AN ENTERPRISE ARCHITECTURE FRAMEWORK OF A LEAN ENTERPRISE TRANSFORMATION

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DEDICATION

To my wife and son

To my mother and loving memory of my father

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Abstract:

Today's business environment is characterized by fast changes, uncertainty, variability, and unpredictability. To be more competitive, firms have to improve their operations performance. To achieve this, one path is to develop a strategy based on the Lean philosophy across the entire organization. However, to transform a company into a Lean Enterprise is not simple. After examining the literature, it was determined that there is no comprehensive Lean framework that provides a complete integration of the Lean elements into a coherent whole or a detailed step-by-step methodology for Lean manufacturing implementation.

This dissertation presents an Enterprise Architecture Framework for a Lean enterprise transformation to guide a company towards operational excellence. This framework integrates holistically the main components crucial to transforming a traditional enterprise into a Lean Enterprise. It can be useful in supporting the whole organization in its Lean journey to transform the company into a more productive system.

For this research, several Lean frameworks, the most well known national quality award models for operational excellence, and the main architecture frameworks for enterprise integration were identified and analyzed. Concepts derived from this analysis contributed to the design and understanding of the enterprise architecture framework. The framework has been designed to guide a company through a Lean enterprise transformation using an analytical, logical, and systematic approach. This approach considers the main tools and principles of Industrial Engineering as well as Lean Manufacturing and Business Improvement Programs. It contains layers that represent the enterprise views. Each layer is divided into groups and each group is broken down into components of the same category. Both layer components and phases have been integrated into a coherent whole, which forms the Lean enterprise transition roadmap. Phases one to four of the framework have been tested in a German engine parts company in the automotive sector.

The methodology used for this dissertation was developmental research, using a qualitative research design approach that encompasses inductive logic to develop the framework and deductive logic to test it. The enterprise architecture framework was designed using an analytical, logical, and systematic approach, based on a three-dimensional thinking scheme.

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CHAPTER 1: INTRODUCTION

1.1 Introduction

Given the globalization of markets, short-run contractions in demand, advancements in technology, fierce global competition, environmental concerns, and other factors, firms are finding it more difficult to remain competitive. Companies around the world are competing, both locally and globally, to attract new customers or get more business. To survive or grow, they must offer products and services to their clients at the lowest price possible, with high quality and reliability. Additionally, they have to reduce the lead-time of the product design and manufacturing or service processes and deliver their products to the right place, in the right quantity and at the right time. Furthermore, enterprises have to work in an integrated way, efficiently and effectively, in all departments and not only in the manufacturing area.

In response to the challenges of the growing global competition, many US companies have been looking for new designs and redesigns of their manufacturing systems to be more competitive (Modarress, Ansari, & Lockwood, 2005). They have attempted to embrace innovative practices to continually improve work productivity (Paez et al., 2004). To satisfy the customer's requirements of lower cost products, many companies have been implementing process improvement programs. Successful companies have to shift from conventional manufacturing to lean, flexible, and agile manufacturing systems to increase their productivity, enhance quality, and reduce costs.

Over the last three decades, companies have attempted to improve their business performance using different organizational improvement approaches. There have been several Business Improvement Programs (BIP), including Lean Manufacturing (LM), Lean Six Sigma (LSS), Kaizen, Just-in-Time (JIT), Business Process Re-engineering (BPR), Total Quality Management (TQM), Total Productive Maintenance (TPM), Agile Manufacturing, Quick Response Manufacturing (QRM), and Business Process Management (BPM), among other initiatives. Additionally, companies have used other improvement approaches that enable technology, including Enterprise Resource Planning (ERP), Supply Chain Management (SCM), Customer Relationship Management (CRM), and Supplier Relationship Management (SRM). However, even though organizations know about most of these organizational improvement tools, many factors inhibit the sustainment of performance improvement.

1.2 Background of the Study

Today's business environment is characterized by fast changes, uncertainty, variability, and unpredictability. To be more competitive, firms must improve their operations performance. To achieve this goal one path is to develop a strategy based on the Lean philosophy across the entire organization. It has been shown that company-wide changes in this area create potential improvement in the key performance indicators of the company.

Lean manufacturing, also known as Lean Production, is a term used to refer to the Toyota Production System, which pursues streamlining throughout the entire system via the elimination of waste and aims at fostering quality across the manufacturing process while recognizing the principle of cost reduction (Ohno, 1988). For the last few years most manufacturing companies have attempted to implement Lean manufacturing (Seth & Gupta, 2005). Through it they realize

benefits like reducing the lead time and inventories and having fewer defects and less rework through more robust processes, less process waste, less human effort, financial savings, less manufacturing space, lower investment in tools, and increased production (Melton, 2005; Womack, Jones, & Roos, 1990). Lean thinking can be implemented in any type of activity, and for either a good or service (Womack & Jones, 2003). It can be applied from agriculture to aerospace and from customization to mass production. Some examples are the TRW Automotive Electronics Group, John Deere, and Lockheed Martin Missile and Space Corporation (Motwani, 2003).

Several manufacturing companies from the USA and Europe started to implement the lean concepts in the 1990's, following China, which began in the late 1970's. However, many of these firms have had problems in becoming a Lean Enterprise and sustaining the improvements (Taj, 2008). According to Fujio Cho, the former chairman of Toyota Motor Company who learned the Toyota Way from Taiichi Ohno, "The key to the Toyota Way and what makes Toyota stand out is not any of the individual elements, but what is important is having all the elements together as a system. It must be practiced every day in a very consistent manner - not in spurts" (Liker, 2004).

1.3 Motivation of the Research Study

Successful Lean Manufacturing implementation is feasible and has been shown to be an appropriate mean to improve productivity, enhance quality, reduce costs and increase workers morale, among other benefits. Several companies have adopted Lean tools and principles as their strategy to improve operational performance and those companies are getting good results (Taj & Morosan, 2011). Although many companies are interested in Lean and implementing Lean tools,

the share of successful companies is relatively low (Bhasin & Burcher, 2006). Approximately 70% of US manufacturing companies are implementing Lean Manufacturing. Of those manufacturers, only 2% have fully accomplished their Lean implementation, 24% have achieved significant results, and 74% are not getting good results (Pay, 2008). According to Bhasin and Burcher (2006), 10% or less of companies succeed at implementing Total Productive Maintenance and other Lean Manufacturing practices. They state that less than 10% of UK organizations have accomplished successful Lean implementation. Far fewer than 1% of companies outside of Toyota get an A or B^{+} on how Lean they become after the implementation (Liker, 2004). According to Sohal and Egglestone (1994), only half of those Australian companies that are implementing Lean are really on the Lean path and of those firms, only 10% have the philosophy properly instituted. As we can infer from these research studies, just a small percentage of enterprises achieve successful Lean implementation. Additionally, a high proportion of the firms that implement Lean tools and principles have difficulty in achieving the expected results and have problems sustaining the Lean Philosophy.

Numerous employees go to work giving their best and attempting to make a contribution to their company. They work hard and try to have a good attitude. Nonetheless, their best efforts and good intentions are not enough and they finish their workday exhausted and frustrated. Frequently they are "putting out fires" because products, people, machines, equipment, information, or other inputs are not available. Even if these items are available, they are not accessible at the right time, the right place or in the right amount. Things get out of control and this may reduce the morale of the employees, decrease the quality of products and service, increase costs, cause late deliveries, and basically create chaos. Organizations may develop a "blame culture" when mistakes occur (Kaye & Anderson, 1999). This scenario can occur on a

daily basis, but it does not have to be that way. In many cases, managers and employees try to change this type of situation, but sometimes they do not know how to do it. Even though they may know the right tools and approaches to improve the performance, the organization may not be aligned to the same vision. In these situations, organizations achieve success in the implementation but they do not sustain changes gained in the improvement programs.

Toyota has been transferring the Toyota Production System (TPS) to all its plants around the world. Additionally, it has been developing its local suppliers through the Toyota Supplier Support Center, which plays a crucial role in aligning suppliers towards the Lean philosophy. Managers played a crucial role in disseminating the TPS within the organization. Key managers and workers are swapped between the plants and Toyota corporate staff to consistently establish the TPS.

Not all companies have the resources to do what was mentioned above. Having an Enterprise Architecture Framework to support a Lean enterprise transformation can be very useful and valuable as a reference guide to those organizations that wish to initiate the long and worthwhile Lean journey to achieve operational excellence as a strategic resource.

1.4 Problem Statement

To transform a company into a Lean Enterprise is not an easy task. The Lean philosophy is easy to understand but difficult to implement and to sustain. Changing the organizational culture to embrace Lean is also challenging. It takes a lot of time and effort to achieve a complete Lean enterprise transformation, to accomplish the expected performance results, and to sustain the Lean changes. Even Toyota took several decades to implement TPS or Lean concepts in its organization (Liker, 2004). Lean thinking has been challenging since its initiation,

including for Mr. Ohno, who had a hard time implementing it. This is also true for the Toyota transplants, for its suppliers, and for other firms (Liker, 1997). This challenge is due to the huge number of variables involved in transitioning into a Lean enterprise, and to the interaction among the variables, which makes it very difficult to accomplish a Lean transformation.

Several issues make the proper implementation of a Lean enterprise transformation a difficult task. Among the main concerns are the following:

- Complexity of the enterprise system
- The organizational silos
- The different subcultures of the organization
- The poor understanding of a Lean enterprise transformation
- The shortage of a Lean management infrastructure
- The lack of knowledge of all the Lean components working as a system
- An improper Lean strategy
- The absence of appropriate direction for incorporating multiple kaizen (continuous improvement) events over time (Aken, Farris, Glover, & Letens, 2010)
- The nonexistence of Lean leadership
- The lack of the enterprise integration

Moreover, in numerous cases, even if people have the desire to do their jobs better, they cannot do it because people from different departments have different objectives and go in different directions. The fragmentation of the system impedes improving its performance. The fundamental issue about a Lean enterprise system is not a problem with any of the individual components but of having all components together working as a system (Liker, 2004).

Most of the time, industrial engineering (IE) efforts of and business improvement programs (BIP) have made significant contributions to the efficiency of the business. However, they work independently instead of working with Lean efforts to achieve the same goal. Also, enterprise architecture frameworks do not focus on a Lean enterprise transformation, and some Lean models do not integrate other BIP or IE tools.

Organizations often lack the understanding of what Lean transformation is accomplishing across the entire firm. Most applications of Lean focus on the shop floor (kaizen events) instead of centering on the entire enterprise (Murman, 2002). There are vast numbers of tools, concepts, methodologies, programs, and approaches to implement Lean; managers must make complicated decisions about what to approaches to consider and the implementation requirements. Many complex variables interact within an organization to achieve quality and continuous improvement. Given the lack of specific processes, firms do not know where to start or what to do to change their cultures (Rich & Bateman, 2003). Additionally, there is no roadmap for accomplishing a kaizen culture, and a high share of organizations fail to find the proper way to implement it (Roper, 2005). Researchers worldwide have proposed several frameworks to help managers and employees in an organization achieve a better understanding of Lean Manufacturing (Anand & Kodali, 2010). However, after reviewing literature related to thirty different Lean frameworks, Anand and Kodali state that no comprehensive Lean framework provides a complete integration of the Lean elements into a coherent whole nor is there a detailed step-by-step methodology for Lean manufacturing implementation. Moreover, according to Kaye and Anderson (1999), a planned and integrated approach is necessary to accomplish such a process.

Up to 94% of the problems or errors that occur in manufacturing are because of the system. The remaining 6% are just special causes (Deming, 1986). Companies need to build an architecture for their transformation or their complete redesign (Mathaisel, 2005). The business sector as well as the academic sector recognizes the need for practical models that can aid in the design or redesign of manufacturing systems (Serrano, Ochoa, & Castro, 2008). Thus, there is a need for a practical enterprise architecture framework to support a Lean enterprise transformation designed with a holistic and integrated vision.

1.5 Purpose Statement

The purpose of this research was to design an Enterprise Architecture Framework of a Lean enterprise transformation to guide a company towards operational excellence. This framework will integrate in a holistic way the main components that are crucial to transforming a traditional enterprise into a Lean Enterprise. It can be useful to support the whole organization in its Lean journey to transform the company into a more productive system.

1.6 Research Goal and Specific Objectives

The chief goal of this research was to design an Enterprise Architecture Framework using the tools and principles of IE, Lean manufacturing, and BIP to guide an organization in how to transform a current enterprise into a Lean enterprise towards operational excellence. To accomplish this goal, several specific objectives were established:

1. Identify existing architecture frameworks or models used for a Lean enterprise transformation.
2. Explore and analyze the main enterprise architecture frameworks.

3. Identify the main components, their interrelationships, and interactions of a Lean enterprise transformation.
4. Determine what tools and principles of IE, besides Lean and other BIP, can be used towards operational excellence.
5. Considering the previous points, design a holistic and integrated enterprise architecture framework of a Lean transformation across the entire organization using an analytical, logical, and systematic approach.

1.7 Research Question

How can a holistic and integrated Enterprise Architecture Framework be designed to guide a company towards Lean enterprise transformation using an analytical, logical and systematic approach that considers the main tools and principles of Industrial Engineering, Lean Manufacturing, and Business Improvement Programs?

1.8 Significance of the Study

At the firm level, this study will be useful for firms to understand the definition of a Lean enterprise transformation, analyze the existing situation, define the Lean strategy, plan how to do the Lean transformation, implement the Lean concepts properly, sustain Lean initiatives, and design the Lean management infrastructure. Additionally, the Lean enterprise transformation framework can be useful for managers and employees from different departments to visualize their organization in a holistic way. Most important, the Lean enterprise transformation framework can help the entire organization integrate and align all its resources to achieve the vision of the company. This framework will also help support business managers, Lean change

agents, and stakeholders at different hierarchical levels of the organization in their transformation towards a Lean Enterprise. Organization-wide changes will create a great potential for productivity increases, lead to quality enhancement and cost minimization, and at the same time improve competitiveness.

Lean Enterprises, controlling for other external factors, should have a better chance to survive and excel in this tremendously competitive world. Being more profitable, such companies generate jobs and tax revenues. Customers get better quality products at competitive prices from those companies. Moreover, countries benefit from the growth of these companies, which sustains and improves the quality of life of their citizens.

1.8.1 Intellectual Contribution

One can find in the literature a large number of frameworks, models, tools and approaches to achieving operational excellence and continuous improvement. Many journal papers and books focus on the Lean Manufacturing philosophy and tools as well as Business Improvement Programs. However, most enterprise architecture frameworks focus on information technology alone. Furthermore, several frameworks show Lean concepts but are very general. Only a few focus on an architecture framework of a Lean enterprise transformation with a holistic and integrated approach.

The proposed enterprise architecture framework is unique in that it is the design of a generic framework that holistically integrates the main components that are crucial to transform a traditional firm into a Lean Enterprise. It is being designed using concepts and tools of IE, as well as Lean manufacturing tools and principles and other BIP with an integrated approach. Also, it focuses on process flows and customer needs involving all stakeholders and

contemplating systems thinking. Additionally, instead of using two-dimensional thinking, the framework focuses on three-dimensional thinking to visualize and carry out a Lean enterprise transformation. Furthermore, the framework encompasses a holistic view instead of the functional silos of the organization. It provides the big picture and the roadmap that can take a company from its current situation to its own future vision by showing what components to consider and how to integrate them. Finally, this framework can be useful in tracking the maturity level of the Lean enterprise transformation and linking it to the company's strategic key performance indicators.

1.8.2 Applicability

The architecture framework being developed is intended to be applied in manufacturing companies, so any productivity increase they may undergo will have a positive impact both for the firm itself and for society in general by increasing productivity in the long term. The architecture framework can also be adapted for use in service organizations, but that topic is outside the scope of this research.

1.8.3 Testing the Framework

Phases one to four of the framework have been tested in one production line of one product of a German engine parts company in the automotive sector. All the stakeholders have been involved and the main resources have been integrated to align them to the vision of the company. This production line will serve as a reference model in expanding the Lean transformation to other processes within the firm. Completing the transformation across the company will take many years, so it is not feasible to validate the transformation of the entire

enterprise during this dissertation research. However, this pilot test is an on-going implementation and will be useful for future research.

1.8.4 Reproducibility

It is feasible to reproduce the Lean enterprise transformation framework in other types of manufacturing companies and also in different sectors. However, the framework has to be adapted to the specific characteristics of the company and to the particular type of sector. It will be important to use only the specific and appropriate tools of the framework to meet the needs of each particular organization. Every enterprise has a different organizational culture, resources, materials, systems, and facilities and different types of production (high volume - low variety, low volume - high variety, high volume - high variety, make-to-order). This variety is one of the reasons why some of the firms that attempt to copy the Toyota Way do not achieve the expected results at their own companies. Chapter 4 explains what issues have to be considered to choose the right tools and concepts according to specific circumstances.

1.8.5 Generalization

The application of this framework in one company is not enough to generalize it. However, the framework can be useful in guiding manufacturing companies to do a Lean enterprise transformation in their organizations. Nevertheless, several components and specifically the Lean Strategy will be different according the size of the company, the sector, and the type of production.

1.9 Delimitations

The components of the framework were determined after a broad review of references in several disciplines focusing on those tools and principles that could be holistically integrated for it to work logically, according to the process flow, and towards operational excellence. The Enterprise Architecture Framework of the Lean enterprise transformation was tested only on one product of a company using one of its production lines as a model. This narrow application focus is due to time limitations, as described below. The following elements are considered:

1. Concepts from: Industrial Engineering, Enterprise Architecture Frameworks, Lean Manufacturing, Lean Enterprise, Enterprise Transformation, Total Productive Maintenance, Lean Six Sigma, Total Quality Management, Enterprise Modeling and Simulation, Systems Thinking, Organizational Learning, Organizational Structures, Leadership, Strategy, and Key Performance Indicators.
2. Testing the model: An engine parts manufacturing company in the automotive sector is being used to test the framework.
3. Time of the study testing: July 2012 through August 2013.
4. Location of the testing study: auto-parts manufacturing company located in Germany.

1.10 Limitations

This research has several limitations. First, the fact that only one researcher is involved in this study implies limited time, so it covers only one example, and only one process of a product is tested. The second limitation is that the impact of the Lean enterprise transformation on the key performance indicators is based on a single case study. However, the broad-based validity of the framework based on multiple case studies is needed to analyze the impact and behavior in

different industry sectors, in diverse regions, with other types of products and processes, in diverse organizational cultures, and in other sizes of companies. Finally, the German language has been a constraint for training the workers. However, a training-of-trainers approach has been used to coach the teams.

1.11 Assumptions

1. The principles, tools, concepts and methodologies of Industrial Engineering, in addition to Lean and the other Business Improvement Programs can be integrated in a holistic framework to support a Lean enterprise transformation.
2. The comprehensive literature review on the main concepts mentioned above related to this study is trustful and adequate for building the Enterprise Architecture Framework.
3. The concepts of the reference architectures for enterprise integration used in this research are suitable for designing the framework.
4. This framework is useful for engineering the Lean enterprise transformation.

CHAPTER 2: LITERATURE REVIEW

The objective of this dissertation is to develop an enterprise architecture framework for a Lean enterprise transformation. Doing so involves identifying and describing two main concepts: an *enterprise architecture framework* and a *Lean enterprise transformation*. Therefore, in this chapter, a section is dedicated to each of these topics. In each section, concepts are disaggregated into working definitions and the most relevant relationships among them are established. This information is based on a thorough literature review that helped choose the most adequate definitions and the soundest model structures that can contribute to the framework developed in Chapter 4.

2.1 Basic Definitions Related to Enterprise Architecture Frameworks

This section describes some of the main concepts needed to understand the definition of an Enterprise Architecture Framework. Definitions found in the literature will help develop a working definition of an Enterprise Architecture Framework relevant to this study.

2.1.1 Enterprise

According to ISO 15704, "An enterprise is one or more organizations sharing a definite mission, goals and objectives to offer an output such as a product or a service" (Chen, Doumeingts, & Vernadat, 2008).

2.1.2 Architecture

The term *architecture* has various meanings depending on the setting in which it is being used. It may refer to "a formal description of a system at component level to guide its implementation; it may describe the structure of components, their inter-relationships and the principles and guidelines governing their design and evolution over time; or it can denote the organizational structure of a system or component" (Chen et al., 2008). The term *architecture* states the "fundamental organization of a system embodied in its components, their relationships to each other and to the environment, and the principles guiding its design and evolution" (ISO/IEC15288, 2008). Finally, according to ISO 15704, *architecture* is a "description of the basic arrangement and connectivity of parts of a system (either a physical or a conceptual object or entity)"(Chen et al., 2008). Thus, in brief, *architecture* can be defined as a "structure with a vision that provides an integrated view of the system being designed or studied" (Jonkers et al., 2006).

The term *architecture* can also be applied in different areas. There are software architectures, hardware architectures, network architectures, system architectures, and enterprise architectures. Definitions vary depending on who is defining the term (Armour, Kaisler, & Liu, 1999) and the field where the concept is being used.

2.1.3 Enterprise Architecture

Enterprise architecture refers to architecture at the level of an entire company, firm, or organization. It is "a coherent set of principles, methods and models that are used in the design and realization of the enterprise's organizational structure, business processes, information systems, and infrastructure. It provides a holistic view of the enterprise." (Jonkers et al., 2006).

Generally speaking, “Enterprise architecture should be organized in a way that supports reasoning about the structure, properties and behavior of the system. It defines the components that make up the overall system and provides a blueprint from which the system can be developed” (Chen et al., 2008).

Enterprise architecture “promotes the belief that an enterprise, as a complex system, can be designed or improved in an orderly fashion, achieving better overall results than ad-hoc organization and design” (Bernus, 2003).

Enterprise architecture can work as a skeleton to help shape the vision of a future system by putting in place its essential features. This allows for an easier identification of strengths and weakness of the system and therefore may help improve it (Chen et al., 2008). Enterprise Architecture provides a “knowledge base and support for decision making within the enterprise and it serves as the blueprint of the current situation and a strategy for future directions of the enterprise” (Armour et al., 1999).

According to the IFAC–IFIP Task Force and ISO 15704, there are various types of enterprise architectures: Type 1 architectures represent the structure and behavior of system or sub-system. Type 2 architectures are frameworks used to structure concepts and activities/tasks that are necessary to design and build a system. Another way to categorize frameworks is into technical and conceptual architectures. The former is based on business needs, while the latter provides the components that allow the firm to achieve its business strategies and functions (Chen et al., 2008).

2.1.4 Generic Enterprise Architecture

According to Rood (1994), "An enterprise is viewed as a complex system with a defined boundary and an assemblage of differentiated but interdependent components." These components include people, organizational structure, corporate culture, strategy, technology, information, processes, and tasks. A generic enterprise architecture contains enterprise-specific descriptions of each of these generic components. The firm as a whole is bounded by an external environment, where it acquires different types of inputs and provides outputs. The components of the enterprise transform the inputs into outputs in the form of products or services and then send them back to the external environment. The elements that do not directly produce the product or service, such as finance, are considered common supporting resources. Figure 1 shows a generic enterprise architecture.

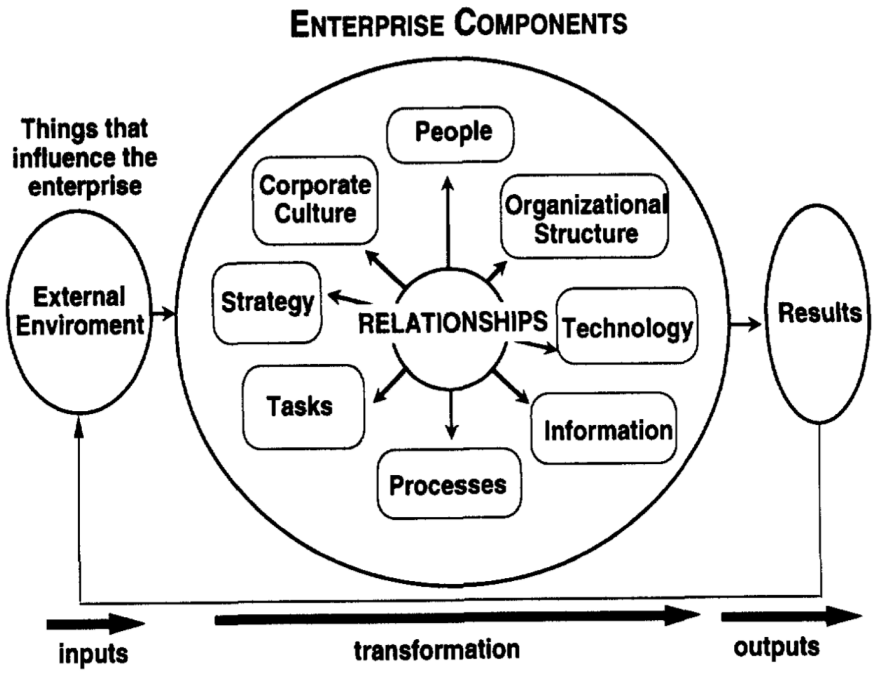


Figure 1. Generic Enterprise Architecture (Rood, 1994, p. 107)

2.1.5 Architecture Framework

An architecture framework is the **"**conventions, principles and practices for the description of architectures established within a specific domain of application and/or community of stakeholders, i.e. the Generalized Enterprise Reference Architecture and Methodologies (GERAM) is an architecture framework" (ISO 15704).

2.1.6 Enterprise Architecture Framework

An *enterprise architecture framework* describes the central elements of an enterprise architecture and the relationships between them. "It defines suggested architecture artifacts and generic definitions for developing architectures and a logical structure for classifying and organizing the enterprise system. This is then used to develop the IT architecture and a logical structure for classifying and organizing complex information" (Lim, Lee, & Park, 2009). These authors classify frameworks depending on the use they may have in descriptive, prescriptive, and combined frameworks. The descriptive framework specifies the elements within the framework using cells and then describes each cell. Prescriptive frameworks describe the activity of the enterprise architecture lifecycle, which includes the definition, development, use, and maintenance activities. The combined framework has the characteristics of both descriptive and prescriptive frameworks (Lim et al., 2009).

These frameworks are still under development, but overall they offer guidance on which areas of business and technology should be considered when creating an enterprise architecture. However, they offer little aid in creating the architectural artifacts themselves (Jonkers et al., 2006).

2.1.7 Enterprise Integration

Enterprise integration is "the process of ensuring the interaction between enterprise entities necessary to achieve domain objectives and can involve physical integration (interconnection of devices, machines, via computer networks), application integration (integration of software applications and database systems), and business integration (co-ordination of functions that manage, control and monitor business processes). Some other approaches take into account integration through enterprise modeling (for example through the use of a consistent modeling framework) and integration as a methodological approach to achieve consistent enterprise-wide decision-making" (Chen et al., 2008).

2.2 Lean Enterprise Transformation

This section describes some of the definitions and concepts of lean and enterprise transformation processes that are relevant to this study. It describes the origin of Lean, its applications, and the different frameworks that have used this term with the goal of achieving a Lean enterprise transformation.

2.2.1 The Origins of Lean

The founder of the Toyota Production System (TPS) was the former Vice-President of Toyota Motor Company, Mr. Taiichi Ohno (Ohno, 1988; Sugimori, Kusunoki, Cho, & Uchikawa, 1977; Womack et al., 1990). He started to apply the first concepts of the TPS in 1947 by developing multi-skilled operators and arranging machines in parallel lines or in L-shape (Ohno, 1988). In 1948, he began to develop his concept of small-lot production at the Toyota engine machining shop, which he later applied throughout the company (Sugimori et al., 1977).

Parts were produced in small lots in order to make this system work. Subsequently, in 1955, the Toyota Motor Company hired Dr. Shigeo Shingo as an external consultant who developed the single-minute exchange of dies (SMED), helping to produce low volumes and high variety (Holweg, 2007). Toyota continued during several decades developing the techniques of the TPS in order to eliminate all types of waste throughout the entire system. In 1965 the TPS was rolled out to Japanese suppliers and two decades later Toyota started its first transplant into the American culture.

The implementation of the TPS was introduced in Chinese companies earlier than in American and European manufacturers. In 1977, the First Automotive Works (FAW) firm was the first company that applied the philosophy of the TPS under the guidance of Taiichi Ohno, who had been born in China. Another example of implementing TPS is the Shanghai Automotive Industry Corporation (Chen, Lee, & Fujimoto, 1997). Other Chinese companies, from non-automotive industries, have also implemented the TPS (Taj, 2008).

The New United Motor Company, Inc. (NUMMI) was one of the first transplants of a Japanese auto manufacturer into the American culture. In 1984 Toyota established a 50:50 joint venture with General Motors creating NUMMI, which is located in Freemont, California (Austenfeld, 2006). A few years later, in 1988, Toyota's Georgetown, Kentucky plant started production (Holweg, 2007). Application of the Lean production by other American and by European manufacturers started in the 1990s.

Instead of using the term of Toyota Production Systems, the concept used was "Lean Production," first crafted in 1988 by the researcher John Krafcik in the International Motor Vehicle Program at the Massachusetts Institute of Technology (Bozdogan, 2010). The term "Lean production" started to be influential with the book *The Machine that Changed the World*

(Womack et al., 1990). However, this was not the first time that the term "Lean" had been used. The first academic paper on TPS, "Toyota Production System and Kanban System: Materialization of Just-in-Time and Respect-for-Human System," was published in 1977 (Holweg, 2007; Sugimori et al., 1977). Since then, a vast amount of research has focused on giving a precise definition to "Lean," and identifying what is needed for it to yield the expected effects on industry.

In 1978, Ohno published "*The Toyota Production System*" in Japanese. In addition, Yasuhiro Monden published a series of articles on TPS in Industrial Engineering and Shingo published "A study of the Toyota Production System" in 1981. Other important references to the TPS or "Lean" appeared in the 1980's. Even though the TPS started in 1947 in Japan, it was not formally documented in English until 1977. Despite the fact that there was academic interest in Japanese techniques in the 1980's, western manufacturing companies showed little interest in that period (Holweg, 2007).

It can be inferred from the previous paragraphs that the historical evolution and the different perspectives are relevant to understanding the Lean definition and concepts. Several phases have contributed to our current understanding of Lean production, as shown in Table 1 (Shah & Ward, 2007).

Even though the terms TPS and lean production appear in 1977 and 1990 respectively, there are many definitions of the same concept. It is important to clearly understand Lean manufacturing and other significant terms, as explored in the next sections.

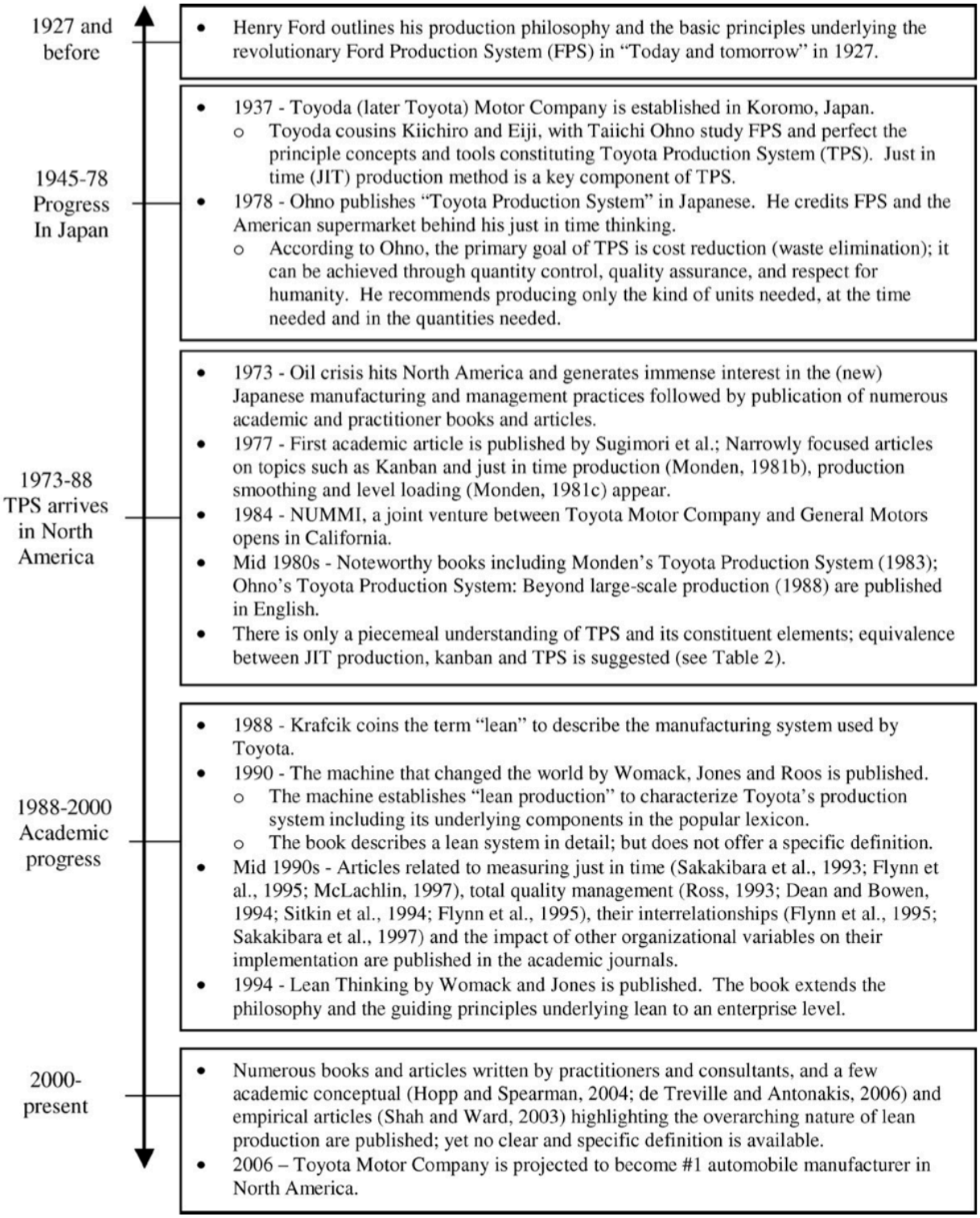


Table 1. Time line marking the critical phases in the Lean production evolution (Shah & Ward, 2007, p. 787)

2.2.2 Lean Manufacturing Definition

Since Womack et al.'s Lean production definition (1990), many other definitions have been published. Some authors refer to it as a systematic approach, others as a philosophy, or as a multi-dimensional approach, and yet others as a socio-technical system. Some of these definitions are listed below according the year of publication:

- ***Definition 1.*** Lean production, known also as the Toyota Production System or Lean Manufacturing, is the manufacturing system developed by Toyota which pursues streamlining the entire system through the elimination of waste, and aims to build quality at the manufacturing process while recognizing the principle of respect for humanity and cost reduction (Ohno, 1988).
- ***Definition 2.*** Lean production is doing more with less of everything compared with mass production -less human effort, less manufacturing space, less time, less inventory, less machinery, fewer defects- and producing a greater variety of products (Womack et al., 1990)
- ***Definition 3.*** Lean Manufacturing is "a philosophy that when implemented reduces the time from customer order to delivery by eliminating sources of waste in the production flow." Lean manufacturing is very challenging because it is not a set of isolated tools but a complete business system that needs to integrate many people and independent organizations to produce products (Liker, 1997, p. 481).
- ***Definition 4.*** "Lean production is a multi-dimensional approach that encompasses a wide variety of management practices, including just-in-time, quality systems, work teams, cellular manufacturing, supplier management, etc. in an integrated system" (Shah & Ward, 2003).

- ***Definition 5***. Lean production is a sociotechnical system based on the interactions of human and technological elements (Paez et al., 2004).
- ***Definition 6***. Lean production is "a multi-dimensional approach that consists of production with minimum amount of waste (JIT), continuous and uninterrupted production flow (Cellular Layout), well-maintained equipment (TPM), well-established quality system (TQM), and well-trained and empowered work force (HRM) that has positive impact on operations/competitive performance (quality, cost, fast response, and flexibility)" (Taj & Morosan, 2011).

The core objective of Lean Manufacturing is to increase production efficiency by the elimination of waste throughout the entire system. Seven basic types of waste can be identified in the process: overproduction, waiting, transportation, over-processing, inventory, movement, and defective products. To eliminate these wastes several lean principles and tools were developed, based on two pillars that support the system, namely Just-In-Time and Jidoka (Ohno, 1988).

2.2.3 Basic Practices that Underlie "Lean Production"

As mentioned earlier, the first research paper on the TPS appeared in 1977. After 1990, the number of research and journal papers on the topic increased considerably. Today, there are thousands of journal papers related to Lean production and the application of Lean in different areas and sectors. A search using "Lean production" in Google Scholar, yielded 1,030,000 entries; for "Lean manufacturing," 278,000; for "Lean enterprise," 202,000; for "Lean thinking," 397,000; for "Lean product development," 527,000; for "Lean logistics," 54,700; and for "Toyota Production System," 117,000 results. The following section identifies, describes, and

categorizes some of the work that has been done in terms of a fundamental/academic basis for defining and understanding the concept and practice of Lean production.

Lean principles and practices have evolved over many years of adaptation, experimentation, and continuous learning. Four decades of academic literature can be described in five phases as follows: Discovery phase (1977-1990), Dissemination phase (1991-1996), Implementation phase (1997-2000), Enterprise phase (2001-2005), and Performance phase (2006-2009) (Stone, 2012).

Another categorization can be in terms of the basic Lean enterprise system, including the developments between 1947 and the mid-1990s, and the contemporary Lean enterprise, comprising the major conceptual and implementation-related extensions of the basic system since the mid-1990s, as shown in Table 2 (Bozdogan, 2010).

Lean System / Key Characteristics	Basic Lean Enterprise System (BLES)	Contemporary Lean Enterprise System (CLES)
History	Since late 1940s; documented mostly in late-1970s to mid-1990s period	Since the mid-1990s
Goal	• Deliver value to customers • Increase production efficiency and profitability	• Create and deliver value to multiple enterprise stakeholders • Build dynamic network-wide capabilities for sustained competitive advantage
Core Principles	• Ensure long-term thinking, stability and constancy of purpose • Focus on the customer to deliver customer-pulled value • Take an end-to-end value stream view of the enterprise • Eliminate waste • Create just-in-time (JIT) production system • Strive for perfect quality • Achieve stability and continuous flow • Pursue continuous improvement • Enhance the capabilities of all people • Establish long-term relationships based on mutual trust and commitment	• Adopt a holistic view of the end-to-end networked enterprise • Cultivate leadership stressing long-term thinking, stability and constancy of purpose • Construct robust value propositions and define value exchanges among stakeholders • Eliminate waste with the goal of delivering customer-pulled value to multiple enterprise stakeholders • Ensure synchronized flow throughout the networked enterprise • Foster a culture of continuous improvement and learning towards the creation of long-term dynamic network-wide capabilities • Develop collaborative relationships and mutually beneficial governance mechanisms • Evolve an efficient, flexible and adaptive networked enterprise
Focus	• Core enterprise operations & workflow processes • End-to-end value stream of the core enterprise • Collaborative relationships throughout the value stream	• Entire *enterprise value stream* (core enterprise, upstream supplier networks, downstream activities linking core enterprise to end-use customers) • Enterprise operations at all scales (strategic, tactical, operational) • Leadership processes, core business processes (product development, production, sustainment, supply chain management), and supporting infrastructure processes (e.g., human resources, customer services, information systems, contracting) • Value exchanges among all enterprise stakeholders • Managing both internal and external interdependencies
Implementation	• *Value* -- *specify value* as defined by the end customer • *Value stream* -- *identify the value stream* to eliminate all non-value-adding activities • *Flow* -- make the value adding steps for the specific products *flow* continuously • *Pull* -- let the customers *pull* value from the enterprise • *Perfection* – pursue perfection through continuous improvement. Source: Womack & Jones (1996)	• Pursue enterprise transformation by adopting a holistic enterprise perspective, lean enterprise principles, conceptual frameworks, methods and tools • Plan and implement enterprise transformation by pursuing a structured process containing, for example, the following major building-block steps: ⇨ Initiate strategic preparedness and learning cycle (e.g., define strategic imperatives, engage leadership in transformation); ⇨ Develop enterprise transformation plan (e.g., define enterprise, understand current state, create future state vision, develop strategic & detailed implementation plan); ⇨ Create required infrastructure systems & capabilities (e.g., enabling policies, metrics, information systems, incentive mechanisms, training of change agents) ⇨ Execute transformation plan (e.g., identify, prioritize, initiate & coordinate high-potential projects) ⇨ Monitor progress, take corrective action and institutionalize systemic change process.
Mode of Change	• Continuous incremental change	• Systemic evolutionary change

Table 2: Summary comparative overview of the key dimensions of the *basic lean enterprise system* and the *contemporary lean enterprise system* (Bozdogan, 2010).

Lean Production Objective

The core objective of Lean Manufacturing is to increase production efficiency by the elimination of waste consistently throughout the entire system, and to build quality into the manufacturing process while recognizing the principles of respect for humans in the system and cost reduction. Seven basic types of waste can be identified in the process: overproduction, waiting, transportation, over-processing, inventory, movement, and defective products. Unused employee creativity can be added as the eighth type. To eliminate these wastes several lean values, principles, and tools have been developed and are described as follows.

Lean Values

Lean production (or TPS) is based on five core values: 1) Challenge 2) Kaizen 3) Genchi Genbutsu 4) Respect 5) Teamwork (Bicheno & Holweg, 2009)

Lean Principles

The Lean principles have been identified by several researchers namely, Womack and Jones (2003), Liker (2004), and Nightingale and Srinivasan (2011). These principles are described in detail in Section 2.3.1.

