to low productivity and constant lapses in lead times and delivery times. The product selected was “Harness 100087.” Table 2 describes the processes and the machinery involved in production. The data contained in the VSM maps have been summarized in tables 2 and 3, which are also used in the creation of MBPM and CTP. One of the most significant changes in the VSM future state was creating a mirror station in the molding area of process number 3. This modification had an important implication for tools data management, and this addition was not reflected in the MBPM current state map. The assumption is that both stations run at the same cycle time, and that times need to be taken into consideration when the metrics are given by the tool, without considering that this resource may reduce the certainty of the results.

While MBPM has defined metrics, personalized ones may also be set. In MBPM, quality can be tracked through the percent complete and accurate (% C & A). This percentage indicates the quality of a “product” received at the station. MBPM seems to be the only tool that has a quality type metric. Full-time equivalent (FTE) is introduced as a measurement of the labor-effort required. In simpler terms, it speaks of the number of people required. FTE is useful in explaining freed capacity. Another preset metric introduced is AR, which can be interpreted as LR, the percentage of time that adds value from the total time invested. One more feature of the tool is the critical path (CP) which is calculated automatically by the software along with an audit that helps us determine if all the data necessary to run the test has been input properly. Figure 13 shows the metrics summary once both states were created.

Table 2: Description of processes and availability of machinery

Process name	**Number of machine / operator available**
1. Cut. Cutting cable and plastic backing	2
2. Lines. Pre- Assembly. Strips, rivets, junction of wires, pre-assemble preparations	1
Stripping machine	2
Rivet machine	1
Cables union machine	1
3. Internal Molding	9
3.1 External molding	
4. Lines. Assembly. Placement of covers, Ferrites, connectors, pins and other accessories, pallets, junction of wires	1
Stripping machine	1
Rivet machine	1
Machine for cable union by heat	1
5. Line. Final assembly	1
6. Inspection	1
6.1 Electrical Test	1
6.2 Voltage Test	1
7. Inspection	1
7.1 Packaging	1
7.2 Labeling	1

[Source] Chavez, Z. (2012) "Redesign of a production system of the medical industry through mapping techniques".

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Table 3: Real processing and waiting times for current state

	Areas								
Time	**1**	**2**	**3**	**4**	**5**	**6**	**7**		
PT (CT)	13.916	22.66	64.08	3.51	6.73	2.2	3.12		
Change over	96	13.43	34.2	12.4	0	0	0		
Waiting time	10.22	2.25	2.58	2.9	37.95	2	2		
Total	120.136	38.34	100.86	18.81	44.68	4.2	5.12	332.146	Min.
							Real production time	5.535767	Hrs.

[Source] Chavez, Z. (2012) "Redesign of a production system of the medical industry through mapping techniques."

Sonora University

Table 4: Processing and waiting times for future state

	Areas								
Times	**1**	**2**	**3**	**4**	**5**	**6**	**7**		
PT (CT)	13.916	22.66	32.04	3.51	6.73	2.2	3.12		
Change over	48	0	22.32	2.48	0	0	0		
Waiting time	0	2.25	2.58	2.9	0	2	2		
Total	61.916	24.91	56.94	8.89	6.73	4.2	5.12	168.706	Min.
							Real production time	2.81176667	Hrs.

[Source] Chavez, Z. (2012) "Redesign of a production system of the medical industry through mapping techniques."

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Figure 13: MBPM Summary metrics

Summary Metrics

0 Decimal Places
1 Decimal Place
2 Decimal Places

Metric	Current State		Projected Future State		Desired Direction		Projected Improvement
Predefined Performance Metrics							
	Value	Units	Value	Units	Up	Down	
Critical Path PT Sum	116.16	minutes	70.20	minutes		◉	39.57%
Critical Path LT Sum	332.10	hours	168.71	hours		◉	49.20%
Activity Ratio	0.58	%	0.69	%	◉		18.97%
Rolled %C&A	32.44	%	32.44	%	◉		0.00%
# of Activities	9	activities	9	activities		◉	0.00%
Capacity Calculations							
Metric	Current State		Projected Future State				Projected Change
	Value	Units	Value	Units			
Sum of Total PTs	121.10	minutes	75.14	minutes			-37.95%
Occurrences per Year	20000	occurrences	20000	occurrences			0.00%
Available Work Hours per Year	2880	hours	2880	hours			0.00%
Labor Requirements	14.02	FTEs	8.70	FTEs			-37.95%
User-defined Performance Metrics							
Metric	Current State		Projected Future State		Desired Direction		Projected Improvement
	Value	Units	Value	Units	Up	Down	
LT sum	332.10	minutes	168.71	minutes	○	◉	49.20%
PT Sum	116.20	minutes	70.20	minutes	○	◉	39.59%

[Source] Chavez, Z. and Mokudai, T. (2016) 'Mapping tools selection towards lean transformation in manufacturing environments,' in Euroma 23rd Conference, Norway, 17–22 June 2016. Norway, pp. 1–10

The considerations for data input differ from the real case in that no overtime is considered, and working 50 weeks a year (available working hours a year) was taken into account. The % C & A was assumed as ranging from 85% to 90% based on the complexity of the activities performed at each station, as information was not available from the original case (Chavez, 2012). The recurrence observed helped determine the most suitable percentage that ought to be assigned. Since the study does not focus on quality, it was deemed safe to play with conservative numbers. The analysis reveals that the future state can be performed safely with nine operators (FTEs) giving a 37.95% reduction. The intention is not to downsize staff, but to make the system more efficient. Thus, people could be reassigned to other processes. The projected improvement area column is a quick summary analyzing the impact that the future state would have if this were to be implemented.

For MBPM, prior process analysis and knowledge of details are needed. Activities need to be prioritized or at least have a sense of relevance because in order for the "critical path" feature to run, this information will be asked to be input. It is a way for the tool to determine and highlight critical activities and to proceed to the audit map.

In order to create a CTP analysis, starting times for each process needed to be calculated. The current and future state times are presented in table 5. The software requires material cost to be entered. In order to test matters, a cost was assigned at the final assembly, on a scale ranging from 1 to 4, with 4 being the most expensive. An hourly rate was necessary, and the one used was the local salary rate at the location of company AAP from the case in Chavez (2012). According to zone A, the rate effective from April 1, 2015 was 8.76 MXN. The daily time by resource considered was 22 hours for non-stop processes such as molding and cutting (excluding breaks, maintenance, and change over time), 10 hours for assembly lines, and 8.76 hours effective time per operator, which is the same as in the original case. Life, maintenance cost, and price were not considered.

A mirror station at molding was created as another resource. This was not possible under MBPM. This enables the tracking of all the resources. Further, predecessors can also be assigned for all the activities. The CTP curve obtained corroborates the reduction that the original VSM provided. This was merely done on waiting time, but the CTP provided a reduction amount in terms of money amounting to 52% reduction upon comparing the cost-time investment in figure 14 versus the future state in figure 15.

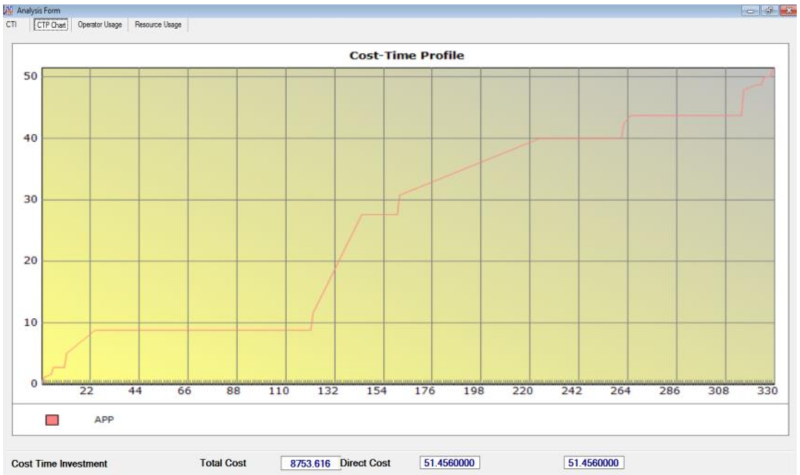
Table 5: Starting times for current and future states

Current state	**Start time per station**	10.22	122.386	161.056	262.236	316.096	324.826	329.026	332.146	
			Previous start time + previous act change over + previous processing time + current station waiting time					5.483767	5.535767	total
Future state	**Start time per station**	1	64.166	89.406	146.666	152.656	161.386	165.586	168.706	
			Previous start time + previous act change over + previous processing time + current station waiting time					2.759767	2.811767	total

[Source] Chavez, Z. and Mokudai, T. (2016) 'Mapping tools selection towards lean transformation in manufacturing environments,' in Euroma 23rd Conference, Norway, 17–22 June 2016. Norway, pp. 1–10

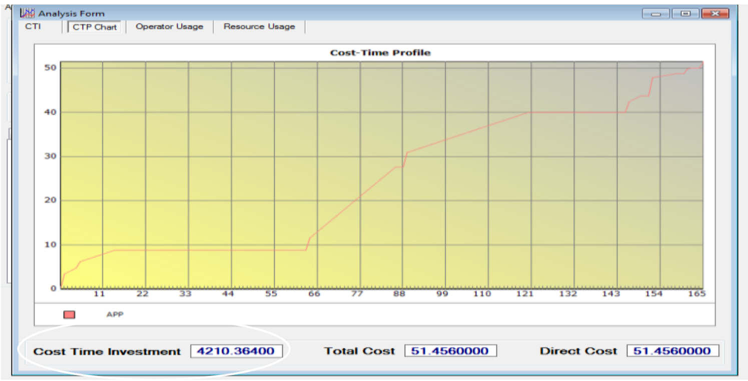
In this case, the direct cost and the total cost remain the same, as no modification to the material was entered. The cost of equipment for the mirror station was not included. If the company needed to analyze its impact, it could be entered accordingly. An analysis of investment versus saving is possible with CTP, but not with other tools. The information for the quantification of results and monetary savings can be obtained faster after the improvements are applied.

Figure 14: Current state of CTP



[Source] Chavez, Z. and Mokudai, T. (2016) 'Mapping tools selection towards lean transformation in manufacturing environments,' in Euroma 23rd Conference, Norway, 17–22 June 2016. Norway, pp. 1–10

Figure 15: CTP Future state cost reduction



[Source] Chavez, Z. and Mokudai, T. (2016) 'Mapping tools selection towards lean transformation in manufacturing environments,' in Euroma 23rd Conference, Norway, 17–22 June 2016. Norway, pp. 1–10

3-1-4. Tool selection

Choosing a tool that is suitable for the problem at hand is often overlooked, and appears to be a common mistake in the literature analyzed. Systems design needs to be more flexible to comply with the needs that the market sets for manufacturers. Applying the same principles that were once created for serial production, lower customization, and mix on customer demand cannot be expected. This does not mean that the higher the complexity of the product, the higher the complexity of the tool. However, it is necessary to understand the processes appropriately, so that when a problem arises, or an improvement is needed, it is clear what may work best, or which tool can ease the problem-solving process and boost improvement. Nevertheless, it is also important to see if the organizational approach at that moment is tactical or strategic. Table 6 summarizes the general characteristics of the tools, and offers a quick presentation for practitioners on what to expect from the tool. However, it is important not to forget that the acknowledgment of the problem is a focal point in efficiently tackling the problem and producing accurate results.

Table 6: A comparison of the general characteristics of mapping tools

CHARACTERISTICS		**TOOL**			
		VSM	**VSC**	**CTP**	**MBPM**
Time	Launch, maps, graphs, charts creation	1-2 Days	2-4 Days	2 - 7 Days	1-2 Days
	Implementation	Improvement and project based			
User perspective	Feasibility: Low (L) - Reasonable (R) - High (H)	H	R	L	R
	Practicability: Low (L) - Reasonable (R) - High (H)	H	R	L	H
	Attainable: Low (L) - Reasonable (R) - High (H)	H	R	R	H
Approach	Tactical (T) - Strategic (S)	S	S	S	T
Measure of value	Economic (E) - Time-based(T) - Both (B)	T	E	E	B
Internal level of use	Managerial (M) - Supervisor (S) - Operative (O)	M-S-O	M-S	M-S	S-O
Type	Standalone (S) - Compatible (C) - Both (B)	B	C	C	B
Software Complexity	Low (L) - Reasonable (R) - High (H)	L	R	H	R
Maturity and Organization level (pre - implementation)	Low (L) - Reasonable (R) - High (H) - Not relevant (NR)	NR	H	R	R
Unique feature - application level	Macro level (MA) - Micro level (MI) - Macro level cost (MAC) - Supporter (S)	MA	S	MAC	MI

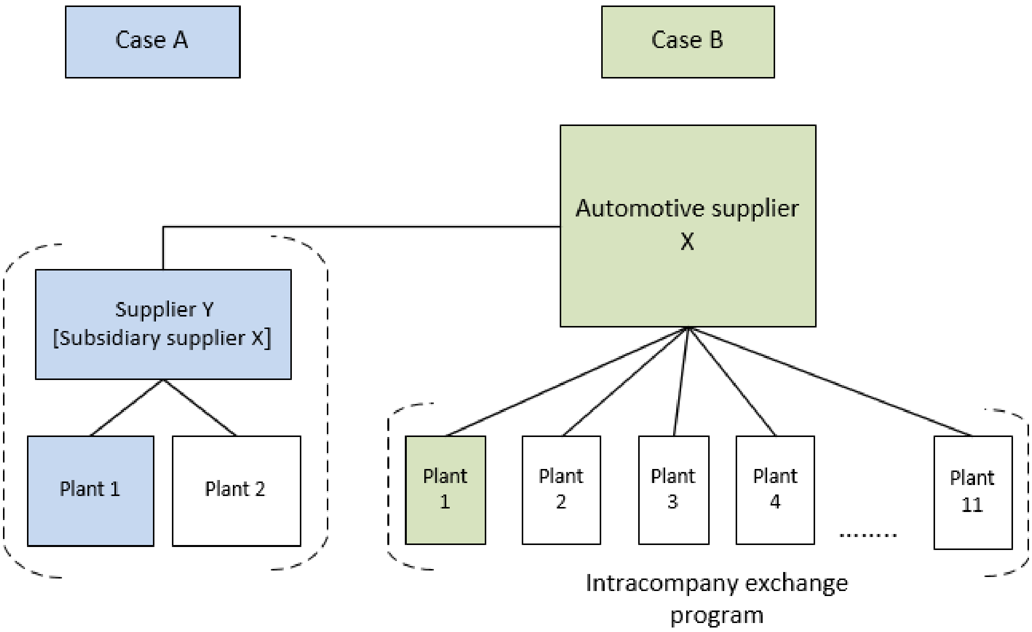
[Source] Author modified version of Chavez, Z. and Mokudai, T. (2016) 'Mapping tools selection towards lean transformation in manufacturing environments,' in Euroma 23rd Conference, Norway, 17–22 June 2016. Norway, pp. 1–10.

The costing system for lean manufacturing was a necessity. VSC seems to be appropriate in covering the need for a costing method. Further, it works better with lean manufacturing as long as there is a level of lean maturity in the organization. VSM reveals opportunities for MBPM investigation and analysis to determine causes. It may present a macro level view of how things work, what the disconnects are, and what the barriers to flow and complications are. On the other hand, MBPM breaks down the activities in greater detail. VSM determines whether you need to drill down the process to be more specific to the micro level. At this point, MBPM comes into place. This is why both tools can work together efficiently. CTP is a complex tool and offers more detailed information in terms of money. It can be recommended for use in evaluating future states that involve a higher amount of changes that translate into high-risk investments. Therefore, it may be hard to picture CTP as a tool to be used on a daily basis. The lack of commitment from the management and poor leadership are potential factors that may affect the performance of a tool. The role of leadership may be one of the key aspects in the effort put in place in creating maps, analyzing and designing future states, and improvements gives results. Otherwise, they will end up as “future plans” that will turn out to be the company’s waste. If all tools were to be used ideally at different stages in a lean transformation, the recommended order would be as follows: strategic planning under VSM, MBPM for tactical execution, and CTP as decision making supporter, along with VSC.

3-2. Phase 2: empirical research

This section validates the selection of the qualitative research design and the strategy involved, and then describe Cases A and B. This study focuses on a particular plant in each case, labeled plant A and plant B, respectively. The direct connection between the two is shown in figure 16. So far, we focused our attention on mapping tools, for which each plant has its own internal nomenclature. In this section, we describe the features of each variation and its practical aspects, application, and integration with TPS in the two environments. The reader may find some similarities in the way they deploy information, although there are significant differences between them.

Figure 16: Organizational relation between cases A and B



[Source] Author collection based on latest company profile (2017).

3-2-1. Empirical research design structure

This project uses a qualitative explanatory multi-cases design in order to make comparisons and develop proposed guidelines and relies on inductive logic. The case study method was selected as the main research strategy following the purposive sampling principle, which is a particularly critical case sampling technique. This study considers an embedded depth for the case studies as we have more than one unit of analysis (Yin, 2013).

Critical case sampling can facilitate "logical generalizations" with the reasoning that "if it happens there, it will happen anywhere," or, "if it does not happen there, it will not happen anywhere" (Patton, 2002). Qualitative design can include interviews, questionnaires, direct observation, content analysis of documents, and archival research (Sousa & Voss, 2002). Through the case study method, a researcher can go beyond quantitative statistical results and understand the behavioral conditions from an actor's perspective (Zainal, 2007).

According to Yin (2013), the generalization of results from case studies (single or multiple design) stems from theory, rather than on populations (sampling). Explanatory case studies examine the data closely both at a surface and at a deep level in order to explain the phenomena observed (Zainal, 2007). Inductive research is a theory building process based on observations from the empirical world and aims to establish generalizations of the study under examination (Hyde, 2000; Lancaster, 2005).