Lean Tools

In addition to the Lean values and the Lean principles mentioned previously, the Lean Production System comprises Lean tools based on:

1) Stabilization of the elements that intervene in a work cell
2) Just-In-Time production (JIT)
3) Build in quality into the manufacturing process
4) A respect-for-humans system
5) Continuous improvement and continuous learning
6) Policy deployment

2.2.3.1.1 Stabilizing the elements that intervene in a work cell

Improvement is not possible without stability. It is important to stabilize all the elements that are directly or indirectly involved in a work cell, namely machine, material, method, equipment, people, information, and the work environment.

- Lean tools: 5'S, Standard Work, Visual Management, Total Productive Maintenance (TPM), Production Control Panel, Eight Waste Elimination

2.2.3.1.2 Just-In-Time production (JIT)

Just-In-Time production (JIT) means producing the right product at the right time in the right quantity.

- Lean tools: Value Stream Mapping, Continuous Flow, Pull System, Single Minute Exchange Die (SMED), Kanban System, Production Leveling (Heijunka), Visual Management, Takt Time Planning, Supermarkets, Line Balancing (Yamasumi), 5'S

2.2.3.1.3 Build in quality at the manufacturing process - Jidoka

Jidoka means giving machines and operators the ability to detect when an abnormal condition has occurred and immediately stop work. Jidoka enables operations to build in quality at each process and to separate people and machines for more efficient work. Toyota defined Jidoka as "automation with a human mind." (Liker, 2004)

- Lean tools: Person-machine separation, Andon, Error proofing (Poka-yoke), Abnormality control, In-station quality control, Problem solving (5 Why's)

2.2.3.1.4 Respect-for-humans system

Lean manufacturing require building a system that allows the workers to display their full capabilities by themselves.

- Lean tools: Problem Solving, Teamwork, Cross-training, Suggestion System (Kaizen Teian)

2.2.3.1.5 Continuous improvement and continuous learning

In a Lean system, not only the managers and foremen, but all workers detect trouble.

- Lean tools: Genchi Genbutsu, Kaizen, Problem Solving, Teamwork

2.2.3.1.6 Policy deployment (Hoshin Kanri)

Hoshin Kanri is a method of strategic planning and a tool for managing complex projects. It helps aligning company resources.

- Lean tools: A3 format, A3-X matrix, Catchball

The fundamental science that underlies Lean production is based on Industrial Engineering methods for developing the Lean tools to eliminate waste throughout the entire company. In addition to the Lean tools, it relies on the Lean principles and Lean values working together. All of them must be practiced, consistently, every day.

2.2.4 Lean Enterprise

When Lean production or the Toyota Production System has been used across the entire enterprise and not only in the manufacturing area, the term *Lean enterprise* is used. Two definitions are as follows: A Lean enterprise is a coordination mechanism needed to bring all the steps involved in the entire process, from product development to the customer, into harmony and on a global scale (Womack et al., 1990). Another definition of a Lean Enterprise established by the MIT's Lean Aerospace Initiative is as follows: "A Lean enterprise is an integrated entity that efficiently creates value for its multiple stakeholders by employing Lean principles and practices" (Murman, 2002). In the US, around 70% of manufacturing companies are implementing Lean Manufacturing. Lean thinking can be implemented in any type of activity, and for either a good or a service (Womack & Jones, 2003). It can be applied from agriculture to aerospace and from customization to mass production. Some examples are the TRW Automotive Electronics Group, John Deere, and Lockheed Martin Missile and Space Corporation (Motwani, 2003).

2.2.5 Lean Enterprise Transformation

By definition, transformation is a complete change in someone or something (Pearson Education, 2006). A transformation is as complex as the entity that we want to transform. Even

though most enterprises have the need to change to achieve competitive advantage, many fall short of the transformation needed. A transformation requires that work processes be analyzed and changed in order to create value (Rouse, 2005). A successful transformation is driven by the strategy of the company and must be driven by the leadership. It must also be managed as a project that involves a systematic change process and continuous learning (Kotnour, 2011).

Organizations start by implementing Lean in local areas to improve performance (Roth, 2011). In a small area of the company, Lean is relatively easy to address and produces good results in a short time. However, Lean efforts applied in isolated areas or processes are not enough; they should be considered in an integrated way at the enterprise level. "Becoming Lean is a process of eliminating waste with the goal of creating value" (Murman, 2002). A holistic approach that incorporates the different points of view of all stakeholders, methods, and disciplines must be considered to achieve a successful enterprise transformation (Valerdi & Nightingale, 2011).

The Lean enterprise transformation is the Lean journey a company takes from its current state to its vision state, converting from a traditional enterprise to a Lean enterprise. It requires a radical change in the mindset of all the stakeholders. A Lean culture culture is based on eliminating all types of waste throughout the entire process and embracing respect for people. Additionally, this transformation embodies the never-ending voyage of a company-wide Lean change, its sustainment, and an organizational culture of continuous improvement and continuous learning.

Finally from an engineering perspective, according to Mathaisel (2008, p.69), "Lean enterprise transformation engineering is a discipline that uses the tools of systems engineering and the management practices of lean sustainment to organize all of the tasks needed to design,

implement, and operate enterprise transformation change. The structure for the transformation is based on the life cycle of the enterprise."

2.3 Categorizing Lean Frameworks

The wide range of Lean frameworks found in the literature can assist in guiding the firms on the Lean journey. From the literature examined, several types of Lean approaches have been identified and the most important approaches have been selected for this study. Overall, researchers depict a descriptive framework, pictorial representations, or diagrams. To achieve a better understanding, those frameworks are categorized into four groups:

a) Descriptive frameworks / Lean principles
b) Pictorial representation frameworks / Lean models
c) Lean enterprise architecture frameworks
d) Diagram frameworks / Lean frameworks

In addition to the previous classifications, there are several frameworks that include the concept and practice of Lean production.

2.3.1 Descriptive Frameworks / Lean Principles

Five principles of Lean thinking for creating a Lean enterprise

Womack and Jones (2003) summarized Lean thinking as the set of principles that help create a lean enterprise:

1) Specify value accurately by specific product
2) Identify the value stream for each product
3) Make value flow without interruptions

4) Let the customer pull value from the producer

5) Pursue perfection

They state that creating a Lean enterprise must be based on identifying the entire value stream for each product or product family and considering these principles. Additionally, these principals must be tied together and applied to the entire firm, from product development to launch, from raw material to finished products, from product order to product delivery. Furthermore, it is also important to consider these principles with the extended enterprise, including suppliers and dealers.

Fourteen Principles of the Toyota Production System (TPS)

Liker has developed another important set of Lean principles. He identified the fourteen principles of the Toyota Production System (TPS) as shown in Figure 2 and divided them into four sections, (Liker, 2004, pp. 37-40) as follows:

- Section 1. Long-term philosophy
- Principle 1. Base your management decisions on a long-term philosophy, even at the expense of short-term financial goals
- Section 2. The right process will produce the right results
- Principle 2. Create continuous process flow to bring problems to the surface
- Principle 3. Use "pull" systems to avoid overproduction
- Principle 4. Level out the workload
- Principle 5. Build a culture of stopping to fix problems, to get quality right the first time
- Principle 6. Standardized tasks are the foundation for continuous improvement and employee empowerment

- Principle 7. Use visual control so no problems are hidden
- Principle 8. Use only reliable, thoroughly tested technology that serves your people and processes
- Section 3. Add value to your organization by developing your people and partners
- Principle 9. Grow leaders who thoroughly understand the work, live the philosophy, and teach it to others
- Principle 10. Develop exceptional people and teams who follow your company's philosophy
- Principle 11. Respect your extended network of partners and suppliers by challenging them and helping them to improve
- Section 4. Continuously solving root problems drives organizational learning
- Principle 12. Go and see yourself to thoroughly understand the situation
- Principle 13. Make decisions slowly by consensus, thoroughly considering all options; implement decisions rapidly
- Principle 14. Become a learning organization through relentless reflection and continuous improvement

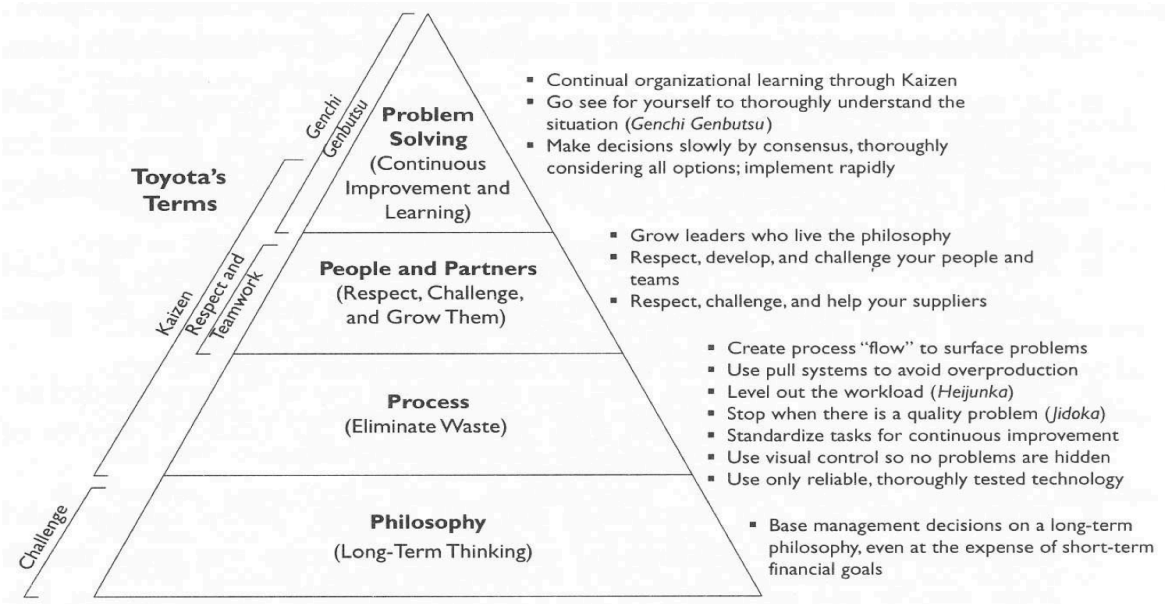


Figure 2. Fourteen Principles of the TPS (Liker, 2004, p. 65)

Liker builds a framework based on these principles as shown in Figure 2. He states that the companies that apply these principles and use the TPS tools are on the path of the TPS and on their way to accomplishing high performance.

The Seven Principles of a Lean Enterprise Transformation

The seven principles of a Lean enterprise transformation have evolved from what researchers and practitioners have written about the five principles of Lean thinking, the Toyota Production System, and Lean enterprises as well as from experience with transformation efforts from the Lean Advance Initiative (MIT) (Nightingale & Srinivasan, 2011).

1) Adopt a holistic approach to enterprise transformation
2) Secure leadership commitment to drive and institutionalize enterprise behaviors
3) Identify relevant stakeholders and determine their value propositions
4) Focus on enterprise effectiveness before efficiency

5) Address internal and external enterprise interdependencies
6) Ensure stability and flow within and across the enterprise
7) Emphasize organizational learning

2.3.2 Pictorial Representation Frameworks / Lean Models

The Lean House

A traditional Lean model is represented in the *lean house* (Figure3). Toyota is the pioneer of this framework and titled it the Toyota Production System (TPS) house. The basic idea is that the house has a foundation, two pillars, and a roof. The TPS philosophy together with visual management, stable and standardized processes, and leveled production are the foundations of the house.

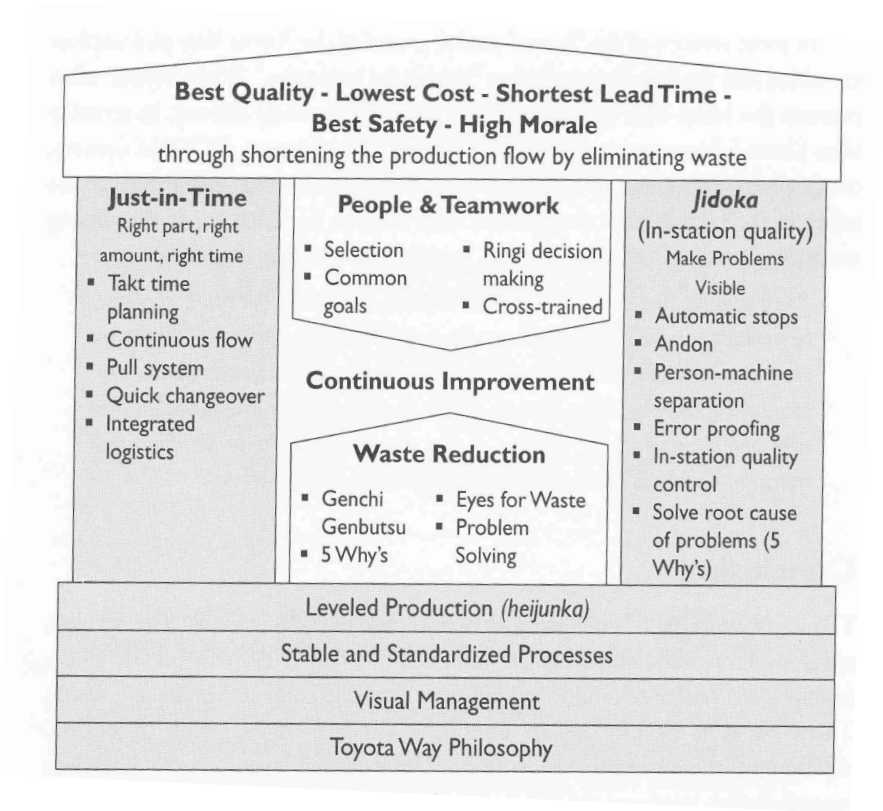


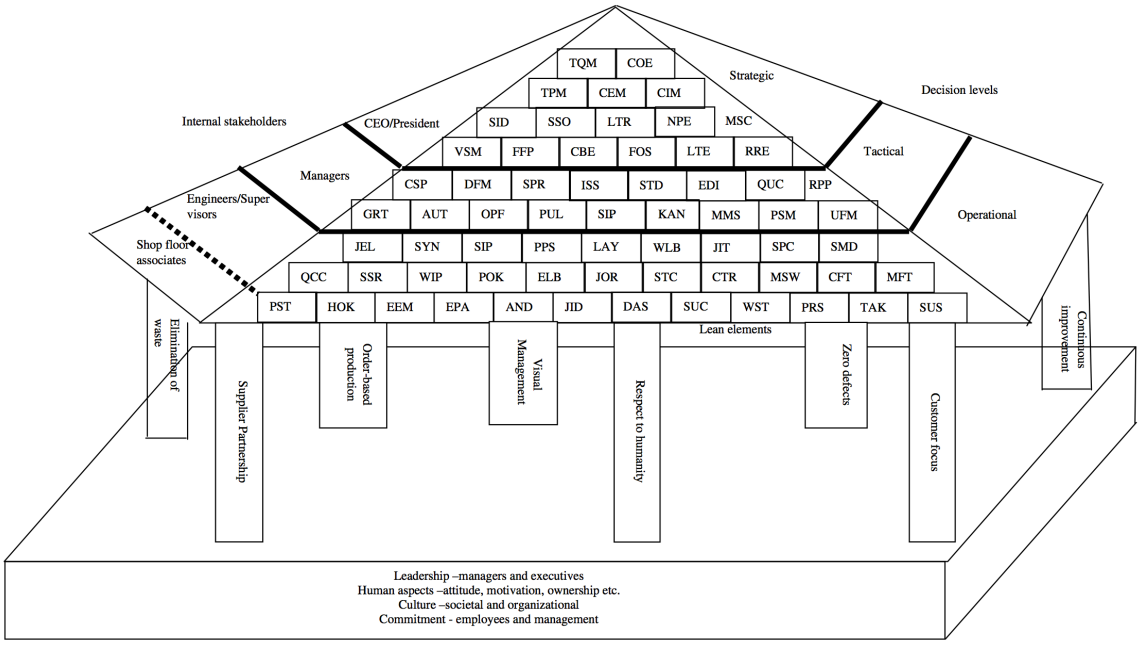
Figure 3. The Lean House (Liker 2004, p.33)

One of the pillars is the Just in Time (JIT) system for "Flow" and the other pillar is Jidoka "to build quality the first time." Between the pillars is continuous improvement by developing people and teamwork to eliminate waste in the value stream. The foundation of the house together with both pillars supports the roof, which is the achievement of the key performance indicators. An advantage of the Lean house is that it is a very simple framework and easy to understand.

There are a huge variety of Lean house frameworks. Many organizations adopt these frames and adapt them to their organization when they start their Lean journey. It is very common to see the TPS house with the name of the company followed by Production System, i.e. "Company X" Production System.

Framework for Lean manufacturing based on the Lean house structure

This framework identifies the Lean manufacturing elements comprehensively, and its main objective is to help practitioners to understand what constitutes Lean manufacturing. The approach of this research was a comparative analysis of the literature using 65 elements for building the framework as shown in Figure 4.



PST – Use of problem solving tools HOK – House keeping (5S) EEM – Employee empowerment EPR – Employee participation AND – Andon (Warning lights) JID – Jidoka (Autonomation) DAS – Defect at source (self inspection) SUC – Successive checking WST – Work standardization PRS – Process sharing TAK – Takt time SUS – Suggestion schemes MFT – Multi functional training CFT – Cross-functional teams MSW – Multi-skilled workforce CTR – Cycle time and lead time reduction STC – Standardized containers JOR – Job rotation or flexible job responsibilities	ELB – Elimination of buffers POK – Pokayoke (Mistake proofing) or defect prevention WIP – WIP reduction SSR – Storage space reduction QCC – Quality circles JEL – Job enlargement or Nagara system SYN – Synchronization SIP – Safety improvement programs PPS – Product and process simplification LAY – Layout change or U shaped cell WLB – Workload or line balancing JIT – Just in time delivery (suppliers and within workstations) SPC – Statistical process control SMD – Single minute exchange of dies UFM – Use of flexible machines	PSM – Production smoothing (load leveling) MMS – Mixed model manufacturing/scheduling KAN – Kanban system SLP – Small lot production PUL – Pull production OPF – One piece flow AUT – Automation GRT – Group technology CSP – Commonization and standardization of parts DFM – Design for manufacturing SPR – Supplier proximity ISS – Information sharing with suppliers STD – Supplier training and development EDI – Use of Electronic data interchange with suppliers QUC – Quality certification (suppliers and self) RPP – Rolling Production Plan	VSM – Value stream mapping FFP – Focused factory production CBE – Communication between employees FOS – Flat organization structure LTE – Long term employment RRE – Rewards and recognition SID – Supplier involvement in design SSO – Sole sourcing or supplier reduction LTR – Long term supplier relationship NPE – New process or equipment technologies CEM – Cellular manufacturing TPM – Total productive maintenance TQM – Total quality management CIM – Computer integrated manufacturing (CAD/CAM/CAE) MSC – Maintain spare capacity COE – Concurrent Engineering

Figure 4. Framework for Lean manufacturing based on the Lean house structure (Anand & Kodali, 2010)

Lean Enterprise Model - Lean Advancement Initiative (LAI) at MIT

The most consistent explanation of the MIT framework, which embarked on the development of an enterprise level Transition to a Lean Roadmap, is the one by Nightingale and Mize (2002) described in Figure 5. This version of the model was developed to assist organizations in their efforts to transform into Lean enterprises. The framework shows all the steps that are necessary to begin, maintain, and continuously improve an enterprise transformation based upon Lean principles and practices. The Roadmap was developed from an enterprise perspective, paying attention to strategic issues, internal and external relations with key stakeholders, and structural issues that must be taken into account if a significant change is to be carried out (Nightingale & Mize, 2002).

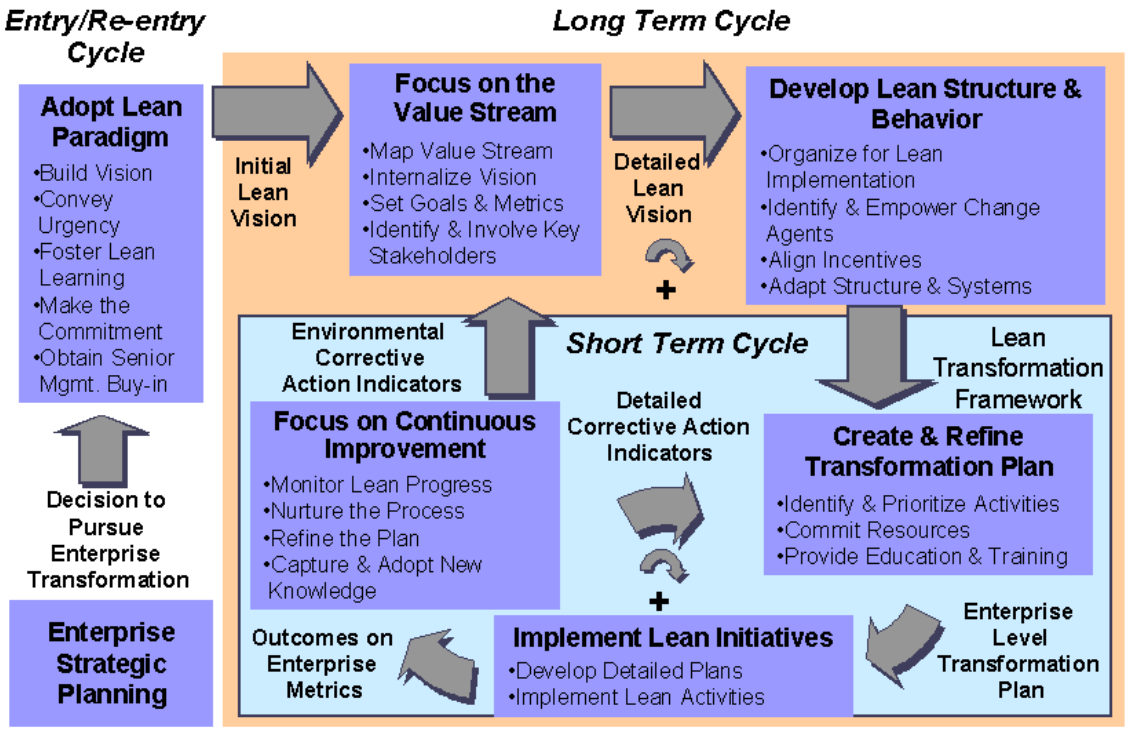


Figure 5. Transition to Lean Roadmap (Nightingale and Mize, 2002)

The Roadmap has three cycles. The first is the *Entry/Reentry Cycle,* which names the actions needed to adopt the Lean paradigm. This cycle is closely related to the enterprise strategic planning cycle. The second cycle is the *Long Term Cycle,* in which the environment and the necessary conditions for a successful transformation are created. After completing this cycle, the organization is ready to begin thorough planning and implementation. The third cycle is the *Short Term Cycle*, when implementation is planned, executed, and monitored. This cycle has a fast clock speed, with ongoing action-monitoring-corrective action phases. The *Long Term Cycle* is re-entered periodically to benefit from the lessons learned during implementation and to accommodate changes that take place in the dynamic external environment.

Experience shows that Lean implementation is definitely influencing how organizations shape their business strategies. Because implementing this process reduces lead times, lowers cost, and improves operating efficiencies, lean enterprises can compete in new markets and business opportunities that were not previously accessible. Lean implementation frees resources like space, labor, and capital, allowing firms to grow or to venture into new markets or businesses. Thus, the third cycle also impacts the first *Reentry Cycle* as an organization becomes leaner. Therefore, the Transition-to-Lean Roadmap is actually a set of nested feedback loops (Nightingale and Mize, 2002).

In addition to the Transition-to-Lean Roadmap, the Lean Advancement Initiative (LAI) at MIT developed a systematic framework that includes the principles and practices that help map a path to becoming a Lean enterprise as shown in Figure 6 (MIT, 2004). LAI comprises the following twelve Lean practices: 1) Identify and optimize enterprise flow, 2) Assure seamless information flow, 3) Optimize capability and utilization of people, 4) Make decisions at the lowest possible level, 5) Implement integrated product and process development, 6) Develop

relationships based on mutual trust and commitment, 7) Continuously focus on the customer, 8) Promote Lean leadership at all levels, 9) Maintain the challenge of existing processes, 10) Nurture a learning environment, 11) Ensure process capability and maturation, and 12) Maximize stability in a changing environment.

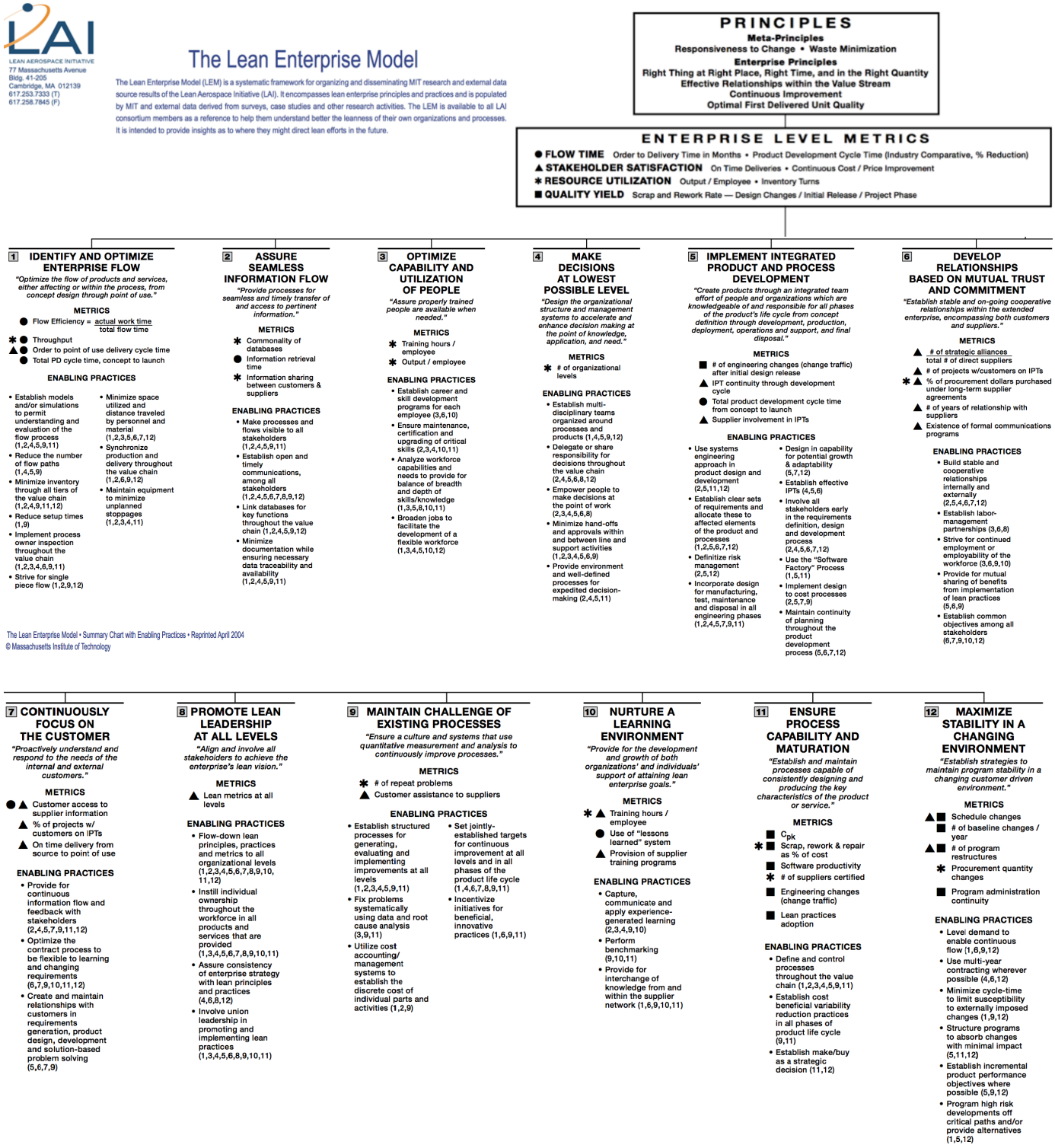


Figure 6. The Lean Enterprise Model (MIT, 2004)

The Seven Disciplines of Enterprise Engineering

In addition to the Lean house previously mentioned, there is a pictorial image for Enterprise Engineering that constitutes the seven disciplines of Enterprise Engineering (Martin, 1995). Martin defines Enterprise Engineering as an "integrated set of disciplines for building or changing an enterprise, its processes, and systems. It integrates the most powerful change methods and makes them succeed. The goal is a human-technological partnership of maximum efficiency in which learning takes place at every level." The basic diagram consists of five categories of change methods: TQM-Kaizen, Procedure Redesign, Value Stream Reinvention, Enterprise Redesign, and Strategic Visioning. Culture development, the organization of human resources, and information technology are required to support these change methods as shown in Figure 7.

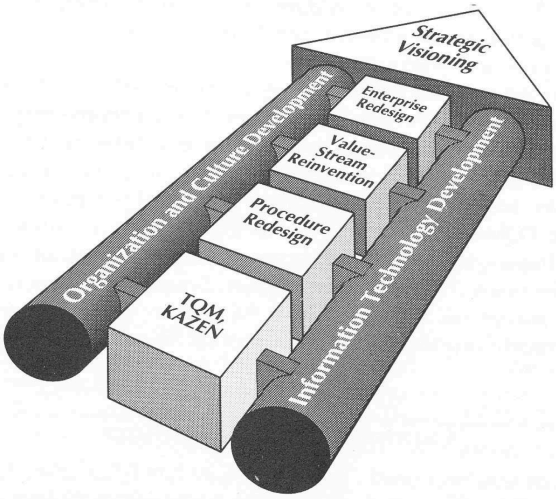


Figure 7. Seven Disciplines of Enterprise Engineering (Martin, 1995)

2.3.3 Lean Enterprise Architecture Frameworks

Lean Enterprise Architecture

Another interesting model is the Lean Enterprise Architecture. This model is a phased approach based on the life cycle of the transformation (Mathaisel, 2005). The Generalized Reference Architecture and Methodology (GERAM) framework was later adapted as the Lean enterprise transformation engineering framework. Mathaisel (2005) integrates the concepts of lean enterprise transformation engineering with the lean enterprise architecture as shown in Figure 8.

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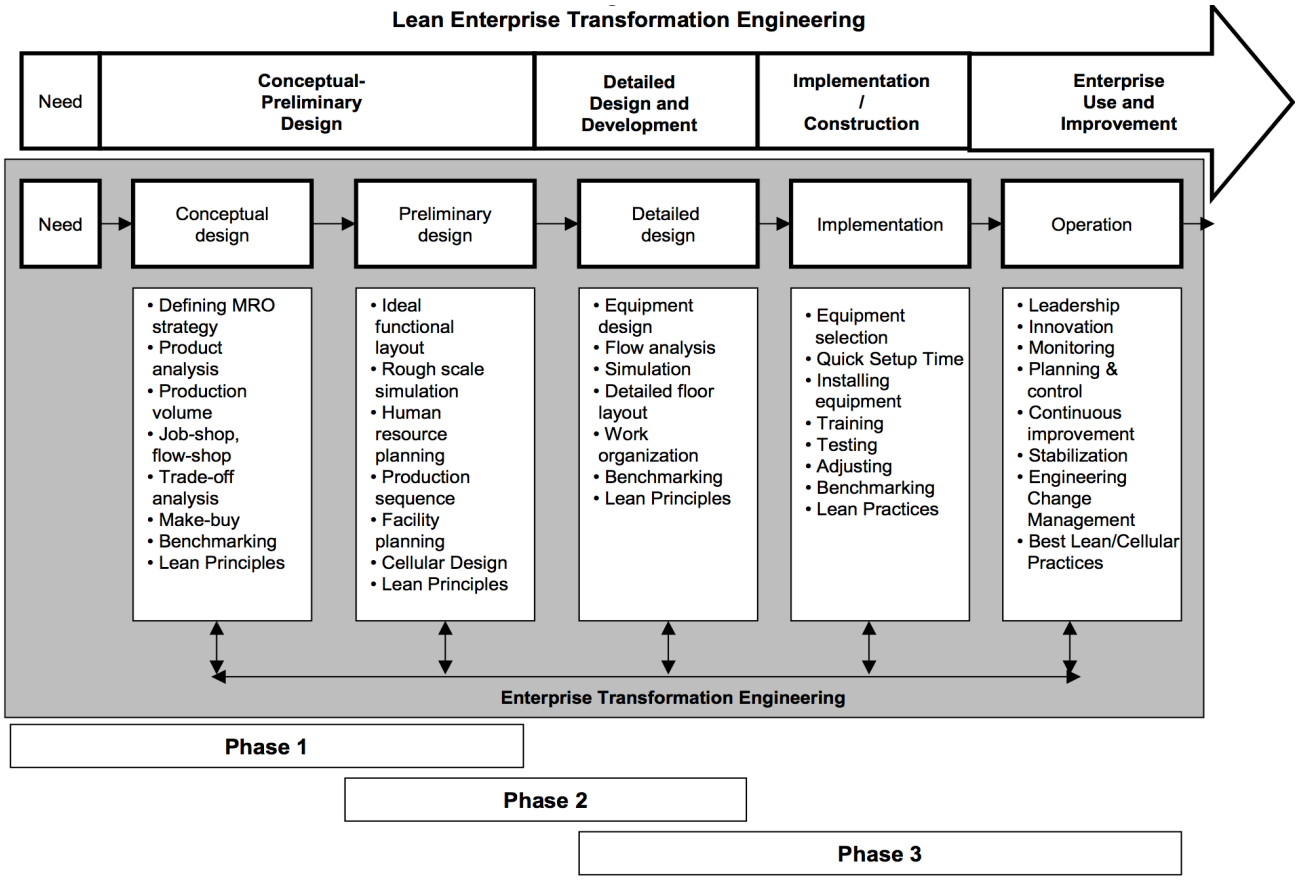

Figure 8. Lean Enterprise Architecture (Mathaisel, 2008)

This framework has three phases. The first one is transformation strategic planning, followed by the phase transformation acquisition and integration, and the third phase is the detailed planning and the transformation implementation. Mathaisel associates the components of the transformation life cycle with the five principles of lean thinking from Womack and Jones (2003) previously mentioned. He links the "need" component with the first Lean principle, "value," "concept and detailed design" with the "value stream and flow," "implementation and construction" with "pull," and finally the "enterprise use and improvement" component with the "perfection" principle.

2.3.4 Diagrams Frameworks / Lean Frameworks

According to Anand and Kodali (2010) these Lean frameworks can be categorized as design/conceptual frameworks, implementation frameworks, and a combination of both. Furthermore, they can also be classified as academic/research-based models, consultant/expert-based models, and organization/industry-based models. These frameworks are shown in Table 3. About 57% of these Lean frameworks are academic/research, 33% consultant/expert, and 10% organization-based/industry-based models.

S. No.	Framework for LM	Author(s)	Classification Scheme Based on: Type	Proposer
1.	Concepts of lean manufacturing	Karlsson and Åhlström[10]	D	A
2.	Conceptualization of lean production	Karlsson and Åhlström[11]	D	A
3.	The components necessary for applying lean manufacturing	Jina *et al.*[6]	D	A
4.	The lean automotive vision model	James-Moore and Gibbons[16]	D	A
5.	Theoretical concept of the lean enterprise	Karlsson and Åhlström[13]	D	A
6.	Small and medium sized firms as lean enterprises	Karlsson and Åhlström[13]	D	A
7.	The 20 keys to workplace improvement	Kobayashi[30]	D	C
8.	Lean manufacturing tools	Adams *et al.*[19]	D	A
9.	Lean enterprise	Czarnecki and Loyd[20]	D	A
10	The lean production model	Oliver *et al.*[18]	D	A
11.	Central theme, principles and characteristics of lean thinking	Bicheno[8]	D	C
12.	Lean shipbuilding	Liker and Lamb[27]	D	C
13.	The Toyota production system	Liker and Lamb[27]	D	O
14.	A lean reference framework	Davies and Greenough[9]	D	C
15.	A lean production model	Sanchez and Perez[15]	D	A
16.	House of lean	Dennis[25]	D	C
17.	Lean production in an enterprise approach — linked functions	Cook and Graser[26]	D	C
18.	Lean — A framework	Hines *et al.*[37]	D	A
19.	Generic framework for the management of change towards a lean enterprise	Smeds[17]	I	A
20.	A conceptual framework for successful JIT implementation	Wafa and Yasin[34]	I	A
21.	Framework for LM with a process view of implementation	Åhlström and Karlsson[14]	I	A
22.	Chrysler operating system	Flinchbaugh[28]	I	O
23.	Six steps to implementing lean	Airbus[21]	I	O
24.	Organizational learning framework	Flinchbaugh[31]	I	C
25.	The lean manufacturing house	Flinchbaugh[31]	I	C
26.	Just in time thinking principles	Kobayashi[30]	D + I	C
27.	The essential elements of lean production	Katayama and Bennett[35]	G	A
28.	Lean production as outcome and process	Lewis[36]	G	A
29.	Theoretical framework for LM implementation	Motwani[32]	G	A
30.	Lean engineering	Morgan and Liker[23]	G	C

Legend
D — Design/conceptual framework
I — Implementation framework
D + I — Combination of Design/conceptual framework and implementation framework
G — General framework
A — Academic/researchers based framework
C — Consultant/expert based framework
O — Organisation based framework

Table 3. Taxonomies for existing Lean Manufacturing Frameworks (Anand & Kodali, 2010)

This section describes some of the most relevant diagram frameworks found in the literature.

Model for Continuous Improvement

According to Kaye and Anderson (1999), the drivers shown in Figure 9 are essential for success and sustaining continuous improvement over time. Additionally, Kaye and Anderson (1999) state that those enablers are fundamental in accomplishing the continuous improvement program.

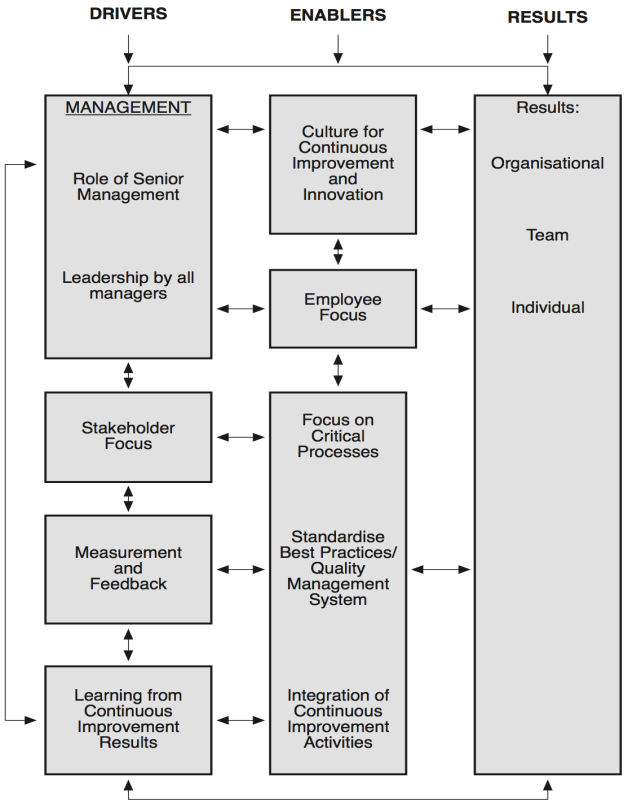

Figure 9. Revised model for continuous improvement (Kaye & Anderson, 1999, p. 504)

The Flow Framework

The Flow Framework (Figure 10) focuses on creating flow and uses Lean tools for each type of flow. However, companies may have to develop their own appropriate toolbox. The framework starts by creating flow, which requires understanding of how the company achieves the fulfillment of customer demand. The next step is to maintain flow, identifying the causes of

variability and the losses of availability. Furthermore, it is important to organize for flow, developing people in problem solving and continuous improvement in a sustainable fashion. The last step is to measure for flow, which allows the managers and workers to ponder how the system is performing in contrast with its expected performance (Mackle, 2012).

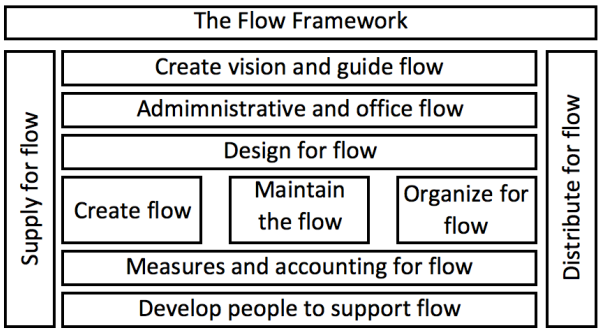

Figure 10. The Flow Framework (Bicheno & Holweg, 2009)

Theoretical framework for Lean manufacturing implementation

This framework, shown in Figure 11, is a business process change framework (Motwani, 2003). Motwani (2003) adapted it from Kettinger and Grover's model of business process management and explains the most important factors concerned in the implementation of Lean manufacturing. A case study approach was used to conduct the research.