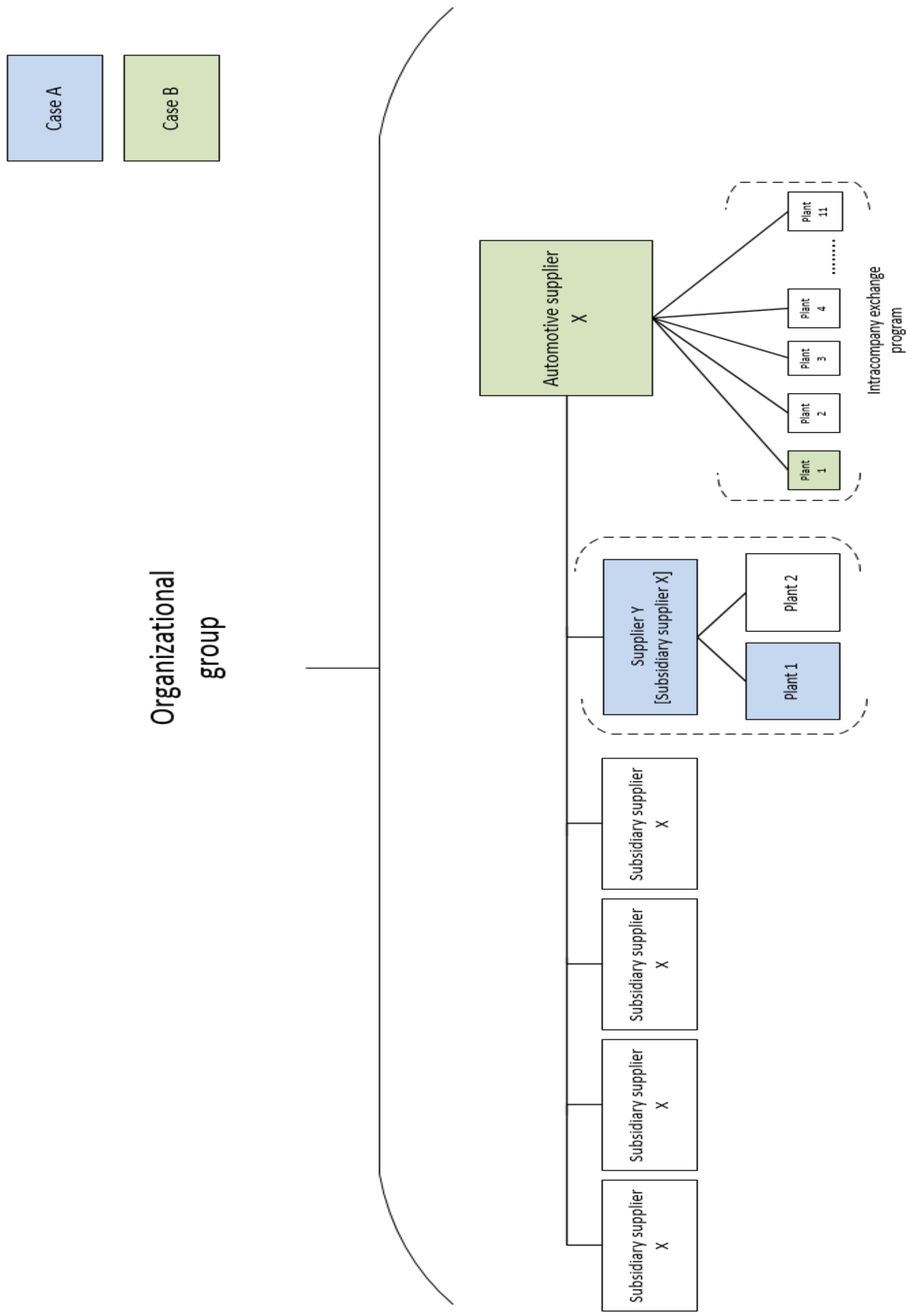
Although statistical findings are mostly generalized to populations, cases have a tendency to generalize to other circumstances and situations, with the help of in depth analytic investigation (Yin, 2013). The statements made while generalizing from cases build theoretical premises that function as tools to make assertions on situations that are similar to the one studied. Whether or not the generalization represents reality remains a determining factor in a theory's fate.

At early stages of this project, during the literature review phase, the author utilized secondary data to test the tools in phase 1. The objective of this phase was to develop a deeper understanding of the performance of mapping tools. Thus, this project does not rely mainly on theoretical assumptions of the characteristics of the tools but compares and assesses each of the tools mentioned in this project through real practical use. In this sense, secondary data serves as a medium to design great ways for the collection of primary data.

Following the purposive sampling principle, the cases selected for analysis in this study belong to a Japanese corporation (automotive supplier X), which develops and produces components and systems for the automotive industry. Currently, it supplies engines, drive-trains, body and chassis, aftermarket, and other main automotive parts for various major OEMs. The largest shareholder of the company is Toyota, and there are different brands within their organizational group. Figure 17 shows the positioning of the different brands as "subsidiaries," and presents the two cases analyzed in this project and the relationship between. For the sake of confidentiality, we will refer to them as Case A and Case B. Case A is a subsidiary of the automotive supplier X in western Japan, which, for confidentiality, will be referred to as supplier Y. This study focuses on one of its plants. For Case B, we selected a plant that is considered as a mother plant for automotive supplier X.

There are three major reasons why both these cases were selected. First, both belong to the same organizational group and actively employ material and information flow charts (MIFC) or VSM in their operations. Second, both seem to be working under the continuous improvement mindset and TPS principles. Finally, both plants have been instructed by Toyota in MIFC, and also work together in activities related to the deployment of TPS and improvements in their group. Details of the visits and interviews performed are presented in table 7, for both plants A and B.

Figure 17: Organizational group for automotive supplier X



[Source] Author collection based on latest company profile (2017).

Table 7: List of research visits and interviewees

Date	Company	Location	Interviewees	Notes
February 16, 2017 (3 hours)	Case A	Kumamoto, Japan	President Senior manager (purchasing) Executive manager (Case B) Senior production control manager (Case B) Logistics manager (Case B)	Semi-structured interview and plant visit
April 7, 2017 (6 hours)	Case B (parent company of Case A)	Aichi, Japan	President Vice president Factory director Senior manager (production control) Senior manager (corporate strategy planning) Senior manager (product development) Senior manager (HRM)	Semi-structured interview and plant visit
May 23, 2017 (3 hours)	Case A	Kumamoto, Japan	Senior technical manager Senior manager (purchasing) Shop floor manager 1 Shop floor manager 2	Semi-structured interview and plant visit
August 22, 2017 (3 hours)	Case A	Kumamoto, Japan	Senior technical manager Senior manager (purchasing) Shop floor manager 1 Shop floor manager 2 Shop floor manager 3	Semi-structured interview and plant visit
April 06, 2018 (3 hours)	Case B	Aichi, Japan	General manager Production control department (Production research group) Production department manager (Production research-Team leader) Chief in production (Control division) Production control department (production research group-TPS practice team 1) Production control (production study group) Production Management Division (General Manager AR Logistics Management Group, Group Manager Commissioner)	Semi-structured interview and plant visit

[Source] Author collection based on Chavez, Mokudai, and Uyama (2018)

During the visits, the automotive supplier X, in both cases A and B, was assessed at first sight with respect to the following areas:

a) Overview of the operations.

b) Kaizen programs in place (if any).

c) The extent of knowledge of lean thinking across the organization.

d) Metrics or indicators in place to track performance and measure improvement on the production floor.

e) The use of mapping tools and support tools such as VSM and variants, MBPM, CTP, and VSC (in case any of them were used).

f) Education and training programs for the utilization of the tool(s), or for any other tool or technique in place.

The researchers expected to get a sense of the best practices and the employees' knowledge of CI, organizational behavior, habits and routines, and leadership. The researchers focused on empirical studies and the gathering of data that would allow a numerical and objective description of the production floor, as well as the future definition of a metric with an economic value, which is, in real terms, based on original data. This data requires that a metric must contain numerical production line information. Data could include CT, production rates, inventory of raw material, WIP, and FG, material control protocols in place (leveling rules, demand, in-line supply systems, etc.), and current performance metrics. These data are the tangible proof and counterparts of visual observations.

This is the reason why data collection consisted of semi-structured interviews, observations by plant tours on each of the selected plants, and data analysis. By "data" we refer to audio recordings during interviews, research notes transcripts by the researchers, pictures, and all kinds of physical documents provided by the cases, such as for example, charts, tracking records (e.g., CT, WIP, takt time, man-hours, etc.), material flow chart (MFC), material and information flow chart (MIFC), and system design diagram (SDD) maps, organizational diagrams, standardized instructions, company profiles, brochures, etc. Both plants granted the author permission to record the interviews and plant tours. Three researchers, both, Japanese and foreign, were involved in fieldwork. The three of them had previous experience and direct relationships with the environment in which cases A and B are located, that is, the Japanese automotive industry. The three have also studied and observed the use of mapping tools in different environments, both, domestic and foreign.

The project seeks consistency in the results based on the triangulation of all sources of information, always taking into account the fact that the information of a qualitative type supports a higher proportion of quantitative information, and not the contrary (Serrano, 2007). All the data from the semi-structured and unstructured interviews, as well as observations, were compared in order to secure the interviewees' impartiality and objective analysis.

3-2-2. Case study A

Case A is a plant that belongs to a subsidiary of a major first tier automotive supplier. It has a satellite plant that produces body and engine components. It also produces semiconductors and LCD manufacturing equipment. This study considers empirical data obtained mostly from their automotive door check production line. A door check is a sub-assembled component that controls the closing and opening of a car door by holding the door with a small arm.

This line has been used as a model line for the introduction of continuous improvement practices and training around lean manufacturing in the organization. The reason why this area was chosen (according to the management) has to do with the simplicity of the processes in the door check production line, and ease of teaching by using this as a base case. In addition, the plant's characteristics allowed for the movement or relocation of any machines or equipment, if required. The door check production line consists of metal part pressing, plastic part injection, and assembly. Technical specifications of door checks differ per vehicle. Even within the same vehicle, there are slight differences between the front and rear doors. These technical features prompt Case A to address a wide variety of the specifications through frequent setup changes.

Case A was studied in two phases. First, a site visit focused on examination, as well as semi-structured and unstructured interviews with the management. The details of these interviews are presented in table 7. Second, we focused on the empirical part and the gathering of data that would allow a numerical and objective description of the production floor, as well as the future definition of a metric with an economic value, which is based on original data. Different forms of data were collected from the plant, including interview recordings and transcripts from researchers, field notes, and documents received from the company. The documents obtained from the company comprised MIFC maps, organizational charts, metric data charts, job instructions, and other hard copies of information (i.e., CT, value and non-value-adding activities, WIP, takt time, etc.). Oral permission to record interviews was obtained from each participant, and official permission was obtained for the photo shoot before the plant tours.

The researchers scheduled and went on four visits (table 7). The first two visits listed in table 7 represent preliminary investigations. One of the researchers in the team interviewed the president and senior managers in Case A on their Kaizen activities and general use of MIFC during the first visit. The researcher then visited Case B, the parent company of Case A, to establish the strategic roles of Case A in the group, and verified that MIFC was used group-wide. A major portion of the study was conducted during the subsequent two visits. The agenda for each of the visits included an interview and a plant tour. All interviews were recorded, and insights from the plant tours were written down as part of the field notes. All content was transcribed. The visits began with a semi-structured interview, followed by a plant tour with an unstructured interview on the production floor while observing the production lines and visiting the relevant meeting points for Kaizen activities. The researchers assessed the visual information on display and clarified unclear facts described by the management during the preceding semi-structured interview. Each visit also involved a briefing session before it was closed, to discuss additional questions and to clarify doubts pertaining to the operations observed. Each of the visits lasted for an average duration of three hours.

During the second formal visit, the senior management presented the history and business profile of the company. One of the members who collaborated with the researchers during those visits was directly involved in the design and deployment of the current continuous improvement program of the organization. Semi-structured questions, therefore, enabled the gathering of knowledge from the dual perspectives of the creator and the implementer.

The second visit focused on the key performance indicators (KPIs) that are used to monitor production lines, CI, and training programs. The focus then shifted to the utilization of MIFC, Kaizen tools, and techniques other than MIFC, as well as the company's collaboration with their group, shared best practices, support for production operations, and the launch of production lines or production systems within the group.

The third visit followed approximately three months after the first, once the information and data gathered during the previous visit (comprising charts, metrics, and visual aids, and mapping instructions) were processed and analyzed. The analysis generated more questions and discussion points to focus on and assisted in the preparation of more pointed questions that facilitated the research team's understanding of the production system model.

The questions on the third visit related to the MIFC that the company employs, which is a hybrid model developed by one of the interviewees. The model in Case A was created as a result of applying TPS techniques and from MIFC mapping principles that were learned directly from Toyota. The researchers aimed to study the application of the model, the requisite training to understand the model, and the integration of the model into daily operations.

Case A allowed the researchers to exemplify how the original mapping technique, as learned directly from Toyota, is applied in an environment similar to where it was developed (the same national culture and employees with similar thinking and customs), and how the users have adapted it to the company's needs.

3-2-3. Case study B

Case study B was selected for three main reasons. First, the plant is owned by the supplier who owned the plant in Case A. Second, it actively employs VSM in its operations. In addition, it seems to be working under a continuous improvement mindset, on the same lines as Case A. Third, Case B adopted TPS and MIFC knowledge learned from Toyota, just as Case A did. As a result of these characteristics, and the fact that it is in compliance with the purposive sampling principle, Case B was considered a good fit.

Case B has relationships with almost all domestic car manufacturers in Japan. They have three categories of products: sunroofs, door handles (interior and exterior), and exterior items (e.g., roof rails and center pillars, etc.). Case B is considered a mother plant because it is in charge of overseas plants in countries like Canada, USA, Mexico, Turkey, India, China, and Indonesia. The sites in these countries are categorized into two types:

1) Primarily managed plants: They produce the same products as the Case B plant, and are instructed by Case B.
2) Assisting plants: They produce products for Case B partially, under the control of other factories in the same group.

For this study, we are interested in and only consider the activities of Case B in conjunction with those plants that are related to lean and improvement efforts.

Semi-structured interviews were performed during a site visit in April 2018, each lasting a duration of around three hours (see table 7, for details). These interviews were carried out bearing in mind the visits undertaken by one of the researchers in the previous year, where it was verified that MIFC was used group-wide at supplier X. First, the plant manager presented an overview of the plant in Case B. This was followed by a semi-structured interview, and then a factory tour where the unstructured interview took place. The three researchers who studied Case A also studied Case B. The plant granted permission to record the interview at the meeting room and on the production floor. The three researchers took notes to avoid any misunderstanding and to ensure that no important information was excluded. They later analyzed the recordings, notes, and physical information in the form of charts and maps obtained from the company. The cross analysis enabled the clarification of information and verification of details.

In Case B, improvement or Kaizen activities (as they called it) are carried out in all areas of the plant. However, in particular, the "technical staff room," is in charge of organizing Kaizen activities.

The technical staff room consists of two types of staff. The first kind comprises ones in charge of establishing targets, directions, and making plans and implementing Kaizen activities. The other is in charge of providing all the physical tools required, such as workbenches, andons (status-display device), switches, etc., as well as any technical gadgets or devices that the type one staff would require.

There are different Kaizen development programs for employees in the organizational group. In general, the organization is segmented into different sections, such as, for example, the headquarters, which handles production, quality assurance, administration, sales, procurement, and technical development. They support all the product groups across the organization. Within the production control section, the following sections exist: production planning, production management, production system, and the production research center, which is in charge of the organizational activities in the corporation.

Studying Case B allowed the researchers to understand how the original mapping technique, as learned directly from Toyota, is applied to an environment similar to the one in which it was developed. Further, it also helped analyze how their adaptation differs in comparison with Case A.

3-3. A gap in research

Since the beginning of this study, based on the literature review, the main topics in consideration were how companies manage to transplant their production systems from one plant to another, and what makes some companies succeed while others fail terribly by applying similar or even the same principles. These two questions started to narrow down. The study suggested that the application of tools and/or techniques in the course of operations was almost compulsory, in the same way in which the metrics seemed to be embedded into tracking improvement. The literature review wound down by the time the exploratory research began. Thus, when the secondary data was used to test the tools, the research had already been centered in three major aspects of lean: transformation, mapping tools, and performance measurement.

The first set of questions included the following:

- Can certifications under excellence models enable a successful lean transformation?
- What are the current equivalent of business excellence models in Japan?
- How do lean and TPS differ in the practical world? Are the terms really interchangeable?
- Why do western companies keep adopting Japanese techniques and tools, instead of developing their own, from scratch?
- How do mapping tools support lean transformation? What are their disadvantages?
- What are the changes required in areas different from production for the implementation of VSC?
- Is it necessary to transition from a traditional accounting method to lean accounting for successful lean transformation?
- What are the compulsory steps to follow to achieve lean?
- Why do top organizations seem reluctant to use mapping software when the investment into resources does not seem to be a major issue?

Mapping is carried out in all lean-related phases of the existing lean transformation models. Thus, mapping is the focus of this study. The apparent gap had different ramifications, and this firmed the author's resolve to carry out empirical research.

After performing a conscious revision of the research outcomes, the practical industry needs, and the setting of the project (i.e., a single industry, case studies, etc.), the author defined three specific questions, after eliminating some questions in the preliminary set, by default. The questions are as follows:

1. How can value be measured in an economical way using mapping techniques to boost improvements acquisition?
2. How can LPS be deployed without affecting target levels of performance?
3. How can LPS and its organizational culture be transferred or replicated to other plants

in the same company?

The following chapters attempt to answer these research questions. Each chapter addresses one question. In each of the sections, first, the observations are addressed and then the insights are presented.

Chapter 4: Measuring value in an economical way

This chapter examines the main characteristics of VSM and the variants utilized in cases A and B (i.e., MIFC and SDD). It aims to describe the way in which metrics assess the outcomes of lean transformation, integrate an economic measure of value, and relate to the mapping tools. Finally, a method approach is suggested based on the case studies examined, tool testing conducted, and insights derived from previous literature.

4-1. Introduction

The time dimension serves as a base to track improvements in mapping tools. It is a common denominator in VSM, CTP, and MBPM, in tracking improvements and measuring performance. However, other data can be associated as well, such as WIP, man-hours, and inventory. The specification level and selection of the element to be tracked will offer a concrete direction in assigning improvement projects and rapid decision making. Moreover, Gunasekaran and Kobu (2007) stated that conventional measures had drawbacks in that they tended to mainly measure financial metrics, and failed to include intangible indicators. Given the inherent complexity of the manufacturing process, a measurement method to deal with these complexities is particularly critical.

4-2. Method

This part of the study is descriptive and follows an inductive approach with a qualitative design. The author took into consideration the testing and analysis of the performance of the tools used in phase 1 (comparison of mapping tools utilizing secondary data) to establish the case study method as the primary strategy. Although exploratory research was performed in the early stages of this study, the cases used in this study are mostly explanatory and demonstrate how value should be measured in an economical way, along with mapping techniques to boost improvement acquisition. The case study method is preferred in three situations: when the questions asked are "how" and "why" questions, when the researcher has little control over the events or circumstances of the phenomena in question, and when the investigation has some real-life context (Yin, 2013). Yin (2013) emphasizes his preference for the multiple case studies approach, as it ensures valid and reliable findings. Thus, carrying out multiple case studies was considered most appropriate. The cases in this study are analyzed with embedded depth, rather than using a holistic approach. This study is mostly concerned with lean transformation, and the processes, protocols, tools, and techniques related to it.

Cases A and B were selected following the purposive sampling principle, where they met the following criteria: they both actively employ mapping, they have both learned the MIFC principles directly from Toyota, and they both work under a continuous improvement mindset and TPS principles.

In the tools testing analysis carried out in phase 1, the author was able to evaluate the parameters of each tool utilizing the same case to test different tools. Further, the researcher was able to determine whether, in reality, the measure of economic value was present or not, besides being able to identify the common elements and the way they are tracked. From this point onward the author established the general characteristics to compare VSM, the MIFC versions at each case, to determine the selected characteristics included in table 9, that are presented later on in this chapter.

The author considered studies on the applicability of VSM (Khaswala and Irani, 2001; Braglia, Carmignani, and Zammori, 2006). CTP and MBPM are not included in this comparison because they focus on mapping a different part of the production process (an in depth explanation is included in chapter five). It was found that they did not directly derivate from Toyota's MIFC. In addition, we did not find a single case in Japan that uses CTP or MBPM. Neither Case A nor Case B used CTP and/or MBPM. Further, in phase 1, guaranteeing the suitability and correctness of primary data collection was allowed in both cases. As part of the empirical work conducted in phase 2, interviews (table 7) and observations took place at both plants. The interview schedule was determined based on the cases' disposition and availability. All the data gathered, in the form of recorded interviews, field trip notes, and all printed material given by the organization, were triangulated and analyzed. The emphasis during interviews was on process mapping, the tools, protocols linked to them, and the measurement of performance in each plant. All the data and information were revised by all members of the research team. Any points lacking clarity were re-assessed by the author and the other two researchers.

The author conducted a final analysis of the results, and presented the findings. The other two researchers on the team revised the content to ensure reliability and unbiased presentation.