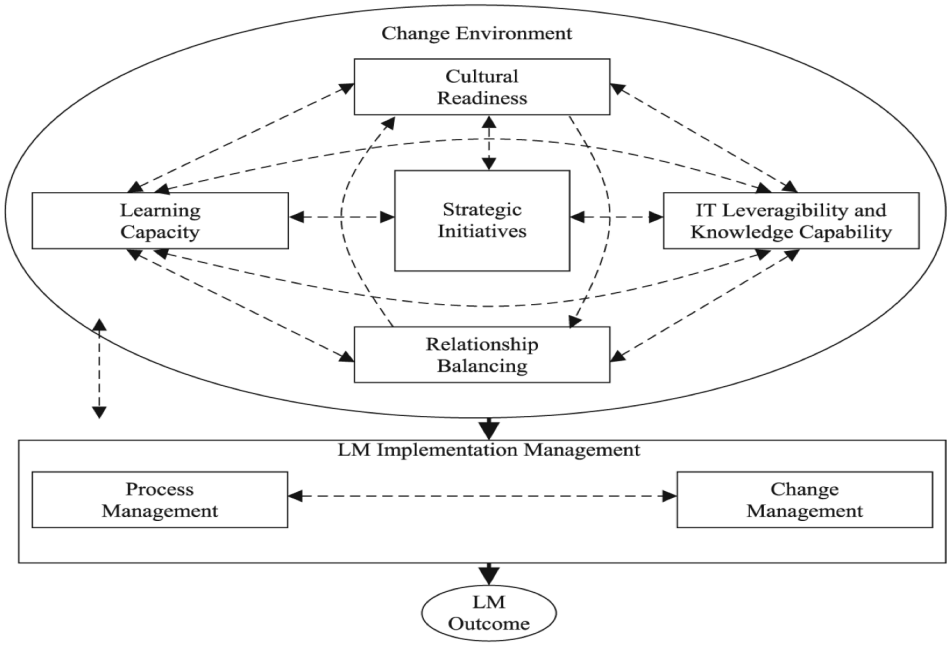

Figure 11. Business process change framework (Motwani, 2003)

A conceptual framework for successful JIT implementation

Wafa and Yasin (1998) identified 23 variables based on a field study and developed this framework for effective JIT implementation. These variables are clustered into four categories namely management, workers, process, and suppliers as shown in Figure 12.

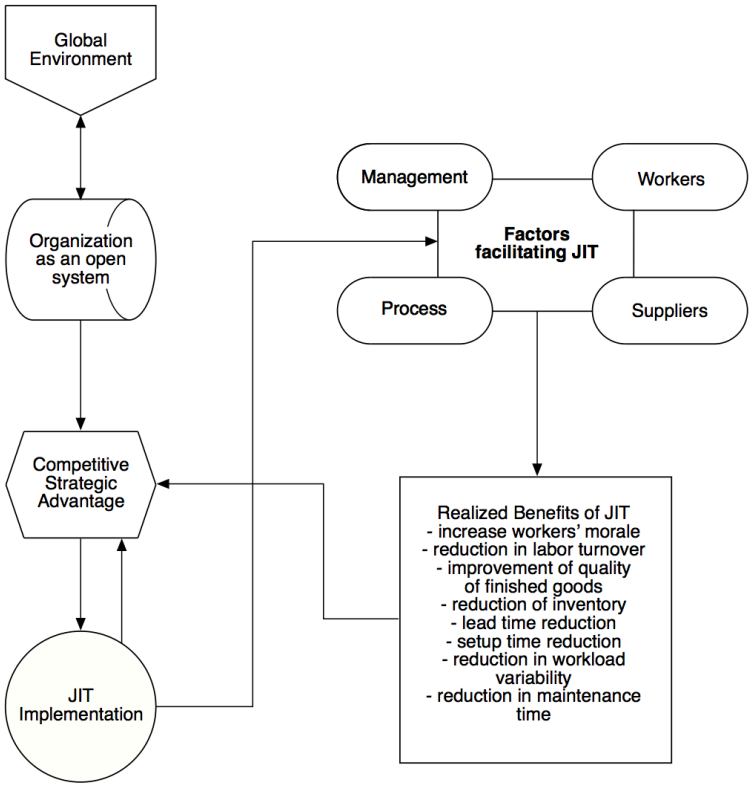

Figure 12. A conceptual framework for successful JIT implementation (Wafa & Yasin, 1998)

A proposed dynamic model for a Lean roadmap

This framework determines the tools that are needed to implement Lean in a company based on its current state as well as the type of industry. The model is organized into four major phases: 1) Preparation, 2) Focus on a specified pilot, 3) Expand to whole system, and 4) Perfection (Anvari, Zulkifli, Yusuff, Hojjati, & Ismail, 2011). Additionally there is one initial phase for assessment of Lean implementation, Phase 0, as shown in Figure 13.

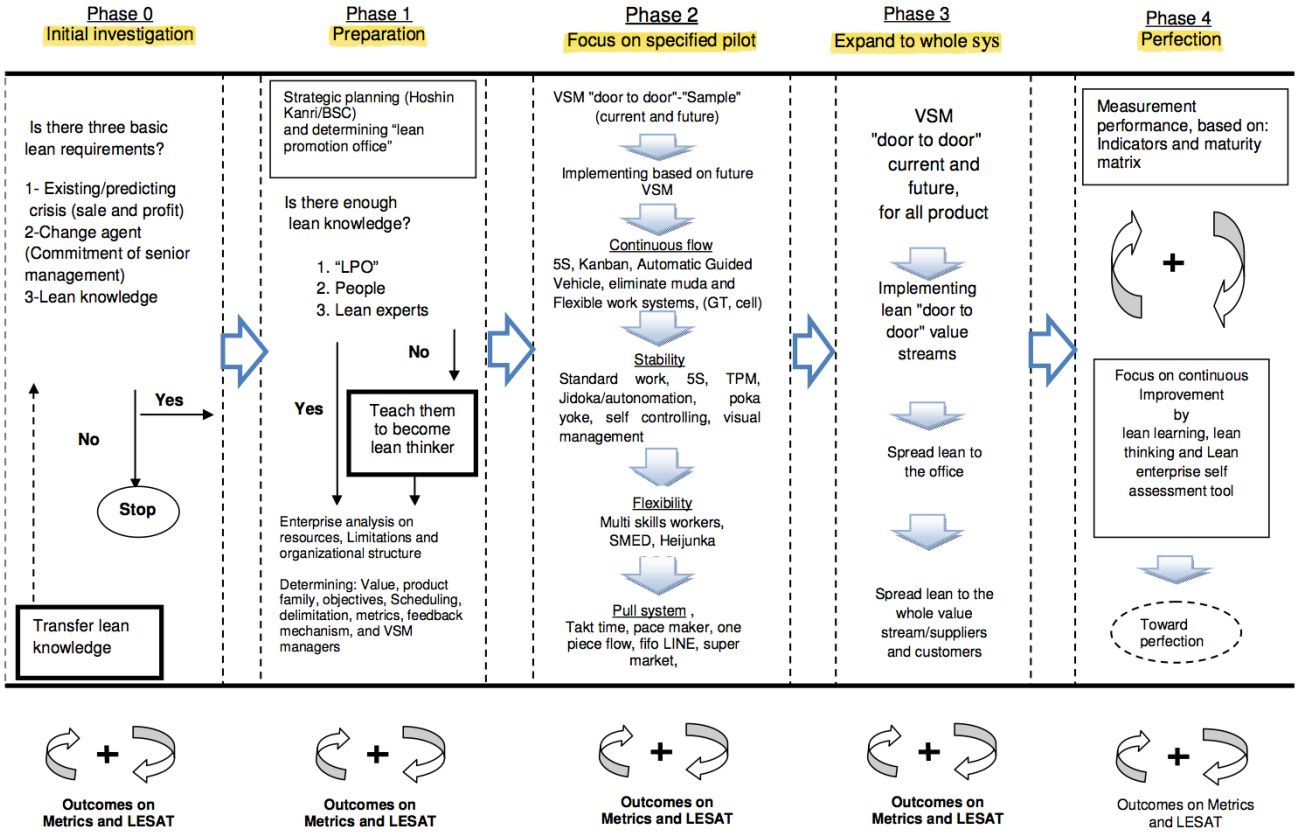

Figure 13. A proposed dynamic model for a Lean roadmap (Anvari et al., 2011)

As we can infer from the previous paragraphs, extensive research has been done to define the principles and practices of Lean production. Despite the contribution of all of this research, most of it focuses on specific issues of Lean. A limited number of authors attempt to put all the Lean concepts together. It is known that all Lean transformations are different and there is no one single recipe to follow. However, having the basic principles, values, and tools that underlie Lean production in a big picture is useful to understand the concept, as described in Chapter 4.

2.4 Excellence Models underpinning the National Quality Awards

This section briefly describes the most well-known excellence models underpinning the national quality awards, whose concepts can contribute to defining the group categories and components of the framework developed in Section 4.1.

National quality awards represent countries' efforts in promoting quality excellence in products and services, providing in their frameworks the fundamental concepts of total quality management (TQM). The purpose of these national quality awards is to give national recognition to companies that achieve performance excellence, as well as to promote business competition (Khoo & Tan, 2003). Many countries have adopted local, national, or transnational quality awards with the goal of improving national competitiveness. The main factors that encourage the introduction of these awards are a) the importance of quality as a key factor of competitiveness, b) the contribution of benchmarking, and c) the need for self-assessment techniques to enhance performance (Sampaio, Saraiva, & Monteiro, 2012). These awards are based on *"a perceived excellence model of TQM" (Ghobadian & Woo, 1996)*. These excellence models and criteria focus not only on product quality or traditional quality control methods, but also on management activities, behavior, and processes that have an impact on the quality of the final offerings (Ghobadian & Woo, 1996). Each national quality award has developed its own excellence model (framework), criteria, and criterion weighting, for assessing the award recipients. Each model is computed based on its own criteria scores (Talwar, 2011).

Mohammad, Mann, Grigg, and Wagner (2011) identified 94 national quality/business excellence awards, in 83 countries. According to the authors, organizations use business excellence models to improve and evaluate their work practices and performance. Most of the quality awards around the world are modeled after the most well-known quality awards: the

Malcolm Baldrige National Quality Award (MBNQA), the Deming Prize and the European Quality Award (EQA) (Pui-Mun, 2002). The excellence models used for this research are the

1) Baldrige Criteria for Performance Excellence Framework
2) Deming Prize Criteria
3) European Foundation for Quality Management (EFQM) Excellence Model
4) Shingo Model for Operational Excellence

The fourth model, "The Shingo Model for Operational Excellence," focuses more on Lean issues than the first three models.

2.4.1 The Baldrige Criteria for Performance Excellence Framework

The Malcolm Baldrige National Quality Award, instituted in 1987 in the USA (Kumar, 2007), is based on the Baldrige Criteria for Performance Excellence Framework. This framework embraces seven interrelated categories to help leaders achieve performance excellence in their organizations: leadership; strategic planning; customer focus; measurement; analysis, and knowledge management; workforce focus; process management; and results (Figure 14).

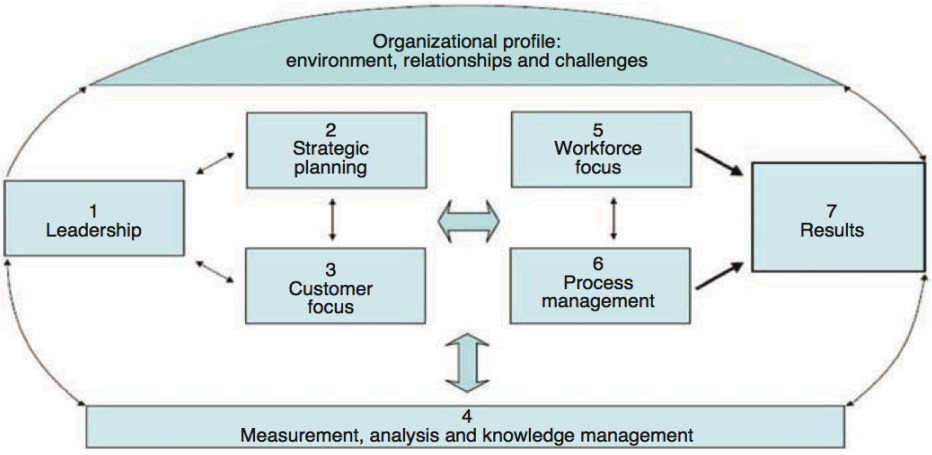

Figure 14. Baldrige Framework for Performance Excellence (NIST, 2011)

These criteria are divided into categories and subcategories as displayed in Tables 4 and 5.

P. Organizational profile	**2.2 Strategy implementation**
P.1. Organizational description	**a. Action plan development and deployment**
a. Organziational environmnet	Action plan development
Product offerings	Action plan implementation
Vision and mission	Resource allocation
Workforce profile	Workforce plans
Assets	Performance measures
Regulatory requirements	Action plan modification
b. Organizational relationships	**b. Performance projections**
Organizational structure	
Customers and stakeholders	**3. Customer focus**
Suppliers and partners	**3.1 Voice of the customer**
P.2. Organizational situation	**a. Customer listening**
a. Competitive environment	Listening to current customers
Competitive position	Listening to potential customers
Competitiveness changes	**b. Determination of customer satisfaction and engagement**
Comparative data	Satisfaction and engagement
b. Strategic context	Satisfaction relative to competitors
c. Performance improvement systems	Dissatisfaction
	3.2 Customer engagement
1. Leadership	**a. Product offerings and customer support**
1.1 Senior leadership	Product offerings
a. Vision, values and mission	Customer support
Vision and values	Customer segmentation
Promoting legal and ethical behavior	Customer data use
Creating a sustainable organization	**b. Building customer relationships**
b. Communication and organizational performance	Relationship management
Communication	Complaint management
Focus on action	
1.2 Governace and societal responsibilities	**4. Measurement, analysis, and knowledge management**
a. Organizational governance	**4.1 Measurement, analysis, and improvement of organizational performance**
Governance system	**a. Performance measurement**
Performance evaluation	Performance measures
b. Legal and ethical behavior	Comparative data
Legal and regulatory behavior	Customer data
Ethical behavior	Measurement agility
c. Societal responsibilities and support of key coomunities	**b. Performance analysis and review**
Societal well-being	**c. Performance improvement**
Commnutity support	Best practice sharing
	Future performance
2. Strategic planning	Continuous improvement and innovation
2.1 Strategic development	**4.2 Management of information, knowledge, and information technology**
a. Strategy development process	**a. Data, information, and knowledge management**
Strategic planning process	Properties
Strategy considerations	Data and information availability
b. Strategic objectives	Knowledge management
Key strategic objectives	**b. Management of information resources and technology**
Strategic objective considerations	Hardware and software properties
	Emergency availability

Table 4. Baldrige framework criteria categories and subcategories (NIST, 2011)

5. Workforce focus	**7. Results**
5.1 Workforce environment	**7.1 Product and process outcomes**
a. Workforce capability and capacity	**a. Customer-focused product and process results**
Capability and capacity	**b. Operational process efectivenes results**
New workforce members	Operational effectiveness
Work accomplisment	Emergency preparedness
Workforce change management	**c. Strategy implementation results**
b. Workforce climate	**7.2 Customer-focused outcomes**
Workplace environment	**a. Customer-focused results**
Workforce policies and benefits	Customer satisfaction
5.2 Workforce engagement	Customer engagement
a. Workforce performance	**7.3 Workforce-focused outcomes**
Elements of engagement	**a. Workforce results**
Organizational culture	Workforce capability and capacity
Performance management	Workforce climate
b. Assessment of workforce engagement	Workforce engagement
Assessment of engagement	Workforce development
Correlation with business results	**7.4 Leadership and governace outcomes**
c. Workforce and leader development	**a. Leadership, governance & societal responsibility results**
Learning and development system	Leadership
Learning and development effectiveness	Governance
Career progression	Law and regulation
	Ethics
6. Operation focus	Society
6.1 Work systems	**7.5 Financia and market outcomes**
a. Work system design	**a. Financial and market results**
Design concepts	Financial performance
Work system requirements	Marketplace performance
b. Work system management	
Work system implementation	
Cost control	
c. Emergency readiness	
6.2 Work processes	
a. Work process design	
Design concepts	
Work process requirements	
b. Work process management	
Key work process implementation	
Supply-chain management	
Process improvement	

Table 5. Baldrige framework criteria categories and subcategories (NIST, 2011)

2.4.2 Deming Prize Criteria

The Deming Prize, which was established in 1951 by the Union of Japanese Scientists and Engineers (JUSE), is the oldest quality award and one of the highest awards in Total Quality Management (TQM). This award is given to organizations that accomplish performance excellence through TQM (Sampaio et al., 2012) . Unlike other national awards, the Deming Prize does not provide a model or framework (Vokurka, Stading, & Brazeal, 2000). In its place, it defines the criteria and evaluates ten equally weighted points that each organization must address, covering the following categories: 1) Policies, 2) Organization, 3) Information, 4) Standardization, 5) Human resources, 6) Quality assurance, 7) Maintenance, 8) Improvement, 9) Effects, and 10) Future plans. The set of criteria in these categories and subcategories is shown in Table 6.

1.0 Top management leadership, vision and strategies	6.0 Effective utilization of information
1.1 Top management leadership	6.1 Positioning of information in management
1.2 Organizational vision and strategies	6.2 Information systems
2.0 TQM frameworks	6.3 Support for analysis and decision making
2.1 Organizational structure and its operations	6.4 Standardization and configuration management
2.2 Daily management	7.0 TQM concepts and values
2.3 Policy management	7.1 Quality
2.4 Relationships to ISO 9000 and ISO 14000	7.2 Maintenance and improvement
2.5 Relationships to other management improvement program	7.3 Respect for humanity
2.6 TQM promotion and operation	8.0 Scientific methods
3.0 Quality assurance system	8.1 Understanding and utilization of methods
3.1 Quality assurance system	8.2 Understanding and utilization of problem-solving methods
3.2 New product and new technology development	9.0 Organizational powers
3.3 Process control	9.1 Core technology
3.4 Test, quality evaluation and quality audits	9.2 Speed
3.5 Activities covering the whole life cycle	9.3 Vitality
3.6 Purchasing, subcontracting and distribution management	10.0 Contribution to realization of corporate objectives
4.0 Management systems for business elements	10.1 Customer relations
4.1 Cross-functional management and its operations	10.2 Employee relations
4.2 Quality/delivery management	10.3 Social relations
4.3 Cost management	10.4 Supplier relations
4.4 Environmental management	10.5 Shareholder relations
4.5 Safety, hygiene and work environmental management	10.6 Realization of corporate mission
5.0 Human resource development	10.7 Continuously securing profits
5.1 Positioning of people in management	10.8 TQM features (shining example)
5.2 Education and training	
5.3 Respect for people's dignity	

Table 6. Deming Prize (2000) set of criteria (Khoo & Tan, 2003, p. 15)

2.4.3 European Foundation for Quality Management Excellence Model

The European Foundation for Quality Management (EFQM) Model is widely recognized to improve total quality management (TQM) from a holistic management view (Kim, Kumar, & Murphy, 2010). The EFQM model encompasses the different elements of TQM being the basis for addressing the process of analysis and change in organizations (Martín-Castilla & Rodríguez-Ruiz, 2008). The EFQM Excellence Model (Figure 15) embodies nine basic criteria as follows: 1) Leadership, 2) People, 3) Strategy, 4) Partnership and resources, 5) Processes, products and services, 6) People results, 7) Customer results, 8) Society results, and 9) Key results.

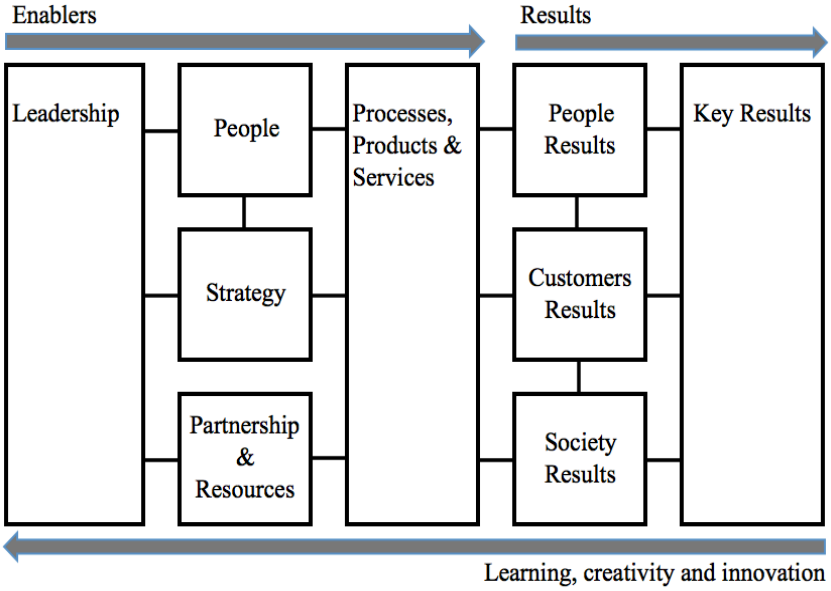

Figure 15. European Foundation for Quality Management Excellence Model (EFQM, 2010)

These criteria categories are divided into subcategories as shown in Table 7.

1 Leadership	a Leaders develop the mission, vision & values and are role models of a culture of excellence b Leaders are personally involved in ensuring the organisation's management system is developed, implemented & continuously improved c Leaders are involved with customers, partners & representatives of society d Leaders motivate, support & recognise the organisation's people
2 Policy & Strategy	a Policy & strategy are based on the present & future needs & expectations of stakeholders b Policy & strategy are based on information from performance measurement, research, learning and creativity related activities c Policy & strategy are developed, reviewed & updated d Policy & strategy are deployed through a framework of key processes e Policy & strategy are communicated & implemented
3 People	a People resources are planned, managed & improved b People's knowledge & competencies are identified, developed & sustained c People are involved & empowered d People & the organisation have a dialogue e People are rewarded, recognised & cared for
4 Partnerships & Resources	a External partnerships are managed b Finances are managed c Buildings, equipment & materials are managed d Technology is managed e Information & knowledge are managed
5 Processes	a Processes are systematically designed & managed b Processes are improved, as needed, using innovation in order to fully satisfy & generate increasing value for customers & other stakeholders c Products & services are designed & developed based on customer needs & expectations d Products & services are produced, delivered & serviced e Customer relationships are managed & enhanced
6 Customer Results	a Perception measures b Performance indicators
7 People Results	a Perception measures b Performance indicators
8 Society Results	a Perception measures b Performance indicators
9 Key Performance Results	a Key performance outcomes b Key performance indicators

Table 7. EFQM Excellence Model - Criteria categories and subcategories (DTI, 2005)

2.4.4 The Shingo Model for Operational Excellence

The Shingo Prize for Operational Excellence, established in 1988, is an award for all industries located in the USA, Canada or Mexico. The Shingo Prize headquarters is at Utah State University (USU). USU is in partnership with the Association of Manufacturing Excellence (AME), the Society of Manufacturing Engineers (SME), the Association for Operations

Management (APICS), and the Greater Boston Manufacturing Partnership (Chakravorty, Atwater, & Herbert, 2008). The Shingo Prize for Operational Excellence is based on the Shingo model, which is founded on the Lean management approach taught by Dr. Shigeo Shingo as well as on the experience of Toyota Motor Company and other companies that have implemented Lean manufacturing. This model encompasses two elements, a diamond and a house, as shown in Figures 16 and 17 respectively. The diamond denotes the transformation process enclosing the operational excellence principles into the organizational culture, while the house depicts the balancing effort across all dimensions (USU, 2010). The Shingo Model has four dimensions and each dimension promotes the following principles:

- Dimension 1. Cultural enablers (People)
  - Respect every individual
  - Lead with humility
- Dimension 2. Continuous process improvement (Process)
  - Focus on process
  - Embrace scientific thinking
  - Flow and pull value
  - Assure quality at the source
  - Seek perfection
- Dimension 3. Enterprise alignment (Alignment)
  - Create constancy of purpose
  - Think systemically
- Dimension 4. Results
  - Create value for the customer

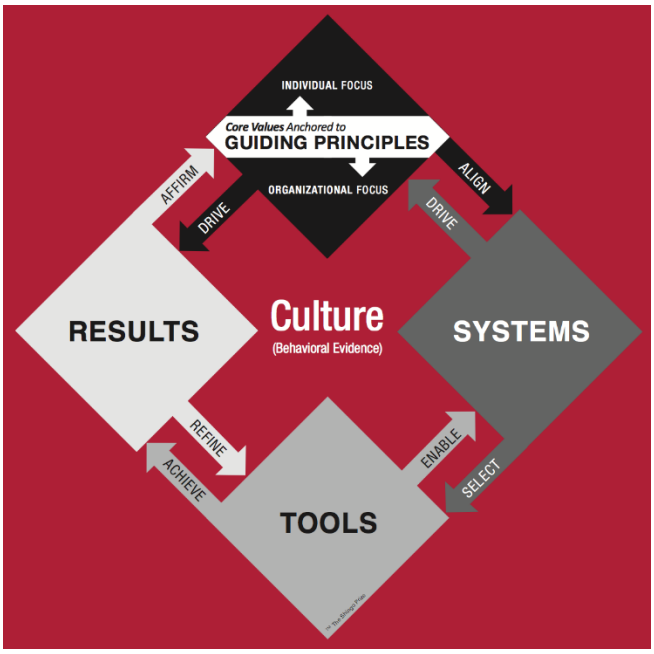

Figure 16. The Shingo Transformational Model (USU, 2010)

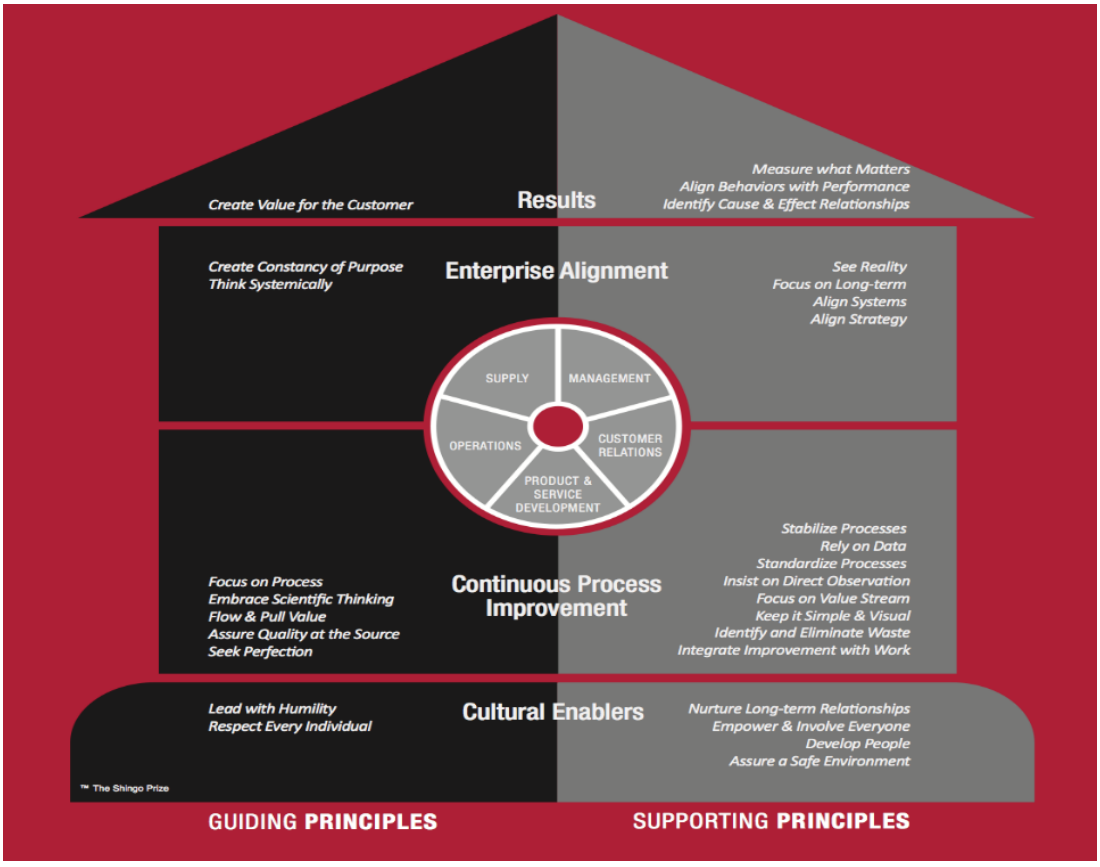

Figure 17. The Shingo Principles of Operational Excellence (USU, 2010)

The suggested systems, tools, and activities that support the guiding principles and supporting principles of each dimension of the Shingo Model are shown in Table 8.

Dimension	Principles	Suggested systems, tools and activities	
Dimension 1	**Guiding principles**	Individual development plans	Cross-training program
Cultural enablers	Respect every individual	On-the-job coaching	Job rotation
(People)	Lead with humility	Structured education programs	Clearly communicated hiring and promotion standards
		Formal systems for capturing & transfering lessons learned	Alignment of job descriptions and compensation to excellence
	Supporting principles	The use of standardized work procedures	Union partnership including collaborative work arrengements
	Nurture long term relationships	Specific training philosophy similar to Training Within Industry	Communication of the measurement system
	Empower & involve everyone	Employee suggestions and improvement activities	Personnel commitment to eliminate the waste
	Develop people	Sharing problems and exchanging ideas	Proactive systems to maintain an ergonomic, clean, and safe work environment
	Asure a safe environment	Recruitment and succession planning system	
		Initiatives regarding environmental issues	Education, awareness, and practices aimed at employee health and wellness
		Scope of environmental, health, and safety efforts	
Dimension 2	**Guiding principles**	Voice of the customer	Distribute work intellegentlyand efficiently or level-loading
Continuous process	Focus on process	Customer-facing process	Theory of constraints - managing bottlenecks
improvement	Embrace scientific thinking	Quality function deployment, concurrent engineering for product development	Benchmarking processes
(Processes)	Flow & pull value		A3 Thinking
	Assure quality at the source	Variety reduction	5S, visual workplace, visual displays, and visual management
	Seek perfection	Involve suppliers & customers in product / service design	Right-sized equipment and facilities
		Flow and Pull	Six-sigma, statistical process control, design of experiments
	Supporting principles	Value Stream Mapping	Tools of quality
	Stabilize processes	Value Analysis	Production Process Preparation (3P)
	Rely on data	Time-based or just-in-time manufacturing	Integration of the company and its suppliers
	Standardize processes	Total productive, preventive, or predicive maintenance -TPM	Distribution and transport alliances
	Insist on direct observation	Quick changeover or setup reductions (SMED)	Respect for suppliers
	Focus on value stream	Zero defects through Poka-yoke	Commitment to supplier development
	Keep it simple & visual	Cellular layout	Alignment and integration of administration functions
	Identify and eliminate waste	Kaizen and breackthrough improvement	Data-based decisions and actions
	Integrate improvement with work	Emphasis on direct observation (go and see)	Visula devices and systems
Dimension 3	**Guiding principles**	A system for creating reporting requirements	A planning system for establishing and deploying the strategy
Enterprise alignment	Create constancy of purpose	Common management & reporting systems across the enterprise	A system for aligning objectives and projects
(Alignment)	Think systematically	A financial reporting system embraces Lean accounting practices	Assessment system to check reality
	Supporting principles	Continuous flow and eliminating waste in the entire enterprise	A system to align tools, systems, and principles to values, mission, and vision
	See reality	Simple and visual information systems	
	Focus on long term	Scientific thinking as a philosophy	A business assessment system that evaluates performance
	Align systems	The use of knowledge management systems & ideas sharing	Systems to develop and sustain ethical behavior
	Align strategy		
Dimension 4	**Guiding principles**	Quality: finished product first-pass yield, rework, unplanned scrap rate, overall cost of quality, process variation measures	
Results	Create value for the customer	Cost / productivity: labor productivity, asset productivity, inventory turns, materials, energy productivity, resource utilization	
	Supporting principles	Delivery: total lead time, on-time delivery, time from supplier to receipt of materials,mis-shipments, reorder rate, system availability	
	Measure what matters	Customer satisfaction:internal & external, lead time, flexibility, synchronized processes, customer audits, surveys & awards	
	Align behaviors with performance	Morale; employee survey, participation in activities, number of ideas per employee, grievances, referrals for work	
	Identify cause & effect relationships		

Scope of transformation	Business & management processes		
	Customer relations	Operations	Management
	Product / service development	Supply	

Table 8. The suggested systems, tools, and activities that support the guiding principles and supporting principles of each dimension of the Shingo Model (USU, 2010)

This section described the most important excellence models of total quality management (TQM) used to improve and evaluate companies' work practices and performance as well as their criteria categories and subcategories. The most relevant concepts of these models are used to determine the key components of the framework developed in Chapter 4.

2.5 Reference Architectures for Enterprise Integration

"A reference architecture for a specific domain is a generic architecture from which other architectures can be compared or derived" (Vernadat, 1996). This section describes the main architecture references commonly used for enterprise integration. Their concepts contribute to the framework design and specifically to the definition of the Lean enterprise transformation life cycle phases developed in Chapter 4. These frameworks are the Purdue Enterprise Reference Architecture (PERA), the Computer Integrated Manufacturing Open Systems Architecture (CIMOSA), the GRAI Integrated Methodology (GIM), and the Generalized Reference Architecture and Methodology (GERAM), which is a result of the previous three.

2.5.1 The Purdue Enterprise Reference Architecture (PERA)

The Purdue Enterprise Reference Architecture (PERA) is a framework or reference architecture developed at Purdue University from 1989 to 1992 as part of the work on the Industry-Purdue University Consortium for Computer Integrated Manufacturing or CIM (Williams, 1994). This framework takes into consideration the human, manufacturing, and customer service components, as well as the information and control system components of any enterprise. It provides an Enterprise Integration process and focuses on the life cycle concept. It comprises the following regions (or views): concept, functional analysis, implementation, operations, and recycle and disposal regions. Each region is composed of phases. The PERA life cycle consists of nine phases: 1) identification, 2) concept, 3) definition, 4) functional design, 5) detailed design, 6) construction and installation, 7) operation and maintenance, 8) renovation or disposal, and 9) enterprise dissolution (Williams, Gary, Rathwell, & Li, 2001). The PERA is shown in Figure 18.

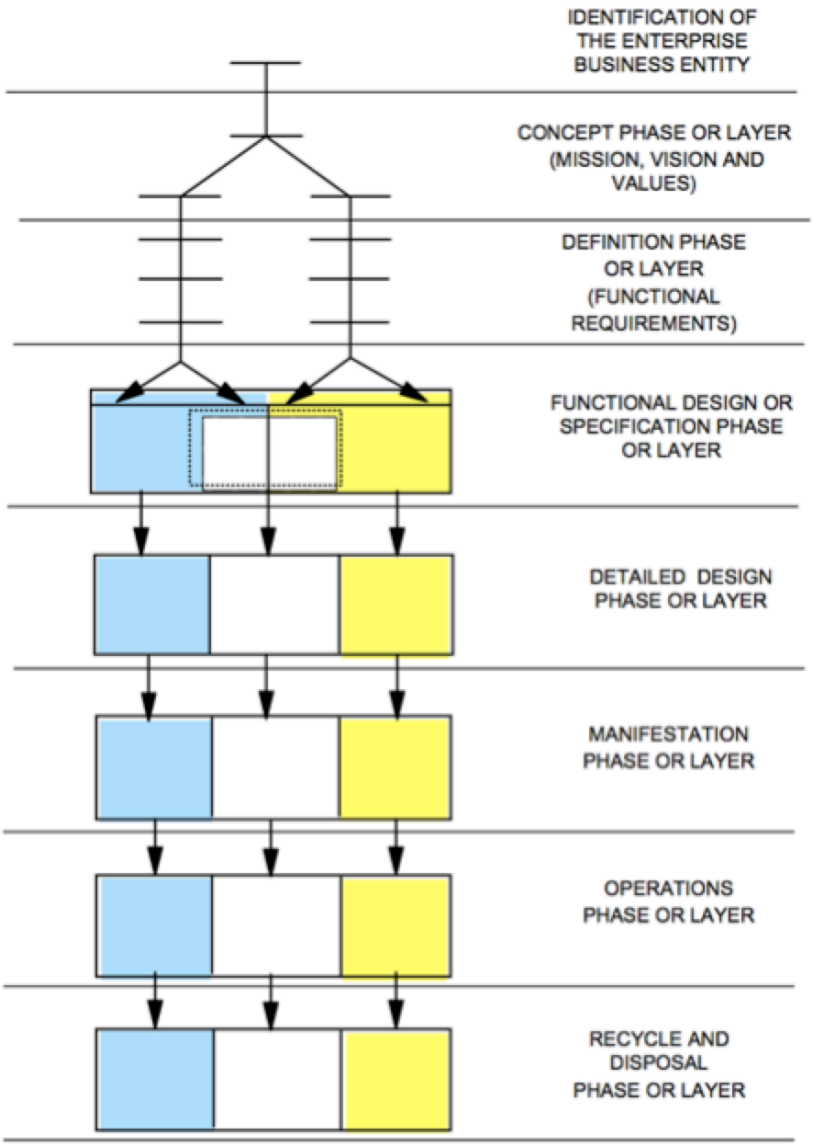

Figure 18. A graphical presentation of the Purdue Enterprise Reference Architecture indicating phases, and the relationship of tasks within phases (Williams et al., 2001).

2.5.2 The Computer Integrated Manufacturing Open Systems Architecture (CIMOSA)

The European Computer Integrated Manufacturing Architecture (AMICE) Consortium jointly with the Computer Integrated Manufacturing (CIM) initiative with the European Strategic Program on Research in Information Technology (ESPRIT) project developed the Computer

Integrated Manufacturing Open Systems Architecture (CIMOSA) framework. The main goal of this enterprise architecture reference is to support process-oriented modeling for operations support (Bernus, Laszlo, & Williams, 1996). CIMOSA is a cube comprising the instantiation of building blocks, the generation of views, and the derivation of models, as shown in Figure 19. The instantiation of building blocks encompasses generic, partial, and particular levels. Further, the generation of views embodies the function, information, resource, and organization views. And finally, the derivation of models supports modeling of the whole enterprise life cycle, namely requirements definition, design specification, and implementation description (Kosanke, 1995). CIMOSA has been a major contributor to developing the GERAM work on enterprise reference architectures (Kosanke, Vernadat, & Zelm, 1999) , which is described in Section 2.5.4.

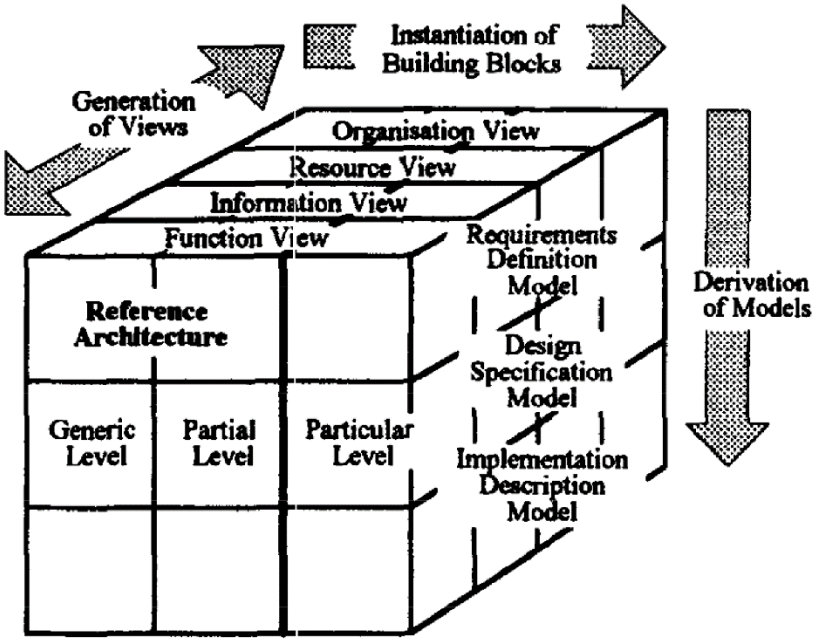

Figure 19. CIMOSA framework (Kosanke, 1995)

2.5.3 GRAI Integrated Methodology (GIM)

The Graphs with Results and Actions Inter-related (GRAI) methodology and its GRAI Integrated Methodology (GIM) was developed in the 1970s at the GRAI Laboratory of the University of Bordeaux, France (Bernus et al., 1996; McCarthy & Menicou, 2002). The GIM approach is based on several PhD research studies and ESPRIT projects (Chen, Vallespir, & Doumeingts, 1997). According to Chen, Vallespir, et al. (1997), the elements of the GIM are as follows:

1) GRAI conceptual model (Figure 20), which is the representation of the basic concepts of a manufacturing system with the information, decision, and physical systems
2) The GIM modeling framework, which includes three dimensions: view points, life cycle, and abstraction level
    a) The four views are information, function, decision, and physical
    b) The life cycle comprises three levels: analysis, user oriented design, and technical oriented design
    c) The abstraction levels are conceptual, structural, and realizational
3) GIM reference architecture
4) GIM modeling formalisms
5) GIM structured approach
6) GIM case tool

The GRAI-GIM method was developed more for a user-oriented design than for a technically-oriented design.