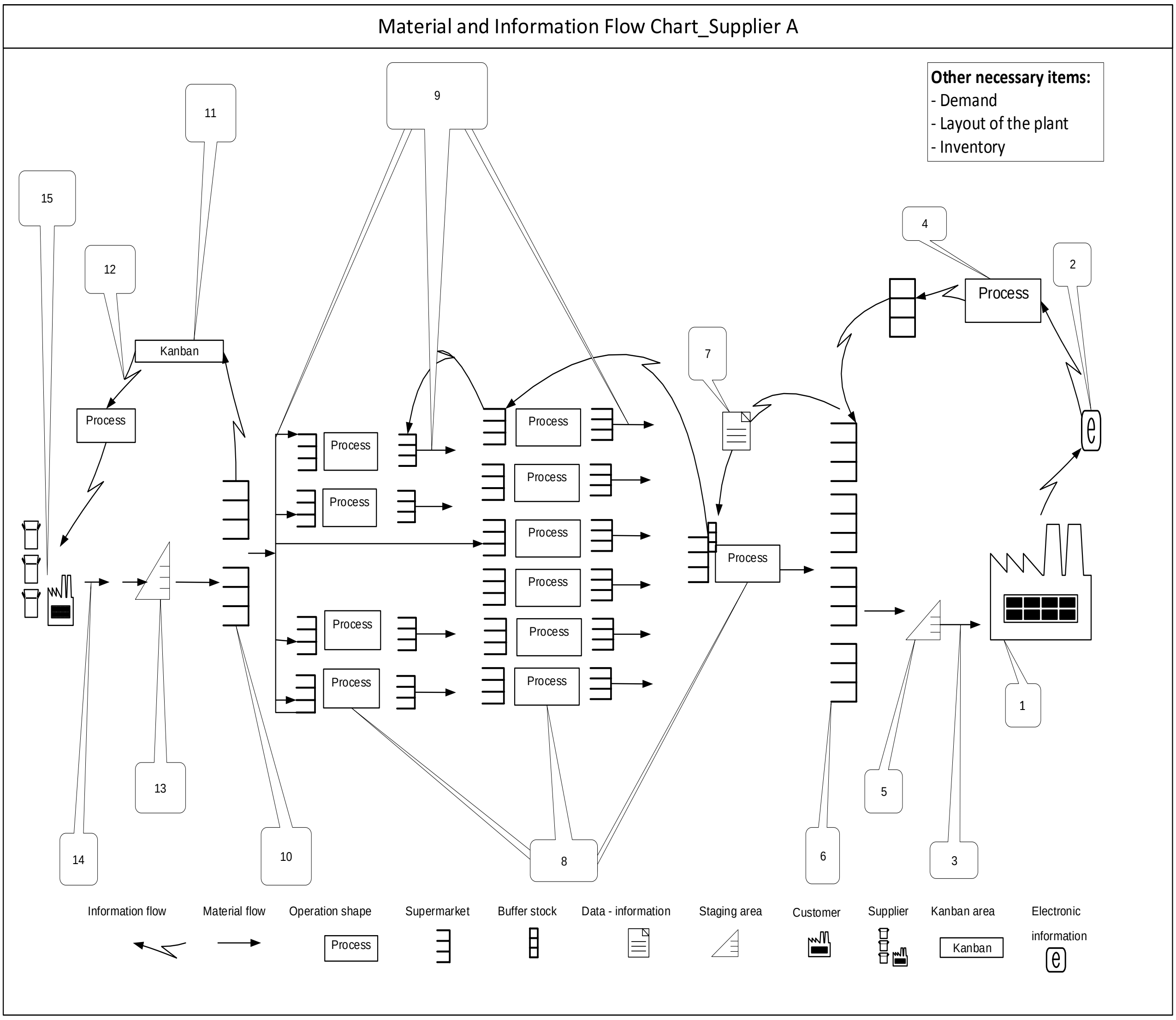
4-3. Results

4-3-1. Case A: Material and information flow chart version

Case A actively employs VSM. This plant learned the principles pertaining to the tool directly from Toyota. Therefore, Case A refers to the tool as MIFC. However, the tool, as they use it, is an altered version of the approach used in western countries. Case A has developed its mapping protocol with the proper chart (figure 18) and formats linked to it. They explained that the tool is a means to an end, which in their case, is to apply TPS, or LPS as it is known in the West. MIFC is also a way to assess an employee's knowledge of the processes and is used as a means to train people.

Another important aspect pertaining to the protocol in Case A around MIFC is the future state. Instead of creating a future state map, as considered in VSM, "future goals" are established as a type of blueprint that contains all the goals set in each process. Each of the processes has future goals that are sectioned into two phases (medium-term goals and long-term goals), with specific metrics associated with each of them (which is considered an SDD map). Teams determine the phases. The members of such teams belong to different areas, and work together to attain their goals. Starting from downstream to upstream, moving backward as they establish the future goals, reaching a consensus, and arriving at agreements among all parties involved in the process, the goals are set with the ultimate objective in mind: "achieve one-piece flow to the maximum extent." In contrast to the traditional VSM approach, a future state for this plant represents a gradual progression that will have two different stages from the beginning. At first, it may seem that not much emphasis is placed on creating a "future state map" by definition, because greater emphasis is laid on developing the most accurate version of the "current state map," while training individuals and implementing short-term actions. The case sees this practice as part of having a solid basis on which to build further improvements. For Case A, developing employees with substantial training and practical experience is a guarantee that improvement will happen without a future state map.

Figure 18: MIFC at Case A



[Source] An original chart provided by Case A, modified by Z. Chavez

In figure 18, MIFC is exemplified for Case A. The chart contains fifteen different numbered elements, and the data components are contained in the boxes. Some of the data components are common with VSM (e.g., CT, bottlenecks, set-up times, man-hours, demand, LT, etc.), while others are particular to MIFC (e.g., delivery frequency, form of packages, location codes, supermarket arrangements, processing methods, production line codes, transportation units, etc.). This provides a better idea of the volume of information that is required while filling the chart.

The sequence of the fifteen elements is illustrated exactly as found in the MIFC maps for Case A (both in their instruction sheet and in their current maps) at the time of our visits. Each element recalls at least four sub-elements, which are information and data that describe each element. The creator of the protocol determined the sub-elements by assessing his acquired knowledge with practical experience. Elements number 8 and 9 in figure 18 are the most comprehensive and recall around 16 sub-elements each. For instance, element number 8 refers to “process” and contains sub-elements such as processing time, units, line code, CT, bottleneck CT, setup, frequency, etc. Element number 9 refers to “materials handling,” and contains sub-elements such as transportation method, transportation equipment, transportation unit, timing, method of supply, form of package, location codes, etc. These examples provide a better idea of the volume of information that is required while filling in the chart.

The level of detail is remarkably high. Example of the detail are found in elements 6, 9, and 10. They require measuring the width and depth of locations and containers. In this sense, we can say that Case A goes a step ahead in gathering the data that can be used not only to assess and understand their current processes, but can also be employed to redesign their material distribution and replenishment systems. The only element that is not fully present in MIFC when compared with VSM is the LT line at the bottom of the map. It is only calculated at certain points in time. It is a dynamic element, while the rest of them are mandatory and necessary to understand the functioning of the system and how the flows integrate.

A differentiating aspect between the MIFC version at case B and VSM is the unit used for measuring improvement. Case A does not have fixed measurement indexes and selects appropriate ones depending on the focus of their improvement activities. For instance, at the time of the visits, Case A was considering inventories (purchased goods, WIP, and FG) and man-hours, each of which could be linked to an economic measure of value. In VSM, a common metric is LR. For VSM, the unit is time, and there is always a LT indicated on the map created. However, the LT or time unit on the MIFC map is not required in every case. It is calculated at specific points only when needed. Case A stated that this is due to the dynamic aspect of the processes, rather than because they do not care about production flow.

The next characteristic, the future state for Case A, consists of two levels, namely, medium-term and long-term goals. Each goal phase is set through a consensus by a team from different areas (fields of work and designations) in the organization, which secures the commitment in the long run. This supports the latest description of a future state value stream map by Rother and Aulinger (2017), that is, a challenge that focuses and aims at individual improvement efforts toward a shared breakthrough goal.

The downside for MIFC is the time it takes to develop a full map. Case A does not use any software as an auxiliary for the steps related to the creation of MIFC and all the tasks are carried out manually. While under lean principles, this could be in the category of a non-value-adding practice or waste, Case A considers it as "learning-by-doing."

4-3-2. Case B: Material and information flow chart version

The managers in Case B gained the knowledge of MIFC around 40 to 50 years ago. Toyota had requested their organization to apply the tool.

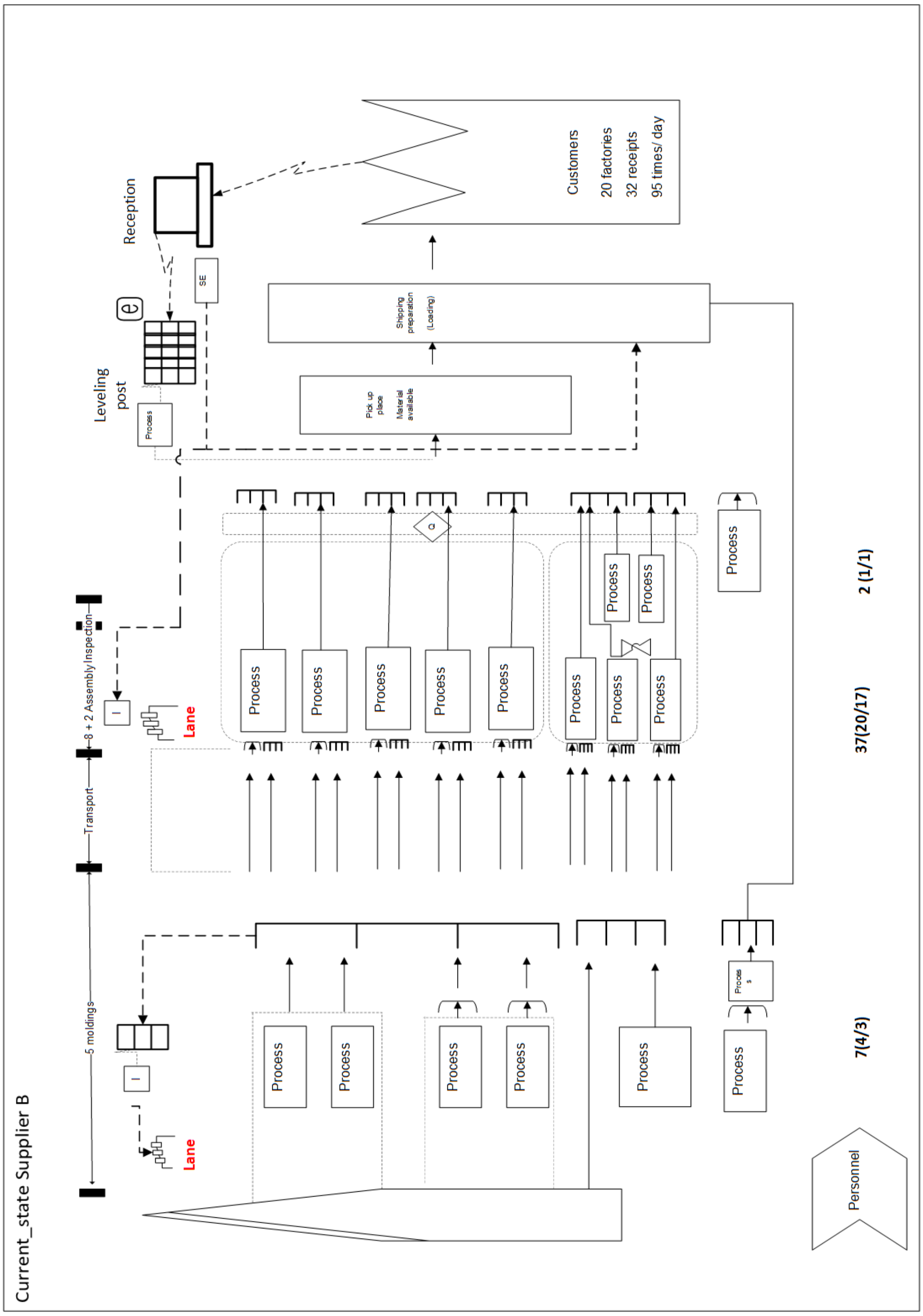
The SDD, as they internally call their version of MIFC, apparently has no major visual difference when compared to the MIFC at Case A in terms of configuration and the icons utilized. The physical configurations of the processes and the flow of materials are depicted from left to right, while the flows of information which start from customer requirements are drawn from right to left. The drawing icons resemble the standard icons in VSM, such as pointed lines for information and regular lines for materials, process boxes, etc. To be able to complete a SDD map, they first need to draw a MFC, and then a process information table (PIT). This is a part of understanding the material and information flows in order to draw the MIFC and finally, the SDD map.

An important part that is drawn in their charts is the difference between “lane” and “store,” (which is explained in annexes 1 and 2, respectively, which are presented at the end of the document for visual reference). Lane is a track-like instrument that supplies a variety of items in a sequence of assembly or processing, and is also known as “flow rack” for the manufacturers of these devices. The store is a shelf-like instrument that stores a certain variety of items laterally on shelves. In the production lines, the material is directly consumed from the “lanes,” as seen in figure 19, which represents an example of a map for a current state in Case B. Lanes are marked up in red and are located next to the storage and supermarket points.

The SDD for Case B is a MIFC with targets for a future state. The targets are defined in terms of transportation, production instructions, and storage methods. In SDD, a timeline is not included. The information gathered is mostly related to inventories, which are observed everyday on the production floor. When they create a SDD, they count inventory at the maximum level, which is either at the beginning of the shift or before starting operations in the morning.

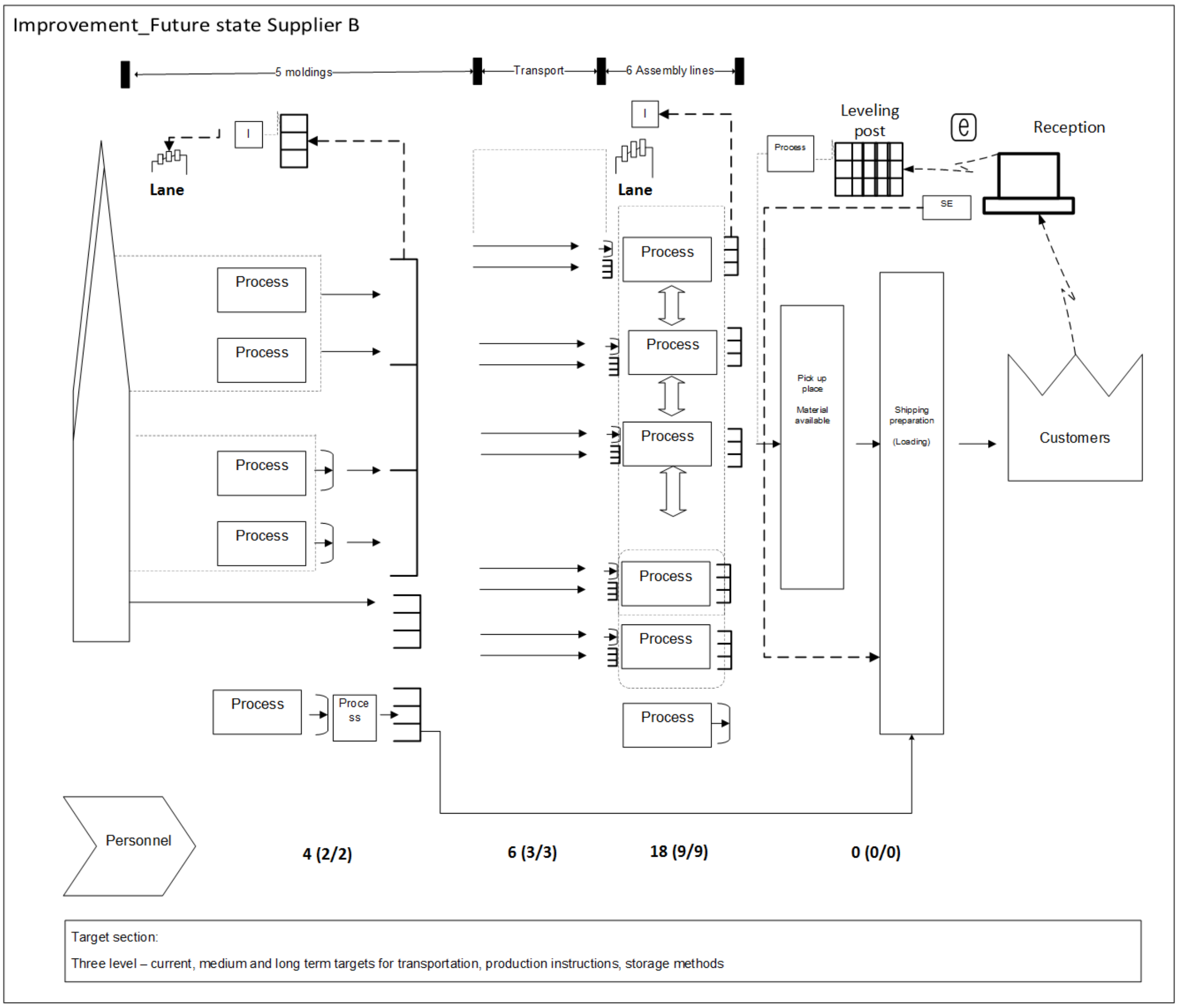
The creators are personnel who supervise an overall work area. For example, assistant managers or staff such as engineers, and the technical staff room, are the ones responsible for making the charts. Currently, employees at the operator level in Case B are not able to do a SDD. The SDD map for Case B is displayed in figure 20. This is a future state for the previous map seen in figure 19. It describes the changes made in the production system in comparison with the previous current state and adds the targets at the bottom.

Figure 19: Current state map Case B



[Source] An original chart provided by Case B, modified by Z. Chavez

Figure 20: SDD map for Case B



[Source] An original chart provided by Case B, modified by Z. Chavez

General steps for drawing a SDD are as follows:

1) Draw a MFC. This chart contains orders and locations of each process along with the flow of materials and presents the basic flows in product lines.

2) Draw PIT. This table contains all the products and processes. Products are listed in rows and processes in columns. The real path of each item is drawn in a way that allows the visualization of the sharing processes. There is no mandatory order to draw MFC and PIT, and it can be done in the order that the practitioner chooses, as they are not sequential.

3) Draw MIFC. A MIFC is drawn from MFC and PIT. The level of abstraction in a MIFC is higher than in a MFC, but not all the traffic lines from a PIT are included here.

4) Draw SDD. MIFC is used as a base. The technical staff room works on including the targets after assessment.

For managers in Case B, the time to draw a MIFC depends on the number of processes in the production line. It usually takes half a day for a rapid drawer. However, in the best case scenario, and for a simple process, if all the necessary data have been gathered, an hour is enough. If MIFC is expanded to SDD, the time increases considerably because mid-term and long-term targets need to be set up in terms of transportation, production instructions, and storage methods.

The time required to learn to draw and assess MIFC and SDD can be around six months, but it also depends on the skill of the person and the training situation. Some may do just a one-day classroom training and then later learn on-the-job, while some others may need more trials to draw their first MIFC.

While one person draws the MIFC, several people are involved in gathering the information to assist the drawer. The process starts downstream, and follows the information flow. This is not an absolute rule, because if the production line has a lot of steps, it will take a lot of time to draw the entire MIFC. In that case, one item is selected, and then the team proceeds to take up Kaizen activities. Taking this area as a model first, the next step is to apply the same in a parallel way to other lines. Investing a long time in drawing a MIFC is not seen as a shortcoming. They believe that mapping is necessary to have a common understanding of the current state of the factory.

As target setting requires an overall perspective of the production line in question, section heads or engineering staff in the technical staff room are responsible for defining the targets. Future goals are determined based on the desired state of TPS. The medium-term and long-term SDD targets come from a team analysis of their capabilities (i.e., machines, people, infrastructure, etc.) and TPS principles. Both need to relate to each other. For example, we suppose a situation where all pieces are withdrawn according to Kanbans (i.e., stop the push production), we then imagine how the production line in question would look, and then define the targets appropriately. In this case, if they are trying to control a production line with Kanban alone, they may find that they need to change a production setup X times per day. Then, they calculate to see if a setup change is needed within Y seconds in order to realize X times setup changes a day. Finally, they will proceed to develop ways to achieve that. Given their capacities at the current state, they figure out the upper limit of targets and define feasible goals. It was emphasized that the “desirable states” should not be “dream numbers.”

Managers in Case B pointed out some common questions that they raise while creating a MIFC:

1) Are orders from customers leveled?
2) Are materials properly withdrawn by Kanbans?
3) Is production controlled by push production plans?
4) Is a proper lot size formed at the injection process by bundling Kanbans?

These questions help them determine improvement activities and target Kaizen with the right priority.

At the moment, Case B does not utilize any specialized software for the creation of charts or maps. One limitation of Case B is that it is not possible to do everything on this chart. Some information is missing. When flows are disconnected, the flow of production becomes complicated, thereby becoming hard to translate into the MIFC. An example for this is the thermal treatment process in the middle of production. They present the need for a better way to reflect such processes in the charts.

The ultimate goal for Case B is to improve the production line. Case B states that changes in MIFC do not mean changes in the production line, but the chart describes the production line alone. The map is an assessment. Therefore, when MIFC does not represent the reality, case B proceeds to remake the MIFC. Management stated, “We remake MIFCs when we can no longer see problems or when we have raised a level of sensitivity.” They then redo the MIFC to “raise the bar,” and set an improved state, while taking into consideration the ultimate goal of achieving zero-inventory.

4-3-3. Performance measurement and economic measurement of value in the system design diagram

Capabilities at the production lines are tracked by machine cycle time, cycle time (excluding waiting time), slower workers, product volume, takt time, up-time, required man-hour, actual man-hour, production volume per hour, and set up change, among other things. These are the basic set-up data that should be gathered before any Kaizen activity. Case B follows a long-term corporate vision, for example, their current aim is to decrease fixed and variable costs to a certain level by 2020. To achieve that goal, they may need to decrease the value of man-hours by increasing productivity. Presently, efforts are directed to reduce waiting time over a period of time, and to increase quality. These efforts depend on improvement activities to achieve these goals. Therefore, the technical staff room efforts are important. It is their common practice to translate the overall targets into cost items because they are constantly seeking to achieve corporate goals that are measured economically. They evaluate the contributions of the Kaizen activities to corporate level targets and tracking, such as for example, variable costs, quantifying headcount, scrap, and cost in purchasing, etc.

4-3-4. Lean level assessment in Case B

Case B has a particular way to assess internal lean level. They use a "performance check sheet," which is a version of their format as displayed in table 8. This sheet is a checklist that assesses the TPS level in four different states or levels that relate to three different categories: production method, conveyance, and the state of materials (inventories). Each of the categories has an explanation sheet that presents the guidelines for assessing the level. For the sake of confidentiality, the formats linked to the main checklist have not been included in this document. The checklist is applied regardless of the product categories, and the same checklist can be used in different product lines. It is applied in the organizational group plants, including in Case B. It is important to note that there is variance across different plants, and those plants with longer experience or history are not necessarily at a higher level. The checklist is applied by the managers, and they claim to be able to tell the TPS level easily by the level of inventory and WIP. The checklist serves as an assessment, where production workers cannot tell their TPS levels by themselves.

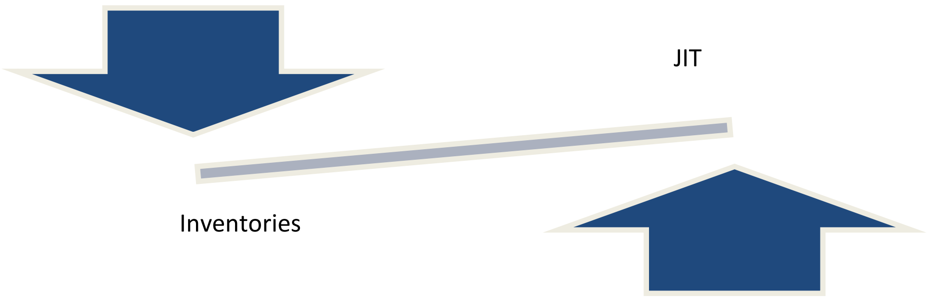
Table 8: Performance check sheet from Case B JIT perspective

Categories	Levels	I (General firms)	Check	II	Check	III		Check	IV (Desired state)		Check
Just in Time	State of materials (inventories)	[Warehouse] Piles of product inventories [Processes] Piles of WIPs		Inventory for one day		Inventory for one delivery cycle			One container or a piece		
						III-1 2 hrs to 8 hrs	III-2 Less than 2 hrs		IV-1 More than 0.2 hrs	IV-2 0.2 hrs or less	
	Conveyance	Push conveyance		Withdrawal from subsequent process (Large lot conveyance)		Withdrawal from subsequent process (Frequent and mixed-load conveyance)			Very frequent conveyance (Choro-biki)		
						III-1 0.5 hrs to 4.0 hrs	III-2 Less than 0.5 hrs		IV-1 More than 0.2 hrs	IV-2 0.2 hrs or less	
	Production method	Monthly planned production (Production instructions for each of the processes)		Daily-based lot production		Production paced by delivery cycles			Production on a little-by-little basis, to refill sold units		
						III-1 2 hrs to 8 hrs	III-2 Less than 2 hrs		IV-1 More than 0.2 hrs	IV-2 0.2 hrs or less	

[Source] Internal document provided by Case B. Translated by Associate Professor Takefumi Mokudai of Kyushu University. Some information is omitted for confidentiality reasons.

The managers stated that inventories reflect the consequences of the way in which production instructions are given, how work-in-processes are withdrawn, and how production works are implemented. For instance, considering the logistics in a production lot, if the lot size grows, the inventory size that corresponds to it will be bigger as a consequence. Through observation, they are able to determine their current level. For instance, high defect rates lead to high inventory rates. This way, higher inventory levels will lead to low JIT levels. The reduction of inventories will be tackled by increasing JIT. A simple visual representation of this is found in figure 21.

Figure 21: Inventory level behavior



Managers stated that self-evaluation could also be relatively easy. However, they have not reached a point where the workers in the production line can assess their level of attainment of JIT. It was pointed out that some operators still link reduction of inventory to the reduction of personal hours and man-hours, but with a direct negative connotation in the form of losing their jobs.

At a certain point in time, when they observe stable inventory levels related to the current situation, they can start thinking about raising TPS and moving to the next level in different categories. This process becomes almost natural for Case B. After introducing a higher level of JIT from the initial current state, the weak points of the production system will be revealed. This is when opportunities for Kaizen are exposed. At this point, they will begin introducing table 8 to facilitate improvement of these activities. The "voluntary study group" is in charge of these activities. More details of the voluntary study group are presented later in this paper.

Table 9 compares the methods used in both cases using the traditional VSM by Rother and Shook (1998). The author analyzed and compared the characteristics of the different versions of the same tools: VSM, MIFC version in case A (referred as MIFC), and MIFC version in case B (referred as SDD). By examining this chart, we may believe that the methods differ to such an extent that they refer to completely different techniques. However, the basics are highly similar. This is not a surprise, considering that both cases learned the techniques directly from Toyota. MIFC and SDD are a detailed analysis of the production floor that requires a higher level of understanding of the production processes by the person who intends to create the chart. It is necessary to highlight that the SDD in Case B includes the basic principles of MIFC from Toyota though the name is different.

Table 9 considers nine different characteristics which are linked to the principal elements of VSM. The selection of the product family is the starting point. Second, it is necessary to stress that, even though Case A has the same approach as VSM, the emphasis is placed on gradually mapping the entire plant as a means for the creator(s) to gain knowledge of all the processes involved and to detect problems along the entire value stream. The same is applicable in Case B.

Table 9: Comparison of the general characteristics of VSM and mapping tools in Cases A and B

Characteristics	VSM	Mapping tool Case A	Mapping tool Case B
Starting point	Family selection	Family selection	Family selection
Performers – enablers	Managerial and supervisory level – Top management and leaders	Operative level supported by management – Team leaders (people who do the work)	Managerial and supervisory level – Target setting: technical staff room
Information volume	Medium	High	High
Time to develop map – chart (current and future state)	1–2 days	~Unknown ~	Minimum ½ day ~ Variable based on process complexity and personnel expertise
Unit to measure improvement	Time – value and non-value activities	Inventories (purchased goods, WIP, and FG) and man-hours	Inventories, man-hours variable costs, headcount, scrap, and cost in purchasing, etc.
Future state	Yes	Yes (medium-term and long-term goals)	Yes (medium-term and long-term goals)
Metric (s) associated	Lean rate (LR)	% WIP, % Man-hours	TPS 4 levels
Economic measure of value	No	Yes	Yes
Link to software	Yes	No	No

[Source] Author collection from initial version in the publication by Chavez, Mokudai and Uyama (2018)

The organizational levels of the employees mapping Case A are lower than those followed for VSM and Case B. In Case A, the people who do the work are the owners of the tool, while the management merely serves as support and trainers. For VSM and Case B, they are the ones mapping and creating the targets, respectively.

The third characteristic is the information volume. Compared with VSM, MIFC and SDD require a significantly higher level of information gathering and entail more data collection on each resource. Presently, Case A was not able to provide a reliable time frame. It comprises a process in which it is not possible to specify the total amount of time required to develop the chart. They stated that it depends on the creator’s expertise and the complexity of the processes that are analyzed at each point in time. Case B had a similar perspective, but even they stated that time was variable depending on complexity and personnel expertise. However, they seem positive that the time range could start from a minimum of half a day.

Looking particularly at the category “unit to measure improvement,” we can see that time is the unit for VSM. However, for cases A and B, inventories remain constant. Both relate to other elements such as man-hours, or variable cost. However, “inventories” is common to both cases and is necessary to track improvements. The term “inventories” includes any of the physical forms such as WIP, raw material, or FG. Inventories are directly related to the lean level assessment (in Case B, higher emphasis). However, we found that inventories are an element that can be converted to cost easily, and this is explained in detail in the following subsection.

Case B considers other specific elements such as variable costs, headcount, scrap, and cost of purchasing that are directly related to meeting corporate goals, as explained in the section on Case B. If we look back at figure 17 on the organizational group for automotive supplier X, we can see that Case B is at a higher level in the organization. Case A has a closer connection to Case B, and their focus on the economic detail is not as explicit as Case B is. This does not mean that economic detail is less important, but rather that less effort may be devoted to breaking down costs into such categories as in Case B.

Directly connected to “unit to measure improvement,” we have the “metric(s) associated” characteristic. The metrics included here are the ways in which each organization measure their lean progress, for instance, in VSM, LR is utilized, and it relies on time (value-adding time vs. non-value-adding time). However, in both, cases A and B, their metrics rely on the unit used previously, namely, inventory. For Case A, it can be expressed as a WIP or man-hour’s percentage. On the other hand, for Case B, a detailed analysis follows the checklist for the determination of the TPS level in three different categories: 1) assessing production method, 2) conveyance, and 3) state of materials, with four levels each (details are not included in order to protect information confidentiality).

MIFC does not require a future state. It is a progressive process that is achieved through small and gradual improvements that are determined by the workers. The improvements arise when there is a complete understanding of the current state, with the empowerment to take action. The rationale behind this framework is that it becomes natural for workers to know the value that their work provides and to employ correct decision making approaches that comply with desirable goals or a desirable future state (by the management). SDD does not require a future state map at all times. Case B generates a new map when they find that the current one does not represent the reality of their production system anymore. The targets help keep track of the goals that are aligned to meet their corporate targets. This study observed the similarity in the principles that both maps follow. Both cases focus on developing a solution to their problems. However, the time taken to develop that solution remains undefined.

Both cases are interested in tracking improvements in an economic way (i.e., economic measure of value). They do not display this information directly in their maps. However, they do carry out separate work and calculations to track the units selected in terms of money, which the VSM does not do. This is a drill that VSM users do not link to mapping. The four-level TPS check sheet utilized by Case B was considered as a novel means for assessing lean. There is consistency in the units utilized. Inventory is a standard unit which translates to the overall goal of TPS, achieving one-piece flow. Tracking and measuring inventories is a quick way to know when their goal may be disturbed by the current production behavior at all times. In that sense, inventory variance comprises the red signs that indicate waste or flow problems on the production floor.

4-4. Discussion

After reviewing the different ways in which organizations track data, with the intent to quantify their improvements, the author arrived at the proposition that the best approach is to think in terms of what we are trying to improve. The metric and the calculation process must be simple. The objective is to spend as little time as possible on calculations, so that we can redirect that time into doing actual work to improve the processes (i.e., leaner).

4-4-1. A cost approach

This study suggests an approach considering the production cost of a product, and then thinks of different components that determine the entire cost. A step-by-step description of the method is provided in figure 22.

The first step in the process comprises the following parts:

1) Starting with the thought process in terms of what it is that they seek to improve.

2) Selecting the improvement of production cost of a product or the set-up of a new line.

3) Classifying the components into four categories (with sub-elements associated with them) in order to determine the cost. These categories are:

A. Inventory (WIP, FG, raw material, and scrap)

B. Transportation of parts (NVA-bad programming or unnecessary distance, and waiting)

C. Man-hours (Waiting time and NVA)

D. CT- LT (waiting time and NVA)

The organization should determine the elements it wants to improve.

4) Measuring the input and output of the selected component. Associated sub-components help determine the output.

5) Searching for the cost associated with the cost component. For example: cost per piece, man-hour cost, etc.

6) Creating the metric (see equation 3 for metric determination formulas) and calculating the current state.

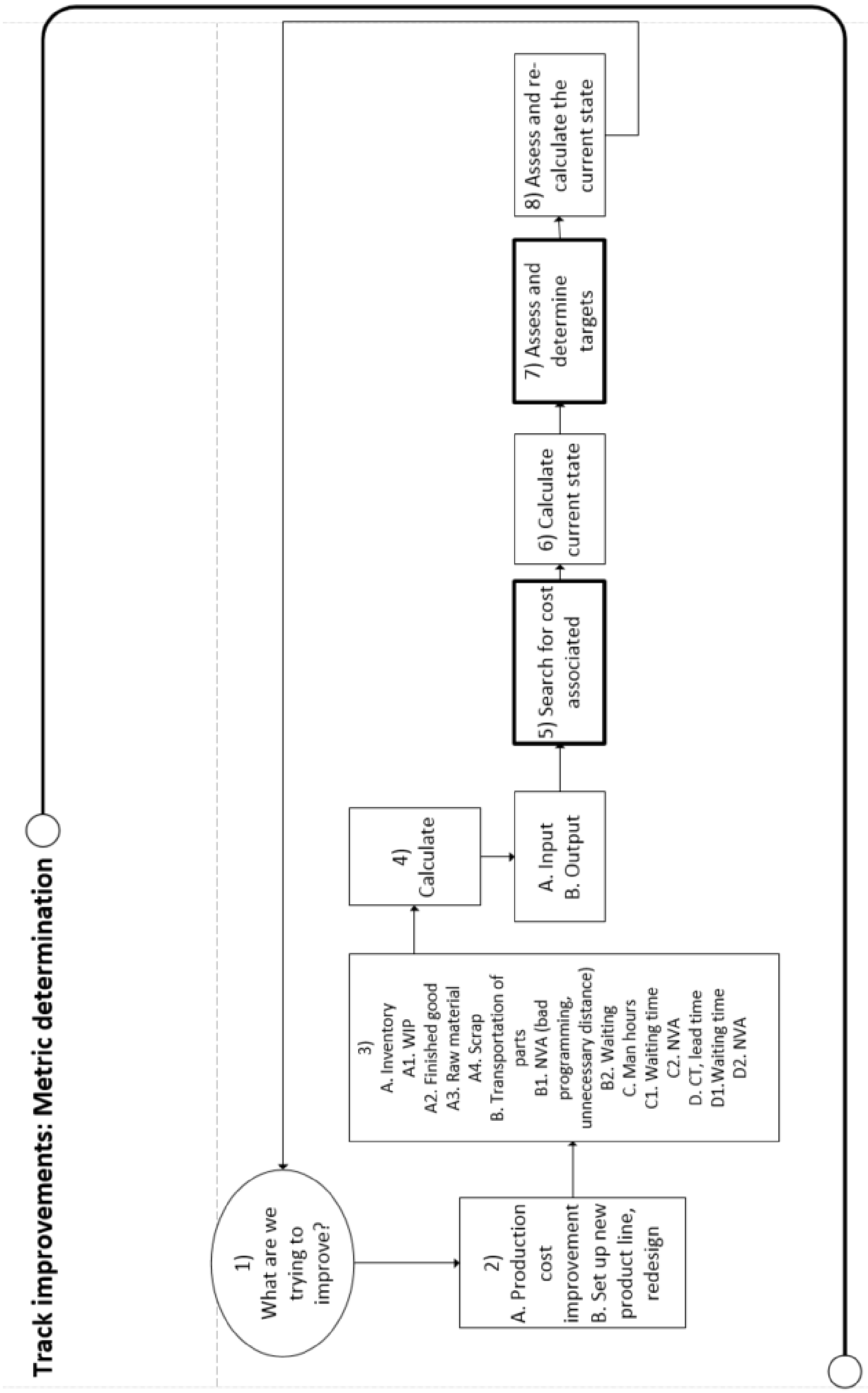
7) Assessing and setting a target and a time frame according to the company's expectations, long-term vision and team capabilities, with consensus from the team involved directly in the process (example: 10% reduction of WIP for next quarter, 2% man-hour decrease per month).

8) Reassessing and calculating: The process should be repetitive and periodic. The organization determines the frequency based on their needs to improve the current state.

Of these, step 4 described above is crucial because it will help prioritize improvements and discard an area that may be problematic. However, it may not yield high returns for the efforts invested when compared to other low problem areas, but higher economic returns are involved. In the end, we strive for improvements to achieve higher revenue. Our objective is to redirect the efforts first toward the high return problems.

Figure 22 shows the proposed method for metric determination, and summarizes the method that the author has described above. The method facilitates the simple and effective tracking of improvement. It can also be adapted to suit the organization's best interests, targeting higher revenues from improvements. It is important to mention that the list of components and the sub-components associated with it are likely to change. Perhaps the organization may find a new element that we have not added in this figure. These are the most common elements that the author has found used in Cases A and B and in the previous literature.

Figure 22: Proposed method for metric determination



In this study, the following are the formulas associated with the method for determination of the metrics:

Equation 3: Metric determination formulas

$$(1)\ Current\ state = \frac{Output}{Input} \times 100$$

$$(2)\ Assessment = Current\ state - Target$$

$$(3)\ Benefit = Total\ cost\ associated \times Assessment$$

Current state (1) is defined as the present state or diagnosis prior to improvement and is defined as a percentage. Assessment (2) is the comparison of the state (current or future) against the set target. Benefit (3) is about money, that is, the total profit or economic advantage from the implementation of improvements. The integration of this method into mapping is a useful direction for future work.