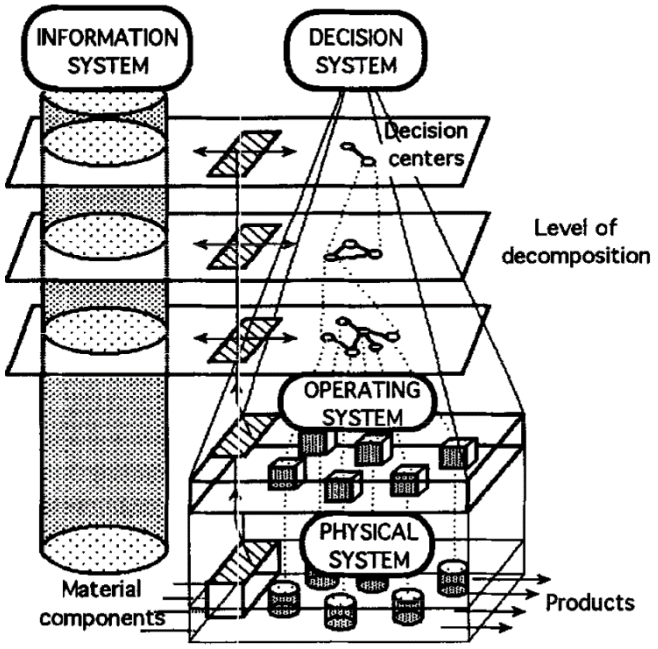

Figure 20. GRAI-GIM conceptual model (Chen, Vallespir, et al., 1997)

2.5.4 Generalized Enterprise Reference Architecture and Methodology (GERAM)

The International Federation of Automatic Control and the International Federation for Information Processing (IFAC/IFIP) Task Force on enterprise reference architectures defined the Generalized Enterprise Reference Architecture and Methodology (GERAM) as a class of complete enterprise architecture systems (Williams & Li, 1997). The generic enterprise reference architecture and methodology includes those models, tools, and methods needed to build an integrated enterprise (Bernus & Nemes, 1996). This framework was developed as the result of an analysis of the major reference architectures: PERA, CIMOSA, GRAI-GIM and TOVE. GERAM encompasses the models, methods, and tools which are needed to build an integrated enterprise (Bernus & Nemes, 1996). According to the standard ISO WD15704 - Requirements for enterprise-reference architectures and methodologies, the GERAM framework components for Enterprise Engineering and Enterprise Integration are the following (IFIP-IFAC, 1999):

- Generic Enterprise Reference Architecture - GERA
- Enterprise Engineering Methodology - EEMs
- Enterprise Modeling Languages - EMLs
- Generic Enterprise Modeling Concepts - GEMCs
- Partial Enterprise Models - PEMs
- Enterprise Engineering Tools - EETs
- Enterprise Models (Particular) - EMs
- Enterprise Operational Systems (Particular) - EOSs
- Enterprise Modules – EMOs

These components are illustrated in Figure 21.

The Generic Enterprise Reference Architecture (GERA) identifies the concepts for enterprise engineering and integration, which can be classified as human; process; or technology-oriented concepts. GERA is based on the life-cycle concept that can be applied to any enterprise entity with three dimensions, namely life-cycle, instantiation, and view dimensions, as depicted in Figure 22.

GERAM expands the concept of enterprise architecture to the life-cycle of products, enterprise integration projects, enterprises, and strategic management. Furthermore, it enables other disciplines such as Concurrent Engineering, Total Quality Management, and Business Process Re-engineering, among other improvement methods, to contribute to enterprise integration (Bernus & Nemes, 1997).

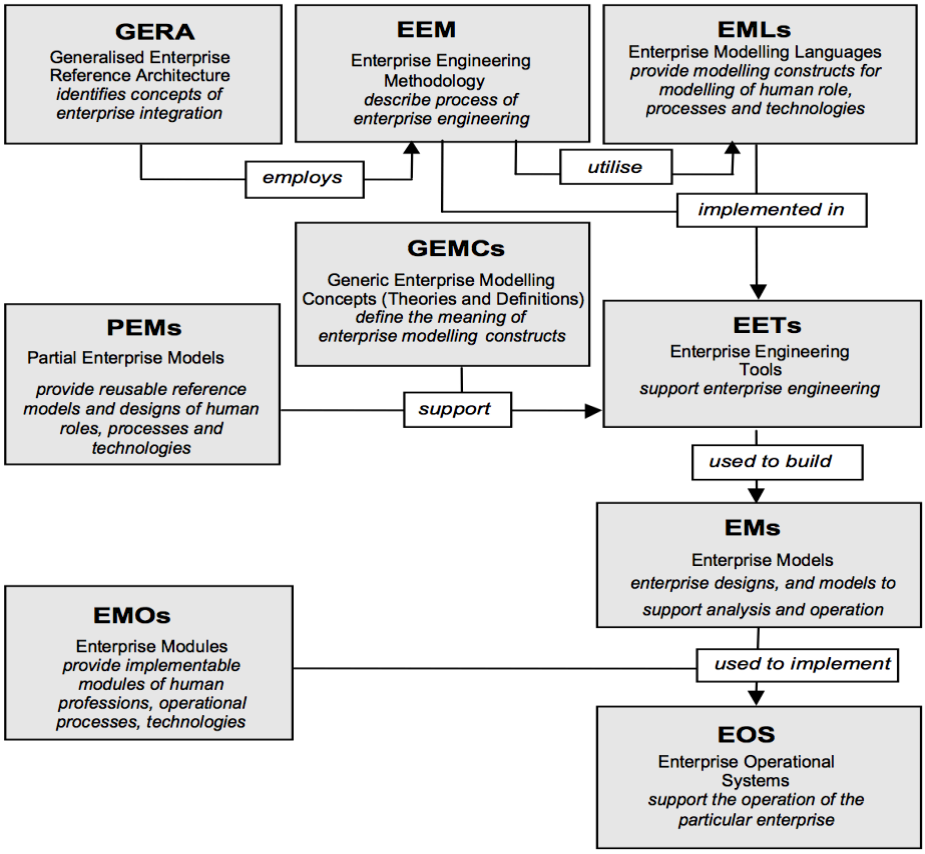

Figure 21. GERAM framework components (IFIP-IFAC, 1999, p. 5)

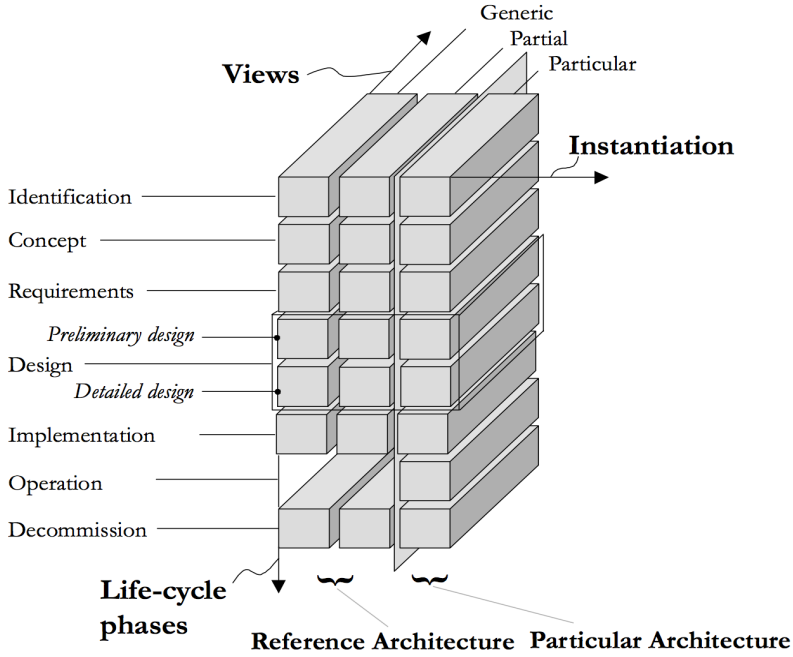

Figure 22. Generic Enterprise Reference Architecture (GERA) (IFIP-IFAC, 1999, p. 18)

2.6 Summary

Basic concepts have been described in this chapter to understand what an enterprise architecture framework is as well as what Lean enterprise transformation implies. Additionally, the origins of Lean, principles and tools that underlie Lean have been considered. Furthermore, several Lean frameworks have been identified and the most important related to this research were selected. These frameworks are categorized as a) descriptive, b) pictorial representation, c) Lean enterprise architecture, and d) diagram frameworks. Moreover, the most important national quality awards-based models for operational excellence have been discussed as well as the main architecture frameworks for enterprise integration. These concepts contribute to the design and understanding of the enterprise architecture framework developed in Chapter 4.

CHAPTER 3: METHODOLOGY

This chapter describes the approach and methodology used to achieve the research goal and the specific objectives of this dissertation, as well as to respond to the research question. Furthermore, it explains the process of testing the proposed framework in a particular product process within a company as a pilot study before it is implemented in the entire firm.

3.1 Research Approach

The proposed methodology for this dissertation is *developmental research* using a *qualitative research design approach* that encompasses *inductive logic* (reasoning) to develop the Enterprise Architecture Framework and *deductive logic* (reasoning) to test it.

Developmental research is frequently related to engineering design and may include the design of a new framework. There are two general approaches to building theory and knowledge, namely deductive and inductive research methods. Deductive research is a *theory testing* process that begins with the generation of a theory or formulation of a hypothesis, which is then tested out through observation of the empirical world. The abstract concepts of the theory or hypothesis are translated into measures that enable the observations to be made. After testing, the next step is decide to reject or accept the theory. If the theory can explain past observations and predict future outcomes it is not rejected (Lancaster, 2005).

Inductive research, on the other hand, is basically the reverse process of the deductive research, and it is a *theory building* process based on observations from the empirical world and aiming to establish generalizations about the study under examination (Hyde, 2000; Lancaster, 2005). All kinds of observed data and information from the real world may be used to develop a theory under inductive research (Lancaster, 2005).

According to Thomas (2006), a systematic method for analyzing qualitative data is the *general inductive analysis approach* and its main purposes are as follows:

a) To shrink extensive and diverse raw text data into a brief summary
b) To determine the relationships between the research objectives and the summary findings
c) To build a model or theory translating experiences or processes from the text data

Thomas (2006) describes the most important principles of the general inductive analysis approach as follows:

a) The data analysis is guided through multiple readings and interpretations of the text data.
b) The main issue in the analysis is the development of categories from the raw data text into a model or framework.
c) The outcomes result from multiple interpretations made from the text data by the analysts who code the data.
d) Different researchers may have results that are not identical.

A holistic understanding of a particular phenomenon such as a Lean enterprise transformation involves the exploration of a large number of factors and the interrelationships and interactions among them. This research approach is useful to identify the main components that support the lean transformation and holistically integrate them into a framework. Inductive

logic is used to explore the field to reveal the elements and variables that are involved, as well as the connections between them.

3.2 Research Methodology

To build the Enterprise Architecture Framework (EAF) of a Lean enterprise transformation (LET), EAF-LET, this research begins by reviewing the literature to identify the core components of a Lean enterprise transformation, as well as possible paths for the implementation and sustainment of the Lean philosophy in a company in order to achieve operational excellence.

The design of the study helped determine the qualitative data categories and identify the core components together with a pattern coding. Journal papers, books, and case studies have been used to obtain the qualitative data and to define the most significant concepts, such as the Lean principles and tools, Lean frameworks, Lean enterprise transformation, and Lean enterprise architectures approaches used in manufacturing companies. The most important architecture frameworks used for enterprise integration and the concepts and tools from Industrial Engineering have been examined, as well as the most important National Quality Awards-based Models for Operational Excellence. Furthermore, the Business Improvement Programs that were reviewed are Total Productive Maintenance (TPM), Lean Six Sigma (LSS), and Total Quality Management (TQM). Moreover, other important concepts from different disciplines useful for this research that have been identified in the literature are Enterprise Transformation, Systems Thinking, Enterprise Modeling and Simulation, Organizational Learning, Organization, Information Technology, Leadership, Strategy, and Key Performance Indicators.

As can be inferred, there is a large number of components to consider and analyze when building the framework. This qualitative data was analyzed using component analysis, tree, affinity, and tree-matrix diagrams. These diagrams helped determine the chief components of a Lean enterprise transformation. These diagrams are four of the seven management tools of quality control (QC), also called the seven new QC tools, which are used for total quality management (TQM). The remaining quality tools are the matrix data analysis, arrow diagrams, and process decision program charts (Nayatani, Eiga, Futami, & Miyagawa, 1994). These tools are used for organizing verbal data diagrammatically and are employed mainly as a mean for generating ideas and formulating plans in the design approach.

The framework has been designed by analyzing the properties of an enterprise system considering the elements of each work area (design via analysis), focusing on process flows and integrating the main components into a whole system (design via synthesis). This process involves envisioning systems thinking towards the company's strategic intent as well as including customer needs, both internal and external, and involving all stakeholders (direct, indirect, and support employees).

Subsequently, the EAF-LET was designed by adapting concepts from the Purdue Enterprise Reference Architecture and other reference architectures, and considering the conceptualization of the chief components. The main components are considered and their interrelations are explicitly shown in Chapter 4. While the framework was being designed, it was tested phase by phase in such a way that changes and adjustments have been done during earlier steps and not at the end of the framework design, as described in Section 3.3. The standard ISO 15704 (Industrial automation systems – Requirements for enterprise reference architectures and methodologies) has been considered, having GERAM as a reference to build the proposed

framework. The methodology for this research has followed a logical, reflective, and iterative process, as shown in Figure 23.

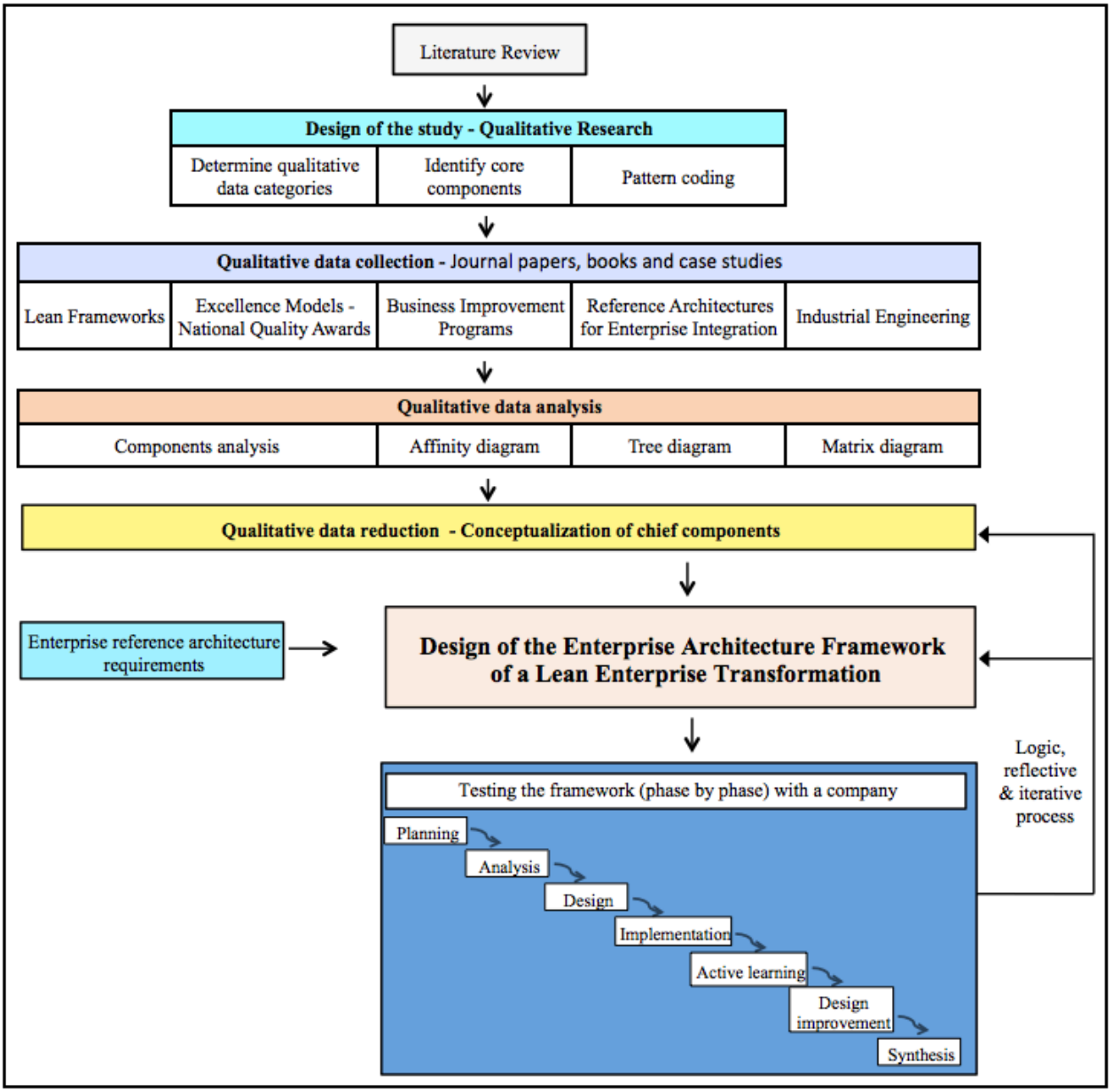

Figure 23. Research Methodology

3.3 Testing the Research

A pilot test using a particular product process within a firm is being used to test the model. Four types of research designs in case studies can be used to address the research question: 1) single-case (holistic) designs, 2) single case (embedded) designs, 3) multiple-case study (holistic) designs, and 4) multiple-case study (embedded) designs. The same single case study can be about a single organization (holistic design) or involve more than one unit of analysis, which are then the embedded units. The holistic design is helpful when the relevant theory of the case study is itself of a holistic nature. One of the challenges is to identify the unit of analysis and the case itself. It is highly recommended that the issues under study in a unit be tested before the study is implemented on a wider scale. This testing helps confirm that the case is relevant to the questions of interest. Therefore, a single case study is justified when it represents a critical case in testing a well-formulated theory. It can represent a meaningful contribution to knowledge and theory- building (Yin, 2009). It can be used to conclude whether the theory's prepositions are correct or whether there are other, more relevant, choices. Thus, this proposed framework is being tested in the process of a product as a pilot test before it is implemented in the entire firm. The pilot test considers the implementation of the components of the framework in the whole life-cycle production process of a product, involving all stakeholders (direct, indirect, and support employees), integrating the main resources, and aligning them to the vision of the company. However, only phases one to four have been tested because of time limitations and company constraints.

The systems development life cycle (SDLC) methodology for building an information system was adopted to test the framework. The SDLC encompasses four phases: planning, analysis, design, and implementation. There are several systems development methodologies,

and they differ in terms of the sequence of these phases (Dennis, Wixom, & Toth, 2008). Some examples of these methodologies are the waterfall development, the rapid application development, and the agile development. Each of the last two methodologies has its own variants that evolved to address the disadvantages of the waterfall methodology.

The four phases of the SDLC methodology were used to test the proposed framework considering additional steps (or phases, but called here "steps" to avoid any confusion with the phases of the framework): 1) Planning, 2) Analysis, 3) Design, 4) Implementation, 5) Active learning from the implementation 6) Design improvement, and 7) Synthesis. All these "steps" are followed within each of the phases of the Lean enterprise transformation, as shown in Figure 23 and Figure 24. This pilot study is an on-going implementation and will be useful for future research.

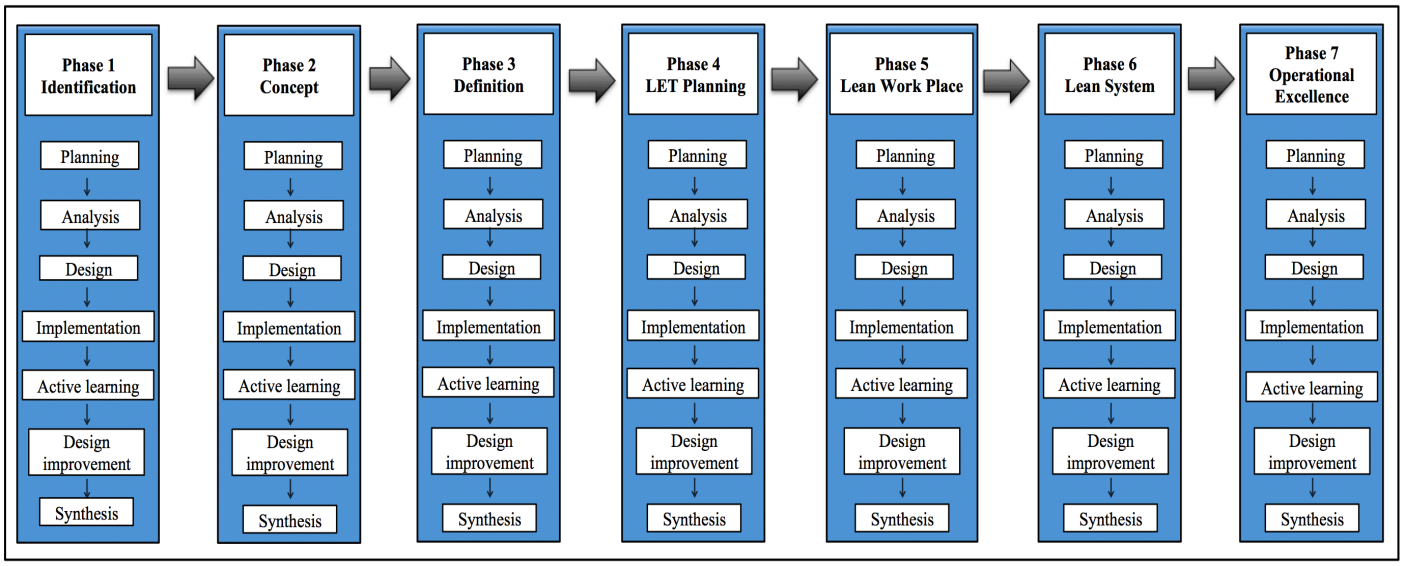

Figure 24. Process of testing the framework phase by phase with a company

CHAPTER 4: DESIGNING THE ENTERPRISE ARCHITECTURE FRAMEWORK OF A LEAN ENTERPRISE TRANSFORMATION

This chapter describes the approach used to design the enterprise architecture framework of a Lean Enterprise Transformation (LET), as well as the logic used to identify the chief components and its categorization. The chapter is divided in six parts: (1) identification of the chief components, (2) the logic underpinning the design of the framework, (3) designing the framework, (4) adapting concepts from the Purdue Enterprise Reference Architecture, (5) determining the chief components and groups of each layer, and (6) reducing the complexity of the Lean enterprise transformation.

4.1 Identification of chief components

Several Lean frameworks and the most well known excellence models that are recognized by the quality national awards were examined in Chapter 2. As can be inferred from the literature review, a large number of components are included in different frameworks and those components are represented in very different ways. Even though all of those frameworks and components were considered and analyzed when building the framework, not all of the components found in the literature can be adopted in the proposed framework because of their vast number and lack of consistency. Furthermore, components of a particular framework cannot be used in a piecemeal fashion because they may not make sense in a different context.

Therefore, for the purpose of analysis and component identification, the total set of components was divided into two subsets, i.e. the principles and the components, as explained in the next two sections.

4.1.1 Lean Principles Identification

To have a good understanding about the Lean principles addressed in previous research, a comparative analysis of existing frameworks is presented so the categories found are easily identifiable. A matrix was developed for the analysis as shown in Table 9, which contains the Lean principles under different frameworks and the researchers who determined them. Moreover, the matrix comprises the frequency of occurrence of each principle as well as its weight (frequency of the principle divided by the total number of principles). Based on all frameworks discussed in the literature review, 63 principles were identified. After the comparative analysis of each principle, 17 of the principles were similar among the frameworks. Therefore, 46 principles were different, and among those 46, only 13 occur more than once. As a result, there is still a large number of principles among the remaining ones that few frameworks share.

The approach to selecting the chief principles for the Lean enterprise transformation was based on the comparative analysis followed by developing an affinity diagram. The affinity diagram is one of the seven management tools of quality control (QC) described in Section 3.2. It is used when issues are too large and complex to grasp (Tague, 2005). It is helpful to organize a large number of ideas that are related in some way. Thus, this diagram was utilized in order to gather the Lean principles into affinity clusters, organizing them according to common relationships as shown in Figures 25 and 26.

	Lean Principles	Authors who determined Lean principles						
		Womack & Jones (2003)	Liker (2004)	Anand & Kodali (2010)	Nightingale & Srinivasan (2011)	USU (2010)	Frequency	Weight
1	Specify value accurately by specific product	1					1	0.02
2	Identify the value stream for each product (Focus on value stream)	1				1	2	0.03
3	Make value flow without interruptions	1	1				2	0.03
4	Let the customer pull value from the producer (Flow & pull value)	1	1	1		1	4	0.06
5	Pursue perfection	1		1		1	3	0.05
6	Long-term philosophy (Focus on long term)		1			1	2	0.03
7	Level out the workload		1				1	0.02
8	Build a culture to get quality right the first time (Assure quality at the source)		1			1	2	0.03
9	Standardized tasks		1				1	0.02
10	Use visual control so no problem is hidden (Keep it simple & visual)		1	1		1	3	0.05
11	Use only reliable technology		1				1	0.02
12	Grow leaders with the lean management philosophy		1				1	0.02
13	Develop exceptional people and teams		1			1	2	0.03
14	Respect the extended network of partners & suppliers		1	1			2	0.03
15	Go and see yourself to thoroughly understand the situation (Insist on direct observation)		1			1	2	0.03
16	Make decisions slowly by consensus, implement decisions rapidly		1				1	0.02
17	Become a learning organization through reflection & continuous improvement		1	1			2	0.03
18	Identify and eliminate waste			1		1	2	0.03
19	Respect to humanity (Respect every individual)			1		1	2	0.03
20	Customer focus			1			1	0.02
21	Adopt a holistic approach to enterprise transformation				1		1	0.02
22	Secure leadership commitment to drive enterprise behaviors				1		1	0.02
23	Identify relevant stakeholders & determine their value propositions				1		1	0.02
24	Focus on enterprise effectivenes before efficiency				1		1	0.02
25	Address internal & external enterprise interdependencies				1		1	0.02
26	Ensure stability & flow within & across the enterprise				1		1	0.02
27	Emphasize organizational learning				1		1	0.02
28	Lead with humility					1	1	0.02
29	Nurture long term relationships					1	1	0.02
30	Empower & involve everyone					1	1	0.02
31	Assure a safe environment					1	1	0.02
32	Focus on process					1	1	0.02
33	Embrace scientific thinking					1	1	0.02
34	Stabilize processes					1	1	0.02
35	Rely on data					1	1	0.02
36	Standardize processes					1	1	0.02
37	Integrate improvement with work					1	1	0.02
38	Create constancy of purpose					1	1	0.02
39	Think systematically					1	1	0.02
40	See reality					1	1	0.02
41	Align systems					1	1	0.02
42	Align strategy					1	1	0.02
43	Create value for the customer					1	1	0.02
44	Measure what matters					1	1	0.02
45	Align behaviors with performance					1	1	0.02
46	Identify cause & effect relationships					1	1	0.02
	Number of principles	5	14	8	7	29	63	1

Table 9. Comparative analysis of existing Lean frameworks to identify the Lean principles

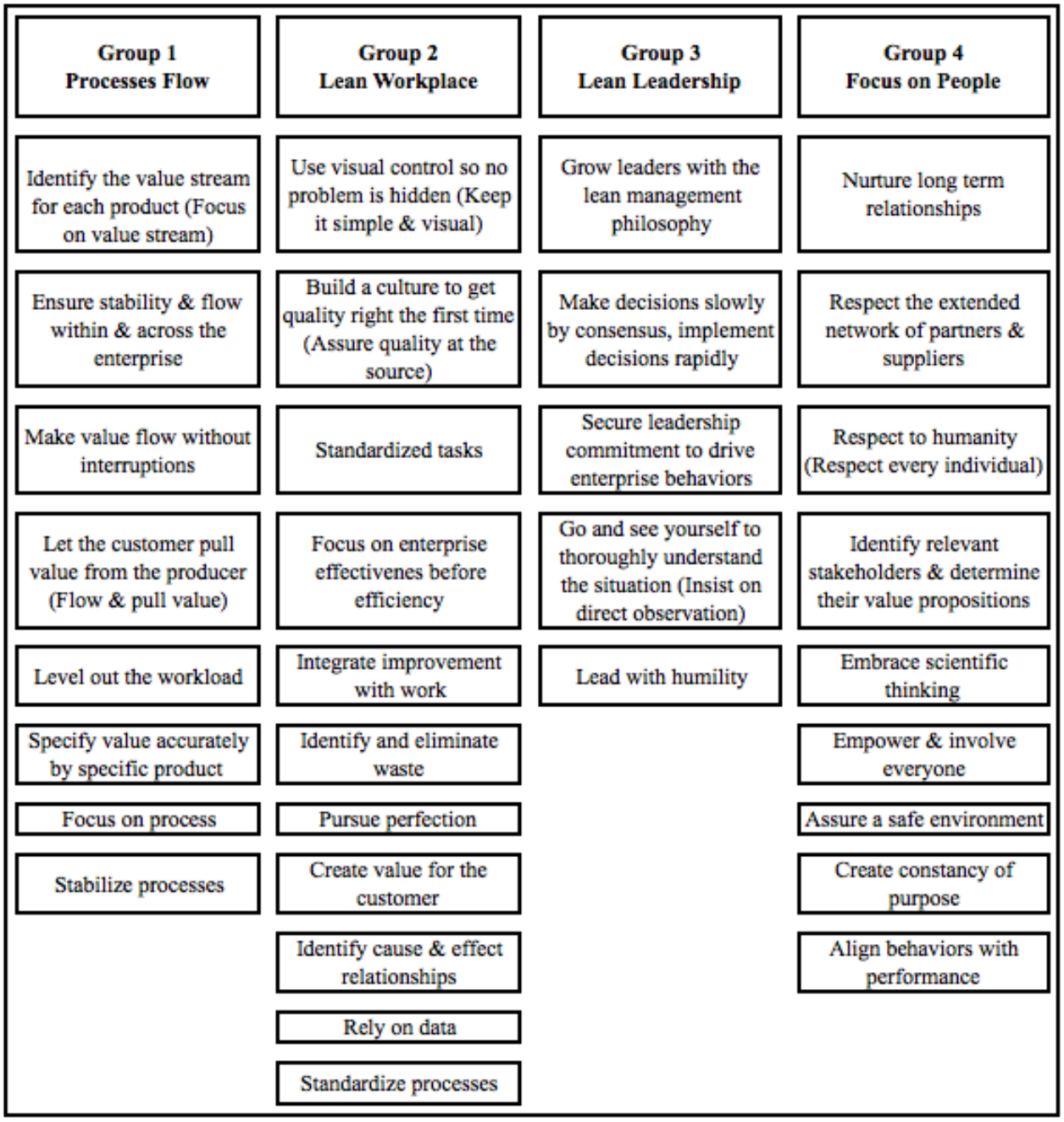

Figure 25. Affinity clusters of Lean principles - Groups 1 to 4

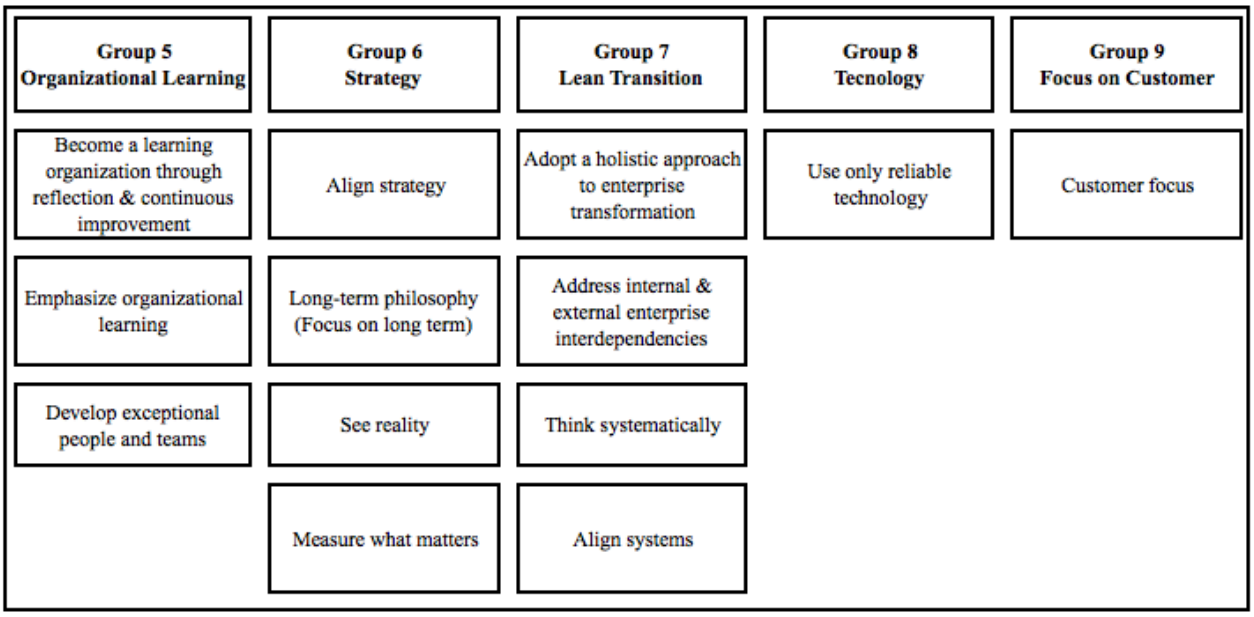

Figure 26. Affinity clusters of Lean principles – Groups 5 to 9

The most representative principle from each group was selected or a new statement was created to represent each affinity cluster. These groups are:

Group 1 - Processes Flow

- Focus on streamlining processes through the identification of constraints, elimination of waste, reduction of complexity and variability sources, and increasing flexibility

Group 2 - Lean Workplace

- Create and stabilize Lean workplaces throughout the value stream

Group 3 - Lean Leadership

- Develop a Lean management infrastructure
- Secure CEO and senior managers' involvement, commitment, and Lean leadership

Group 4 - Focus on People

- Respect people, suppliers, and partners
- Involve internal and external stakeholders that are related to the value stream

Group 5 - Organizational Learning

- Emphasize organizational learning

Group 6 - Strategy

- Develop a Lean strategy monitoring the key performance indicators

Group 7 - Lean Transition

- Plan the Lean transition embracing a holistic approach to integrating and aligning the enterprise resources towards the strategic intent of the company

Group 8 - Technology

- Use the right technology

Group 9 - Focus on Customer

- Focus on customer

4.1.2 Identification of Chief Components

The chief components were identified using the same process as that for the Lean principles, based on the comparative analysis of existing frameworks followed by developing an affinity diagram. Additionally, the logic underpinning the framework as well as the design of the Enterprise Architecture Framework is described in Sections 4.2 and 4.3, respectively. The determination of the chief components and their related groups is developed in Section 4.5. Based on the Lean frameworks and the most relevant excellence models recognized by the national quality awards reviewed in the literature review, 645 components were identified in total as shown in Appendix B. After the comparative analysis of each component, only 49 were similar among the frameworks.

After identifying similar components among all the frameworks through the comparative analysis, affinity diagrams were used to select the chief components by organizing them according to common relationships as shown in Table 10. However, given the large number of components and the complexity of grouping similar components into clusters, this step was completed after understanding the enterprise system described in Section 4.2 and after the layers categorization as described in Section 4.3. Once the layer categories were defined, the components were clustered into each category.

The layer categories are (1) Data, Information, and Knowledge Management, (2) Industrial Engineering, (3) External Environment, (4) Process Flow, (5) Lean and Business Improvement Programs, (6) Lean Management Infrastructure, (7) Technology, (8) Organization, (9) Facilities, (10) People, (11) Organizational Learning, (12) Strategy, and (13) Lean Enterprise Transformation. Appendix C shows the comparative analysis of existing frameworks used to identify the Lean components. Given that the weight of each component is very low, the components cannot be selected using this analysis. As a result, a large number of components still remain (596)

Processes Flow	
Flow analysis Design for flow Create flow Supply for flow Distribute for flow Maintain flow Administrative & office flow Production sequence Activities covering the whole life cycle	Flow
Process Processes are systematically designed & managed Processes are improved, as needed, using innovation in order to fully satisfy & generate increasing value for customers & other stakeholders Develop capable processes Develop flexible processes Focus on critical processes Benchmarking processes Business & management processes	Processes
Organization	
Organization & culture development Culture / social & organizational Cultural readiness Organzational environment Culture for C.I. & innovation Cultural enablers Union partnership including collaborative work arrangements Long term employment	Organizational culture
Flat organization structure Organize for flow Align organization with flow Organizational profile Organizational description Organizational powers Organizational structure and its operations Strategic decision level (CEO / President) Tactical decision level (Managers) Operational decision level - Engineers, supervisor Operational decision level - Shop floor associates	Organizational structure
Governance system Legal and ethical behavior Systems to develop and sustain ethical behavior Legal and regulatory behavior	Organizational governance
Stakeholders focus	Stakeholders focus

Table 10. Similar components grouped into clusters

External Environment	
Voice of the customer Customer listening Listening to current customers Listening to potential customers Determination of customer satisfaction and engagement Satisfaction and engagement Satisfaction relative to competitors Dissatisfaction Customer engagement Product offerings and customer support Product offerings Customer support Customer segmentation Customer data use Building customer relationships Relationship management Complaint management Understand customer value Customer relationships are managed & enhanced Customer-facing process Customer relations Customers and stakeholders Customer data Customer engagement	Customer focus
Supplier involvement in design Sole sourcing or supplier reduction Long term supplier relationship Supplier proximity Supplier training & development Quality certification (suppliers & self) Suppliers Integration of the company and its suppliers Respect for suppliers Commitment to supplier development Involve suppliers & customers in product / service design	Supplier relations
Distribution and transport alliances Suppliers and partners External partnerships are managed Social relations Shareholder relations Governance and societal responsibilities Societal responsibilities and support of key communities Societal well-being Community support Partnerships & Resources Governance Law and regulation Society Employee relations People & the organization have a dialogue Regulatory requirements Relationship balancing	Organizational relationships

Table 10. Similar components grouped into clusters (continued)

People	
Respect for people's dignity / Respect for humanity Human resource planning People resources are planned, managed & improved People (Lean knowledge)	People
Selection Common goals Cross-functional teams People & teamwork- Cross trained	People & teamwork
Sharing problems and exchanging ideas	Ringi decision making
Multi skills workers Job rotation or flexible job responsibilities Job enlargement Job rotation	Multi-skilled workforce
Personnel commitment to eliminate the waste Commitment / employees & management	Human aspects / attitude, motivation,
People are rewarded, recognized & cared for Alignment of job descriptions and compensation to excellence	Rewards & recognition
Employee empowerment Employee participation Workforce engagement Elements of engagement Assessment of workforce engagement Assessment of engagement	People are involved & empowered
Employee suggestions and improvement activities	Suggestion schemes
Workforce profile Workforce focus / Employee focus / Workers Workforce environment Workforce capability and capacity Work accomplishment Workforce climate Workforce policies and benefits Capability and capacity Workforce performance Workforce change management Workforce capability and capacity Workforce development Workforce climate Workforce engagement New workforce members	Workforce focus
Positioning of people in management Workforce plans Clearly communicated hiring and promotion standards Recruitment and succession planning system	Career progression

Table 10. Similar components grouped into clusters (continued)

Lean Management Infrastructure	
Leadership/ managers & executives / Senior leadership /Top management leadership Leadership by all managers Top management leadership Role of senior management Leadership Leaders develop the mission, vision & values and are role models of a culture of excellence Leaders are personally involved in ensuring the organization's management system is developed, implemented & continuously improved Leaders are involved with customers, partners & representatives of society Leaders motivate, support & recognize the organization's people Management Genchi Genbutsu - Emphasis on direct observation (go and see) On-the-job coaching	Leadership
Cross-functional management and its operations Management Process management Change management Daily management Management systems for business elements Cost management Environmental management Creating a sustainable organization	Lean manufacturing implementation management
Ethical behavior Ethics	Promoting legal and ethical behavior
Organizational Learning	
Learning capacity Structured education programs Specific training philosophy similar to Training Within Industry	Learning and development system
Workforce and leader development Education and training Learning and development effectiveness Individual development plans Education, awareness, and practices aimed at employee health and wellness Provide education & training Scientific thinking as a philosophy Training Multi-functional training People & teamwork- Cross trained Learning from C.I. results Cross-training program Develop people to support flow People's knowledge & competencies are identified, developed & sustained	Human resource development

Table 10. Similar components grouped into clusters (continued)

Lean Manufacturing	
Standard work 5S The use of standardized work procedures Eliminate muda Workplace organization Stable and standardized processes Waste reduction - 5 Why's - Eyes for waste - Problem solving (Problem solving tools) Jidoka - Automatic stops (Automation) - Andon - Person-machine separation - Error proofing (Mistake proofing - Pokayoke) - In-station quality control (Defect at source) - Solve root cause of problems Zero defects through Poka-yoke -Self controlling Stabilization Production Process Preparation (3P)	Stability
Use of flexible machines - Layout change or U shaped cell - Successive checking - Work standardization - Cellular design - Best Lean / cellular practices Cellular layout	Cellular manufacuring
Visual workplace, visual displays Visual devices and systems A3 Thinking	Visual management
Takt time planning Continuous flow Integrated logistics Small lot production Pull production One piece flow - Cycle time & lead time reduction - Standardized containers - Elimination of buffers - WIP reduction - Storage space reduction - Synchronization Factors facilitating JIT JIT implementation - Continuous flow Kanban Automatic guided vehicle - Pull system Takt time Pace maker One piece flow Fifo Line Supermarket Fit for use of pulling Align production with demand Manage the inventory Organize material flow by pull Continuous flow and eliminating waste in the entire enterprise Flow and Pull Time-based or just-in-time manufacturing	Just-in-time

Table 10. Similar components grouped into clusters (continued)