4-5. Conclusion

The first question in this study was: "How can value be measured in an economical way, using mapping techniques to boost improvement acquisition?" This study suggests that each organization should determine the most suitable data to track according to their needs and goals, such as, for example, Case A currently tracks man-hours and inventories (purchased goods, WIP, and FG) and Case B focuses on inventories as well, but breaks down the analysis, and focuses deeper. Value can be tracked in different ways, and companies should determine the most suitable data to track according to their needs in compliance with corporate goals.

All VSM variants presented in this study can function with time as a base measurement. The tools help track the data that the organization selects, but the required degree of detail varies across tools. For instance, the level at which Case B (higher) operates in the organization, makes it necessary for the management to report to headquarters and measure their performance in a more detailed manner. This means that their economic measure of value needs to be more comprehensive.

Most of the weaknesses in VSM that are highlighted while analyzing applicability (Braglia et al., 2006; Khaswala & Irani, 2001) relate to the mapping tools used in these case studies. Nevertheless, some can be excluded, because while applying MIFC, Case A considers factors such as container size and trip frequency between operations and can measure value by tracking inventories on their map. In Case B, they implement the “lane” devices and track inventory, as well.

An outstanding difference, not specified in table 9 is that the mapping tools MIFC and SDD for cases A and B, respectively, are not seen as tools themselves, but as a means to deliver knowledge and training on TPS and lean principles. This is not the case in VSM. This insight will be studied further in the following chapters.

The integration of the method proposed into mapping remains a direction for future research to follow. It can serve as a base for researchers in the field. For instance, we have the case of supplier X who is already performing calculations of this type determining cost relating inventories and man-hours to improvements. Redesigning or developing a mapping tool that addresses this necessity can assist and simplify the work of organizations.

Chapter 5: Deployment of a lean production system

The purpose of this chapter is to address how a LPS can be deployed and, at the same time, reach target levels of performance. Utilizing the findings of the case studies, this chapter presents the outcomes of the various interviews as triangulated with the data analysis from the different visits, findings from the tools testing, as well as first-hand interpretations from both plants. The analysis allowed the determination of key components in a lean journey, which are illustrated in a gradual and cyclical deployment model linked to the placement of tools. By testing the tools and reviewing the literature, the author determined guidelines for the placement of the tools and explained their connection with maturity levels. The author presents a logic VSC introduction process to support lean efforts. It is beyond the scope of this study to enable the creation of an assessment process. However, the authors' recommendation is to use the recognized AME assessment (as explained in the discussion section) instead.

5-1. Introduction

In theory, the effect of a production system on a plant's performance depends on two variables: (1) how widely the production system has been implemented in different areas of the plant, and (2) how thoroughly these areas follow its prescriptions (T. H. Netland & Ferdows, 2014).

Existing methods of selecting the appropriate lean strategy rely on the manufacturers' common sense rather than any logical justification (Karim & Zaman, 2013). They highlight the existing gap. It is necessary to develop a method to implement appropriate lean strategies along with a proper methodology to evaluate continuous performance improvement.

The absence of visible improvements leads managers and operators in the plant to question the value of the production system. It can also cause impatient senior managers at headquarters to withdraw their support and deprive the plant of the resources and the time that it needs to get through this stage (Netland, Schloetzer, and Ferdows, 2015). Lean maturity in a higher state should be the projection for an organization starting a lean transformation, and therefore, higher lean levels (Maskell & Baggaley, 2003). Organizational contexts have largely been ignored in research on the implementation of lean strategies.

5-2. Method

The selected method for this part of the study is a qualitative design with a multi-case strategy that adopts an embedded depth and an inductive approach. Instead of trying to adopt an existing theoretical scheme and taking those theories as the background, this study, throughout the analysis of the data collected through the case studies, defines the key components for the effective deployment of the lean/ TPS system, considering the peculiarities of the analyzed context. It also bears in mind the existing differences with organizations outside of this spectrum (e.g., the western world), and all other key elements in comparison to the ones in the existing literature. The connections and differences to other empirical research or theoretical frameworks are disclosed and illustrated. Further, it also presents the new aspects concerned with how to deploy a system without affecting the levels of performance.

According to Yin (2013), qualitative studies are often judged by construct validity which refers to the need for the researcher to apply the operational measures that are appropriate for the study. Yin (2013) emphasizes his preference for the multiple case studies approach as it offers better validity and reliability in the findings, and recommends "the use of multiple sources of evidence, to establish chains of evidence and to let key informants review the draft study" (p.42).

Phase 1 (secondary data to test tools) was crucial for the understanding of the elements in the maps and the characteristics of each mapping tool used in tracking and controlling for performance measurement. Further, the secondary data testing in phase 1 served as a major catalyst to ensure the correctness of the primary data collected in the case studies and enabled the major findings of the analysis of that data in the empirical work. By "data" and "to secure reliability," this study refers to all forms of material granted by the cases in printed form (e.g., graphs, charts, maps, tracking records, etc.), and the data collected by the researchers, such as field notes, audio recordings from the semi-structured interviews at each plant, and on-site pictures.

The empirical work done with Cases A and B focused on the implementation processes of the improvement activities as guided by mapping tools. Each case was analyzed as a separate entity, because even though they both belong to supplier X, each manages their internal TPS activities and transformation by themselves. However, they share knowledge of and the base principles concerning TPS and MIFC that they learned from Toyota directly, which is the reason why both cases comply with the purposive sampling technique.

First, the author analyzed the technical and practical aspects of the mapping tools themselves, but the part on how they integrate in a real environment where we have the people (user) and the problem (target) was missing. For this reason, the case study method allows the understanding and explanation of the factors that relate to the implementation and deployment of the tools in a system that aims to achieve one-piece flow. The interviews at each plant started out with a similar set of questions that was adapted along the way, during each visit. As the visits progressed, the questions turned out to be more specific to the development and application of mapping protocols. This allowed the author a gradual understanding of the cases, the reasoning involved, and the operational approach. Both cases had an open disclosure of critical information during the interviews and plant visits. The researchers were not only able to hear the principles, but to also observe the approaches in action. Nevertheless, the multiple case studies approach is not envisioned to be a macroscopic study and aims for only limited generalization (Sousa & Voss, 2002; Yin, 2013).

5-3. Results

5-3-1. Use of MIFC and Kaizen activities in Case A

Based on management experience, Case A stated that there are numerous ways to introduce TPS. For this plant, MIFC represented ways to introduce and trigger Kaizen activities. Depending on the context, other organizations may require different tools. For example, in some cases, a simple or more basic approach, such as 5S, is sufficient, while in other cases a full Kaizen analysis is necessary, which could lead to the use of more tools to help in problem-solving. MIFC for Case A could be considered in the manner shown in figure 23 below. MIFC is used to train people as a means to achieve TPS.

Figure 23: Categories in achieving lean

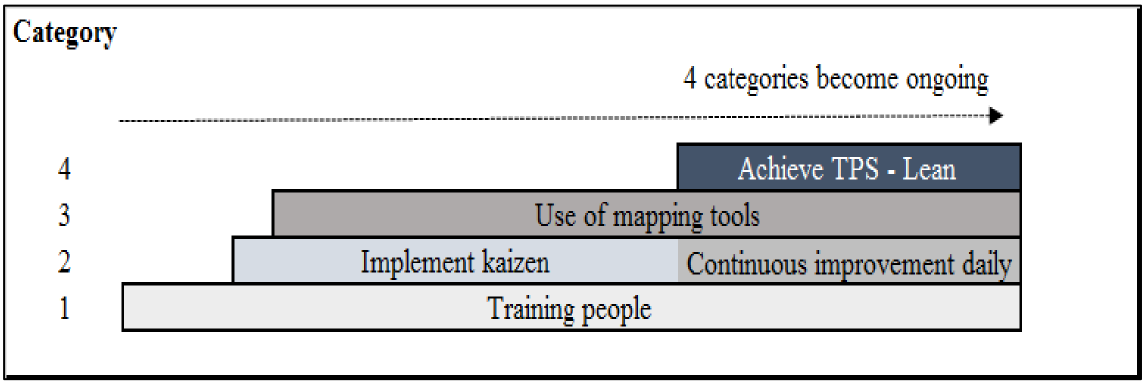


Figure 23 describes four categories, introduced at different points of time in the organization's evolution. Categories from bottom to top are: first, "training people" to start employees on their journey; and second, Kaizen projects can be implemented to boost continuous improvement on a daily basis. The goal is to add value with incremental daily improvements, and not just to respond to crises with standalone Kaizen events that require more intense efforts. Category three is introduced when Kaizen implementations are already ongoing, and involves mapping tools to aid in the diagnosis and problem-solving processes. Category four represents the maturity level at which the organization has mastered the knowledge around the three previous categories, and works with TPS and lean principles. The organization still recognizes that the journey is endless, because it is not problem-free. The organization is more resilient and eager to learn when problems appear.

5-3-2. Training approach at Case A

Training is an ongoing activity, and begins with the start of operations. The journey starts with the training of employees in the basic principles and methods of implementing Kaizen or other improvement activities. Once employees have reached the desired level of understanding of the mapping tool (in this case MIFC), they start using the tool and continue implementing improvements. With time, this becomes a habit, which later turns into a routine that allows the plant to reach the desired lean level. Once they reach a certain lean level, the four categories function at the ongoing pace. Training people and daily improvements with the help of MIFC then become part of a continuous path toward attaining higher lean levels.

Case A implements cross-functional activities through the voluntary study groups. The development and training of employees is their core objective. These groups are in charge of improvement projects that result from the application of MIFC. Problems or waste areas are called challenges, which become projects that are to be addressed by teams. Each team member, be it a leader or an operator, has a preset training journey to follow, along with the completion of the project to which he or she has been assigned by the direct supervisor. This way, the project becomes a practical means of knowledge acquisition. The team members learn-by-doing. Answers are not given by leaders. Instead, the team members are encouraged to seek answers through observation and experimentation.

The knowledge that employees need to address the challenges that occur are obtained gradually, from basic to complex levels. People cannot move to the next stage until they are ready, which is determined by their superiors before their required qualifications are approved. The meaning of "being ready" refers to "mastering by understanding." For instance, MIFC demands the ability to gather data to create a process profile, which is a chart containing line information such as CT, machine cycle time (MCT), inventory, shifts, etc. Employees must be able to gather that information before they can start thinking about creating a MIFC map. Approximately 50% of Case A's employees on the door check production line can currently create the line profile. It took approximately five years to achieve that level of understanding. Case A trusts the competent decision making ability of their employees, as knowledge preparation and projects take place in parallel.

5-3-3. Use of MIFC and Kaizen activities at Case B

The improvement or Kaizen activities at Case B are based on three pillars. All the plant initiatives are based on these principles:

1. Standard works
2. Self-maintenance
3. Processing-point control

The first pillar refers to following the standard work and changing it for improvement, while the second is related to each workstation by the workers themselves. The third pillar refers to measuring, assessing, and inspecting the control points that are critical for quality in a piece and need to be controlled.

The researchers were able to observe a peculiar activity on the production floor called Yokoten, which is encouraged as a way to trigger benchmarking of improvements, or in other words, adopting best practices. In short: What others have improved that I can improve in my own area. It is the management's desire to have a visual representation of the production floor, such as videos and pictures, besides write-ups containing the descriptions of those improvements. Yokoten encourages the display of information on the production floor, but MIFC is not usually displayed on the production floor in Case B. The internal name for the final MIFC with targets (further explained in chapter four) in Case B is SDD.

Some tangible examples of improvements achieved by MIFC and TPS activities are as follows:

a) Reduction of lead time from 3.04 days to .65 days by achieving a Heijunka pitch of 5 minutes.

b) Reduction of the production area from 1800 m^2 to 1345 m^2. Before the 5 minutes pitch change (before 2 hrs. of orders), they would receive orders 8 times a day. However, with the new pitch they reduced the inventory, which led to a decrease of 455 m^2. The area is in use for production preparation or the production of grille shutters.

There are cases that are still not optimal, where they have implemented "stock-out Kanbans," which are colored in pink. The stock-out Kanbans are used when WIPs are not withdrawn from a downstream due to machine troubles. This Kanban signals that the WIP in question must be produced and supplied as soon as possible. Case B did not hesitate to talk about the struggles or challenges they were facing at the time of our visit, which highlights the mindset and philosophy of continuous improvement.

The frequency of activities related to MIFC is usually six months apart. They require a big Kaizen event. After that, they have a follow up assessment after three months. Based on the magnitude and significance of the Kaizen events, the time frame could be larger. There are also coordinated Kaizen activities with Toyota, lasting for a duration of four to five months.

This study does not intend to suggest that all organizations striving for or already at a high maturity level should pursue the application and use of all the tools mentioned.

The study focused on studying how the mapping tools are utilized to deploy TPS and encountered a commonly shared point of view between both cases, that is, that the tool, MIFC or SDD is a means to an end. More specifically, both cases A and B have a solid belief in the effects that the use of the tool can trigger. It is not by default, but is a result of the environmental characteristics that they continuously set for success. These characteristics include team building, training, best practices, and the knowledge that is transferred (know-how) and learned directly on-the-job (learned-by-doing). The previous affirmation led to a new interrogation: How do we make sure that we have the proper settings to deploy lean or TPS, assisted by mapping tools? This study infers that there are no predefined steps. Both cases have developed their current settings along the way, following strong shared principles that have been instructed by their leaders. Both MIFC and SDD are not only diagnosis tools, contrary to what is observed in most western cases as illustrated in the literature. The tools are a medium to spread TPS, but each case does it in their own way. The workers are instructed in TPS principles in both cases.

However, the level of utilization at each plant is different. For instance, in Case A, the operative level is able to perform MIFC and the management serves as support. On the other hand in Case B, the operative level is not trained to carry out mapping, but management is in charge of these tasks. The TPS principles are taught but structured protocols and periods to re-assess the maps do not exist at the plants. Both expressed a sense of general frequency with which mapping is performed. However, this is not based on a formal or structured plan. It comes from the evaluation and observation that they undertake on a daily basis. If such inventory variances are observed, they opt for mapping.

This study observed a standard element in the measurement of improvements and the goal of TPS, namely, inventories. Inventories are observed and tracked at all times. In both maps, they need to be tracked and analyzed in depth, when in VSM, the focus tends to be on time (CT, PT, LT, or waiting time). Inventories carry on with metrics uniformly. These metrics are able to economically track the value through inventories in any of their forms, and also identify the elements they chose, which may vary based on their current targets. A slight discrepancy in the inventory triggers a red light for assessment. The assessment, either by measuring inventory levels physically (Case A) or performing a TPS level checklist (Case B) allows them to determine how close they are to or how far they are from achieving one-piece flow. Having that uniformity is a means by which both cases make sure that their performance levels are not impacted by any change or amendment in their production systems.

5-4. Discussion

The author found the need for an analytical and systematic framework to follow in the deployment of lean that does not lead to drawbacks in performance. Organizations like supplier X, have managed to put in place a system that allows them to gradually introduce the modifications that the system requires. Some of the protocols in place are standardized work, but some others are shared know-how as gathered by the learning-by-doing approach. Organizations in an initial state of lean may need a blueprint to follow that would enable the shortening of the error margin. The knowledge of TPS in cases A and B may have evolved through different paths, as a result of exposure to each environment and plant settings. However, they maintain the core principles.

Neither Case A nor Case B utilizes MBPM or CTP. Nonetheless, they could benefit from their application. As we can see from the data analysis, they have a considerable amount of required data that is already being generated. Non-standardized processes that could be formally established to support decision making by the application of MBPM or CTP exist. The deployment or transplantation of their systems could become smoother, considering, for example, their expansion overseas. It is not that they need the three tools in place. It will follow only after analyzing the problem that we are trying to solve, which is when we can decide to apply a tool that is different from VSM, MIFC, or SDD. Ideally, they should not need any (i.e., problem-free organization), but unfortunately, that is not the case.

The evolution and innovation using the emerging mapping tools and VSM variants mentioned can be observed. They have shown potential in constantly changing and complex environments, while the cases demonstrate that they are tackling needs that regular VSM cannot solve. The solutions may not always be optimal regarding achieving JIT in the long-term. However, the progress is noticeable since they are already looking for solutions to the challenges encountered with VSM. Further, they are incorporating elements that enhance the tool, instead of accepting the constraints. The literature on lean transformations, however, could employ a deeper analysis of the selection of those tools, to avoid applying efforts erroneously.

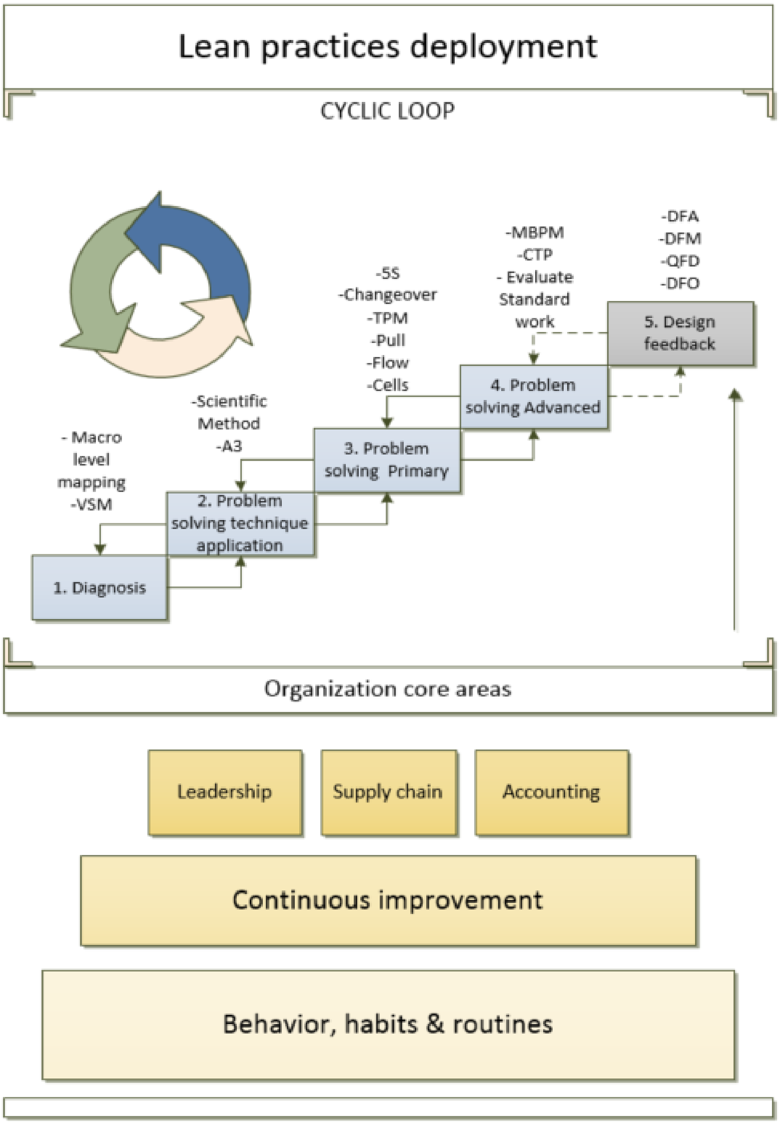
Knowledge transfer systems must be in place to facilitate routines for the learning of internal protocols. Reducing the weaknesses and shortcomings of a system is a challenge in itself, but it is also necessary to adapt to a particular application environment.