Lean Manufacturing	
Hoshin Kanri Value Stream Mapping VSM "door to door" sample (current & future) Implementing based on future VSM Compress lead time Products & services are produced, delivered & serviced	Lean deployment
Focus on continuous improvement by Lean learning, Lean thinking and Lean enterprise self assessment tool - Tools for standardization, communication & problem solving Performance improvement systems - Standard work / Standard operating procedures (SOP's) - Continuous improvement - Continuously improve Kaizen and breakthrough improvement Continuous improvement and innovation Integration of C.I. activities Kaizen Innovation Lean practices Standardize best practices Commonolization & standardization of parts Toyota way philosophy Product & process simplification Lean principles Performance improvement	Continuous process improvement
SMED- Quick changeover or setup reductions (Single minute exchange of dies - Quick Setup Time) Multi skills workers Level production (heijunka) Production smoothing (load leveling) Flexible work systems (group technology & cellular manufacturing)	Flexibility
Technology	
Core technology New process or equipment technologies Computer integrated manufacturing Hardware and software properties Technology is managed Information technology development IT leveraging & knowledge capability	Group technology

Table 10. Similar components grouped into clusters (continued)

Industrial Engineering	
Quality function deployment, concurrent engineering for product development Concurrent engineering Design for manufacturing Product analysis New product and new technology development Value Analysis Design concepts Products & services are designed & developed based on customer needs & expectations Variety reduction	Product / service development
Mixed model manufacturing / scheduling Rolling production plan Production volume Planning & control Maintain spare capacity	Tools for understanding demand & capacity, material planning & scheduling
Distribute work intellegently and efficiently or level-loading	Workload or line balancing
Job-shop, flow-shop Flow-shop Operations Work process design -Design concepts -Work system requirements Work system management Operation focus Work system design Work systems Work process requirements Work process management -Supply-chain management -Key work process implementation -Process improvement Work system implementation	Work processes
Rough scale simulation	Simulation
Quality/delivery management Process control Statistical process control Quality circles Tools of quality Six-sigma, statistical process control, design of experiments Test, quality evaluation and quality audits Purchasing, subcontracting and distribution management	Quality assurance system
Emergency readiness Emergency preparedness Proactive systems to maintain an ergonomic, clean, and safe work environment Safety, hygiene and work environmental management Initiatives regarding environmental issues Safety improvement programs	Scope of environmental, health, and safety efforts

Table 10. Similar components grouped into clusters (continued)

Business Improvement Programs	
TQM frameworks Relationships to other management improvement programs Relationships to ISO 9000 and ISO 14000 TQM promotion and operation TQM concepts and values Total quality management Quality Scientific methods Understanding and utilization of methods Understanding and utilization of problem-solving methods Assessment system to check reality TQM features (shining example) Quality management system	TQM
Total productive, preventive, or predicive maintenance -TPM	Total productive maintenance

Data, Information and Knowledge Management	
Data, information, and knowledge management Data availability Use of electronic data interchange with suppliers Data-based decisions and actions Comparative data	Data
Information systems Simple and visual information systems Information sharing with suppliers Positioning of information in management Data and information availability Emergency availability Effective utilization of information Support for analysis and decision making Properties Management of information, knowledge, and information technology Management of information resources and technology	Information
The use of knowledge management systems & ideas sharing Process sharing Best practice sharing Standardization and configuration management Lean knowledge Information & knowledge are managed Knowledge management Measurement, analysis, and knowledge management Formal systems for capturing & transferring lessons learned	Knowledge Management

Table 10. Similar components grouped into clusters (continued)

Lean Enterprise Transition Management	
Focus on the value stream - Map value stream Future Value Stream (Value stream reinvention) - Internalize vision - Set goals and metrics - Identify and involve key stakeholders	Focus on specific pilot
Organize for Lean implementation Identify and empower change agents Develop Lean structure & behavior Change agent Align incentives Adapt structure and systems Lean promotion office (Lean knowledge) Lean experts (Lean knowledge)	Develop a Lean structure
Initial investigation Create & refine transformation plan Identify & prioritize activities Commit resources Preparation Procedure redesign Determine: value, product family, procedures, metrics, feedback system &VSM managers Maintenance and improvement Communication between employees Monitoring Engineering change management Action plan implementation Action plan modification Change environment Conceptual design Preliminary design Detailed design Implementation Implement Lean initiatives - Develop detailed plans - Implement Lean activities - Outcomes on enterprise metrics Performance management Enterprise redesign Operation Drivers Enablers Alignment and integration of administration functions Correlation with business results Theory of constraints - managing bottlenecks Manage the constraint Communication Focus on action Trade-off analysis Benchmarking Focus on continuous improvements - Monitor Lean progress - Nurture the process - Refine the plan - Capture & adopt new knowledge	Scope of transformation
Toward perfection Tools for availability improvement & variability reduction Surface root causes of problems Reduce variation, mistakes, complexity Sustain operations	Perfection
VSM "door to door" for all products (current & future) Implementing Lean "door to door" value streams Spread Lean to the office Spread Lean to the whole value stream / suppliers & customers	Expand to the whole system

Table 10. Similar components grouped into clusters (continued)

Strategy	
Strategic development Strategic planning process Strategy considerations Strategic objectives Key strategic objectives Strategic objective considerations Strategy implementation Values Mission Enterprise strategic planning / Strategic initiatives / Strategies Competitive strategic advantage Create vision & guide flow	Strategic context
Policy management Policy & strategy are based on the present & future needs & expectations of stakeholders Policy & strategy are based on information from performance measurement, research, learning and creativity related activities Policy & strategy are developed, reviewed & updated Policy & strategy are deployed through a framework of key processes Policy & strategy are communicated & implemented A planning system for establishing and deploying the strategy A system to align tools, systems, and principles to values, mission, vision Contribution to realization of corporate objectives Enterprise alignment Realization of corporate mission A system for aligning objectives and projects	Policy & Strategy
Customer-focused results Customer-focused product and process results Customer-focused outcomes Customer satisfaction	Customer Results
Strategy implementation results Team results Individual results Measures & accounts for flow Lean manufacturing outcome Organizational results Workforce results People Results Leadership & governance outcomes Financial and market results Leadership, governance & societal responsibility results	Results
Competitive environment Comparative data Competitive position Competitiveness changes	Organizational situation
Existing/predicting crisis Adopt Lean paradigm - Build vision / Vision / Organizational vision and strategies - Convey urgency - Foster Lean learning - Make the commitment - Obtain senior management buy-in / - Make-buy	Decision to pursue enterprise transformation
Organizational structure (Analyze the whole system) Resources (Analyze the whole system) Limitation & delimitation (Analyze the whole system) Global environment Foundation Need Organization as an open system	Analysis the whole system

Table 10. Similar components grouped into clusters (continued)

Strategy	
Tools for defining measures linked to the overall company goal Balance Scorecard Action plan development Focused factory production Resource allocation	Action plan development and deployment
Financial performance Financial and market outcomes A financial reporting system embraces Lean accounting practices Flow accounting for financial information A system for creating reporting requirements Common management & reporting systems across the enterprise Continuously securing profits Assets Cost control	Finances are managed
Perception measures Key Performance Results Key performance outcomes Key performance indicators Performance evaluation Measurement performance, based on : indicators & maturity matrix Performance indicators Quality: finished product first-pass yield, rework, unplanned scrap, rate, overall cost of quality, process variation measures Cost / productivity: labor productivity, asset productivity, inventory, turns, materials, energy productivity, resource utilization Delivery: total lead time, on-time delivery, time from supplier to receipt of materials, miss-shipments, reorder rate, system availability Customer satisfaction: internal & external, lead time, flexibility, synchronized processes, customer audits, surveys & awards Morale; employee survey, participation in activities, number of ideas per employee, grievances, referrals for work Performance measures Performance measurement Performance projections Future performance Measurement, analysis, and improvement of organizational performance Measurement agility Performance analysis and review Product and process outcomes Operational process effectiveness results Operational effectiveness A business assessment system that evaluates performance Product and process outcomes Marketplace performance Society Results Communication and organizational performance Communication of the measurement system Operational process effectiveness results Operational effectiveness Results - Best quality - Lowest cost - Shortest lead time - Best safety - High morale Measurement & feedback	Performance indicators

Table 10. Similar components grouped into clusters (continued)

The logic underpinning the design of the Enterprise Architecture Framework is discussed in the Sections 4.2 and 4.3. In Section 4.4, the chief components and their related groups that are necessary for the design of the Enterprise Architecture Framework are described.

4.2 Logic Underpinning the Design of the Enterprise Architecture Framework

To design the framework for this research in a holistic way, it was important to grasp a systems thinking approach with the aim of synthesizing separate components into a coherent whole. Therefore, it is necessary to comprehend the core concept of enterprise. To understand the enterprise as a whole requires developing a generic model. A basic value stream map was drawn to describe the dynamics of the production flow. Moreover, the structure of the workplace was represented by showing its main components. This model represents at a conceptual level the central components that constitute the enterprise system and the relationships among these components. The generic enterprise architecture from Rood (1994), which was reviewed in Section 2.4, was adapted to develop the generic enterprise model shown in Figure 27.

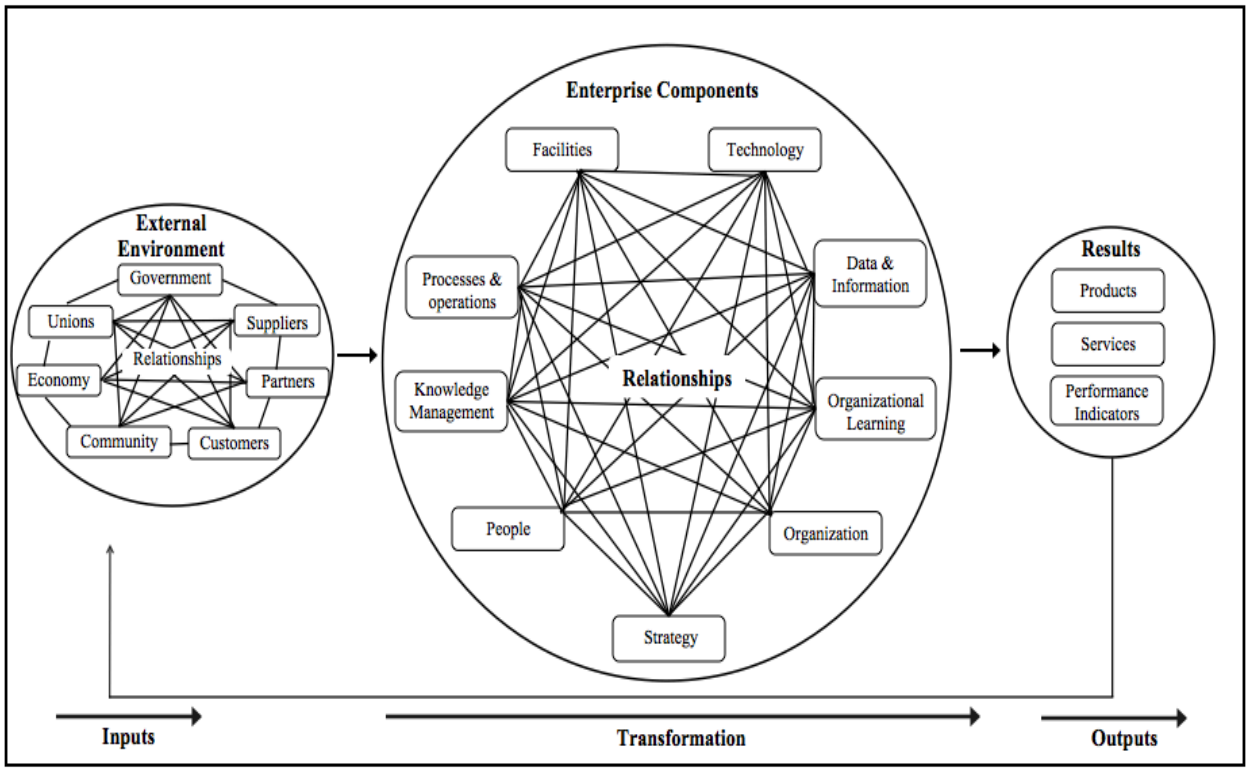

Figure 27. Generic enterprise model adapted from Rood (1994)

An enterprise is a complex system that embodies interrelated and interdependent components: processes, facilities, technology, data and information, knowledge management, people, organizational learning, and organization. These components must be designed based on the strategic intent of the company. The enterprise as a whole is bounded by an external environment, where it acquires different types of inputs and provides outputs. The external environment encompasses factors outside the enterprise boundaries, namely suppliers, customers, partners, government, community, economy, and politics. The enterprise components transform the inputs into outputs in the form of products, services, and performance indicators and send them back to the external environment.

A value stream map in its simple form was drawn to understand the dynamics of the process as shown in Figure 28. A value stream is all value-added and non-value-added activities required to bring a product through the main flows essential to every product. It encompasses the

production flow from customer demand back through raw material, which is the flow that usually relates to Lean manufacturing (Rother & Shook, 2003). It is useful to understand the dynamics of the enterprise processes and not just individual processes, with the aim of improving the whole and not just the parts.

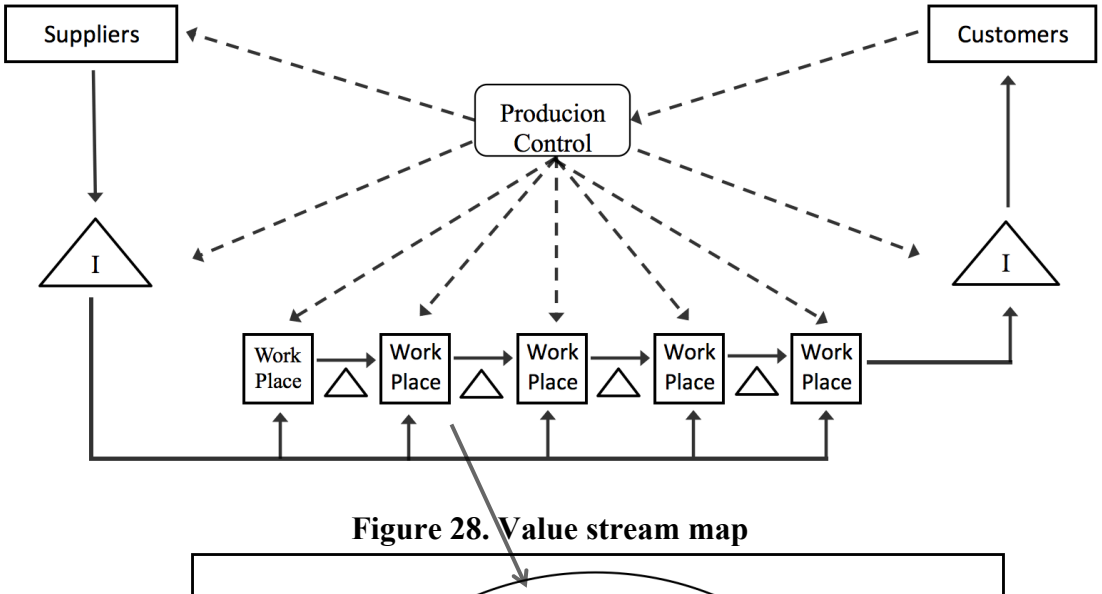

Figure 28. Value stream map

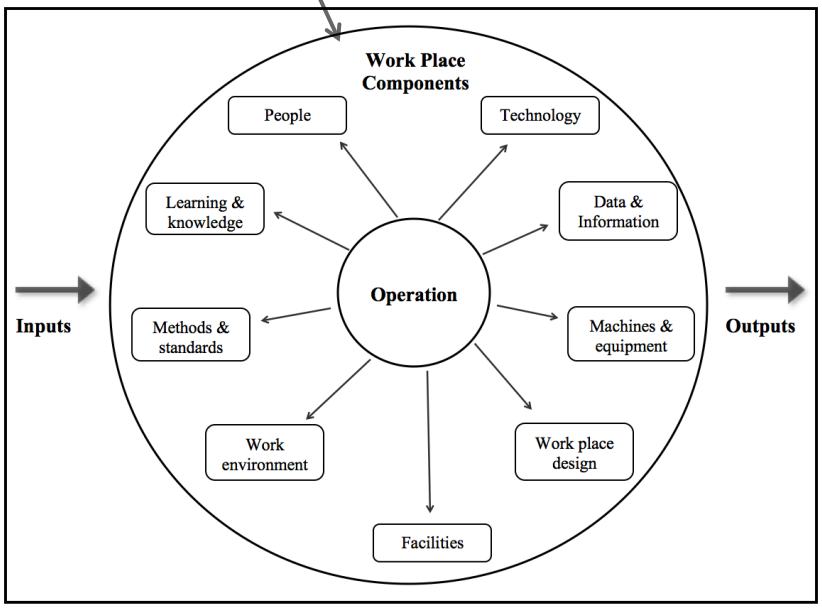

Figure 29. Structure of the work place with the main components

Considering the generic model of the enterprise and the value stream map described in the previous paragraph it can be assumed that an enterprise is a network of processes and a process is a network of operations. Therefore, it is relevant to have a good understanding about the workplace where the operations are fulfilled as well as the main components that are integrated in the work place to accomplish the operation. Moreover, it is important to be aware of the interconnections among the components as well as to identify the relationships among them. Having the right workplace components, as well as good synchronization among them, allows for efficient execution of the operations. Given the aforementioned, in addition to the generic model of the enterprise and the value stream map, it is relevant to understand the main components that integrate the structure of the work place, as shown in Figure 29. Therefore, the logic underpinning the design of the enterprise architecture framework is based on the generic enterprise model, the dynamics of the enterprise system, and the structure of the work place, including its main components.

4.3 Designing the Framework

This section describes how to design a holistic and integrated framework for a Lean enterprise transformation. This design involves using an analytical, logical, and systematic approach, based on a three-dimensional thinking scheme, instead of using two-dimensional thinking. The framework design is based on three dimensions: framework layers (y-axis), layer groups (z-axis), and group components (x-axis), as shown in Figure 30.

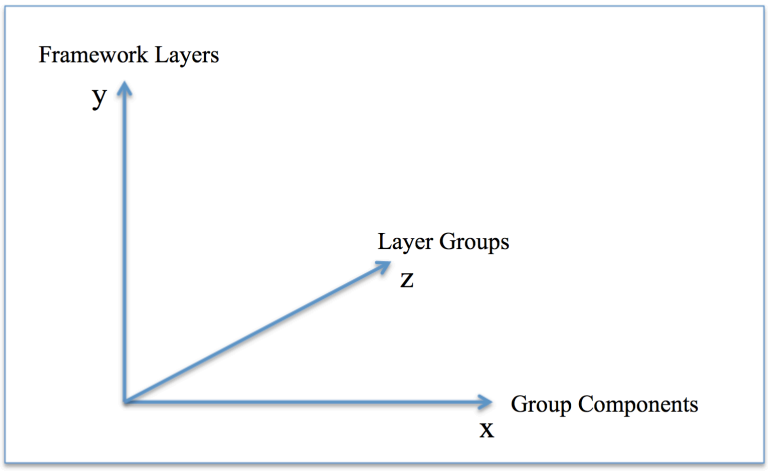

Figure 30. Framework composition in three dimensional views

The framework is based on a multi-representational description of the Lean enterprise transformation. It comprises layers, which represent the enterprise views. According to Vernadat (1996, p. 39) "An enterprise (or modeling) view is a selective perception of an enterprise that emphasizes some particular aspects and disregards others." Vernadat states that a modeling view defines a viewpoint from which the enterprise is considered for a given purpose, focusing only on the most relevant aspects in order to reduce complexity.

The framework is composed of layers, which represent the viewpoints of the enterprise as described in the generic enterprise model as well as other viewpoints of the Lean transformation. The framework has eleven layers, as shown in Figure 31. The layers (viewpoints of the enterprise) have to be integrated and aligned to work together in each phase of the Lean transformation to achieve good results. Each layer is divided into groups and each group is broken down into components of the same category as is explained in detail below.

The enterprise was analyzed as a whole from a high level viewpoint in order to define the framework layers. The layers were defined in a holistic way by synthesizing the enterprise into its main components as described in the generic enterprise model. Furthermore, a value stream

representation was used in order to understand the components that are related to the dynamics of the enterprise system. Moreover, the main components that are related to the structure of the workplace were considered. As a result of the enterprise analysis, the layers were defined as the Strategy, the Processes Flow, the Organization and External Environment (which combines the Organization and External Environment layers mentioned in Section 4.1.2), the People, Organizational Learning, Facilities, Technology, Data – Information, and Knowledge Management. In addition to the viewpoints of the enterprise mentioned above, other views have been considered for the accomplishment of the Lean transformation. They include the Lean Enterprise Transition Management, the Lean Management Infrastructure, and Lean, Industrial Engineering (IE), and Business Improvement Programs (BIP) (which combines the Lean, IE, and BIP layers in Section 4.1.2), as shown in Figure 31.

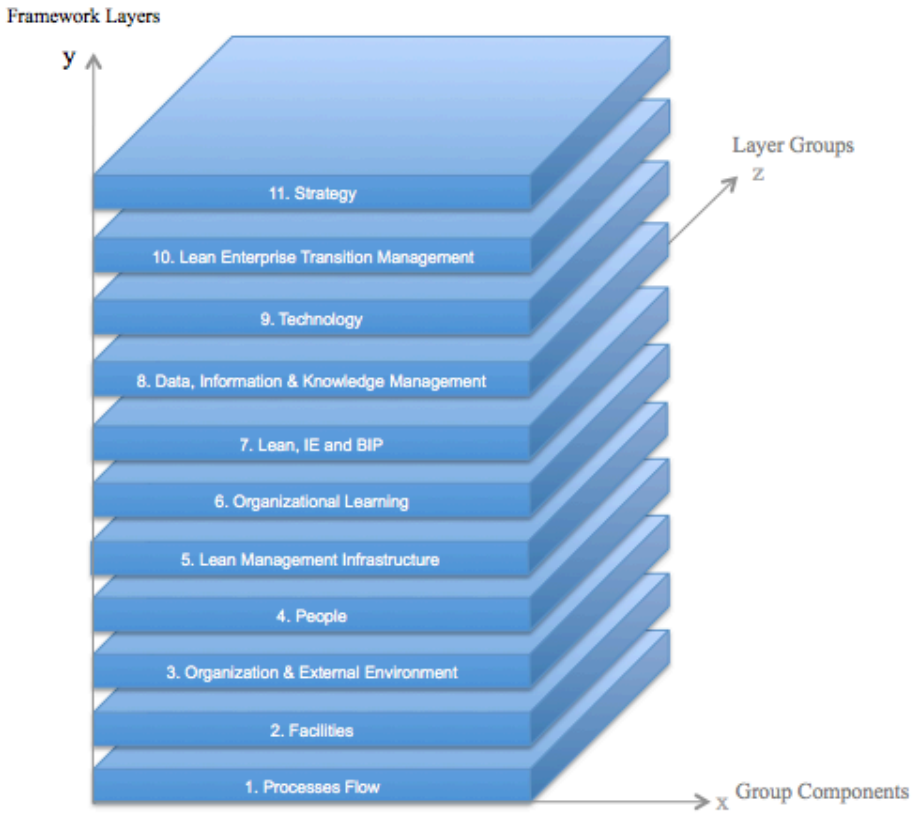

Figure 31. Enterprise Architecture Framework of a Lean Enterprise Transformation

Each of the framework layers shown in Figure 31 is divided into groups, as shown in Figure 32. Each group, in turn may be divided into subgroups, as shown in Figure 33.

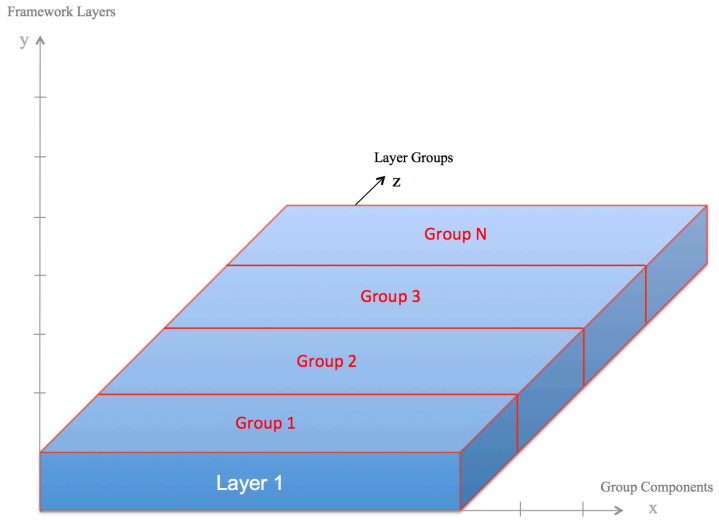

Figure 32. Layer Groups

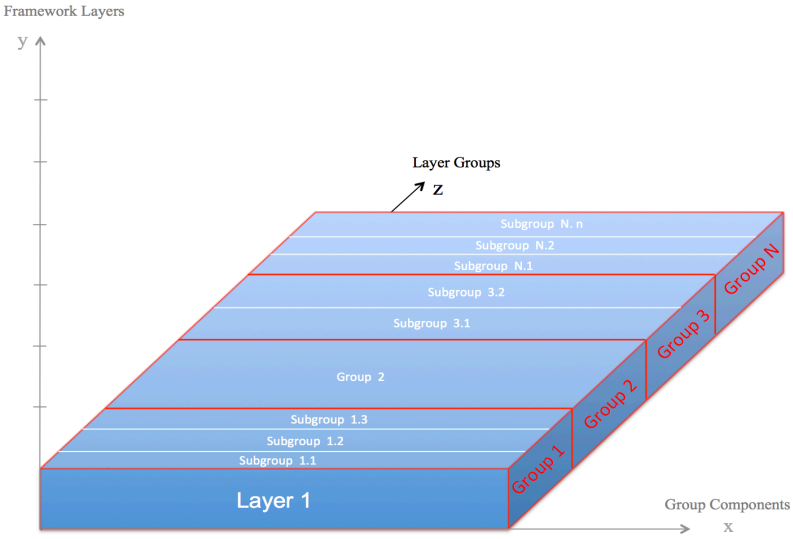

Figure 33. Layer Sub-Groups

Furthermore, each group or subgroup is divided into components, as presented in Figure 34.

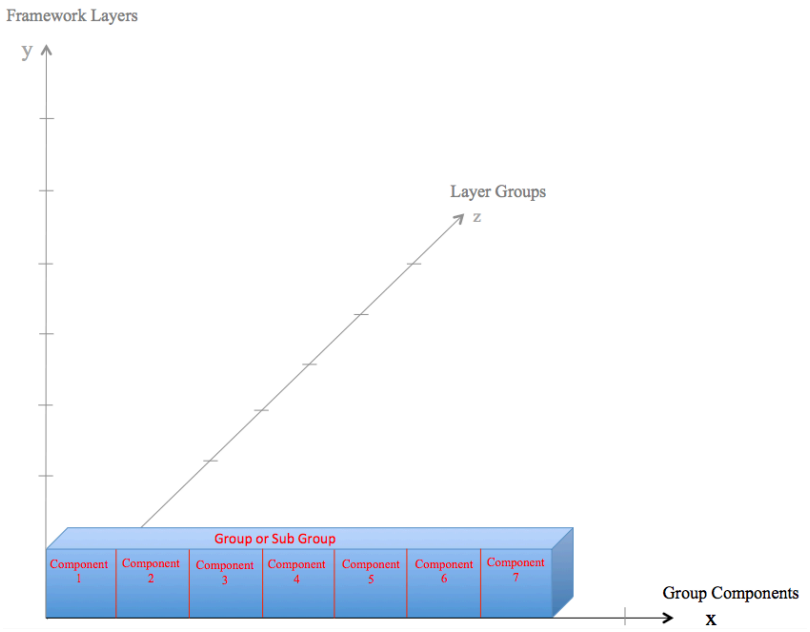

Figure 34. Group Components

Finally, each component may be made up of different elements, as reflected in Figure 35.

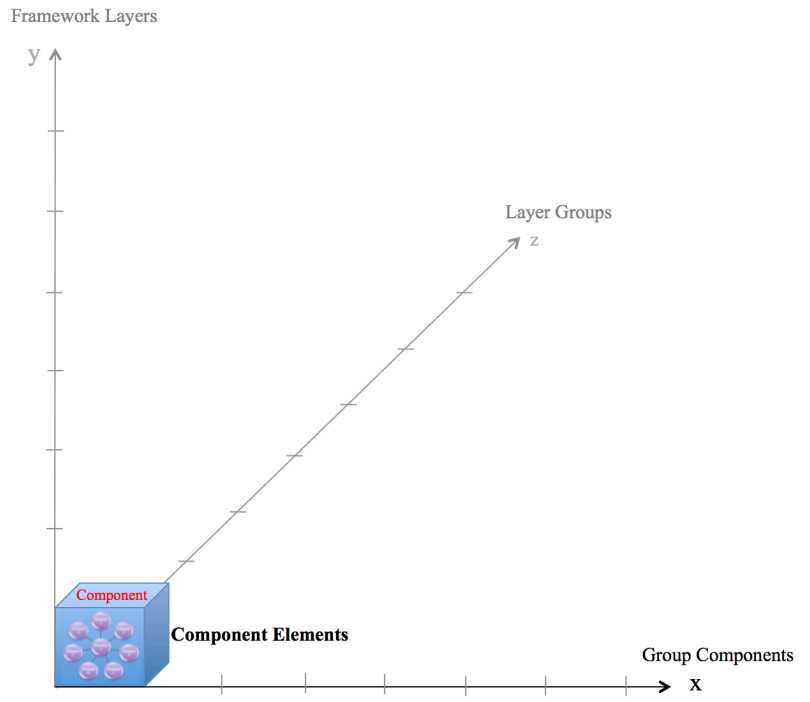

Figure 35. Component Elements

The layers, groups, components and elements of the framework have been codified using a logical notation with the aim of identifying the components of each group/layer as well as to identify the relationships among them. Furthermore, this codification gives a clear understanding of the Lean transition path as well as links the Lean transformation with the key performance indicators of the firm as described in Section 4.5.3.

The component codification shows *layer, group/subgroup, component, element* (see Figure 36). In this particular example, element 3 of component 5 that belongs to subgroup 2 of group 1 in layer 1 is indicated by the arrow.

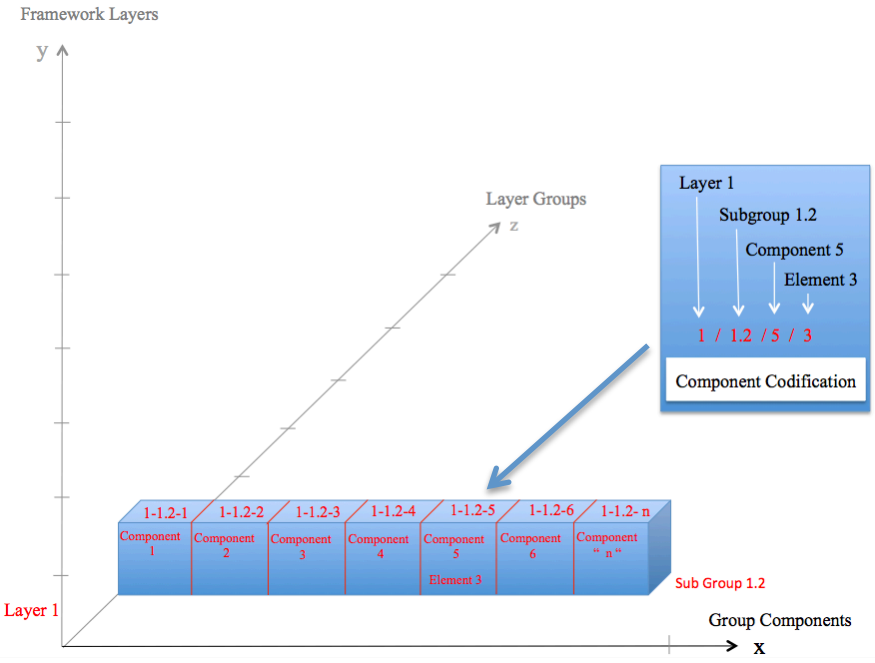

Figure 36. Component Codification

Going through a similar decomposition exercise for each framework layer leads to schemes such as those in Figures 37 and 38.

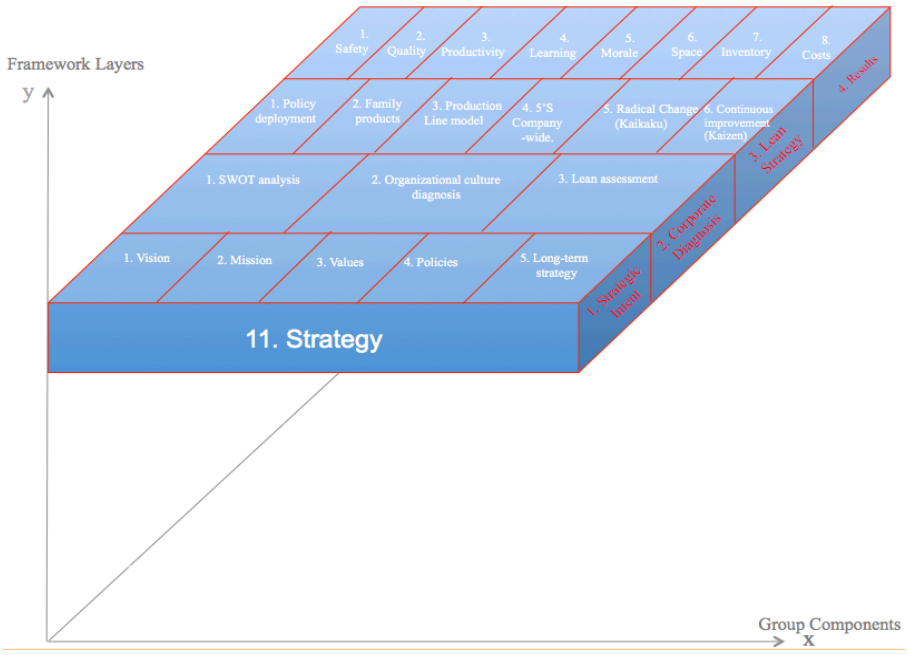

Figure 37. Strategy Layer Decomposition

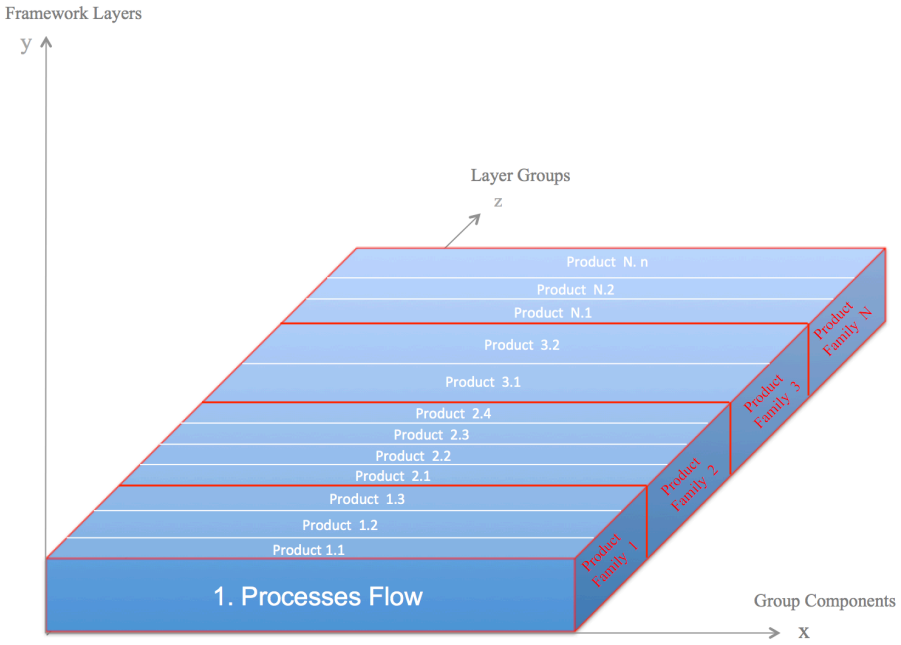

Figure 38. Processes Flow Layer Decomposition

When they are depicted together, Figure 39 is produced. By linking different components from one layer to groups or components in another layer, for example, the Strategy is deployed

in the entire company by focusing on the groups and subgroups of the Process Flow. This approach facilitates applying the Strategy in each Process Flow in the company.

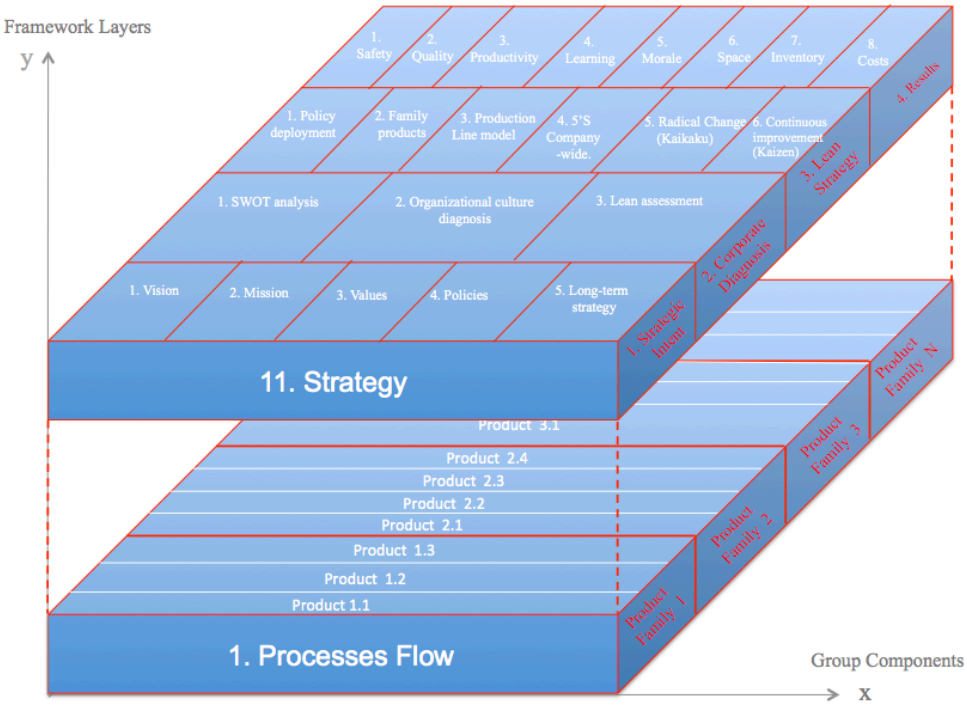

Figure 39. Deploy Strategy to the Entire Company focusing on Processes Flow

This approach may then be structured as shown in Table 11, where a matrix has been developed to show all the parts of the Strategy layer.

11. STRATEGY LAYER									
LAYER GROUPS	GROUP COMPONENTS								
11-1 Strategic Intent	11-1-1 Vision	11-1-2 Mission	11-1-3 Values	11-1-4 Policies	11-1-5 Long-term Strategy				
11-2 Corporate Diagnosis	11-2-1 SWOT Analysis	11-2-2 Organizational Culture Diagnosis	11-2-3 Lean Assessment						
11-3 Lean Enterprise Transformation Strategy	11-3-1 Policy Deployment (Hoshin Kanri)	11-3-2 Product Families	11-3-3 Production line model	11-3-4 5'S Company-wide	11-3-5 Radical Change (Kaikaku)	11-3-6 Continuous Improvement (Kaizen)			
11-4 Results	Strategic Key Performance Indicators								
	11-4-1 Safety	11-4-2 Quality	11-4-3 Productivity	11-4-4 Learning	11-4-5 Morale	11-4-6 Space	11-4-7 Inventory	11-4-8 Delivery	11-4-9 Costs

Table 11. Strategy Layer Matrix

Once a detailed matrix such as this has been developed for each layer, namely Processes Flow, Facilities, Organization and External Environment, People, Lean Management Infrastructure, Organizational Learning, Lean - Business Improvement Programs (BIP) and Industrial Engineering (IE), Data - Information and Knowledge Management, Technology, Lean Enterprise Transition Management and Strategy, the framework is complete. This framework with the Lean transition roadmap (shown in results Section 5.3) may then be used as a guide towards Lean enterprise transformation based on an analytical, logical, and systematic approach.

4.3.1 Processes Flow – Led Framework

Given the vast number of products and processes, all products are categorized into a group of products called a "product family," as shown in Figure 38 and Table 12. A product family is a group of products that pass through common processes and shared machines or equipment in the downstream processes from the door-to-door flow in a plant. For example, a product family may be composed of five products that undergo the same three processes through the same three machines.

Once these product families are constructed, a single product is chosen from one family, the most important to the company and most representative of those production processes. Then all the layers of the framework are applied to that product to make the lean transformation of the processes involved in the production of that product. To illustrate, the production line of Product 2 is selected in the case shown in Table 12. The Strategy, as shown in Figure 40, is then applied to all the processes flow (direct and indirect) involved in the development of Product 2 by applying the transformation to each component of the production line (Figure 41). Additionally,

this production line will serve as a reference model in expanding it to other product families within the firm.