With the intention of discussing the desired and ideal path toward lean and also providing a concrete illustration, the author put together the key pieces that kept showing up in the literature with other aspects that were encountered in cases A and B. This can be seen in figure 24. These key pieces enabled the attainment of a system as close as possible to the one-piece flow.

5-4-1. Deployment model

Figure 24 presents the proposed lean deployment model, which can be seen as an ascendant ladder but at the same time, as a repetitive and progressive sequence that can start at each of the stages or blocks 1, 2, 3, or 4, depending on the organization's current level of lean knowledge and maturity. The levels of inventory (desirable low and stable) define the maturity of the organization, along with short lead times and flexible value chains.

Figure 24: Proposed lean deployment model



The organizational core areas are stated at the bottom: behavior, habits, and routines, followed by continuous improvement; and above, leadership, supply chain, and accounting. These form the desired solid roots from which the deployment and change begin to happen. The level to start at and the tools associated with it are defined after conducting an analysis of the current problem or problems that we are trying to solve, along with a study of the organizational skills. The deployment in figure 24 follows a logical progression.

It is beyond the scope of this study to create an assessment. The author recommends the use of the recognized AME assessment as explained earlier, because it is an easy and very straightforward way for an organization to have a visual representation of their strengths and weaknesses. Further, it has been studied before in depth by academics (Shah, 2007). Later on, the organization may develop a particular way to do so, such as in Case B (check sheet on table 8).

The author states this is a cyclic loop process because as the organization moves forward or starts new projects, it may encounter new challenges that will require the analysis and determination of whether the current tool(s) in place is (are) suitable or not. Figure 24 indicates the cyclical loop process at every block.

The first block contains a VSM diagnosis for an overall picture. At the same time, in the early stages, basic mapping can assist training in TPS principles and can help reinforce the core areas at the bottom of the model. In the second block, the problem-solving technique application includes the scientific method or A3 process utilization (systematic problem solving based on PDCA principles). These two relate closely to TK principles (Rother & Aulinger, 2017) with the members of the organizations already in raining on behavior, habits, and routines. The third block is the problem-solving primary, which includes techniques such as 5S, changeover, TPM, pull, flow, cells or line balancing, among a range of others. The author listed the most common and already proven solutions that have been implemented in the industry. These techniques are a solution to problems in the process due to disconnected flows of materials and information. The sources of waste can be visualized with a macro level mapping tool.

It is not until block four in the problem-solving process that the author includes CTP and MBPM, along with the evaluation of standard work. Standard work evaluation can be performed by assessing the 3Js from TWI, because at this point, standard work requires a separate assessment. For instance, let us say that we have already analyzed the sources of waste at a macro level and applied proper solutions. Let us say that the inventory level is far from optimal. It is clear that extra inventory continues to be generated in one area while the production quota is not reached in the other area. This may be a sign to assess the standards not only by assessing work instructions, but also by assessing the methods utilized in production, and the relationships and environment in the work area.

In applying MBPM and CTP, after passing the initial macro analysis and applying the solutions for problems at that level, a deeper breakdown is required if the organization needs to either assess the processes at the activity level or relate the cost directly in mapping. In the same way, a particular tool, either MBPM or CTP, will be used to assess the problems based on the approach level, namely, micro cost or macro cost. The solution will be the same here.

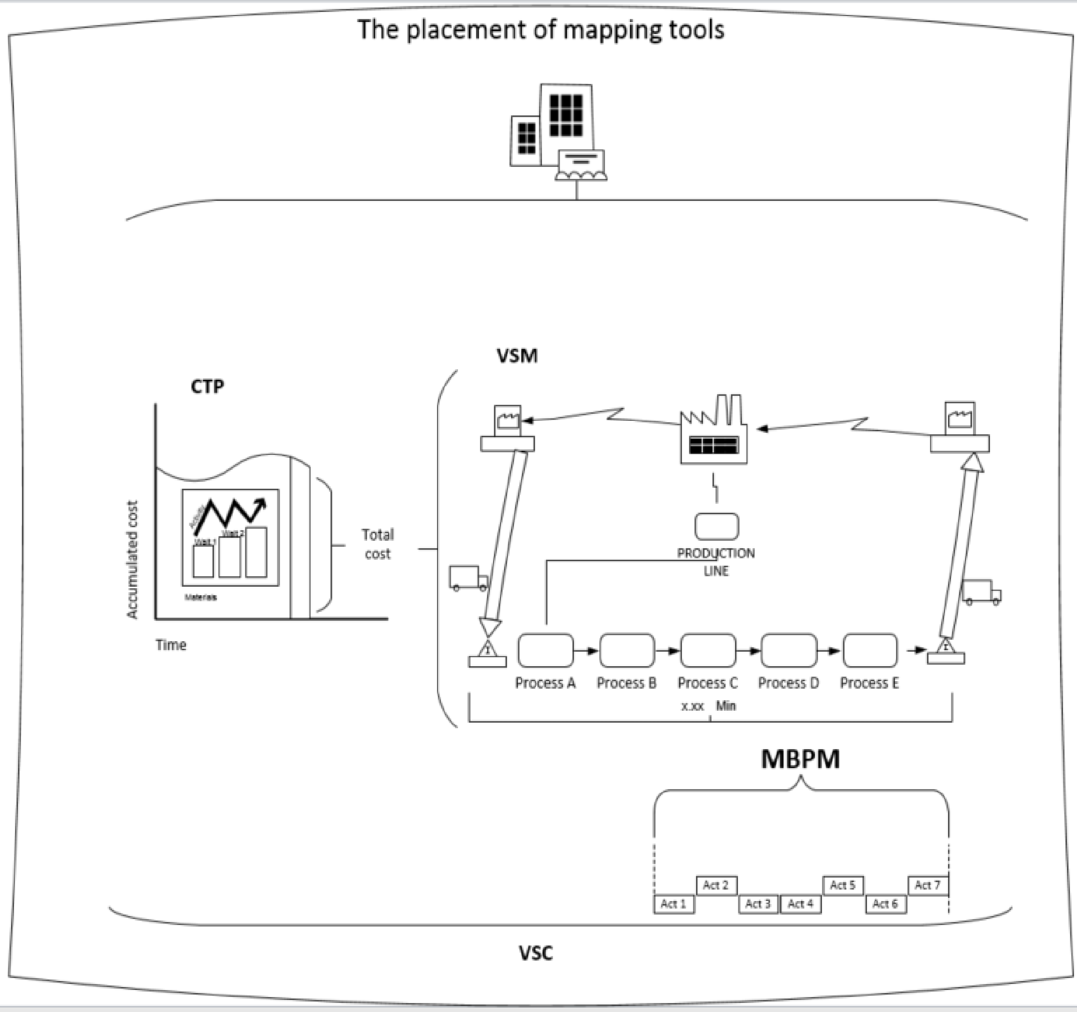
The fifth block is concerned with design for assembly (DFA), design for manufacturing (DFM), quality function deployment (QFD), and design for operation (DFO). It is beyond the scope of this study. However, it requires a high lean maturity, and is an advanced organizational goal, which is not recommended for an organization going through early lean transformation.

Given the fact that most readers are familiar with VSM as a mapping tool, the author refers to it in all the figures with its western name. However, it is important to consider the previous chapter where we included a comparison among VSM, MBPM, and SDD, and talked about how MIFC and SDD, are the adapted forms in each case in this study. Any organization that intends to follow the lean deployment model in figure 24 must consider the openness at the first block containing VSM diagnosis. The organization has the freedom to utilize their version or any mapping tool they choose, as long as the selected one complies with TPS principles or pursues the achievement of one-piece flow as the ultimate goal.

Figure 25 graphically presents the level at which this study suggests that the tools should be placed inside a manufacturing environment, if we go from the macro level with VSM and CTP. Meanwhile MBPM is at a micro level, assessing the activities in detail. VSC is pictured at the bottom of this figure as it can serve as support for any of the other tools. It follows the same level of application and placement in the deployment model in figure 24, proposed above. Figure 25 shows the whole organization. On the top right side, we can see an example of a production line and its processes (A to E). VSM works at this level, allowing one to see the entire process, and at a strategic level with a systematic vision, it reflects the inefficiencies of the manufacturing system. It also serves as a training medium for individuals in the organization both in TPS principles and in understanding the flow and connections between the processes for waste reduction. If the organization is interested in assessing cost over the long-term, they can start thinking about utilizing CTP, which will help them assess and measure how much money is invested in the manufacturing process of a product and for how long (time). As mentioned previously, it creates a graph that presents the accumulated cost at every point in time, measuring the area under this curve (total cost-time investment), and then, it uses this quantification to measure the impact. On the other hand, if the organization requires a deeper analysis in a particular process, such as, for example process D (as seen in figure 25), they can opt for MBPM instead. They will be able to break down and track the activities of a particular process at a micro level, obtaining more specific detail and greater focus on the activities.

In this context, CTP comes out as the most complex tool among the three. It can also offer more detailed information in terms of money and can require the highest level of investment (in training individuals on using and understanding the tools, but not in information gathering). Therefore, it is not recommended as a daily use tool, or a tool for application at an operational level.

Figure 25: The placement of mapping tools



Most of the information, that is, the data that MBPM and CTP require, are already being gathered and the information that they provide is already being requested or needed for the decision making processes as carried out by someone in the organization, usually, the management and top leaders. These tools can be a standardized means of making the process smoother and simpler. There can be a way to track and use that information efficiently.

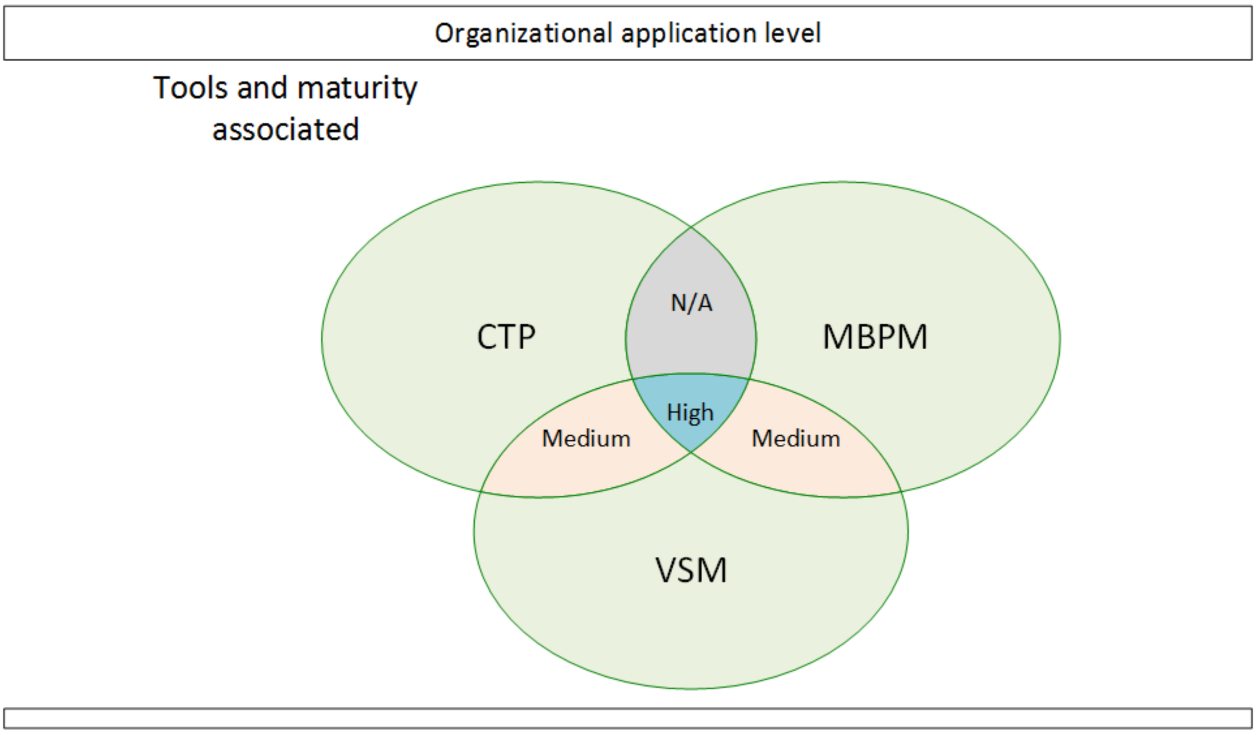
5-4-2. Maturity levels and the application of the tools

The level of maturity associated with the application of tools comes from trying to understand when a company is ready or whether it should utilize a certain tool or not. The term “maturity of the organization" is defined by the levels of inventory, the desirable low and stable short lead times, and flexible value chains. In this sense, lean maturity in a higher state should be the projection for an organization starting a lean transformation, and therefore, higher lean levels (Brian Maskell & Baggaley, 2003).

The author considered lean accounting principles (Maskell, 2006) to underscore the connection between mapping tools and an organization's maturity level, because it relies heavily on inventory levels. This is a common point with the lean assessment method in Case B (check sheet in table 8) and agrees with the goal of TPS, namely, of achieving one-piece flow.

Figure 26 illustrates the organizational maturity level and the compatibility of the tool. For instance, VSM and MBPM can be found in an environment with a medium maturity level and the same goes for VSM and CTP. Ideally, a company will be ready to use the three tools when they have reached a high maturity level, and have the characteristics that have been mentioned previously. It is not recommended to apply CTP and MBPM without having utilized VSM. It will be difficult for an organization to skip a systematic view and blindly choose an area for application of CTP and MBPM. VSM offers an idea of how to strategically target improvements and decide when a more specific approach needs to be taken into consideration (applying CTP, MBPM, or VSC). The author did not find a single case where only CTP or MBPM were applied as standalone tools for targeting improvement or assisting in lean transformation. Figure 26 shows that CTP or MBPM can be utilized by themselves as well, as recommended by their creators, as standalone tools that are not as part of a Kaizen event (Martin & Osterling, 2013; Rivera, 2006). However, the findings from the analysis presented in chapter 3 suggest that for the context of this study, it is not optimal to apply them in a lean transformation environment, in an isolated manner without conducting a macro analysis first. It is recommended to do so, only in a project environment or in a process where changes are tested separately, such as, for example while evaluating the feasibility of engineering changes. Figure 26 aims to visually represent the compatibility among the tools for an organization persuading lean and how their maturity level is associated with the application level, demonstrating their readiness. It does not indicate that in order to be at a higher maturity level, an organization should aim to apply a higher number of tools.

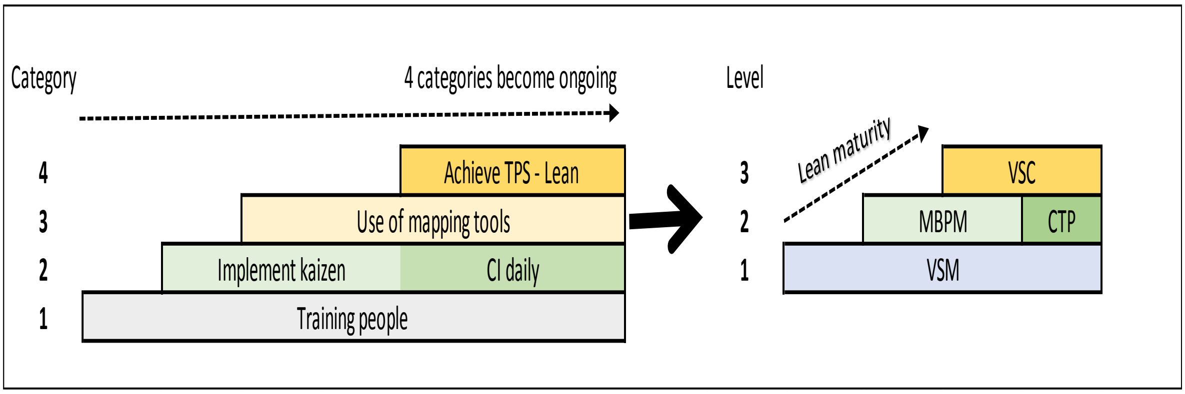
Figure 26: Organizational maturity and application level



5-4-3. Ideal deployment process of the mapping tools and the introduction of VSC

The author considers the categories of achieving lean in Case A. Figure 23 summarize the lean principles in an ideal evolution. Augmenting figure 23, in figure 27, a second ladder has been added on the left and category number three, “Use of mapping tools” has been deployed further. It can be broken down into three different levels, which at the same time, relate to an ascending maturity level.

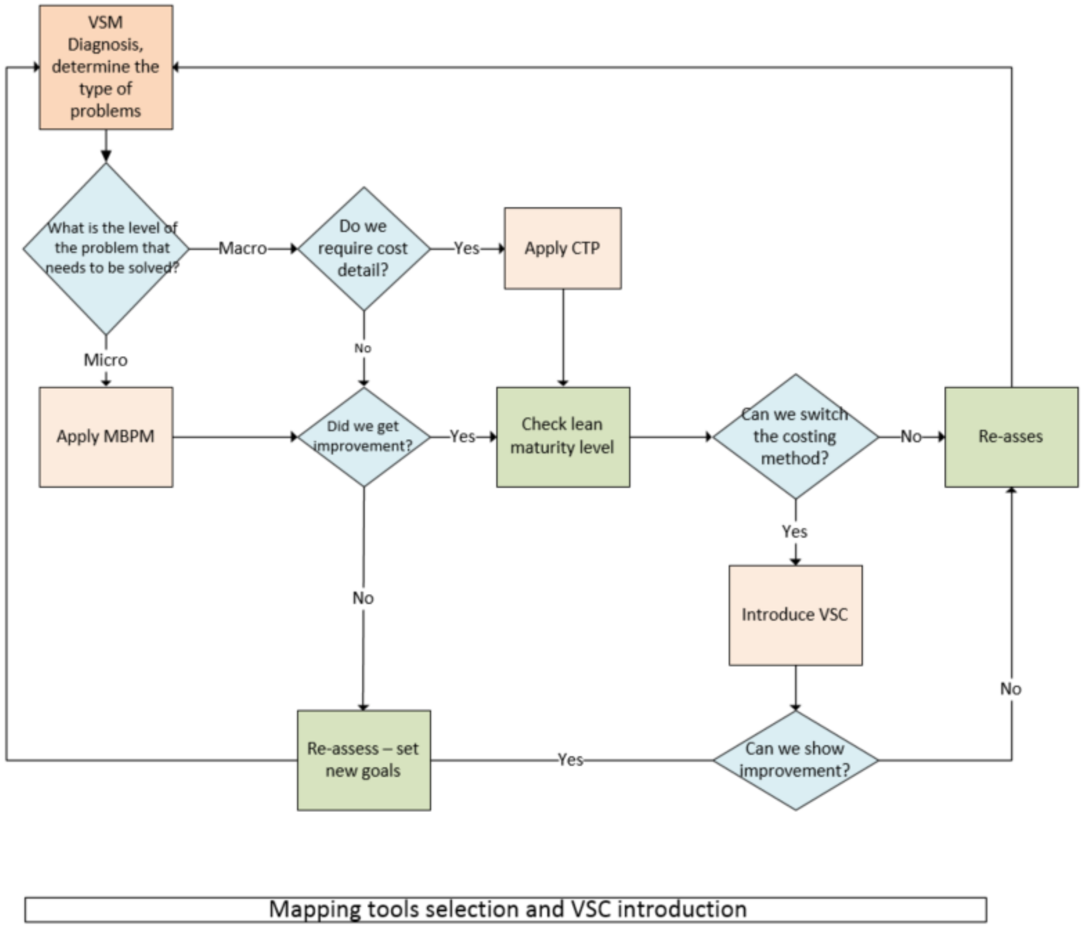
Figure 27: Use of mapping tools and levels associated



At the bottom, we find VSM, which functions as a foundation. On the second level, organizations can start thinking about introducing MBPM or CTP in the same process, either one or both at a time. It could be in the same or different production lines or product, depending on the problem they are trying to solve. They can be either exclusive or inclusive. On top, we find VSC on level three. As it is not a standalone tool, it support any of the other tools used. The introduction of VSC is depicted in figure 28. This is assessed in detail as it relates to our first research question, since VSC relates to performance metrics and improvements acquisition in an economical way.

Figure 28 integrates the three different levels of tool selection (described in figure 27) from VSM until VSC in the last level. First, VSM is utilized as a way to diagnose problems and their type. From here onward, it takes two paths: the micro or macro level. If it is a problem at a micro level, we opt to apply MBPM. If we select the macro level approach, we should question whether or not we require the cost detail. If we do so, we can apply the CTP and then check the maturity level. If the answer to the previous question was that we did not require cost detail, we question whether we gained improvement by utilizing MBPM. If there has been no improvement in all the cases, there would be a need to re-assess and set new goals.

Figure 28: Selection of a mapping tool and introduction of VSC



The re-assessment process involves utilizing VSM again, from the beginning. When we check the maturity level after the application of CTP, the next question is whether or not we can switch the costing method. If the answer is no, we re-assess utilizing VSM from the beginning. If the answer is yes, and the organization is ready, we proceed with introducing VSC. Later, we question whether VSC is shows improvements or not. At this point, both answers will require re-assessment. No improvement leads to the determination of problems that are blocking improvement with VSC, and the affirmation of improvement leads to setting new goals for continuous improvement.

When the organization gets to the last part, questioning whether they can introduce the VSC or not, barriers can come in, but not only from the production section. Other production related aspects include issues like still having unstable inventories, demand having high variance, some crucial flows continue to be disconnected, etc. However, there could also be aspects beyond the scope of production, such us unengaged personnel, accounting processes under traditional scheme or management opposition because of non-compliance with corporate goals measurement. This is why the introduction of mapping tools must be gradual and linked to the deployment blocks in figure 24. In cases A and B, neither has introduced MBPM, CTP, or VSC. This is a clear example of the fact that the amount and complexity of lean tools in place is not the equivalent of the lean level. In both cases, their level of lean understanding and application can be considered higher than those of most manufacturers, and it has been achieved without MBPM, CTP, or VSC. However, the amount and type of data they use to track performance allows the author to infer that they could benefit from employing at least CTP and MBPM, and the tools would provide standardized methods to unify procedures. Utilizing these does not imply that they will be leaner. Ideally, the leaner they are, the few the problems, and the fewer the tools used. Figure 27 is a scientific abstraction which that can help organizations that are far behind in the assimilation of lean principles to make a thoughtful selection of a tool that can support their lean journey.

The implementation of an inappropriate lean strategy in a given situation can sometimes lead to an increase in waste, cost, and production time for a manufacturer. Consquently, it will affect the levels of performance. The key lies in the selection of the strategy, that is, in whether it is at the micro or macro level. The author recommends assessing the selection according to the maturity level in which the organization is positioned before proceeding to the implementation of the lean strategy, and then following a pragmatic path that allows the achievement of progress while changes are taking place. Otherwise, the poor selection of a lean strategy can lead to changes that may cause disruptions in the process that it is meant to improve.

5-5. Conclusions

This study found that previous research is oriented toward showing the benefits of a particular tool. However, we can identify a further outcome if we choose a suitable tool based on the problem that we are trying to solve. Therefore, it is important to understand tool placement.

The author found that the maturity level is highly correlated with the appropriateness of the application of each tool. In Case B, they already determine their TPS level, which is clearly a means to measure maturity level in a tangible way, as it is directly related to assessing inventories in a comprehensive manner. In response to the second research question, the author illustrated an ideal lean deployment model that is directly related to the placement of tools and maturity level. Evaluating the organizational lean level and maturity along with a gradual introduction of lean, based on the proper assessment of the current situation in the first place can prevent the disturbance of the levels of performance.

The author set up levels and categories for achieving lean, but they are not static and can and should become cyclical as an organization progresses on the path to excellence or adapts its own operations to meet new challenges.

The lack of commitment from the management and poor leadership is a potential drawback in tool performance. When companies go on board the implementation of any new initiative, such as a support tool like VSC, disengagement can be one of the major detriments to their success.

Chapter 6: Interplant transference of a lean production system

This chapter addresses the topic of the transfer of the production system that takes place particularly between plants in the same organization. The chapter analyzes an automotive supplier undergoing lean transformations in different plants through qualitative case studies. The case findings are triangulated with the findings from the review of literature, leading to the rationalization of a structure for a transfer model that practitioners can apply in real settings. The same structure can serve as a starting point for researchers to expand on the knowledge in the field.

6-1. Introduction

In spite of the success of lean companies and the benefits recognized by the literature (Jones et al., 2011; Shah & Ward, 2007), organizations struggle when they try to deploy the same system in a different setting (e.g., an overseas or domestic plant of the same organization). Those practices can either help or diminish the efforts toward the implementation of a new production system (Karlsson & Åhlström, 1996; Liker & Hoseus, 2010; T. Netland et al., 2015).

Aoki (2008) suggests that such shopfloor-based methods may lead to the sharing of company goals among the workers and the management, and may also create a trust relationship among them. The organizational capabilities that have been developed through their own history consist of complex social relationships that are difficult to transfer to other plants.

6-2. Method

This study applies a qualitative research design since it aims to study relationships between entities. The case study method was selected as a strategy, following a purposive sampling technique. Sampling is aimed at gaining insights on the phenomenon, but not for an empirical generalization derived from a sample that is applied to a population (Patton, 2002; Yin, 2013). With embedded depth in the cases, the study follows an inductive approach. An automotive supplier (supplier X) was analyzed as an entity formed by different pieces: cases A and B (see figure 17). Due to the time constraint, only the cases A and B are analyzed in depth.

The empirical work (phase 2 under chapter 3) focused on implementing Kaizen programs across the organization. The aim was to assess the level of knowledge of lean across the group, the system in place, and the protocols that enable the organization to transfer that system among their plants. The primary data is composed of all sources of physical information gathered at the sites, organizational charts, metrics charts, pictures of corporate targets, etc., as well as recorded interviews. The supplier gave full access to the recordings of the semi-structured interviews and plant tours, in addition to which the three researchers on the team who assisted in all the site visits (table 7), took notes from the field that were shared among them later, for the triangulation of information to guarantee impartiality in the presentation of the data.

Both Cases A and B were assessed with the same degree of meaning accorded to the research question. The plants were evaluated individually on the same topic without disclosing any previous knowledge of the practices in place at supplier X, for two reasons: first to appraise each plant perspective separately and second, to examine each plant’s reference of the other plant’s positioning in the group as a whole.

6-3. Results

Even though both cases were assessed and deemed to have the same significance for the research question, Case B presented a higher involvement in the transference of TPS knowledge. Assessing both cases provided great insights from the programs in place at supplier X, because each case provided a reference for another case standing in the group. In that sense, we were able to understand the protocols and their connections beyond their functional descriptions on paper. There is a higher involvement of Case B in the transference of TPS knowledge.

MIFC is currently used in overseas plants for supplier X as a support tool, mostly for the establishment of a new production site or the setup of new product lines. After that, a follow up is carried out by personnel from the regional headquarters. The goal is to have workers understand, digest, and master TPS by developing instructors through the launch of the technical staff room. It was mentioned in Case B that it is currently not possible to apply it on a daily basis along with Kaizen activities in all overseas plants, as there are too many. In the future, they would like to implement MIFC as a daily tool of continuous improvement.

The organization has a voluntary study group which consists of 14 group companies, of which 13 are production companies. They get together to share Kaizen activities and exchange expertise and knowledge. In other words, they educate each other. They also input the knowledge related to Kaizen initiatives and best practices in a database, which is only within their organization. Although they wish to expand such activities in other companies in their group, there are some unsolved challenges (e.g., legal issues concerning the provision of intellectual properties among the companies in the group) in making it happen. They are, at the moment, checking the feasibility of this issue. There are divisions like the Operations Management Consulting Section in other companies in the group. Staff from these sections gathers to discuss issues on Kaizen and share knowledge.

Case B has an internal employee exchange program, which involves an exchange of different plants, following the learning-by-doing mindset. They also have an inter-companies exchange program where companies of the same group exchange employees, for a period of one to two years. In addition, there are also intra-company exchange programs where Case B receives employees from other plants for a period of two years. The activities in these programs are related particularly to the production area and are devoted to learning about TPS. The program has been in place since 1988, and has accepted around 20 workers per year. At the time of the visit, it was mentioned that they only had five “exchange students” (as the students are called) in the plant. Internally, they held plant observation workshops regularly. Case A also participated in these programs with Case B.

The Production Human Asset Development division provided supervisors with education on standard work in order to spread knowledge to factories overseas. The section-head level and unit head-level managers are sent to the United States, China, Thailand, and Europe (Belgium), which are the four major areas and regional headquarters. The group has internal sections, such as the Operations Management Consulting Group in the overseas regional headquarters. They have people who have learned TPS through classroom lectures. The plant has also setup Technical Staff Rooms at overseas sites, to facilitate on-the-job training in cooperation with the regional headquarters to coordinate Kaizen activities. Although they have been offering classroom lectures, these efforts have not been pervasive yet because there are too many overseas sites.

Through these case studies, we were able to assess how automotive supplier X is transferring its continuous improvement culture with foundations in TPS. By assessing both plants, we can state that the term “replicate” may not be accurate to describe the way in which supplier X is deploying TPS along with different plants.

Plant B is connected to the other 10 plants by the inter-companies exchange program as seen in figure 16, which depicts the organizational relationship between cases A and B. As far as this study is concerned, they may not have an established protocol to transfer their production system step-by-step. However, this is not a diminishing aspect, because instead, they pass the core knowledge and principles through a learn-by-doing approach.

The effort to establish connections and links among the different companies, such as through the group-wide voluntary study group, which consists of 14 group companies and divisions such as the “Operations Management Consulting Section” in other group companies of the organization is observed. Gathering staff from these sections to discuss issues on Kaizen and to share knowledge is a way to ensure that uniformity prevails in the TPS principles.

When it comes to knowledge transference in overseas plants, lesser progress is observed, not because they are not taking action to support it, but because the magnitude of the organization makes it hard to assign resources to all overseas sites. Spreading TPS overseas seems to take more time and lags far behind when compared to the domestic situation where solid protocols are in place. Nevertheless, those sites are being instructed in the basic principles, such us standard work, which can serve as a starting point later, in introducing specific formation in TPS principles.

Adaptation happens not because it is requested, but because it is a part of the progress in each plant that Cases A and B go through during the implementation of the TPS principles. This affirmation adds to the findings of previous studies on the systems hybridization approach (Abo & Kumon, 2004; Giroud, 2015) where the adaptation was studied at the overseas level. The "hybrid model of the application and adaptation" framework was developed with the intention of examining the transference and internationalization of the Japanese system to other countries. In this case we detected adaptation at plants located within the same national context.

Ongoing efforts continue mostly in Case B, to strengthen group activities and to reinforce TPS with the cooperation of and development by the members who can, later on, spread the knowledge to other plants.

6-4. Discussion

For overseas plants, workforce aspects such as national culture and customs can influence the acceptance of a foreign organizational culture. This was also pointed out by managers in Case B. Developing a structured program with standards that can be handed over by the members who are participating in global integration meetings, will ensure that the knowledge is passed on as accurately as possible. This does not mean stopping the empowerment of the local workforce. On the contrary, it ensures that they are on the right path. Later on, by adapting the protocols in place, the organization can make sure that the national background and customs have only a positive influence or at least do not alter the essence of the TPS principles.

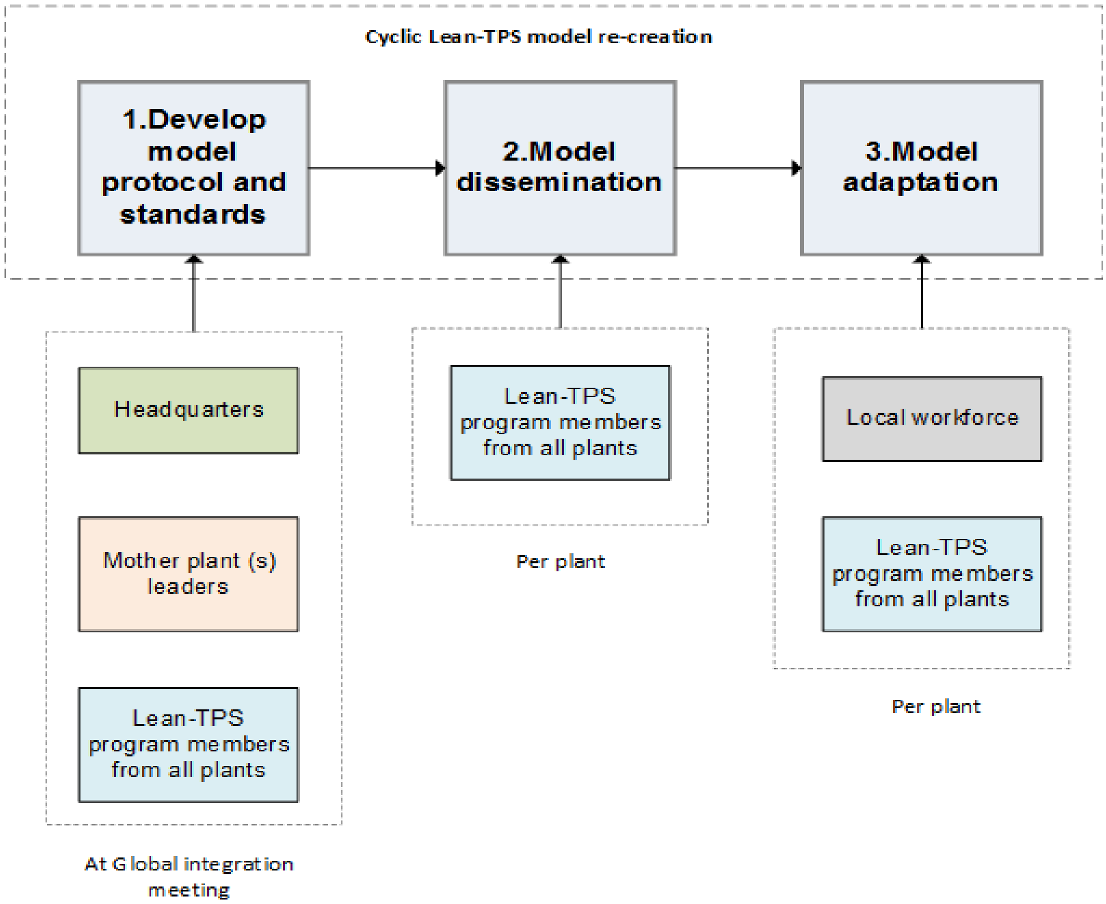
The author states that adaptation must be a compulsory step in system transference, because it cannot be assumed that all environments will naturally mold to a production system as originally created. Such adaptation should be performed by personnel who already have a solid foundation in TPS knowledge, have had the opportunity to experience the TPS principles first-hand, and have used the mapping tools in real settings. The results particularly support the second formal adaptation option that Abo and Kumon (2004) propose as organizational options for overseas managerial environments in Japanese companies. They require adaptation at the formal level. However, to apply the practices at the functional level, exploiting similarities between the elements of the different systems and utilizing them in a functionally equivalent manner is ideal. Undeniably, a protocol in which members of the different sites are forced to interact face-to-face strengthens the essence of the best practices and principles that the organization is trying to cultivate.

6-4-1. Structure for model transference

With the aim of making a contribution to the existing body of knowledge and practice, the author put together a structure for model transference which takes into consideration some principles observed in cases that are not formally established. The author triangulated the case insights with the analysis of existing knowledge in the presented literature. Practitioners may use this as a blueprint for leading efforts in a system transfer. Researchers are encouraged to test it in a real setting for improvements and/or amendments.

The model in figure 29 is a general representation of the proposed structure for model transference. By “model,” this project considers both, integrated lean and/or the TPS production system principles, and particular organizational culture in standardized formats and protocols. This takes into consideration the culture that the organization wants to spread, and is based on continuous improvement. Figure 29 has established three main blocks at the top that form the main processes for the transference model (i.e., develop protocol and standards, model dissemination, and model adaptation). Next, below each of these blocks, we find the enablers. The first includes headquarters, the mother plant leaders, and direct lean/TPS program members from each plant in the group.

Figure 29: Proposed structure for model transference



They will be in charge of gathering and deciding the features (i.e., the characteristics of the model). These members will conduct global integration meetings. As stated at the top of the three blocks, the model will be revised and re-created when deemed necessary. The second block concerns model dissemination. The lean-TPS program members from each plant will be in charge of spreading the model according to the protocols determined with the team in block one. Finally, the third block addresses model adaptation where lean/TPS program members from each plant and local workforce will work together to decide which model features need adaptation to comply better with internal culture, once the routines are in place. It will be the responsibility of the lean/TPS program members from each plant to notify the global integration meeting team of the model adaptations, as a way of feedback for the possible evolution of the model or for other members to use it as a benchmark in their own plants. The model will remain dynamic as production processes keep changing constantly. The cyclical model re-creation will polish the team's capabilities in the three main blocks.

6-5. Conclusion

This chapter is aimed at responding to the third research question: How can a LPS and its organizational culture be transferred to or replicated in other plants in the same company? In response to this question, this study contributed to the literature on lean production by analyzing the extent to which plants in the same organization use current practices in lean implementation.

The author proposed a visual and logical structure for model transfer that can be extrapolated to other organizations by practitioners or researchers.

The findings from the case studies are in agreement with the case presented by Netland, Schloetzer, and Ferdows (2015) where the implementation of corporate lean programs was analyzed. The findings of this study are in agreement, particularly, with one that speaks of a favorable relationship between management control practices and lean implementation: the use of dedicated implementation teams (e.g., organizing a small team of lean experts who assist in the implementation). Although this is a single industry case, the information and data gathered from the empirical work are meaningful, as we had direct access to confidential information and were able to hold discussions with key personnel in the organization. The author determined adaptation as a crucial and mandatory step in the success of the system transfer. Thus, the author believes that the term "replicate" does not fit and should not be used in illustrating the acquisition of LPS.

It was not the intention of this study to assess the degree of adaptation in systems. On the contrary, it is a pure finding of the empirical work. Therefore, it is out of the scope of this project to go beyond and analyze conditions such as: Which aspects of the local environment must the system adapt, and in what manner? What sort of application–adaptation pattern emerges as a consequence? What are the business results? Subsequently, specific research (Abo & Kumon, 2004; Giroud, 2015) tackling this topic already exists at the international level. This study sets a new path for other studies focusing on hybridization not only in international firms, but also in domestic sites.

Future work should ideally be devoted to testing the structure for model transference in one of the plants of supplier X. It should ideally be a plant that may just be initiating TPS formation and joining the voluntary study group, and preferably be an overseas plant. A second option will be to test in another organization that complies with lean or TPS principles that is looking to transfer their production system to an overseas plant.

Chapter 7: Conclusions and future research

This study considers that mapping tools play a significant role in transformation toward lean or TPS. It is, therefore, aimed at understanding their role in lean transformations and continuous improvement environments. The design in this study offers a different perspective that can enhance the understanding of readers who may have studied tools and lean methodology only from western versions. The study focused on three main challenges which translate into the research questions.