1. PROCESSES FLOW LAYER							
GROUPS		COMPONENTS – PROCESSES FLOW					
PRODUCT FAMILIES	Product	A	B	C	D	E	F
1-1	1-1.1	A	B	C	D	E	F
	1-1.2	PRODUCTION LINE MODEL					
	1-1.3		B	C	D	E	F
	1-1.4	A	B	C	D	E	F
	1-1.5	A	B	C	D	E	F
1-2	1-2.1	A		C			F
	1-2.2	A		C			F
	1-2.3	A		C			F
1-3	1-3.1	A	B		D	E	
	1-3.2	A	B		D	E	
1-N	1-N.1	A		C	D	E	F
	1-N.2	A		C	D	E	F
	1-N.3	A		C	D	E	F
	1-N.n	A		C	D	E	F

Table 12. Processes Flow Layer Matrix

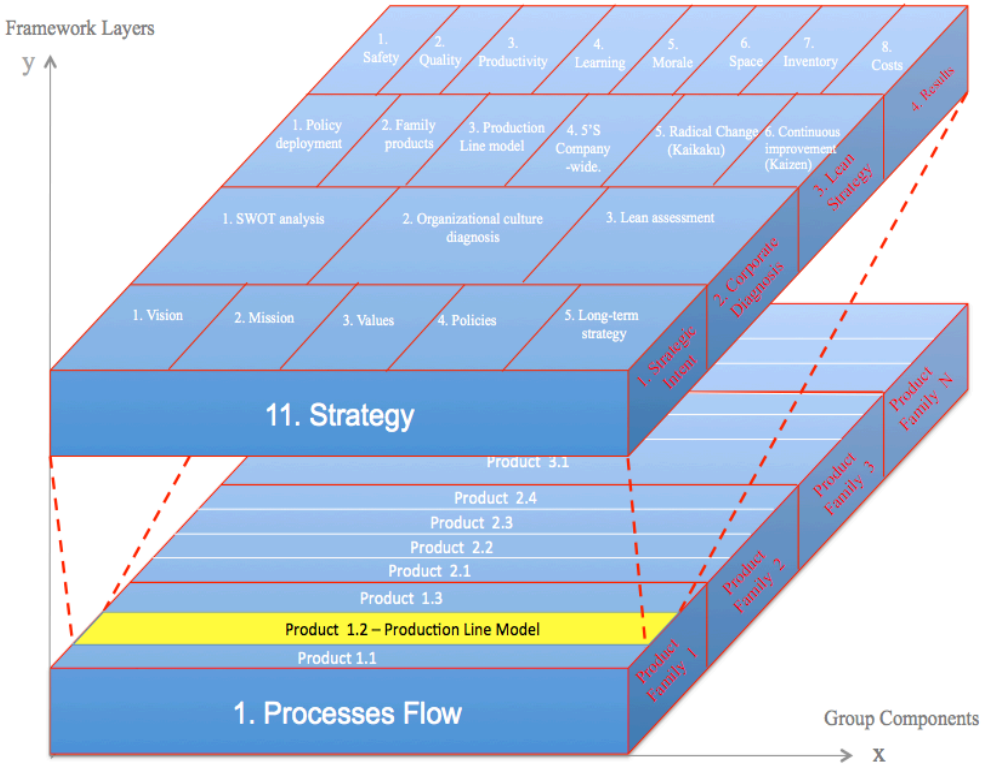

Figure 40. Strategy deployment focusing on a Production Line Model

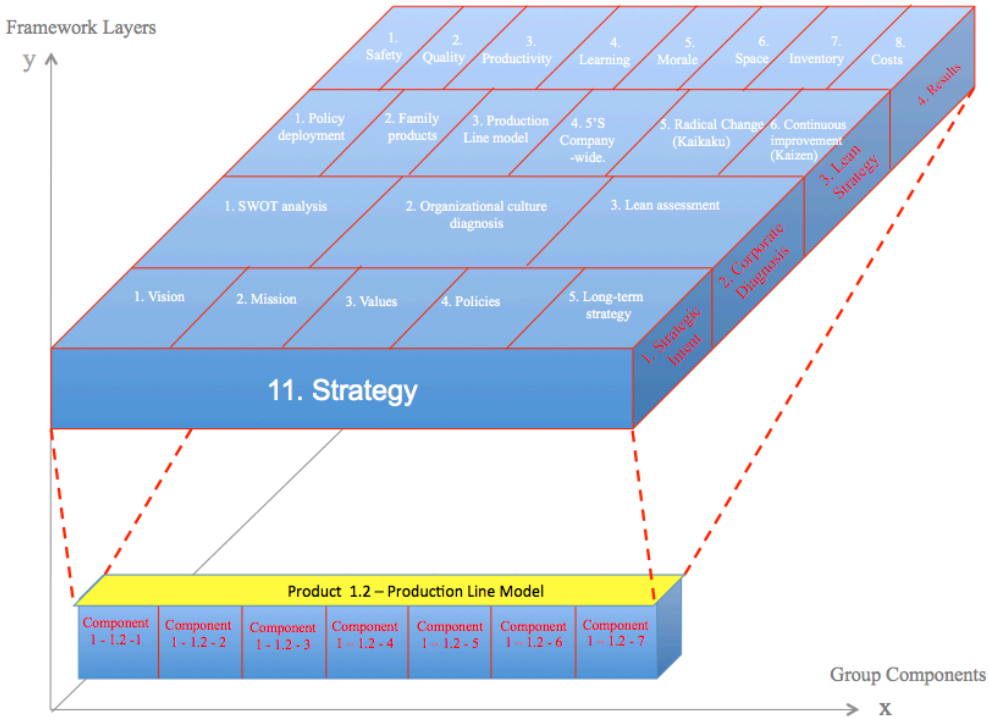

Figure 41. Strategy deployment focusing on each component of a Production Line Model

This model structure can be applied to every layer and the relationships necessary for success can be clearly shown. Because this is a model of how to undergo the transformation in individual processes and families of products, it can eventually lead to the transformation of the firm. Throughout the entire transformation process, the components of each layer that are directly or indirectly involved with the processes flow of the production line model should be touched upon in the phases of the transformation. Section 4.6.2 describes which components have to be considered in each phase.

Concepts from the Purdue Enterprise Reference Architecture (PERA) can be adapted to enhance the robustness of the proposed framework as described in the following section.

4.4 Adapting Concepts from the Purdue Enterprise Architecture Framework

The main characteristics of the Purdue Enterprise Reference Architecture (PERA) (introduced in Section 2.5.1) and their relevance to this proposed framework are described as follows:

1. The PERA is a generic and widely applicable an enterprise reference architecture (or framework). The proposed framework focuses on the manufacturing sector.
2. The PERA provides an Enterprise Integration process. The purpose of this proposed framework is to provide a Lean enterprise transformation (LET) process.
3. The PERA is a Type 2 architecture, which models and describes the steps of the enterprise integration, and therefore, the framework or the structure of the relationship of these development steps to one another. This proposed framework is also a Type 2 architecture; therefore several characteristics of PERA can be adapted.
4. The PERA describes graphically the steps or structure of the analysis, design, and development of an enterprise integration project. This type of description is very useful and easy to follow; therefore, it can be used to develop the LET life cycle process.
5. The PERA provides the capability for modeling the human, manufacturing, and customer service components, as well as the information and control system components of any enterprise. The intention of this proposed framework is to model the components of the eleven layers and the different stages, which includes the PERA components.
6. Both the PERA and the proposed framework focus on the life cycle concept.
7. The PERA comprises the following regions (or views): concept, functional analysis, implementation, operations, and recycle and disposal. This proposed framework has eleven layers: the Processes Flow, Facilities, the Organization and External Environment,

the People, the Lean Management Infrastructure, Organizational Learning, Lean Manufacturing, Industrial Engineering (IE) and Business Improvement Programs (BIP), Data -Information and Knowledge Management, Technology, the Lean Enterprise Transition Management, and the Strategy,

8. Each region is composed of phases. The PERA life cycle consists of nine phases: 1) identification, 2) concept, 3) definition, 4) functional design, 5) detailed design, 6) construction and installation, 7) operation and maintenance, 8) renovation or disposal, and 9) enterprise dissolution. Figure 42 shows the form of the architecture describing this life cycle as expressed by the PERA. The phases of the Lean enterprise transformation (LET) proposed here have been developed adapting this concept of PERA as well as other frameworks as described in Section 4.5.2.
9. Each phase is decomposed in different areas of interest to the enterprise, having twenty-eight in total, as shown in Figure 43. Each phase of the framework developed in this research encompasses several components, as described in Section 4.6.2.
10. After the functional design phase, the PERA encompasses three sub-architectures, the information systems architecture, the human and organizational architecture, and the manufacturing architecture. The proposed framework includes those sub-architectures as well as others: Lean Enterprise Transition Management, Organizational Learning, and Lean and Business Improvement Programs, among others.

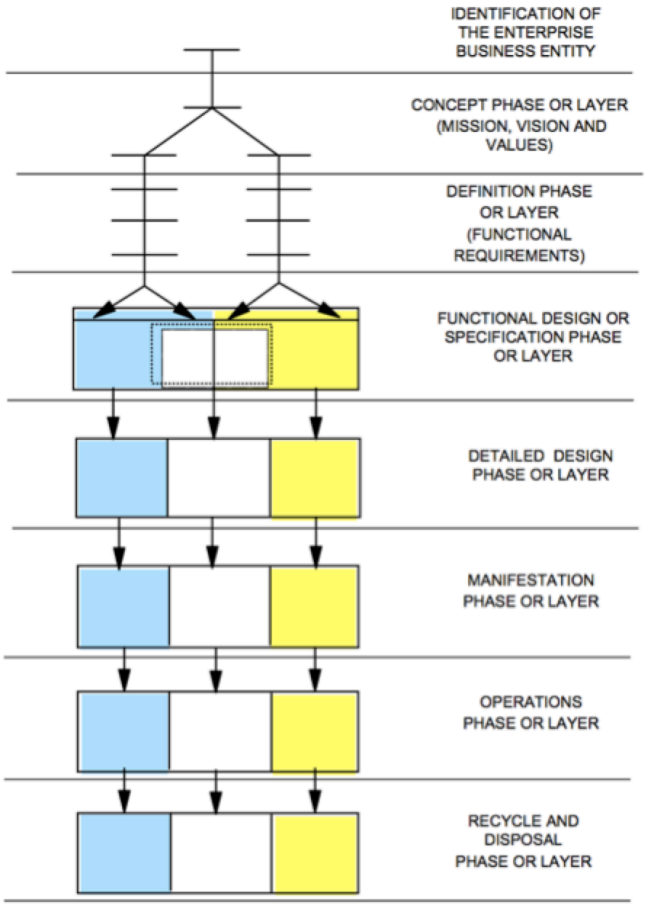

Figure 42. A graphical presentation of the Purdue Enterprise Reference Architecture indicating phases, and the relationship of tasks within phases (Williams et al., 2001)

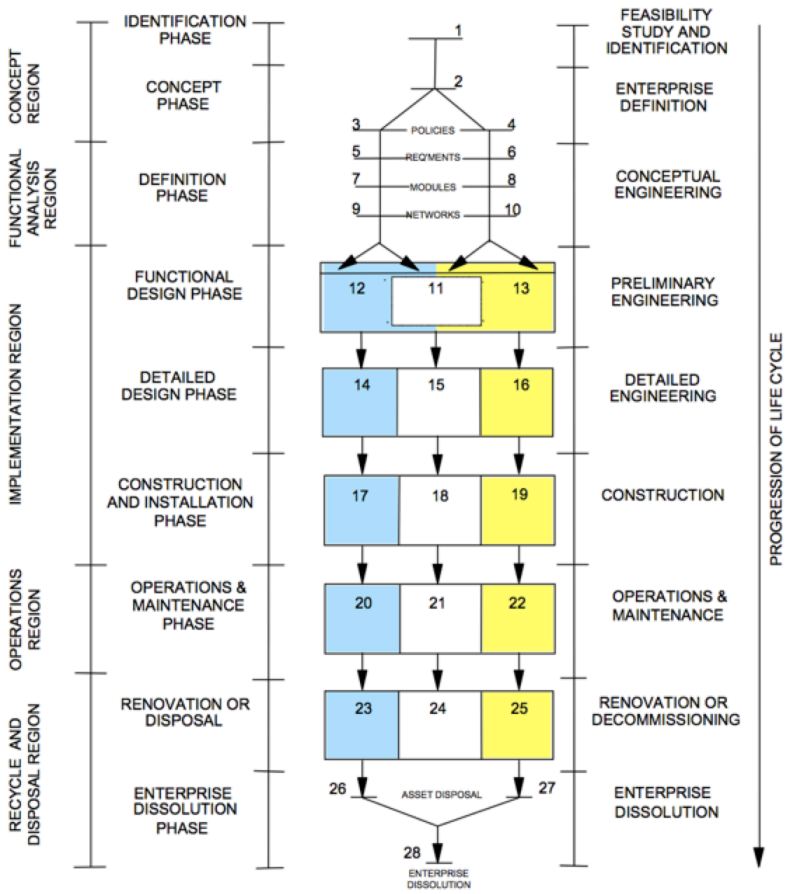

Figure 43. Overall form of the Purdue Enterprise Reference Architecture diagram showing various forms of the life cycle

11. The PERA provides a *"migration path"* or *"road map"* to help the organization in its integration efforts in moving from the current state (AS-IS) of the business enterprise to the desired state (TO-BE). This process is represented in Figure 44, which shows the relationship of the chapters of the handbook and the master plan to the PERA, and also in the PERA master planning work flow, shown in Figure 45. The framework in this dissertation also considered a road map in a different format as described in the results section.

12. The PERA has a detailed master plan and instructional manual to guide and simplify the operational integration of the enterprise. The numbers in the PERA master planning work flow (Figure 45) are the chapter numbers in both the handbook and the master plan.
13. The PERA starts with a description of management's mission, and the vision and values of the business entity, similar to this proposed framework.
14. The basic classes of tasks of the information architecture of the enterprise include communications, information storage, and mission fulfillment. These tasks are included in this proposed framework in the Information, Strategy, and Transition Management layers.
15. One of the major innovations of the PERA is that it considers the place of all tools as aids to functions carried out at each location on the framework. This relevant issue is considered in this proposed framework as described in the results section.
16. Tasks become collected into modules or functions, which can be connected into networks of information, materials or energy flow. In this proposed framework, the main components of each layer are connected into networks in each LET life cycle phase.

The PERA and this proposed enterprise architecture framework have some similarities, namely layers, views, and components. However, the PERA incorporates in the same framework the regions (views) and the phases, as well as the progress of the life cycle and the components (Figure 43). Additionally, it describes graphically the steps of the migration path related to the chapter numbers in both the handbook and the master plan (Figure 44). Moreover the PERA shows the master planning work flow in a different diagram (Figure 45).

Some important issues can be adapted from the PERA:

1. The PERA as a reference architecture is an instrument for defining, explaining, organizing and guiding the development of a Computer Integrated Manufacturing enterprise. The proposed architecture framework is also a reference architecture like PERA, but the main goal is to identify the main components and the interactions among them to guide an organization in a Lean enterprise transformation (section 4.5).
2. The PERA includes the phases of the enterprise life cycle in the framework (as shown in Figures 42 and 43). The same concept can be adapted in the proposed framework (section 4.6.1).
3. The sequence of the transition path (as shown in Figure 44) can be added at the implementation process of the framework in the future but it is outside of the scope of this research.
4. A diagram similar to the PERA master planning work flow can be designed and each step can be numbered sequentially (as shown in Figure 45).
5. As shown in Figure 45, the PERA Master Plan starts the process by identifying the business entity and continues by describing the management's mission, vision, values, objectives, and goals. This point can be adapted in the Strategy layer.
6. Step 3 defines the TO-BE policies. This step can be included in the proposed framework at the level of the Strategy layer.
7. Step 4 defines significant opportunities. Something similar can be adapted in the Strategy layer by using a SWOT analysis.

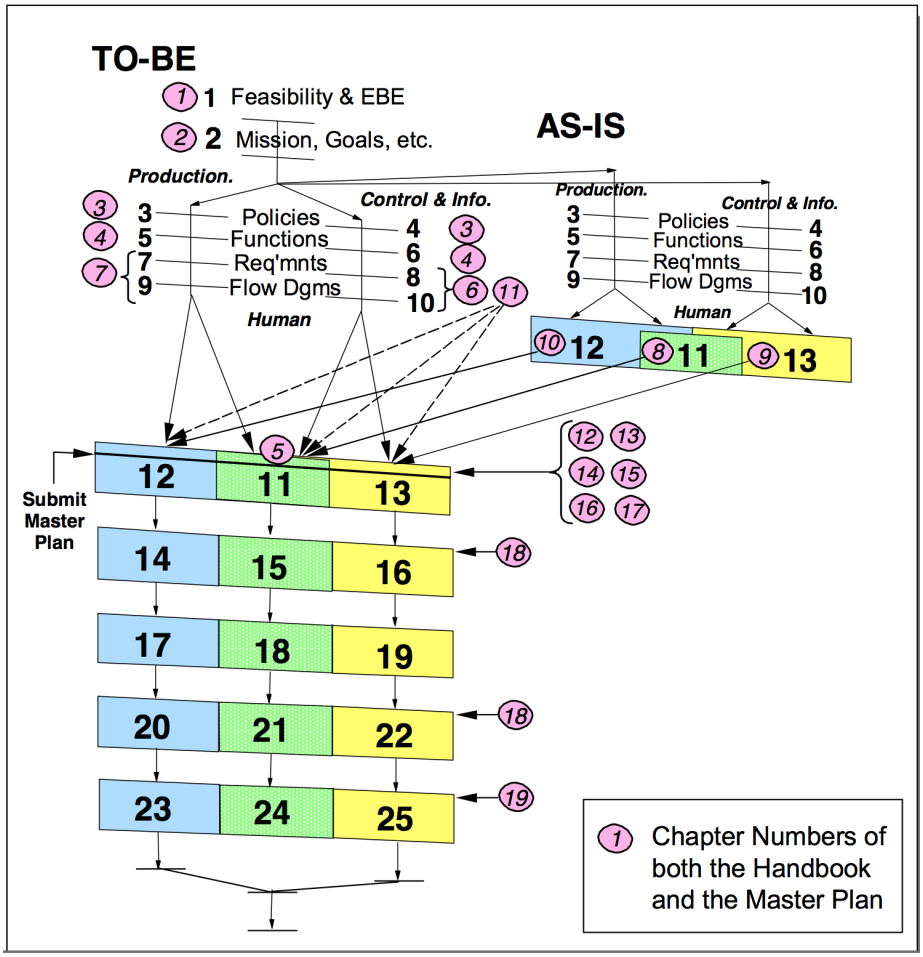

Figure 44. Relationship of chapters of the handbook and the master plan to the PERA (Williams et al., 2001)

8. Steps 5, 6, and 7 describe the desired future state (the TO-BE) of human, information, and physical components. These points can be adapted in the future Value Stream Mapping in the Lean layer and in the Strategy layer.
9. Steps 8, 9, and 10 describe the present state (the AS-IS) of human, information, and physical components. These points can be adapted in the current Value Stream Mapping in the Lean layer and in the Strategy layer.

10. Step 12 is the transition, which describes the modification path between the AS-IS and the TO-BE states. These points can be adapted in the Lean Transition Management layer as well as step 14 (projects) and step 17 (develop program and buy-in)

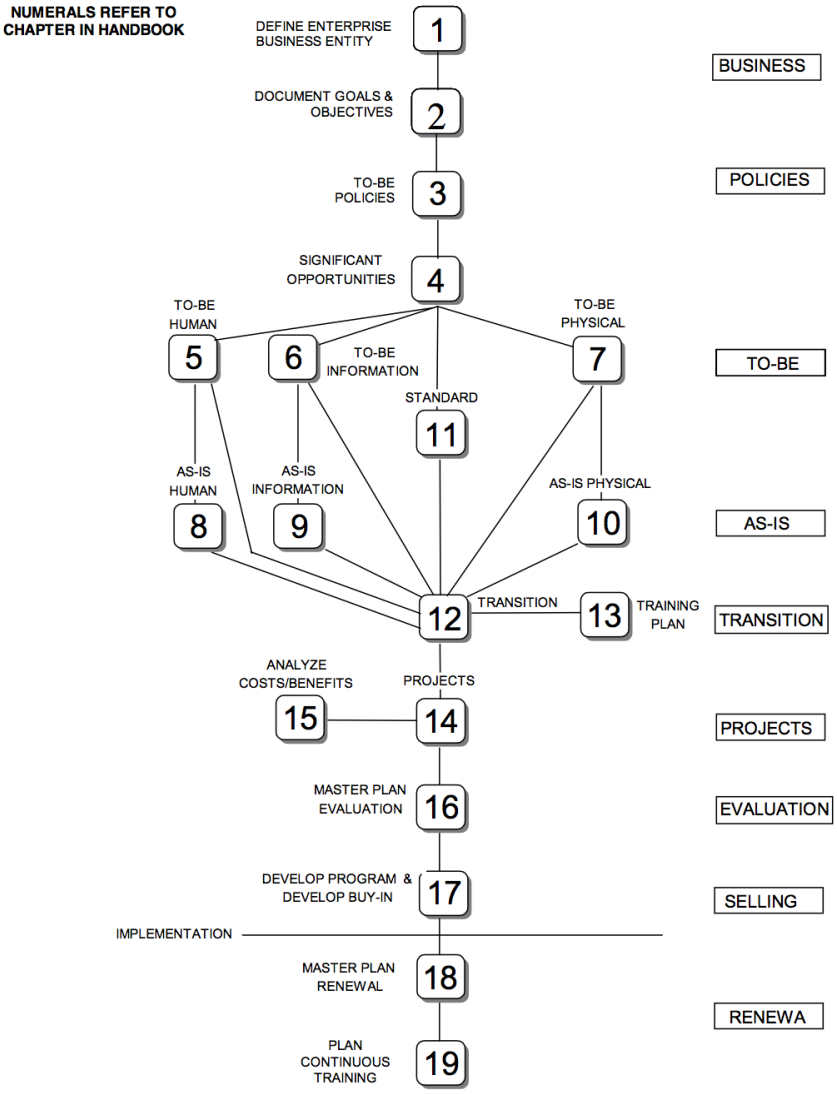

Figure 45. PERA Master Planning Work Flow (Williams et al., 2001)

11. Step 13 (training plan) and step 19 (plan continuous training) can be adapted in the Organizational Learning layer.

12. Step 15 (Analyze cost-benefits) can be adapted in the Strategy layer.

The previous twelve points of the PERA framework are considered in each layer of the framework as described in Section 4.5. Furthermore, the concept of the PERA phases of the enterprise life cycle are adapted to the proposed framework, which is discussed in Section 4.6.1. The result of applying the PERA phases' concept will be a Lean Enterprise Transition Roadmap, which is described in Section 5.3.

Before decomposing the Lean Enterprise Transformation into phases, it is necessary to determine the chief components as well as the groups to be considered in each layer as described in the next section.

4.5 Determining the Chief Components and Groups of each Layer

The approach to selecting the chief components and groups in each layer was based on the comparative analysis (Appendix B) followed by developing affinity diagrams (Table 10). Furthermore, it was grounded on the logic underpinning the framework as well as on the structure of the framework.

As can be inferred from the comparative analysis in Section 4.1.2 and Appendix B, the improvement concepts that integrate the frameworks have many variations. They can be principles, criteria, tools, practices, techniques, or methodologies. In most cases, there is not any distinction among them. The frameworks differ in their focus and concepts; however, they are common in their goal to achieve business excellence. The aim of this section is, then, to determine the chief components of each group that integrate each layer of the proposed framework that can be useful for implementing the Lean enterprise transformation.

In order to determine the chief components it is important to define "component." A component is defined as "one of the several parts that together make up a whole system,

machine…" (Pearson Education, 2006). The definition of component differs depending on the context in which it is used. In this context, a component is "one of several parts that together make up groups and layers of an architecture framework of Lean enterprise transformation to achieve operational excellence." Thus, similar components clustered into groups within layers in the proposed framework as well as in a part of all the Lean enterprise transformation life-cycle phases. The components in this case can be concepts, principles, tools, practices, techniques, or methodologies

Given the large number of components, only the chief components of each cluster are listed in Table 10. There might be differences in judgment as to which components are crucial and which are not. The components listed in all frameworks are very important in their own context; however, for the proposed framework, only the chief components for the Lean enterprise transformation are included. Answering the following question is useful for determining the chief components: *Is this component crucial for the Lean enterprise transformation in order to achieve operational excellence?* The answer is based on domain knowledge and takes into consideration the layers and the logic underpinning the proposed framework as well as the consequence of the active learning gained during the testing phase of the framework. The chief components and groups for each layer are shown in Figures 46 to 56. The Figures show the components that have been identified as the chief components, and those highlighted were selected from the reviewed frameworks. The non-highlighted components are those proposed for this research in order to have a complete set of chief components to execute a Lean enterprise transformation. The suggested components have been determined based on the same approach used to identify the most important components from other frameworks, but also answering the following question: *In addition to the chief components from other frameworks,*

what other crucial components are important for the Lean enterprise transformation? The complete set of components clustered into groups and layers is shown in the following figures.

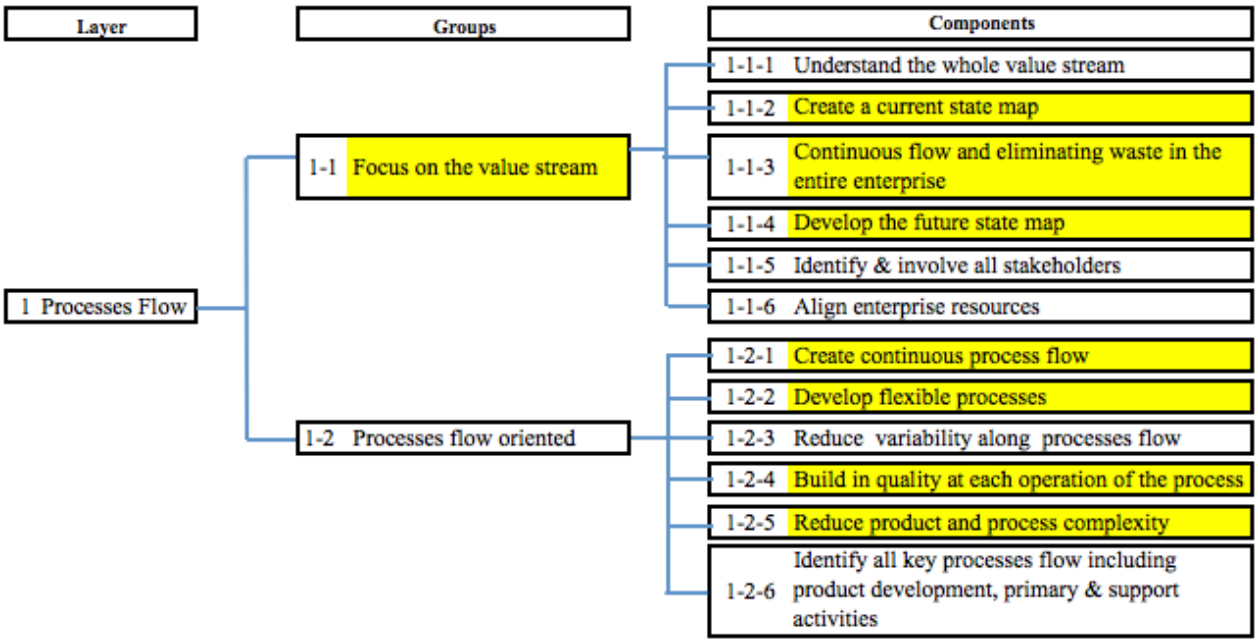

Figure 46. Component and groups of the Processes Flow layer

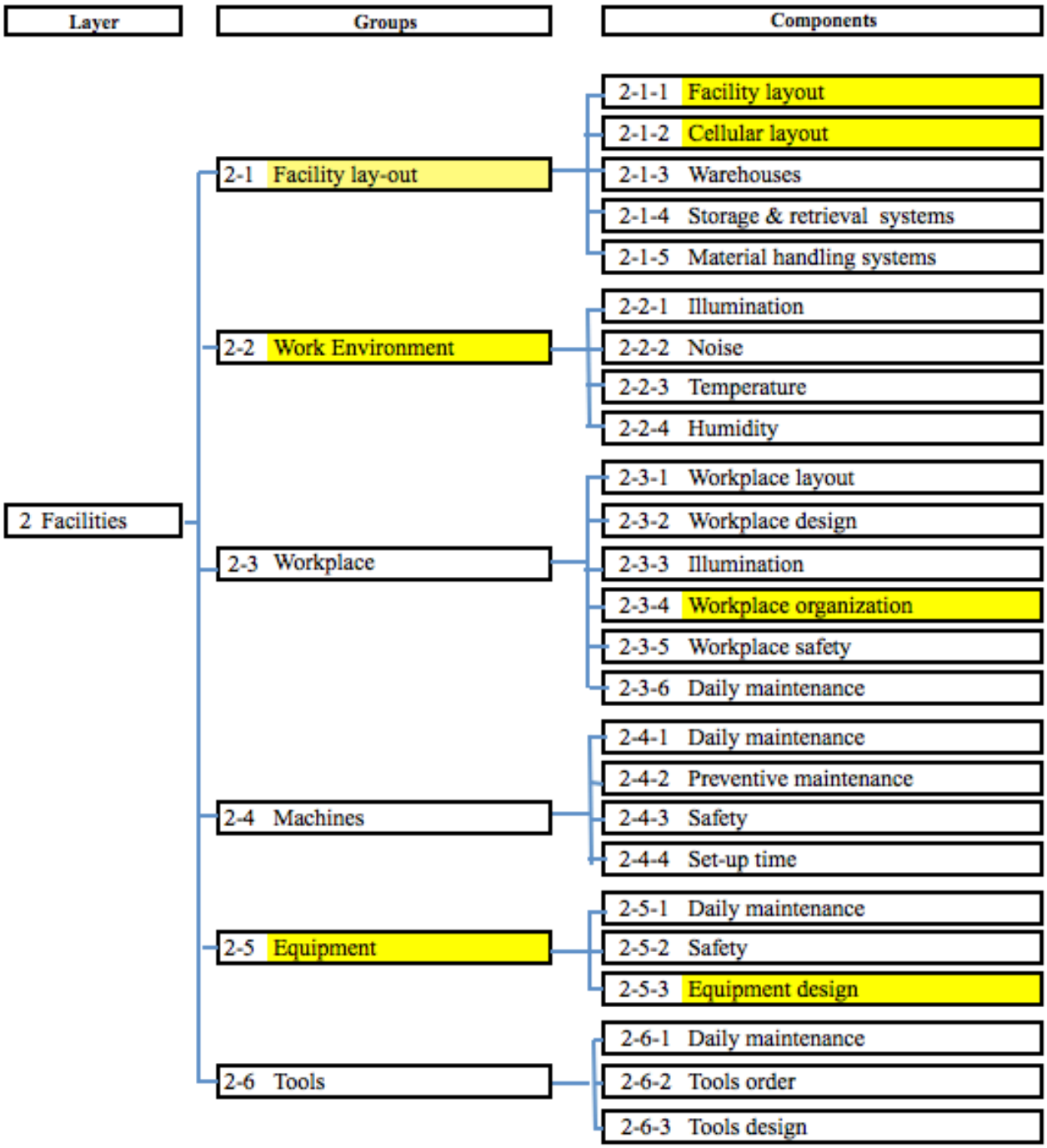

Figure 47. Component and groups of the Facilities layer

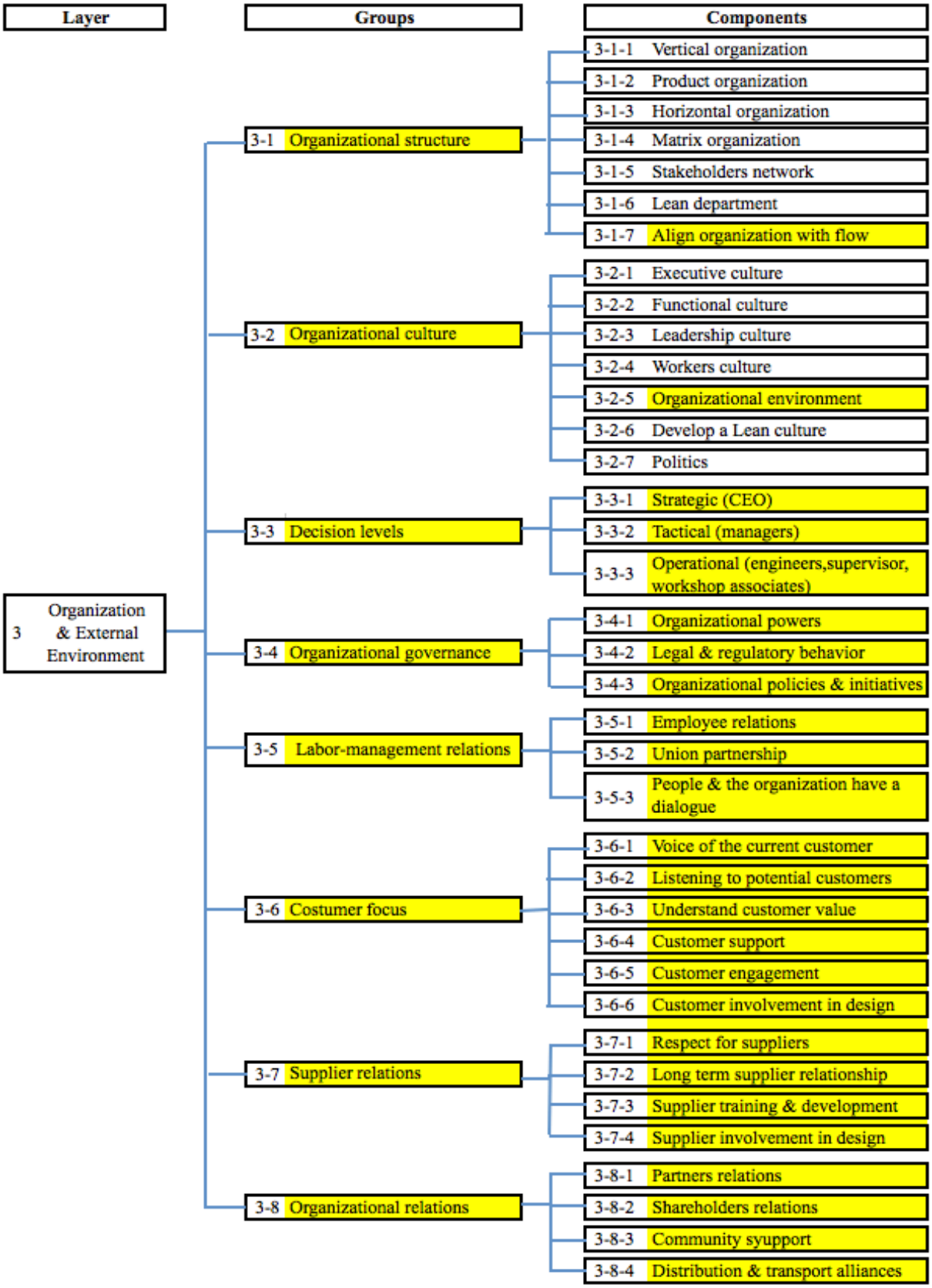

Figure 48. Component and groups of the Organization and External Environment layer

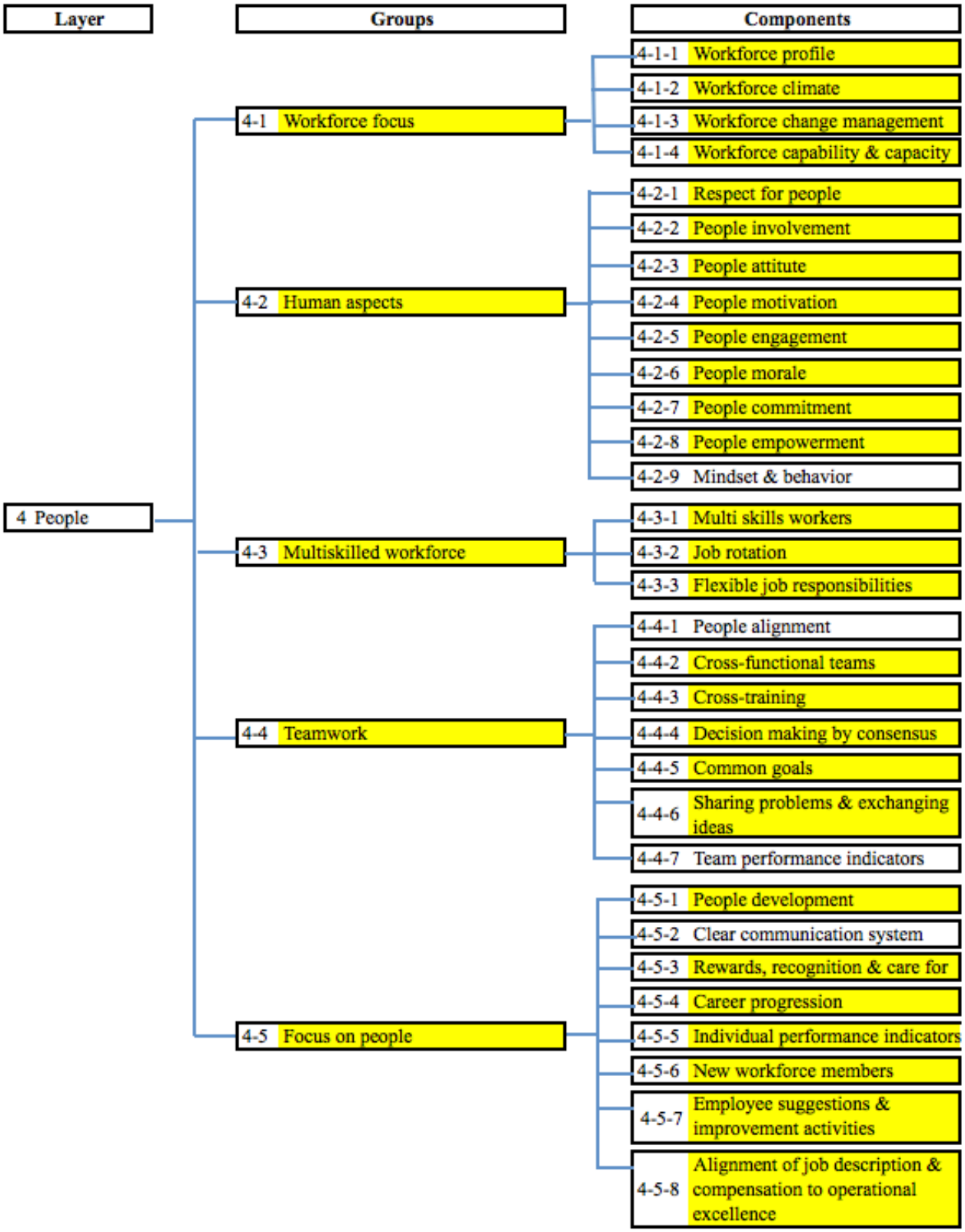

Figure 49. Component and groups of the People layer

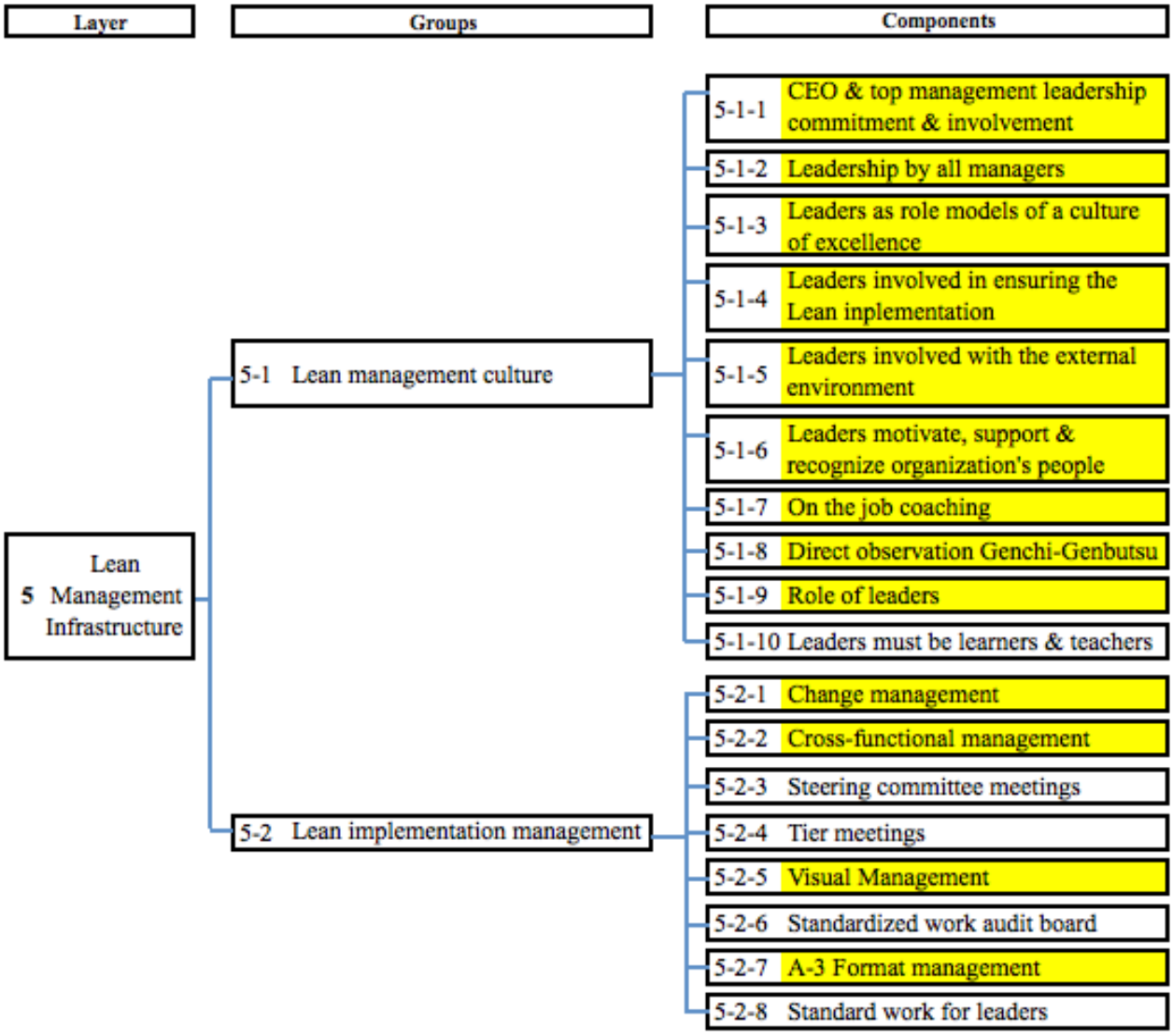

Figure 50. Component and groups of the Lean Management Infrastructure layer

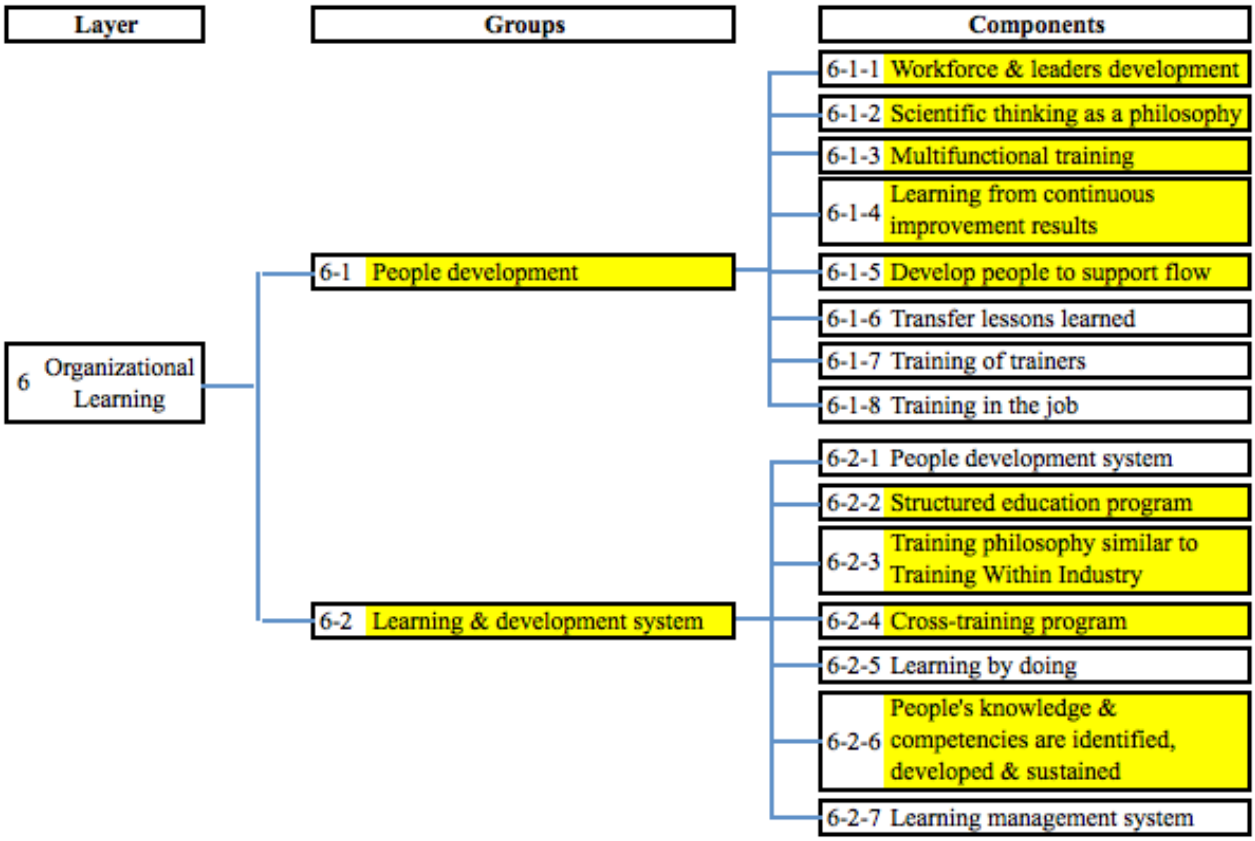

Figure 51. Component and groups of the Organizational Learning layer

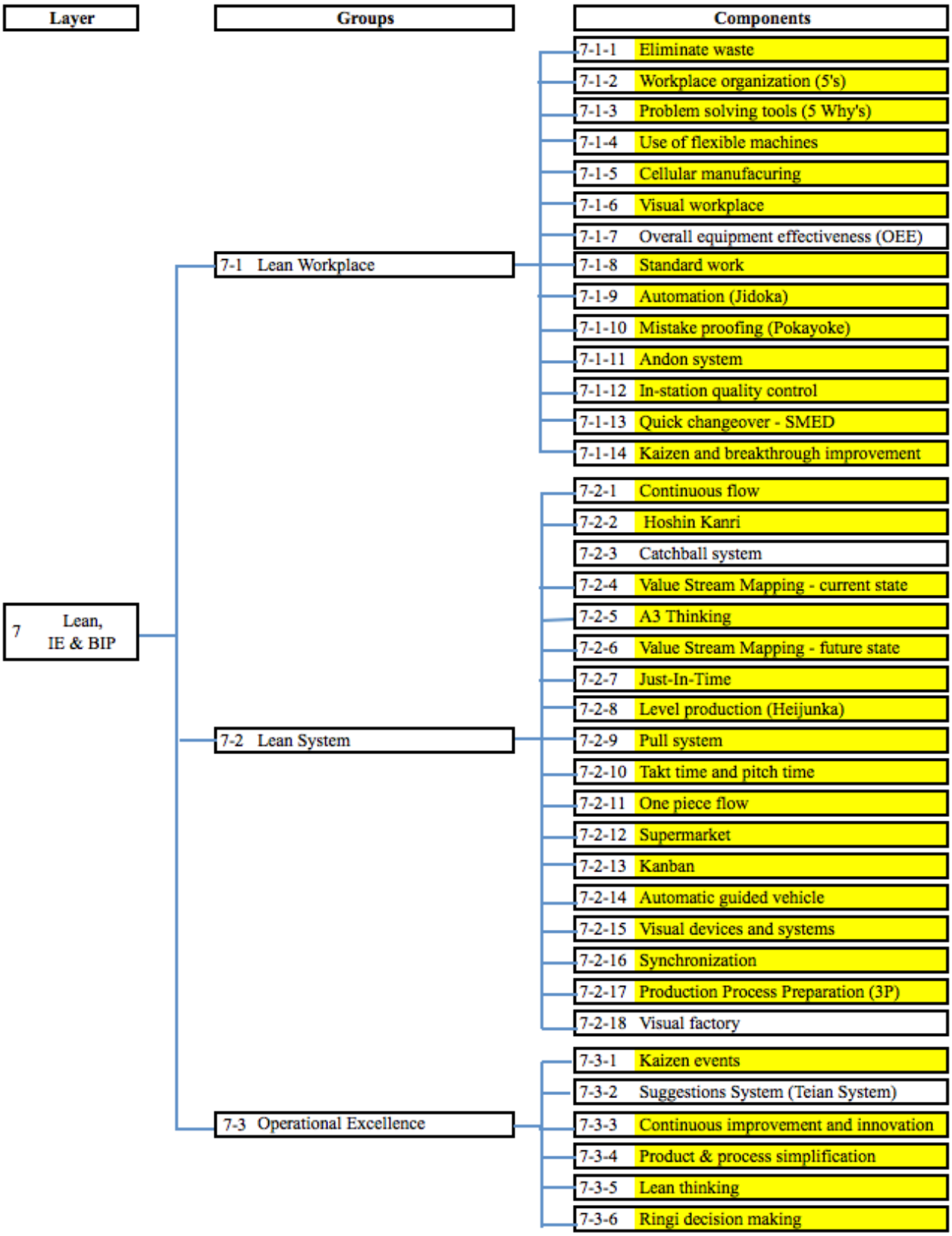

Figure 52. Component and groups of the Lean, Industrial Engineering & Business Improvement Programs layer

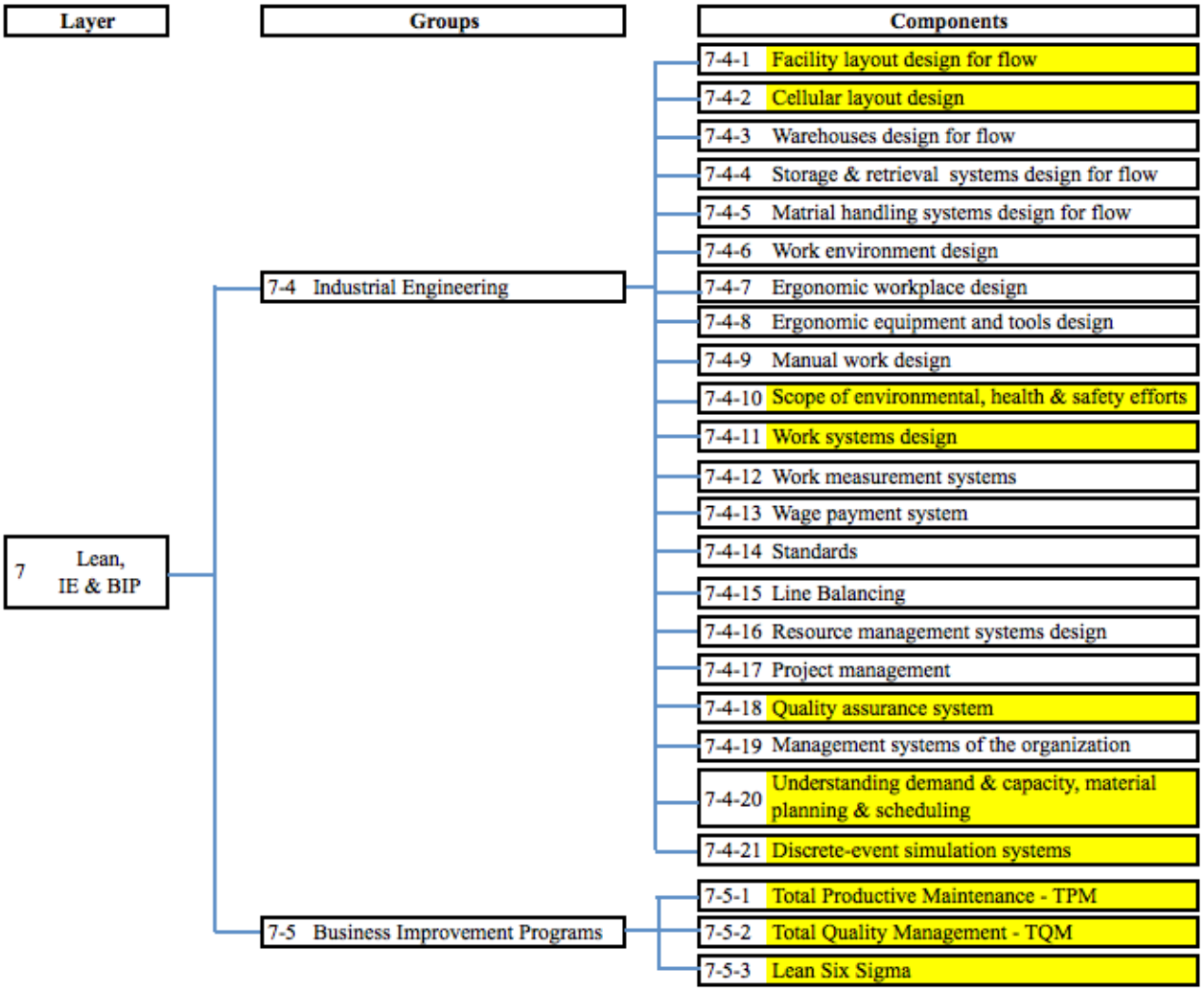

Figure 52. Component and groups of the Lean, Industrial Engineering & Business Improvement Programs layer (Continued)

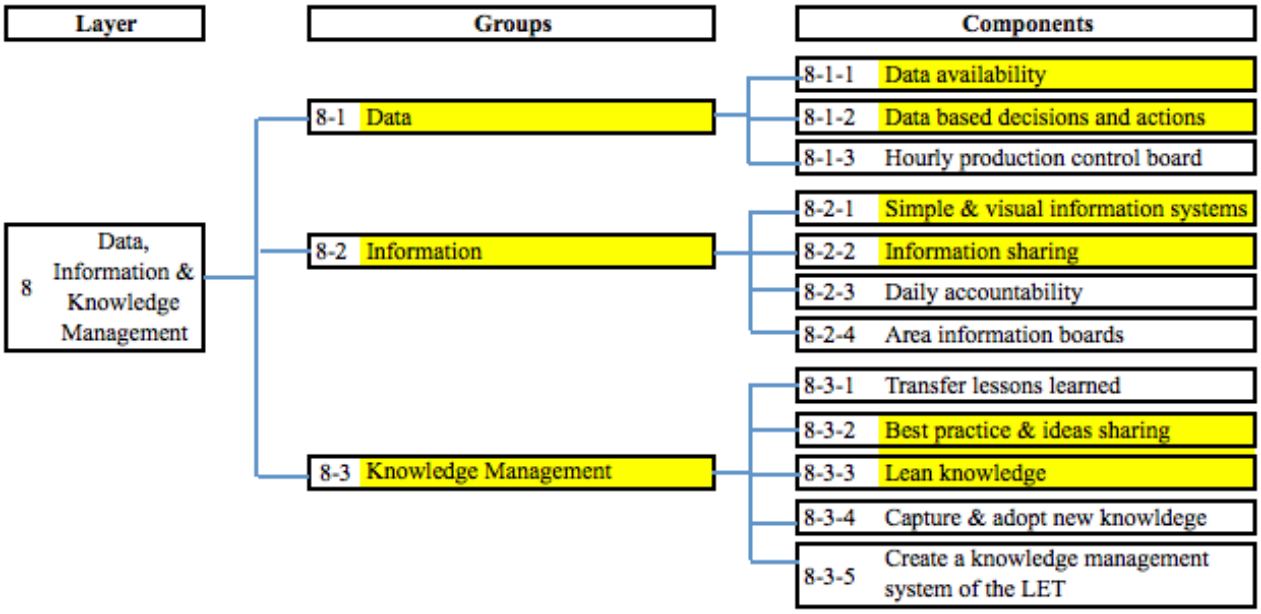

Figure 53. Component and groups of the Data, Information and Knowledge Management layer

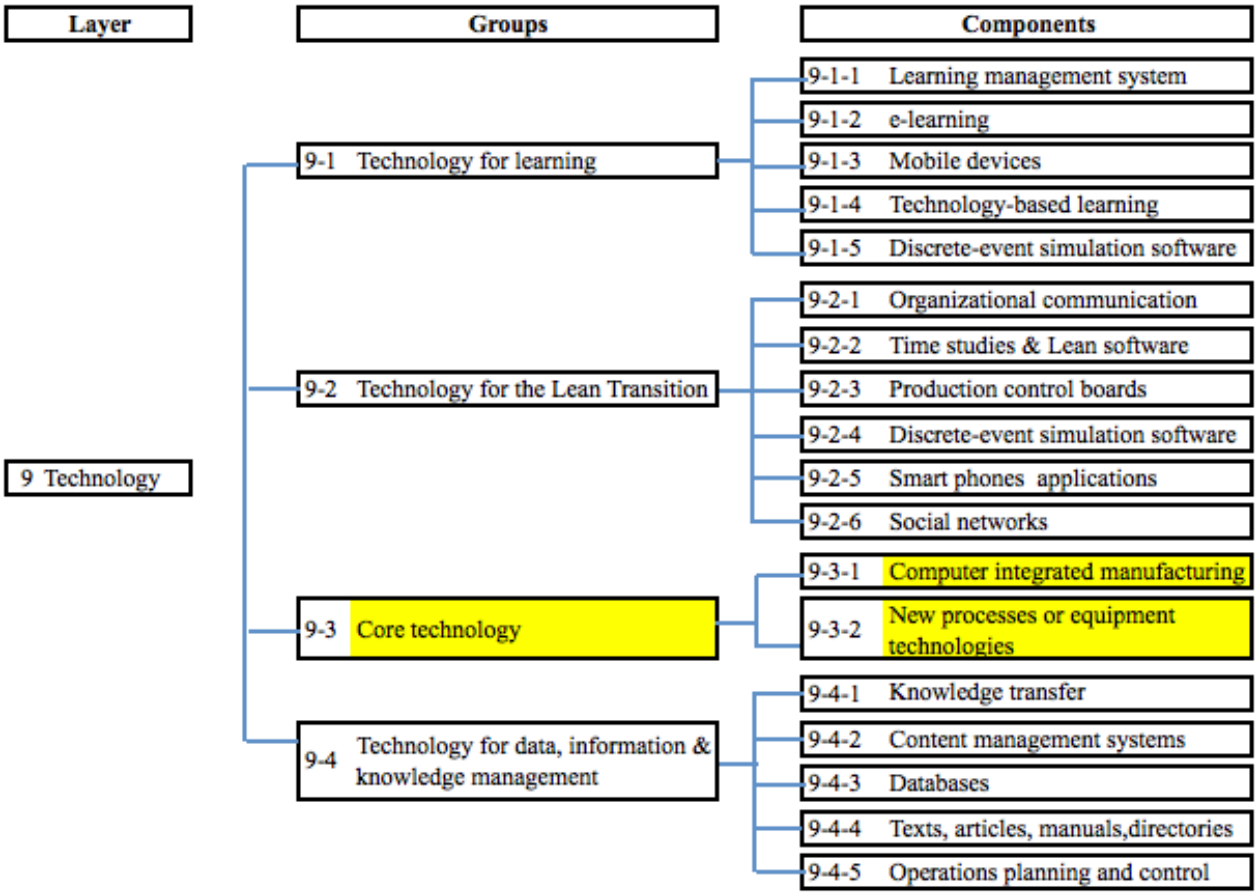

Figure 54. Component and groups of the Technology layer

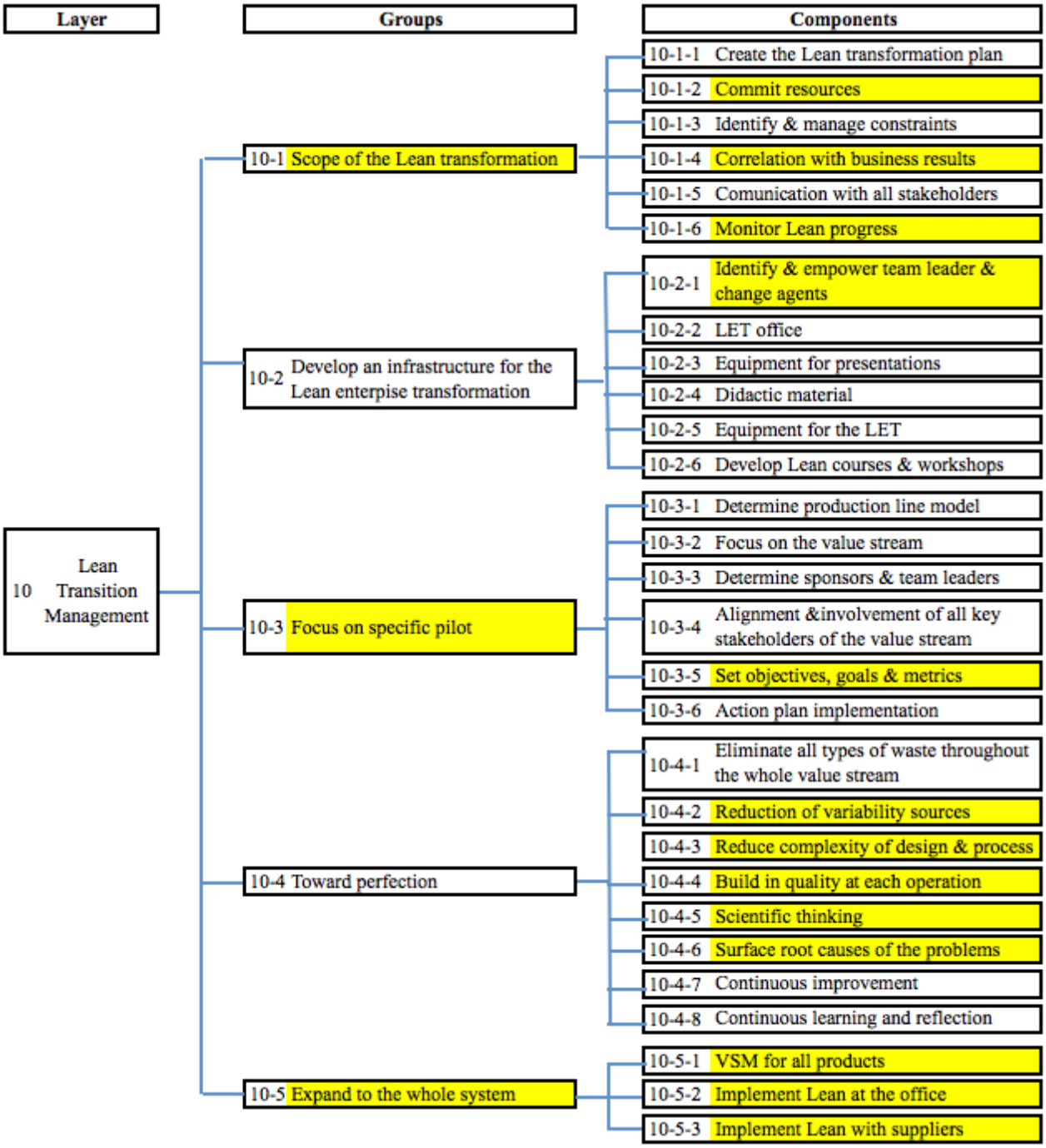

Figure 55. Component and groups of the Lean Transition Management layer

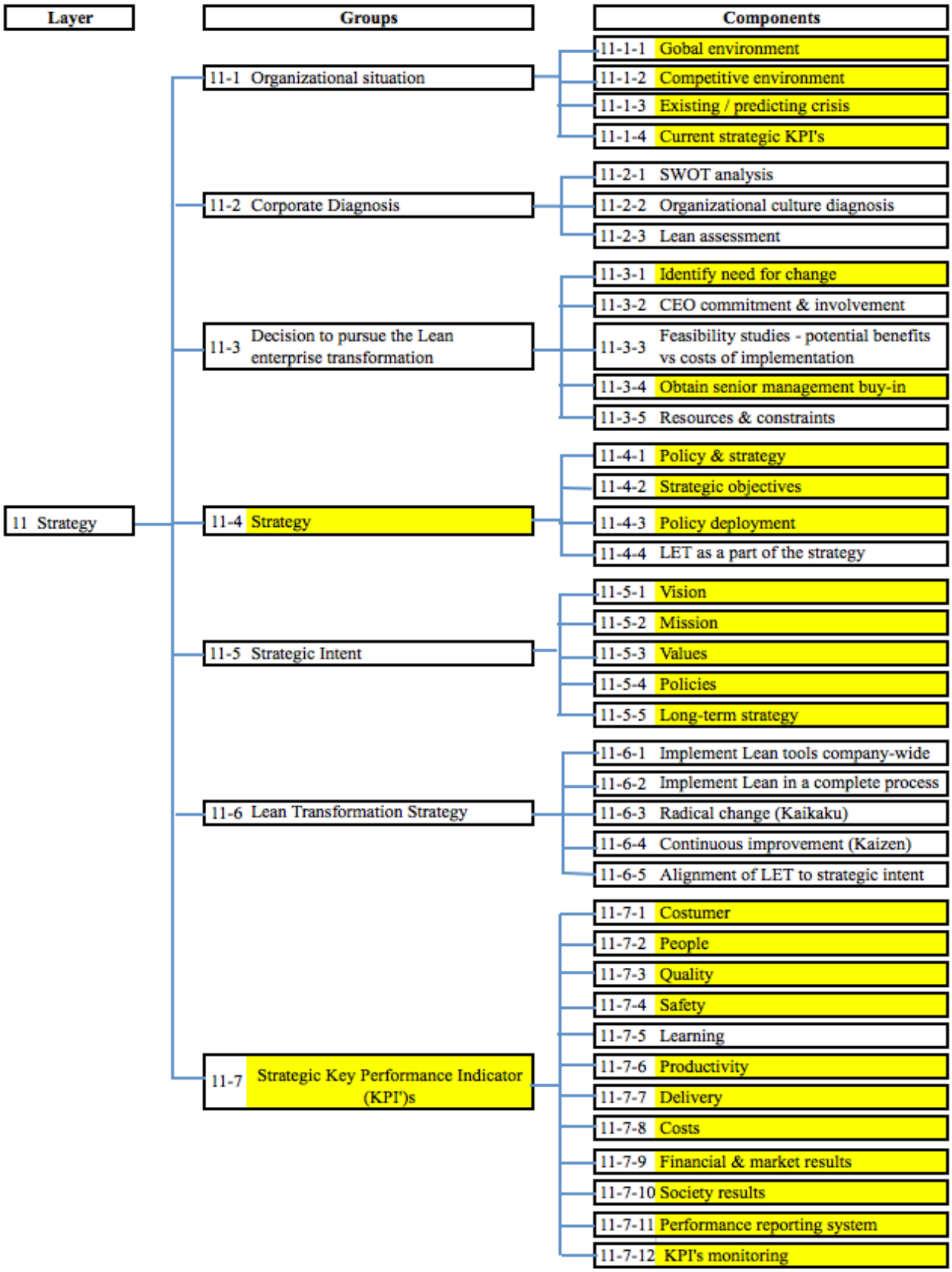

Figure 56. Component and groups of the Strategy layer

The chief components as well as the groups in each layer have been determined in this section. All framework layers, layer groups, and group components have been determined; therefore, the enterprise architecture framework of a Lean enterprise transformation is complete. The next step is to reduce the complexity of the Lean enterprise transformation by using the proposed framework as a reference and by decomposing the transformation into phases as described in the following section.

4.6 Reducing the Complexity of the Lean Enterprise Transformation

To reduce the complexity of the Lean enterprise transformation framework as well as to have a good understanding of how to implement such a general framework into practical applications, a transition roadmap has been developed. The approach to designing this roadmap first decomposes the Lean enterprise transformation life cycle into phases. Then, each component is matched to the phase where it is addressed. All components across the different phases are described in the following sections.

4.6.1 Decomposing the Lean Enterprise Transformation into Phases

The proposed framework has eleven layers. Each layer has a different number of groups and each group has a different number of components. As can be inferred from this situation, there are a vast number of components, making the Lean enterprise transformation very complex. To reduce its complexity, the Lean transformation process has been decomposed into several phases.

The initial approach to defining the phases of the Lean enterprise transformation life cycle was to consider the concept behind Purdue Enterprise Reference Architecture (Figure 43).

Additionally, an analysis of the main enterprise architecture frameworks (Table 13) as well as the Lean frameworks (Table 14) has been done to determine the number of phases to include in the model and to elaborate the final definition of each phase.

Nr. of Phases	CIMOSA	GRAI	PERA		GERAM
	Phases	Phases	Region	Phases	Phases
1	Systems requirements definition	Initialization	Concept	Identification	Identification
2	System design specification	Definition of the domain study		Concept	Concept
3	System build and release	Analysis	Function analysis	Definition	Requirements
4	System operation	User oriented design	Implementation	Functional design	Preliminary design
5	System change / maintenance	Technical oriented design		Detailed engineering design	Design
6				Construction & installation	Detailed design
7			Operations	Operations & maintenance	Implementation
8			Recycle & disposal	Renovation or disposal	Operation
9				Enterprise disolution	Decommision

Table 13. Enterprise Architecture frameworks - Phases analysis

(Nightingale & Mize,2002)		(Mathaisel,2008)		(Anvari et al. 2011)
Entry - Re-entry cycle (decision to pursue enterprise transformation)	Enterprise strategic planning	Strategic planning	Need	Initial investigation
	Adopt Lean paradigm		Conceptual - preliminary design	Preparation
Long term cycle (create the environment)	Focus on the value stream	Transfomation Acquisition & Integration		Focus on specific pilot
	Develop Lean structure & behavior	Implementation	Planning	Expand to whole system
Short term cycle (detailed implementation)	Create & refine transformation plan		Execution	Perfection
	Implement Lean initiatives		Monitoring	
	Focus on continuous improvements			

Table 14. Lean frameworks - Phases analysis

The Lean enterprise transformation life-cycle phases have been defined after analyzing the frameworks and considering the logic underpinning the proposed framework discussed in Section 4.2. The defined phases are 1) Identification, 2) Concept, 3) Requirements, 4) Lean Enterprise Transformation (LET) Planning, 5) Lean Workplace, 6) Lean System, and 7) Operational Excellence. Phases 5, 6 and 7 have been broken down into sub-phases namely i) Planning, ii) Analysis, iii) Design, iv) Implementation, v) Operation, and vi) Sustainment. The life-cycle phases define types of actions that have to be executed during the Lean enterprise transformation. Each life-cycle phase encompasses the components (concepts, tools, activities, techniques, methodologies) from different layers of the framework that are related and

interconnected and can be used to execute the Lean transformation. These phases are shown in Table 15.

1	Identification		
2	Concept		
3	Requirements		
4	LET Planning		
5	Product Families - Value Stream	Lean Workplace	Planning
			Analysis
			Design
			Implementation
			Operation
			Sustainment
6		Lean System	Planning
			Analysis
			Design
			Implementation
			Operation
			Sustainment
7		Operational Excellence	Planning
			Analysis
			Design
			Implementation
			Operation
			Sustainment

Table 15. Phases of the Lean enterprise transformation life cycle

The attributes of each phase are described as follows:

1) Identification Phase

The identification phase identifies the issues related to boundaries and relations to external and internal environments. It identifies the present or foreknown critical business problems, the need for change, as well as the key elements to be considered for the Lean enterprise transformation. Moreover, it identifies the current situation of the key performance indicators of the company as well as the main company constraints to executing the

transformation. Additionally, these actions have to be well documented to generate the right information to justify the Lean enterprise transformation as well as to assure its viability.

2) Concept Phase

In the concept phase, the concepts underlying the enterprise are developed. These concepts include the statements that describe where the company is in terms of the nature of its products and its market. Furthermore, it should also include statements that describe a future desired state as well as strategic objectives, policies, and fundamental beliefs, among other concepts.

3) Requirements Phase

The requirements phase involves the requirements for accomplishing the Lean enterprise transformation. It includes the collection of actions, physical resources, people, and knowledge, among other issues, that support the transformation process.

4) Lean Enterprise Transformation (LET) Planning Phase

In the LET planning phase, actions are required in order to plan the Lean transformation. This phase comprises the type of Lean strategy that the company plans to follow as well as planning the activities that must be carried out to execute all phases of the transformation.

5) Lean Workplace Phase

The Lean workplace phase includes the activities that are necessary to eliminate all types of waste in the workplaces that are related to the value stream determined in Phase 4. Furthermore, this phase comprises the actions that are needed to design or improve the workplace components to transform the inputs into outputs. Moreover, this phase incorporates the activities that support the specification of the workplace with all of its components and their interactions to satisfy the operation requirements. Components from the framework layers and

mainly the concepts, tools, techniques, and methodologies from Lean, IE, and BIP are integrated to reduce the variability of the operation as well as to stabilize the workflow and increase the flexibility of the workplace.

6) Lean System Phase

The Lean system phase comprises activities similar to those in Phase 5, but instead of focusing on the workplace, this phase focuses on the entire process flow from customer demand back through raw material, with the aim of improving the whole and not just the parts. It comprises the activities that are needed to stabilize and to eliminate all types of waste through the process flow as well as to reduce its variability and increase flexibility. This phase involves seeing the whole system by understanding the components' interconnections and their relationships as well as the sequence of operations and flow of activities. The aim of this phase is to synchronize the flows of the entire process.

7) Operational Excellence Phase

The operational excellence phase includes the activities to make improvements in operations and process flow involved in the value stream determined in Phase 4. Continuous improvements and continuous learning as well as stakeholders' involvement play a central role in this phase.

Finally, Phases 5, 6 and 7 are subdivided into sub-phases, which are described as follows:

i) Planning

The planning sub-phase is the process of determining and organizing the activities and resources needed to accomplish the goals of the related phase. It comprises the creation of a plan defining specific goals as well as monitoring their progress.

ii) Analysis

The analysis sub-phase is the process of understanding the structure of the system by thinking about its parts and how they work together to produce an outcome. Common sense questions like who, what, where, when, and what if, can be used to analyze the entity.

iii) Design

The design sub-phase incorporates the design or improvement activities that support the specifications to satisfy the requirements of the workplace, process flow, or system including their components and interactions. The Lean team decides how the entity of analysis needs to operate according to certain specifications. The design activities can include the design of human and machine tasks, operations methods and standards, work environment, facilities, machines and equipment, workplace, and enterprise systems, among others.

iv) Implementation

The implementation sub-phase involves the activities for the implementation of the design in a broad sense, involving stakeholders, training personnel, purchasing material and devices useful for the Lean transformation, validation and testing of the design phase, and releasing into operation.

v) Operation

The operation sub-phase comprises the activities that are required during the components framework operation to produce products or services. The resources of the entity are managed and controlled to carry out the operations and processes. The framework components can aid the employees in their operations in a workplace that is ergonomically well designed by having the right workplace components.

vi) Sustainment

One of the most challenging tasks of the Lean enterprise transformation is sustaining the Lean changes. The sustainment sub-phase involves the activities that support the sustainment of each stage in all phases of the Lean transformation.

4.6.2 Determining the Phase in Which Each Component is Addressed

Given the vast number of components, it is important to determine which components need to be considered in each phase. The tree diagrams described in Section 4.5 in conjunction with the phases described in Section 4.6.1 have been combined in a single diagram to determine the phase in which each component is addressed. This diagram encompasses a matrix showing the relationship of each layer component with the phases of the Lean enterprise transformation life cycle. Each layer is decomposed into its groups and components. The component is marked on the matrix with an "X" if it has to be considered in the corresponding phase, as shown in Figures 57 to 67. The decision as to the possible components at each phase has been determined by (1) considering the steps in each stage for Lean implementation and (2) with reference to the interrelationships between the component and the phase by answering the following question: *Is this component interrelated to the specific attributes of this phase?* This decision has been made based on domain knowledge, consideration of the layers and the logic underpinning the proposed framework, and the active learning gained during the testing phase of the framework. The tree-matrix diagrams are shown in the following figures.

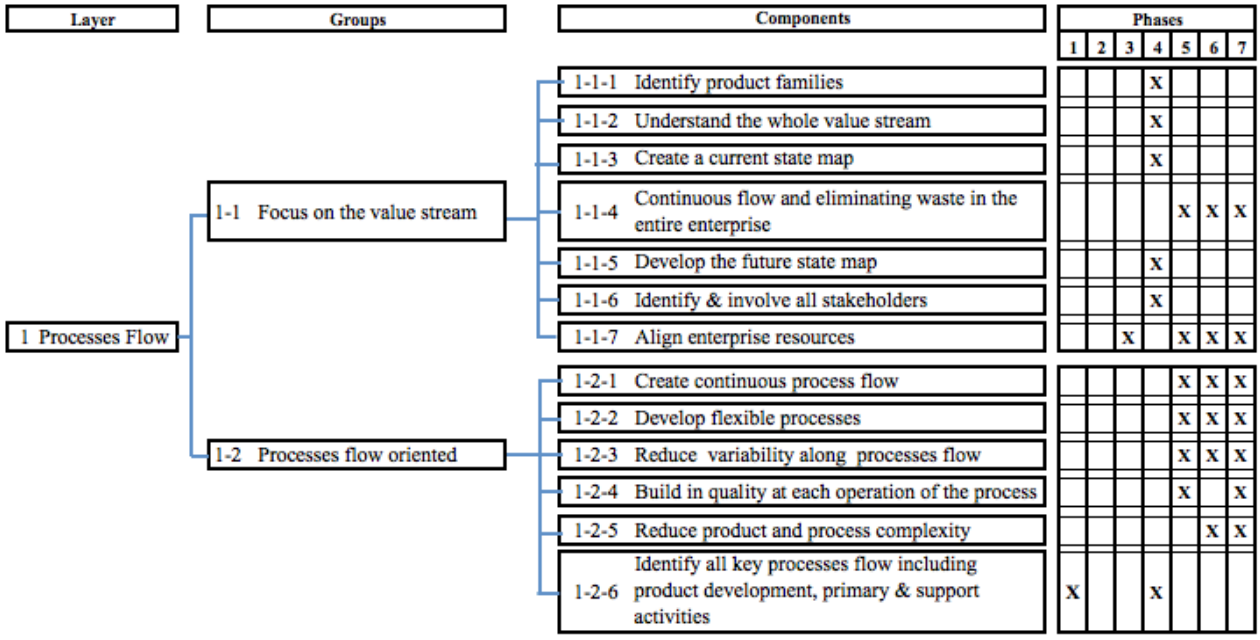

Figure 57. Phase in which each component is addressed – Processes Flow layer

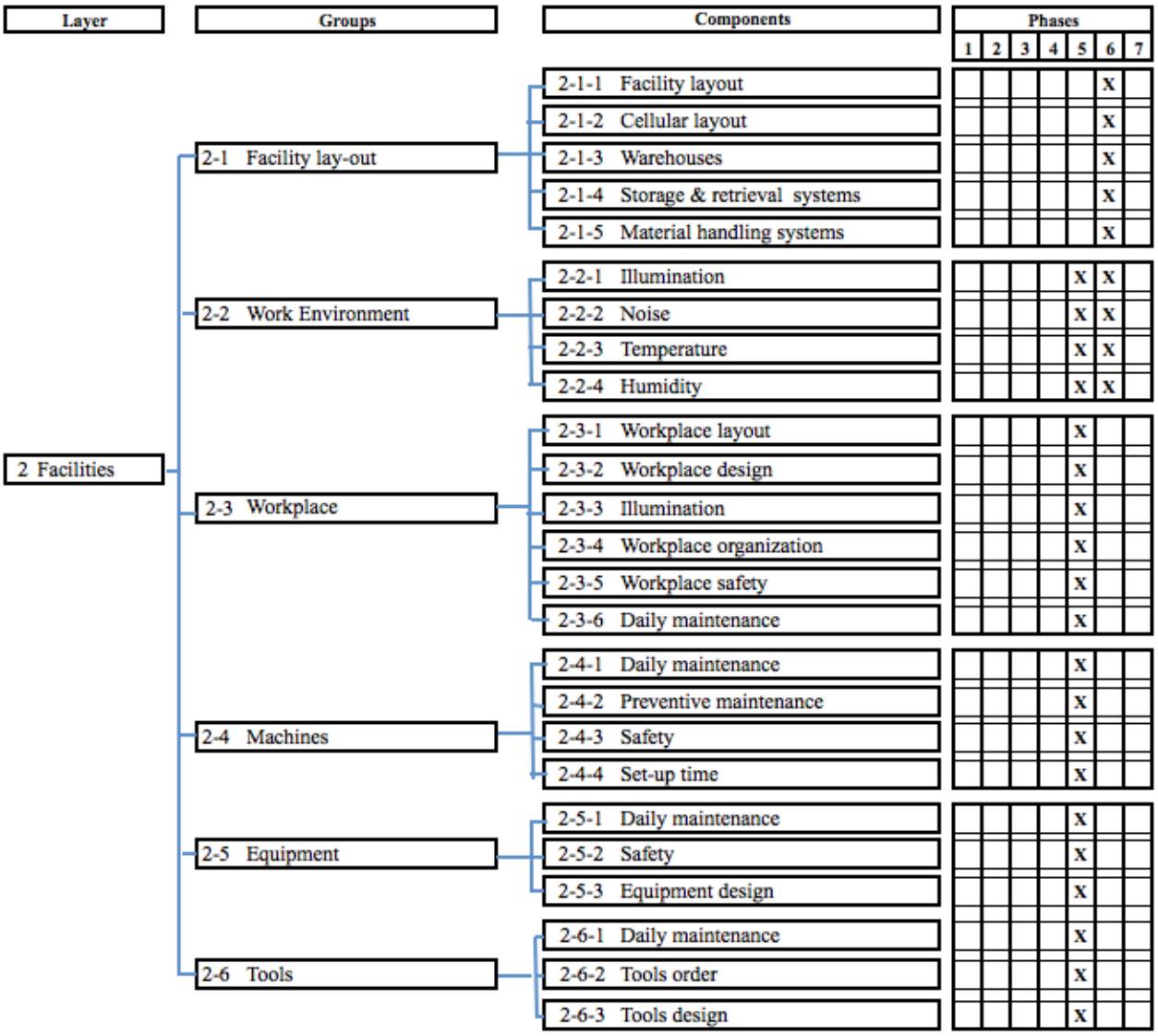

Figure 58. Phase in which each component is addressed – Facilities layer

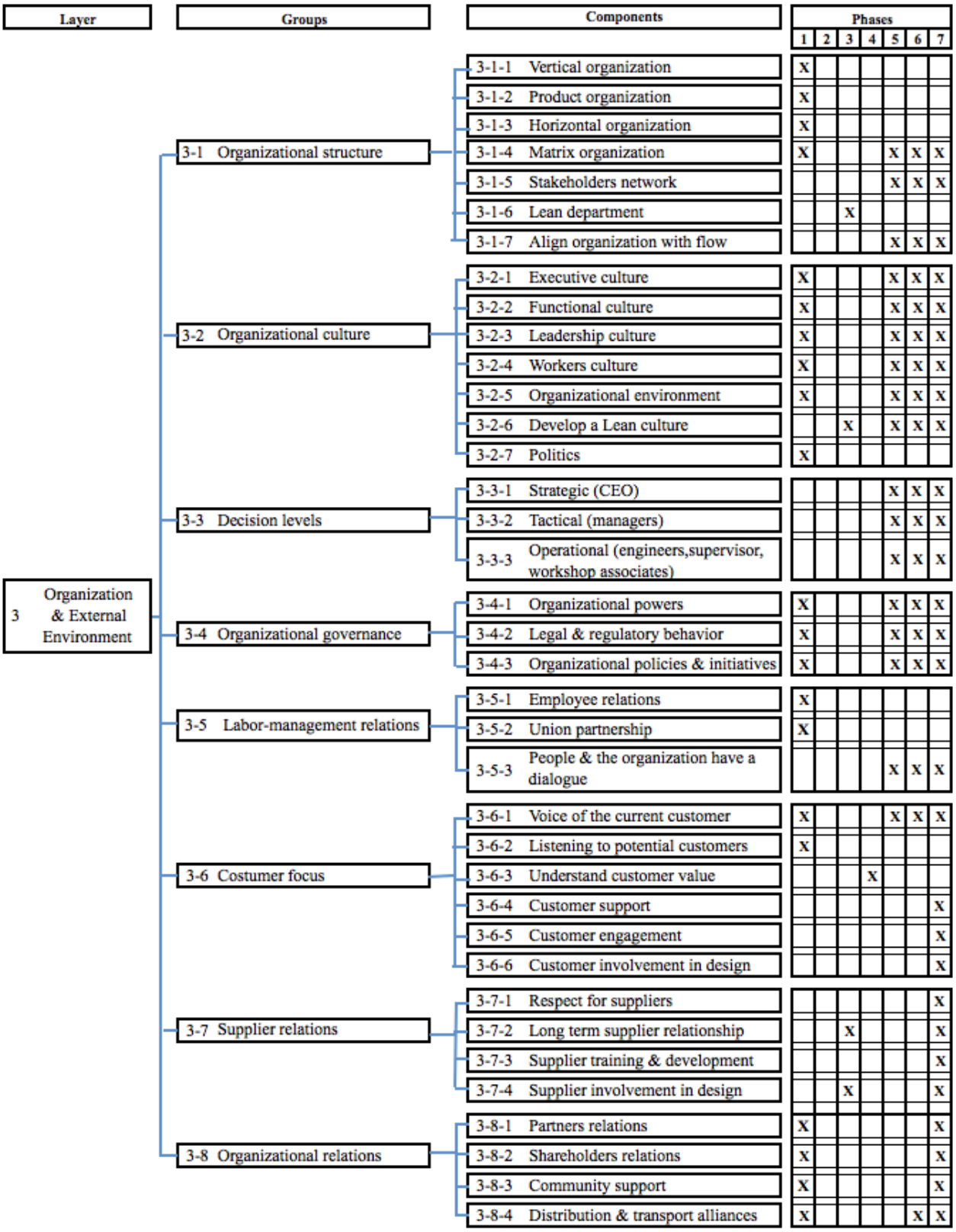

Figure 59. Phase in which each component is addressed - Organization & External Environment layer