For the first research question, this study described current metrics to measure the outcomes of lean transformation, particularly those that integrate an economic measure of value and their relationship with mapping tools. This project presented a comprehensive and practical comparison of the different tools, and included the two variants of mapping tools (MIFC and SDD) in chapter four, based on the case studies. It described the way in which both plants assess value in an economical way. This study suggested an approach based on the case studies, tool testing, and the review of literature.

The literature shows that the implementation of tools, often with remarkable test results from their originators, does not necessarily lead to the same outcomes in other companies. Each organization has unique features and needs. Therefore, the replication of tools and techniques from company to company is not equivalent to success. Regardless of the company leanness degree that originates from using the tools, the adopter organization needs to adapt to some extent.

The applications in the literature suggest that practitioners often omit the internalization and adaptation of the tool. Achieving targets and metrics is considered a priority in comparison with internalizing a best practice or technique. For instance, the future state in VSM is a step in the process of applying the tool that serves as a goal setting (quantifiable) step. It is also a way to lead workers toward the same vision, and is often created by the management's need to ensure that all members of the organization are working toward the same objectives. Thus, a greater emphasis is placed on the creation of the future state than on the conception and understanding of the current condition, and then, on developing solutions. This differs from the conventional understanding of mapping tools, as transferred by the original source, Toyota.

The cases provide a new perspective, and aim to modify the practitioner's understanding of mapping tools and VSM. They show that tool adaptation is required even in non-western environments. Cases A and B used the basic form of an existing tool to develop their internal protocol that might or might not enable other organizations to accomplish the same improvements. Even in the same organizational group, differences exist in the way in which the tool is deployed, as a result of tool dissemination and internal evolution per plant.

The second research question was assessed in chapter five. The project investigated the way in which LPS can be deployed without affecting target levels of performance. Key components necessary to follow the lean path were determined and linked together in a gradual and cyclical deployment model linked to tools placing. For placing the mapping tools VSM, CTP, and MBPM, their positioning in a production system was explained and delimitated. This is a mere scientific abstraction that can serve as a guide for early-stage organizations in their pursuit of lean to shorten their learning curve. By "positioning," the author refers to the part in the production system where each tool can function at its best. In the same chapter, the author explained the connection they have with maturity levels and brought together a logic VSC introduction process to support lean efforts.

When Karim and Zaman (2013) found a negative effect of VSM on the performance of organizations, they highlighted that a possible explanation for this might be that the organizations studied have not been able to obtain such benefits due to implementation, management, and/or sustainability problems with lean methods. This study supports their explanation and the reasoning behind it. In their study, however, when they mention JIT as one of the five lean methods analyzed, they seemed to disregard that the objective of lean is to make a production system as close as possible to JIT, and hence produce just what is needed when it is needed, as exampled by cases A and B striving to achieve TPS. The cyclical model described in chapter five follows this same principle.

This study agrees with the new representation of TPS by Rüttimann and Stöckli (2016) , which is a multilevel mono-pillar in which they show the interaction between the main lean tools. Their model demonstrates the relationship between the complexity of production and techniques, as well as the purpose, theory, vision, and philosophy behind each of the levels. While VSM was portrayed merely as a tool to reveal inefficiencies, in the present research, we found that mapping, in this case, MIFC and SDD, can also be used as a way to achieve TPS and to train people, and not just act as a tool to diagnose and reveal waste. This could be due to their work referring particularly to western VSM. In this instance, it validates the need for MIFC and SDD to be studied as well, and the need to understand the accurate application levels of different mapping tools.

The third challenge, as assessed in chapter six, was to understand the way in which organizations can transfer an interplant model that preserves an optimal performance level while pursuing lean or TPS. This study found that knowledge transference is a critical component, as are the systems in place to develop workers' routines associated with learning techniques, tools, or any internal protocols. Supplier X created different study groups to ensure this essential component. These groups integrate members of the organization and disseminate TPS principles among them. At first, having several divisions and categories may seem confusing for an outsider. However, in reality, the different groups maintain organizational accountability to achieve not only the set targets by the corporate group, but to also perform under a continuous improvement mindset in each of the plants that the members of the study groups work in. Without them, the plans and protocols around MIFC and SDD may not be functional. Based on these insights, the author provided a structure for model transfer that can be used in a real setting. This is a contribution to the existing knowledge because practices and tacit knowledge are not often rationalized for others to use. The protocols around system transference in lean transformation are a clear example of this.

Further, the author would like to emphasize a few aspects that were also brought up in the publications included (Chavez & Mokudai, 2016; Chavez et al., 2018):

1) This study found that western practitioners seem to be more advanced when it comes to the technology linked to the tools. However, their pursuit of tool simplicity can lead to more abstract comprehension, which may sometimes result in a misunderstanding. In that sense, being lean becomes less strenuous and not simple. On the other hand, in a Japanese environment, practitioners may opt for "simplicity," even if it requires more effort. A tangible example is performing manual tasks rather than using technology for repetitive activities, such as maps, physical counting of parts, and daily production planning. An understanding of the reasoning behind the decision to keep those methods helps interpret the manner in which practitioners respond to these needs. Nevertheless, adopting technology in the form of mapping software can benefit organizations with the elimination of monotonous tasks once these do not give any learning benefit, efforts can be redirected to tasks that actually add value.

2) Since lean is an operations-focused culture, it is interested in simple measures that are well-timed and support ongoing improvement properly. In an environment of continuous improvement, static standards are meaningless when continuously changing "standards" look for improvement. In such cases, the path becomes endless.

3) The aim and focus for tools may be process cost improvement rather than product cost improvement. Companies are applying lean principles, but are not modifying their cost management systems. Aligning under value streams is a must for becoming a lean welcoming organization. Eliminating functional departments and implementing value chains implies grouping products with similar flow or similar processing path. This way, we can align financial statements, production costs, and value chains.

4) Digging into lean accounting while studying these tools is particularly important because as we become more in tune with the use of tools, we may discover that the information we need to perform the analysis is supplied better by an organization whose accounting system complies with lean. Further, the incompatibility between traditional management systems and costing methods becomes evident.

Previous literature and practical work have strong tool-based beliefs. The cases attained a certain level of improvement, but did not seek to improve the system flow as a whole, or to achieve one-piece flow. Therefore, it is important to present research that helps understand how the organization's approach with VSM, MIFC, or SDD directly affects the level of success in the implementation of TPS, lean, or JIT systems. The tools of TPS, as stated by Shook (2010), are all designed around making it easy to see problems and to learn from mistakes. Learning from mistakes means that we should change our attitudes toward mistakes. That is the difference in the approach in tool-based beliefs which misleads organizations and becomes a burden in the long-term lean improvement journey.

This study agrees with existing work on model adaptation by Abo and Kumon (2004) , but contribute to the field at a deeper level, particularly in production management. They studied adaptation in their hybridization evaluation in the section on production management. They assessed the aspects of equipment, maintenance, quality control, and process management. However, they did not include mapping tools, their protocols, and the role they play in systems transference. Adaptation was assessed at the international level, and not between sites sharing the same national backgrounds. Therefore, their study sets a new path for adaptation studies.

This study has a few limitations which are related to the definition of the research method. Accordingly, this presents opportunities for future work. Cases from a single industry were assessed. The research questions have not been applied in the context of a Japanese supplier that is actively employing the VSM in its western or any other version. One useful direction for future research would be to study whether a different tool or no tool is in place, as well as to identify the metric(s) for tracking performance. Based on the analysis of more cases, future work should aim to develop the proposals further and test them, as well as to integrate the method (as described in chapter four) into mapping, thereby simplifying the practitioner's work. The ultimate goal will be to assist an organization in their lean journey, following the proposed ideal deployment blocks path, with the integration of mapping tools.

Annexes

Annex 1: Lane visual example

[Source] www.ipsmaterialhandling.com/pages/marketplace-racks , accessed on July 23rd, 2018

Annex 2: Store visual example

[Source] www.ipsmaterialhandling.com/pages/marketplace-racks , accessed on July 23rd, 2018

References

Abo, T., & Kumon, H. (2004). *The Hybrid Factory in Europe : The Japanese Management and Production System Transferred* (Palgrave M). New York: Elsevier.

Alan, G., & Dean, M. (1993). Training, continuous improvement, and human relations : The U. S. TWI program and the Japanese Management style. *California Management Review*, 35(2), 35.

Álvarez, R., Calvo, R., & Peña, M. M. (2009). Redesigning an assembly line through lean manufacturing tools. *International Journal of Advanced Manufacturing Technology*, 43, 949–958. https://doi.org/10.1007/s00170-008-1772-2

Aoki, K. (2008). Transferring Japanese *kaizen* activities to overseas plants in China. *International Journal of Operations & Production Management*, 28(6), 518–539. https://doi.org/10.1108/01443570810875340

Braglia, M., Carmignani, G., & Zammori, F. (2006). A new value stream mapping approach for complex production system. *International Journal of Production Research, Taylor & Francis: STM, Behavioural Science and Public Health Titles*, 44(18–19), 3929–3952.

Chavez, Z. (2012). *Redesign of a production system of the medical industry through mapping techniques*. Sonora University.

Chavez, Z., & Mokudai, T. (2016). Mapping tools selection towards lean transformation in manufacturing environments. In *Euroma 23rd Conference, Norway, 17–22 June, 2016* (pp. 1–10). Norway.

Chavez, Z., Mokudai, T., & Uyama, M. (2018). Divergence between Value Stream Mapping Western Understanding and Material and Information Flow Chart Principles : A Japanese Automotive Supplier ' s Perspective. *Journal of Service Science and Management*, 11, 219–241. https://doi.org/10.4236/jssm.2018.112016

Dinero, D. (2005). *Training within industry. The foundation of lean*. CRC. Taylor and Francis Group.

Doolen, T. L., & Hacker, M. E. (2005). A review of lean assessment in organizations: An exploratory study of lean practices by electronics manufacturers. *Journal of Manufacturing Systems*, 24(1), 55–67. https://doi.org/10.1016/S0278-6125(05)80007-X

Fontanini, P., & Picchi, F. a. (2004). Value stream macro mapping—a case study of aluminum windows for construction supply chain. In *Proceedings of the 12th Annual Conference of the International Group for Lean Construction (IGLC-12)* (pp. 576–587). Elsinore, Denmark. Retrieved from http://www.iglc2004.dk/_root/media/13104_110-fontanini-picchi-final.pdf

Giroud, A. (2015). Abo's "application-adaptation (hybrid) model": A commentary. *Asian Business and Management*, 14(1), 37–42. https://doi.org/10.1057/abm.2014.17

Goubergen, D. Van, Landeghem, H. Van, Aken, E. Van, & Letens, G. (2003). Using value stream mapping to redesign engineering project work. In *IIE Annual Conference. Proceedings.* (pp. 1–6). Retrieved from https://search.proquest.com/openview/eb7c875555c697de3413acf33372d560/1?pq-origsite=gscholar&cbl=51908

Gracanin, D., Buchmeister, B., & Lalic, B. (2014). Using cost-time profile for value stream optimization. *Procedia Engineering*, 69, 1225–1231. https://doi.org/10.1016/j.proeng.2014.03.113

Gunasekaran, A., & Kobu, B. (2007). Performance measures and metrics in logistics and supply chain management: A review of recent literature (1995–2004) for research and applications. *International Journal of Production Research*, 45(12), 2819–2840. https://doi.org/10.1080/00207540600806513

Hyde, K. F. (2000). Recognizing deductive processes in qualitative research. *Qualitative Market*

Research: An International Journal, 3(2), 82–90. https://doi.org/https://doi.org/10.1108/13522750010322089

Jones, D., Womack, J., & Brunt, D. (2011). *Seeing the whole value stream*. Lean Enterprise Institute, Inc. Retrieved from https://books.google.co.jp/books?hl=en&lr=&id=llLhQ93jKyYC&oi=fnd&pg=PR1&dq=womack+and+jones+mapping+the+extended+value+stream&ots=vc8EUQlXAt&sig=HKkaVvJBVMSf_9IgAxsNg-fPWSg#v=onepage&q=womack and jones mapping the extended value stream&f=false

Karim, A., & Zaman, K. (2013). A methodology for effective implementation of lean strategies and its performance evaluation in manufacturing organizations. *Business Process Management Journal*, 19(1), 169–196. https://doi.org/10.1108/14637151311294912

Karlsson, C., & Åhlström, P. (1996). Assessing changes towards lean production. *International Journal of Operations & Production Management*, 16(2), 24–41. https://doi.org/10.1108/01443579610109820

Khaswala, Z. N., & Irani, S. a. (2001). Value network mapping (VNM): Visualization and analysis of multiple flows in value stream maps. In *Proceedings of the Lean Management Solutions Conference, St. Louis, MO*. Retrieved from http://www.lean-manufacturing-japan.com/Value Network Mapping (VNM).pdf

Krafcik, J. . (1988). *A comparative analysis of performance indicators at world auto assembly plants*. MIT.

Kuhlang, P., Edtmayr, T., & Sihn, W. (2011). Methodical approach to increase productivity and reduce lead time in assembly and production-logistic processes. *CIRP Journal of Manufacturing Science and Technology*, 4(1), 24–32. https://doi.org/10.1016/j.cirpj.2011.02.001

Lancaster, G. (2005). *Research Methods in Management: a concise introduction to research in management and business consultancy* (Second). Oxford: Elsevier/Butterworth Heinemann.

Lau, H. Y. K., & Mak, K. L. (2004). The design of flexible manufacturing systems using an extended unified framework. *Journal of Manufacturing Technology Management*, 15(3), 222–238. https://doi.org/10.1108/17410380410523461

Liker, J. K., & Hoseus, M. (2010). Human Resource development in Toyota culture. *International Journal of Human Resources Development and Management*, 10(1), 34. https://doi.org/10.1504/IJHRDM.2010.029445

Marshall, D. A. (2015). Classifying Lean Production : A Review of Empirical Research. *International Journal Supply Chain Management*, 4(4), 71–81.

Martin, K., & Osterling, M. (2013). *Metrics-based process mapping: identifying and eliminating waste in office and service processes.* (2nd Editio). Florida, United States.: CRC Press, A Productivity Press Group.

Maskell, B. (2006). Lean Accounting: What is it all about? *TWG Finance Magazine*, 22(1), 35–43.

Maskell, B., & Baggaley, B. (2003). *Practical Lean Accounting: A Proven System for Measuring and Managing the Lean Enterprise.* Florida, United States.: Productivity Press.

Netland, T. H., & Ferdows, K. (2014). *What to expect from a corporate lean program. MIT Sloan Management Review*. Retrieved from https://ssrn.com/abstract=2726186

Netland, T., Schloetzer, J., & Ferdows, K. (2015). Implementing corporate lean programs: the effect of management control practices. *Journal of Operations Management*, 36, 90–102. https://doi.org/https://doi.org/10.1016/j.jom.2015.03.005

Patton, M. Q. (2002). *Qualitative research and evaluation methods*. Thousand Oaks, CA.: Sage Publications.

Perez, G. (2014). *An enterprise architecture framework of a lean enterprise transformation*. Oklahoma State University.

Rivera, L. (2006). *Inter-Enterprise Cost-Time Profiling*. Virginia Polytechnic Institute and State University.

Romero, L. F., & Arce, A. (2017). Applying value stream mapping in manufacturing: a systematic literature review. *IFAC-PapersOnLine*. https://doi.org/10.1016/j.ifacol.2017.08.385

Rother, M. (2004). *Toyota Kata: Managing People for Improvement, Adaptiveness and Superior Results* (1st ed.). United States of America: Mc Graw Hill.

Rother, M., & Aulinger, G. (2017). *Toyota kata culture. Building and organizational capability and mindset though kata coaching.* New York.: Mc Graw Hill Education.

Rother, M., & Shook, J. (1998). *Learning to see: value stream mapping to create value and eliminate muda*. *Lean Enterprise Institute Brookline*. Cambridge, MA.: Lean Enterprise Institute. https://doi.org/10.1109/6.490058

Rüttimann, B., & Stöckli, M. (2016). Going beyond triviality: the toyota production system—lean manufacturing beyond muda and kaizen. *Journal of Service Science and Management*, 9(April), 140–149. https://doi.org/10.4236/jssm.2016.92018

Serrano, I. (2007). *Análisis de la aplicabilidad de la técnica value stream mapping en el rediseño de sistemas productivos*. Universitat de Girona.

Serrano Lasa, I., Ochoa Laburu, C., & de Castro Vila, R. (2008). An evaluation of the value stream mapping tool. *Business Process Management Journal*, 14(1), 39–52. https://doi.org/10.1108/14637150810849391

Seth, D., & Gupta, V. (2005). Application of value stream mapping for lean operations and cycle time reduction: an Indian case study. *Production Planning and Control*, 16(1), 44–59. https://doi.org/10.1080/09537280512331325281

Shah, H. (2007). *A Role Delineation Study for the SME*. Eastern Michigan University.

Shah, R., & Ward, P. T. (2007). Defining and developing measures of lean production. *Journal of Operations Management*, 25(4), 785–805. https://doi.org/10.1016/j.jom.2007.01.019

Shingo, I. (2016). *The Shingo Model for Operational Excellence*. (T. S. Institute, Ed.), *The Shingo Institute*. Retrieved from http://lean.nh.gov/documents/Shingo Model Handbook.pdf

Shook, J. (2010). How to Change a Culture : Lessons From NUMMI. *MIT Sloan Management Review*, 51(2), 63–68.

Soltero, C., & Boutier, P. (2012). *The 7 Kata: Toyota Kata, TWI, and Lean Training*. Florida, United States: CRC. Taylor and Francis Group.

Sousa, R., & Voss, C. A. (2002). Quality management re-visited: A reflective review and agenda for future research. *Journal of Operations Management*, 20(1), 91–109. https://doi.org/10.1016/S0272-6963(01)00088-2

Srinivasaraghavan, J., & Allada, V. (2006). Application of mahalanobis distance as a lean assessment metric. *The International Journal of Advanced Manufacturing Technology*, 29, 1159–1168. https://doi.org/10.1007/s00170-005-0004-2

Toivonen, T. (2015). Value stream analysis for complex processes and systems. *Procedia Engineering*, 131, 963–974. https://doi.org/10.1016/j.proeng.2015.12.408

Tolich, M., Kennedy, M., & Biggart, N. (1999). Managing the Managers: Japanese Management Strategies in the USA. *Journal of Management Studies*, 36(5), 587–607. https://doi.org/10.1111/1467-6486.00150

Toma, S.-G., & Naruo, S. (2017). Total Quality Management and Business Excellence : the Best Practices At Toyota Motor Corporation. *Amfiteatru Economic*, 19(45), 566–580.

Warren, M. (2010). *The Training Within Industry Report*. (M. Warren, Ed.).

Williams, R., Bertsch, B., Van Der Wiele, A., Van Iwaarden, J., & Dale, B. (2006). Self-assessment against business excellence models: A critique and perspective. *Total Quality Management and Business Excellence*, 17(10), 1287–1300. https://doi.org/10.1080/14783360600753737

Womack, J. ., Jones, D. T., & Ross, D. (1990). *The machine that changed the world*. New York: Rawson Associates. https://doi.org/https://doi.org/10.1002/hfm.4530040310

Yin, R. (2013). *Case Study Research: Design and Methods.* (5th ed.). London, United Kingdom.: Sage publications.

Zainal, Z. (2007). Case study as a research method. *Jurnal Kemanusiaan*, 9, 1–6. https://doi.org/10.1177/15222302004003007