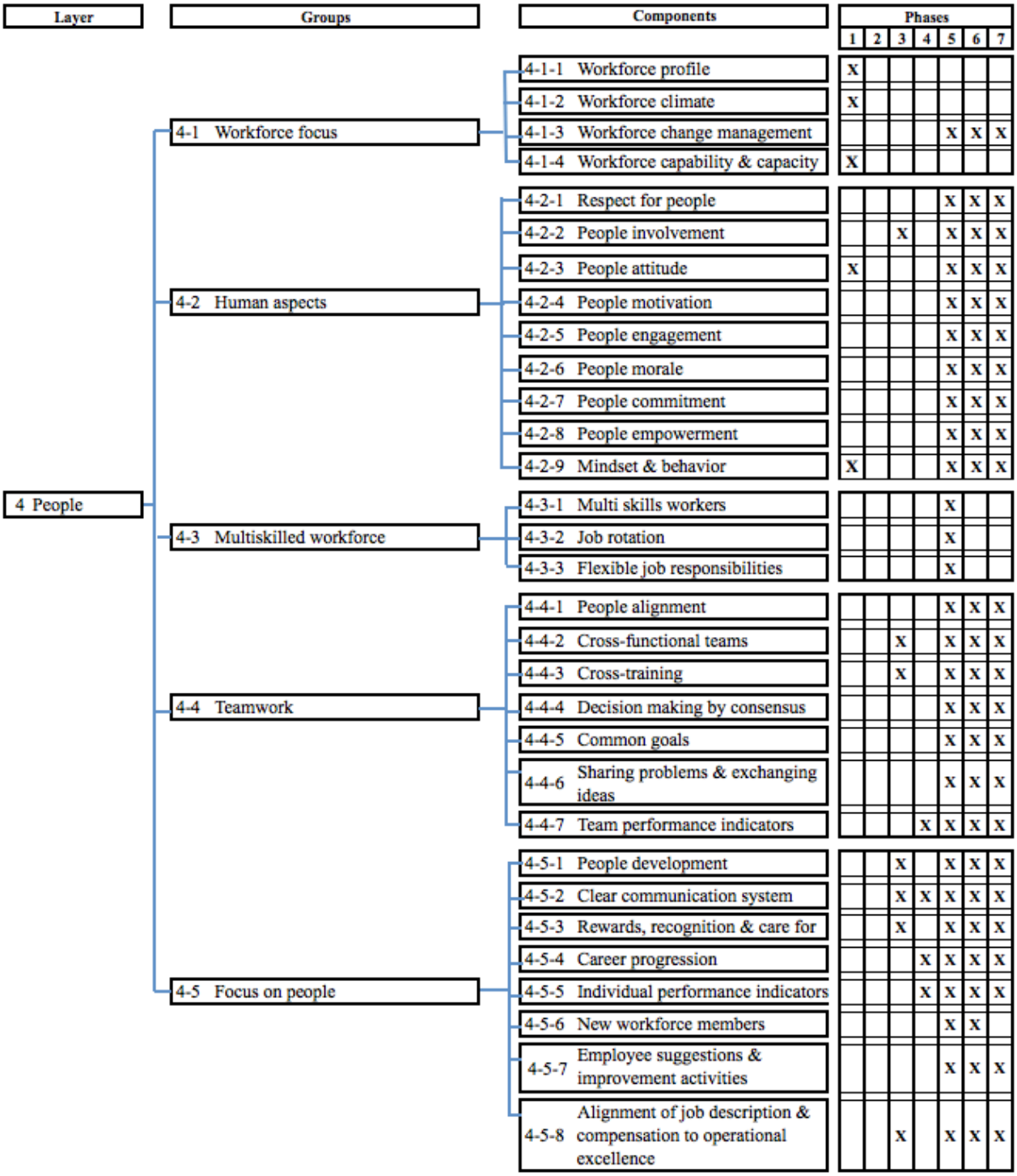

Figure 60. Phase in which each component is addressed - People layer

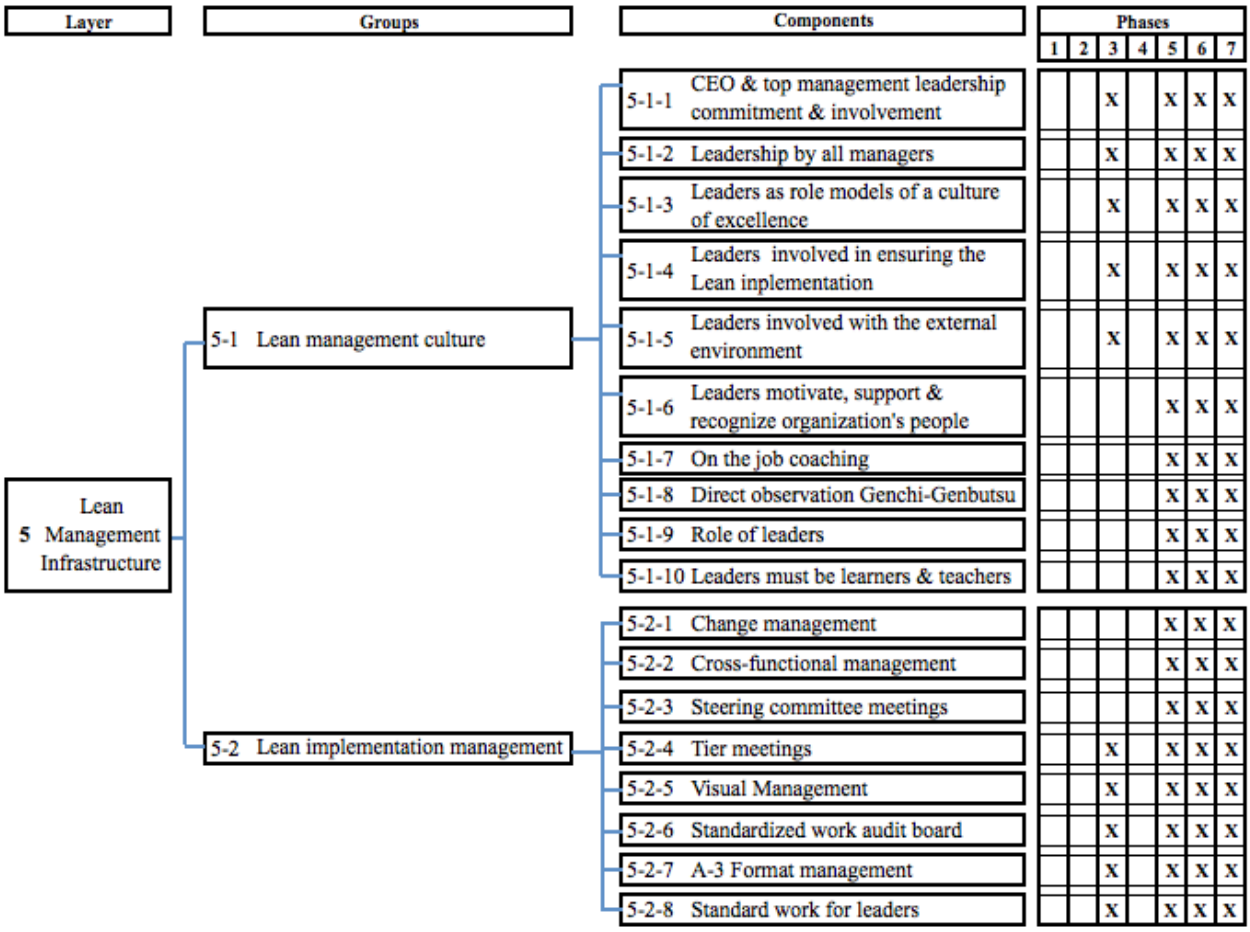

Figure 61. Phase in which each component is addressed – Lean Management Infrastructure layer

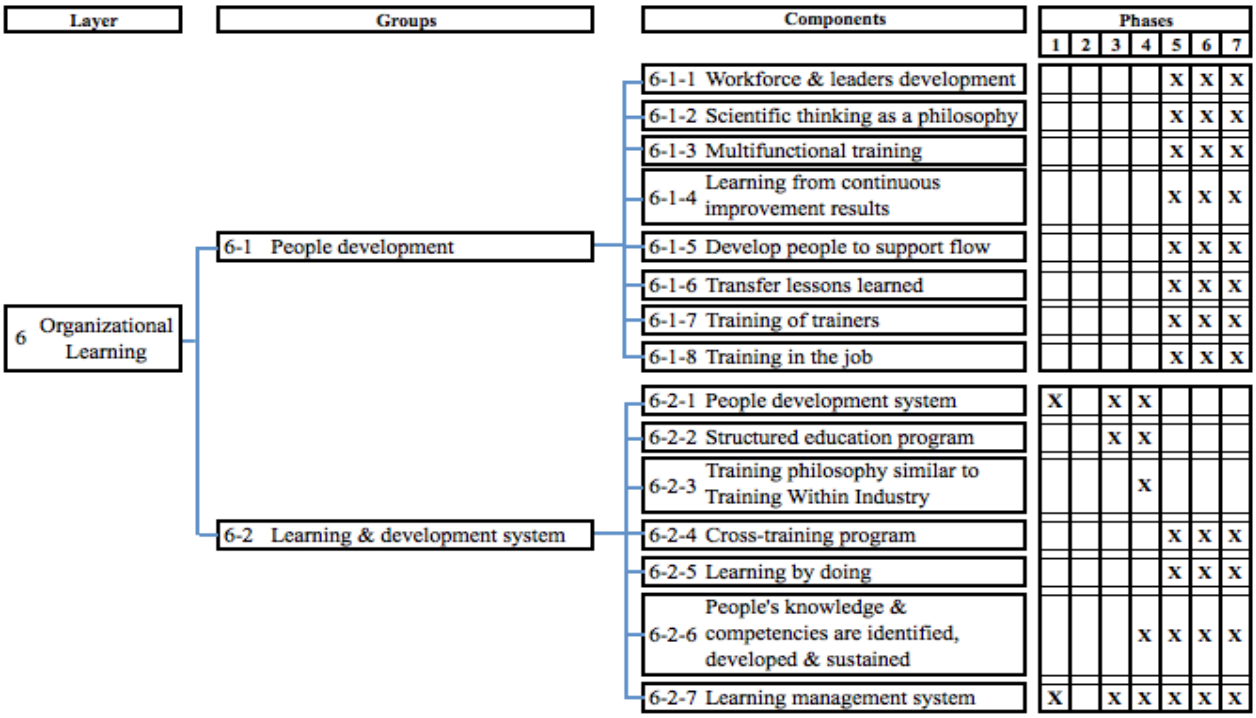

Figure 62. Phase in which each component is addressed – Organizational Learning layer

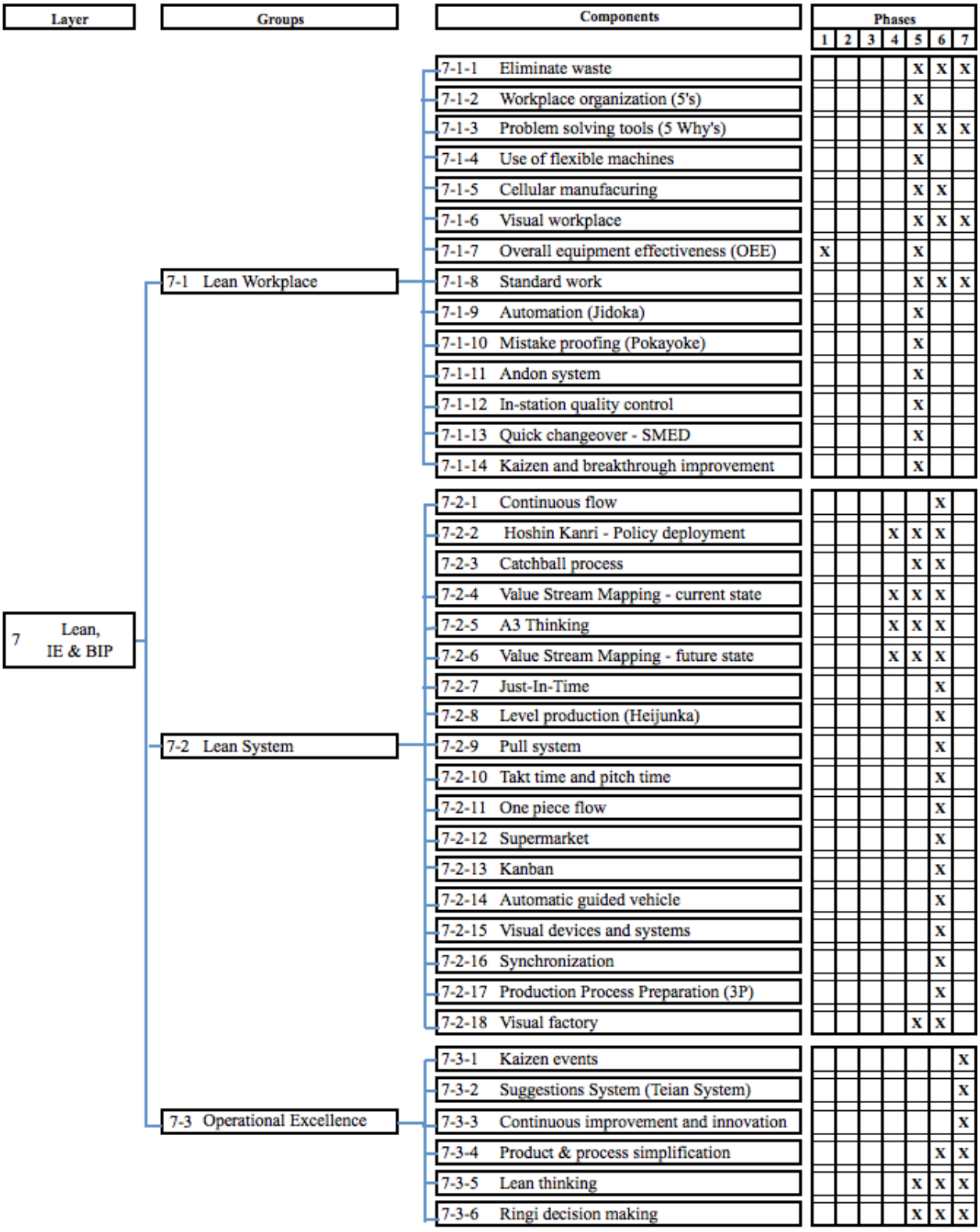

Figure 63. Phase in which each component is addressed – Lean, IE & BIP layer

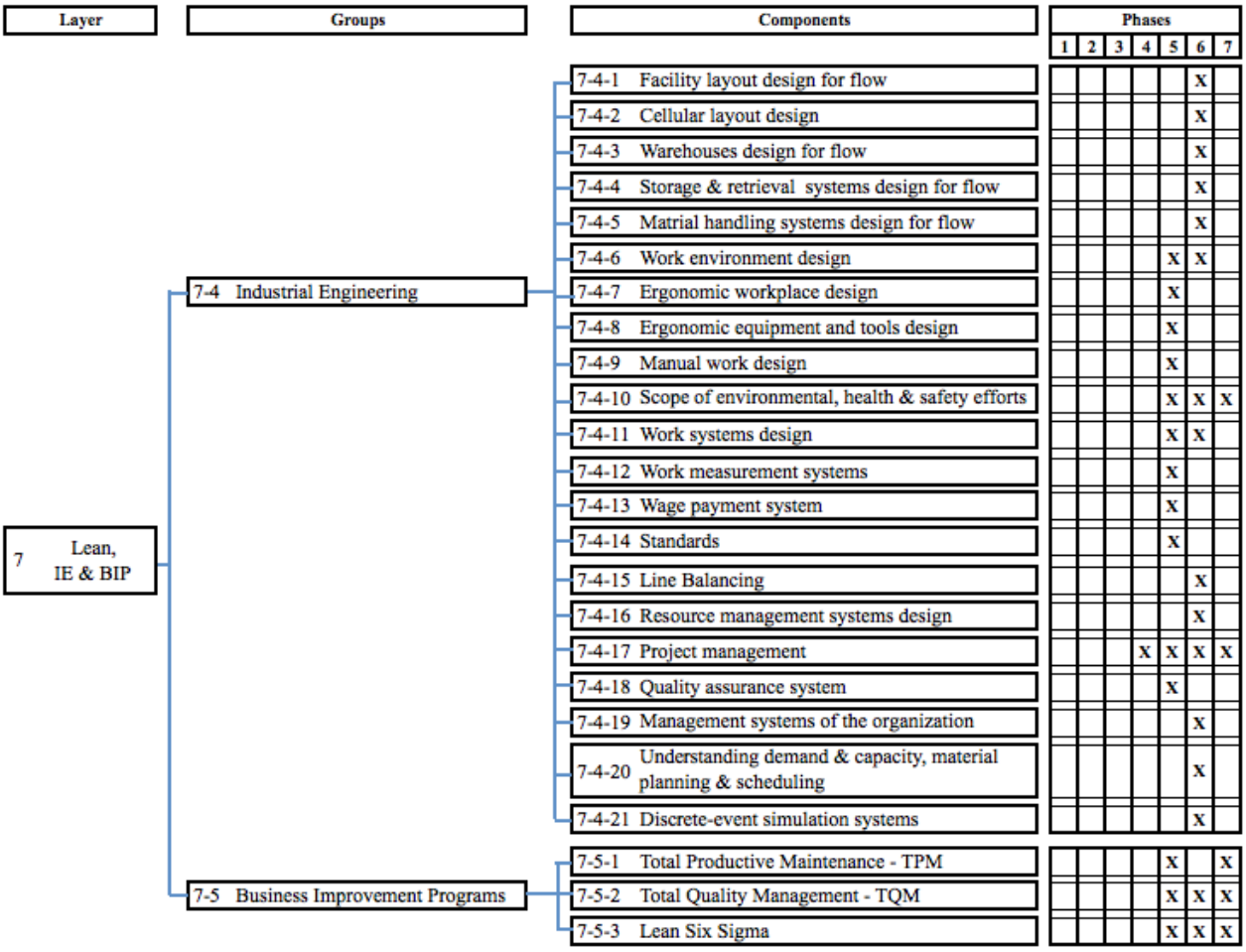

Figure 63. Phase in which each component is addressed – Lean, IE & BIP layer (continued)

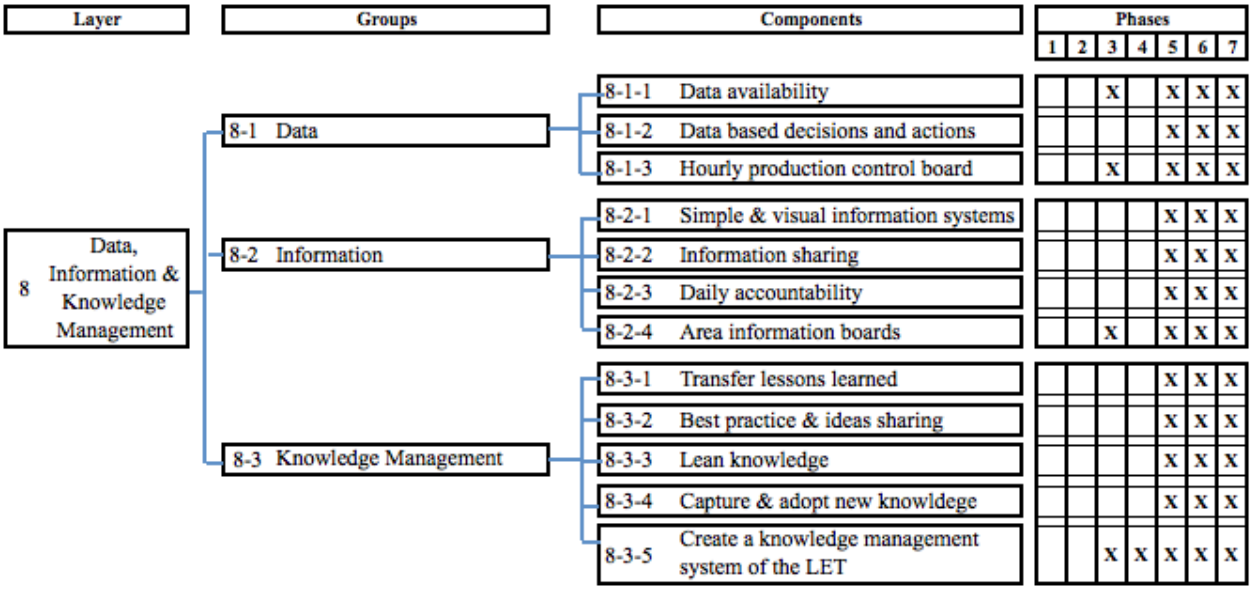

Figure 64. Phase in which each component is addressed – Data, Information & Knowledge

Management layer

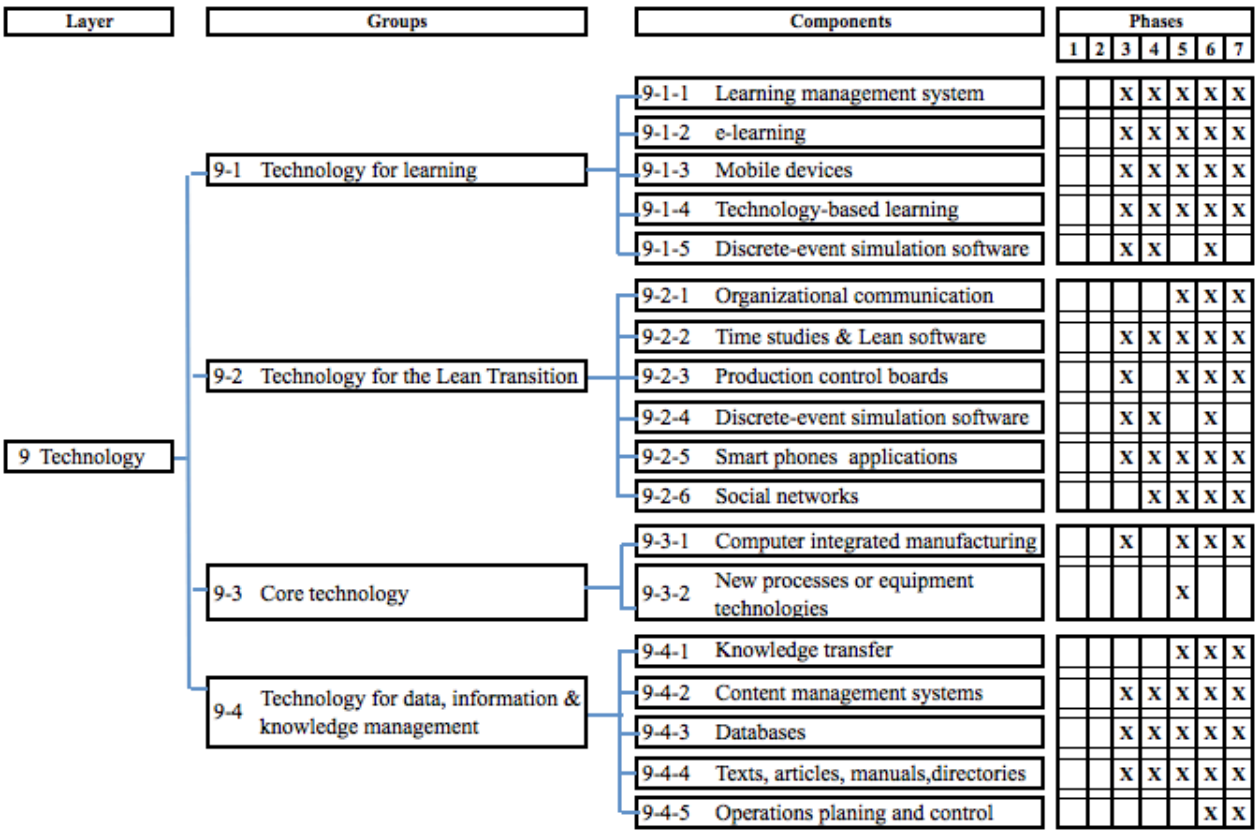

Figure 65. Phase in which each component is addressed – Technology layer

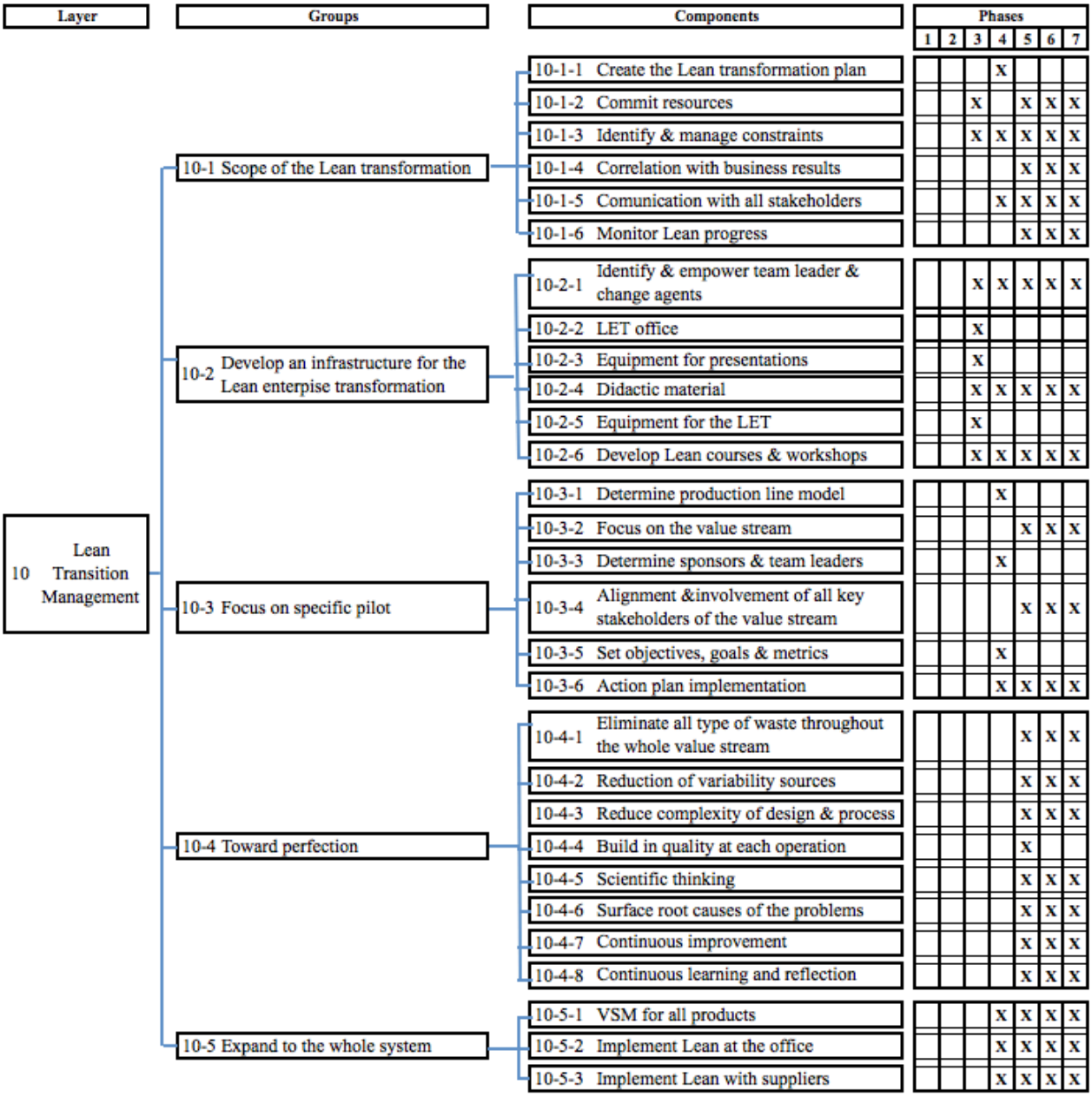

Figure 66. Phase in which each component is addressed – Lean Transition Management layer

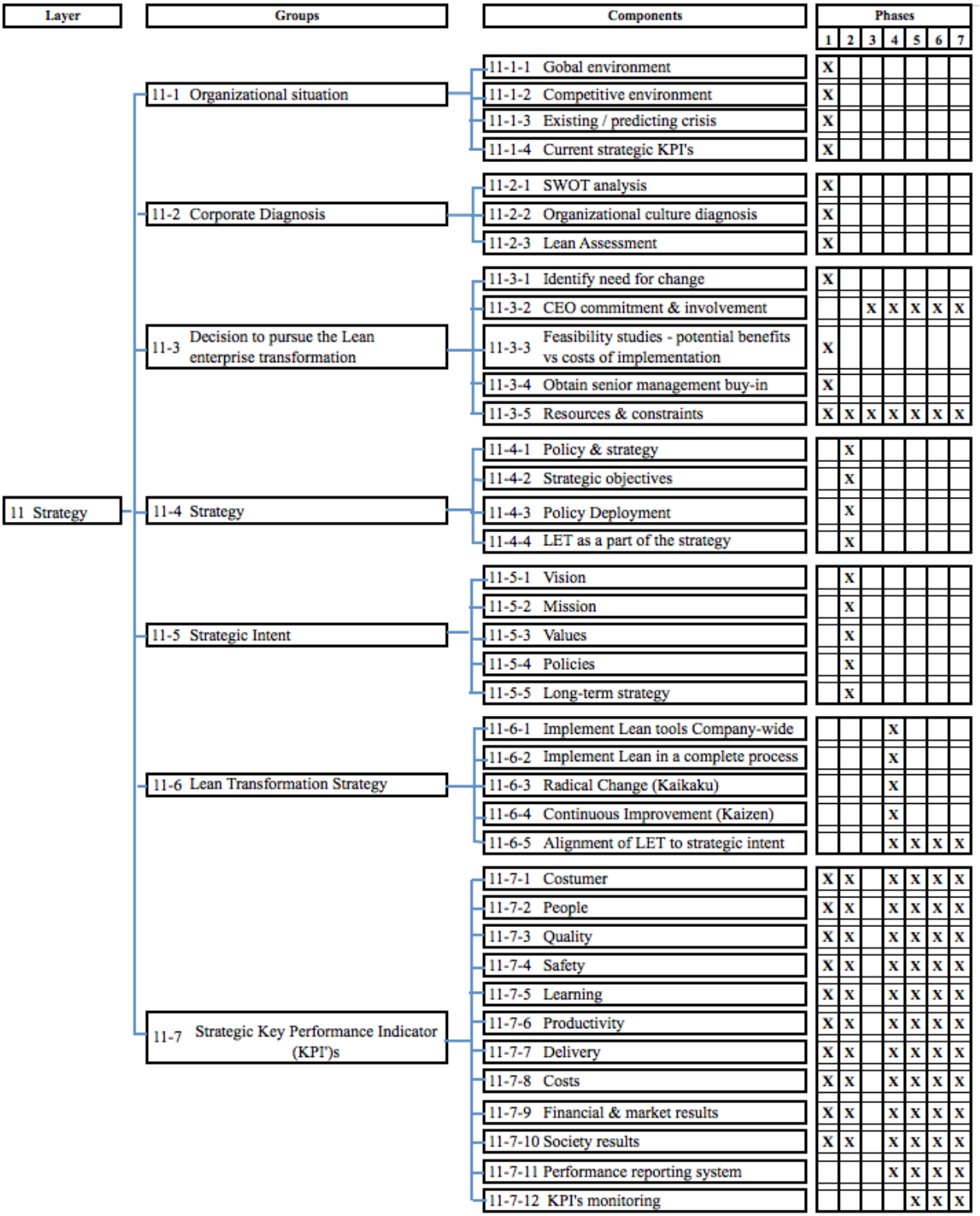

Figure 67. Phase in which each component is addressed – Strategy layer

Finally, after the components encompassed in each phase have been determined, a coherent integral Lean enterprise transformation process has been designed, as described in the following chapter.

CHAPTER 5: RESULTS

This chapter summarizes the results derived from the research described in the previous chapters. Using the most representative Lean principles and components from various frameworks, the framework developed here was designed with eleven layers. Each layer encompasses a number of groups and each group has a number of components. In addition, the Lean enterprise transformation life cycle comprises seven phases. Phases 5, 6, and 7 also include five sub-phases. Each life-cycle phase contains the components from the various layers of the framework. This chapter summarizes the layers, groups, and components of the Lean enterprise architecture framework by translating the three dimensional view into a two dimensional matrix that includes the codification of the components. Additionally, the transition roadmap of the Lean transformation is described, as well as the components included in each phase. The chapter is divided into six sections, namely the Lean enterprise transformation principles, the Lean enterprise architecture framework matrix, the Lean enterprise transition roadmap, and the pilot test. The fifth section compares different frameworks and the last section includes conclusions.

5.1 The Lean Enterprise Transformation Principles

Components from several Lean frameworks and the most well-known excellence models recognized by quality national awards were analyzed for this framework. The most representative Lean principles under those frameworks were selected, as follows:

Group 1 - Process Flow

- Focus on streamlining processes through the identification of constraints, elimination of waste, reduction of complexity and variability sources, and increasing flexibility

Group 2 - Lean Workplace

- Create and stabilize Lean workplaces throughout the value stream

Group 3 - Lean Leadership

- Secure the involvement and commitment of the CEO and senior managers for Lean leadership

Group 4 - People Focus

- Respect people, suppliers and partners
- Involve internal and external stakeholders that are related to the value stream

Group 5 - Organizational Learning

- Focus on organizational learning

Group 6 - Strategy

- Develop a Lean strategy by monitoring the key performance indicators

Group 7 - Lean Transition

- Plan the Lean transition, embracing a holistic approach to integrate and align the enterprise resources towards the strategic intent of the company

Group 8 - Technology

- Use the most appropriate technology

Group 9 – Customer Focus

A set of additional principles, which are proposed as a result of designing the framework, follows:

- Develop a Lean management infrastructure
- Create an infrastructure to manage the Lean enterprise transition
- Develop data, information, and knowledge management systems to transfer the Lean knowledge uniformly throughout the entire company

- Identify the interrelated network of components that work together in each phase of the Lean transformation
- Adopt the tools and methodologies from diverse disciplines that fit the needs of each phase of the Lean transformation

5.2 The Lean Enterprise Architecture Framework Matrix

The framework developed has been designed using an analytical, logical, and systematic approach, based on three-dimensional thinking as described in Section 4.3 and shown in Figure 68 (repeated from Figure 31). To have a detailed view of each layer of the framework, a matrix has been built that shows all of the layers and components of the framework, as described in Figure 69. The first column shows the layers, the second column shows the groups within each layer, and the third column shows the components within each group for each layer. The numbers in this figure, which come from Section 4.5, represent all the sets of layer-group-component combinations throughout the Enterprise Architecture Framework. This matrix therefore represents the entire framework and helps identify all its elements, following the component codification shown in Figure 36.

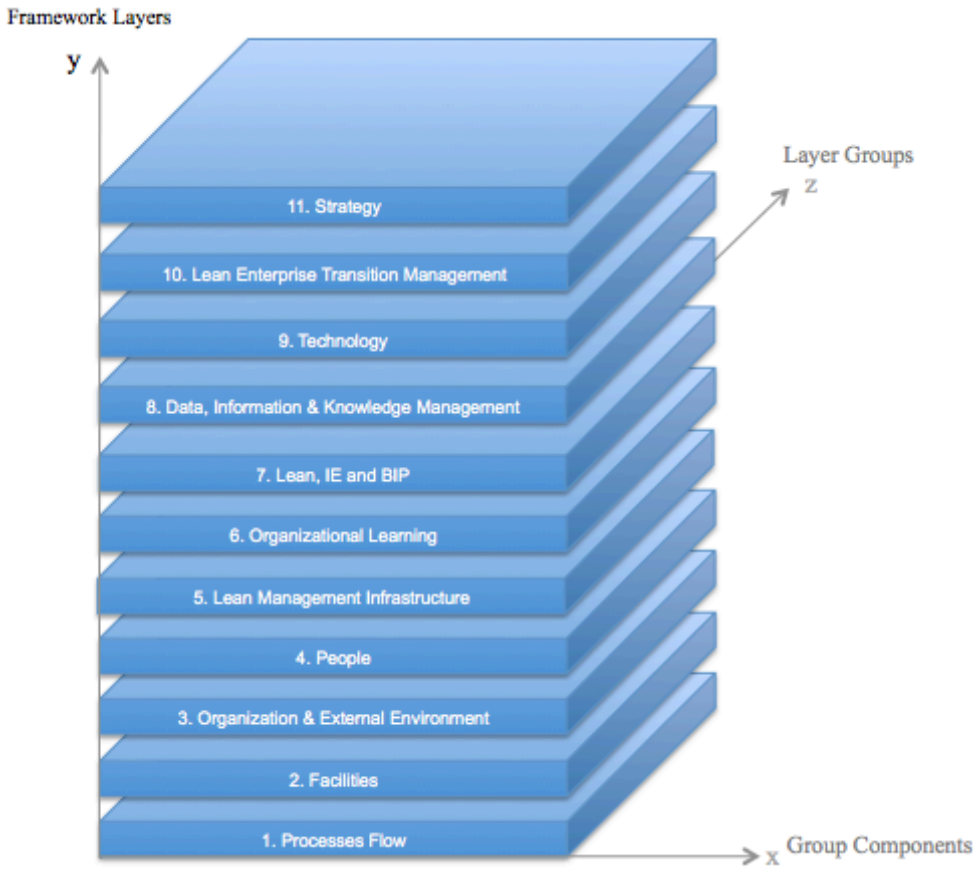

Figure 68. Enterprise Architecture Framework of a Lean Enterprise Transformation

(Repeated from Figure 31)

Layer	Groups	Components									
11	11-7	11-7-11	11-7-12								
		11-7-1	11-7-2	11-7-3	11-7-4	11-7-5	11-7-6	11-7-7	11-7-8	11-7-9	11-7-10
	11-6	11-6-1	11-6-2	11-6-3	11-6-4	11-6-5					
	11-5	11-5-1	11-5-2	11-5-3	11-5-4	11-5-5					
	11-4	11-4-1	11-4-2	11-4-3	11-4-4						
	11-3	11-3-1	11-3-2	11-3-3	11-3-4	11-3-5					
	11-2	11-2-1	11-2-2	11-2-3							
	11-1	11-1-1	11-1-2	11-1-3	11-1-4						
10	10-5	10-5-1	10-5-2	10-5-3							
	10-4	10-4-1	10-4-2	10-4-3	10-4-4	10-4-5	10-4-6	10-4-7	10-4-8		
	10-3	10-3-1	10-3-2	10-3-3	10-3-4	10-3-5	10-3-6				
	10-2	10-2-1	10-2-2	10-2-3	10-2-4	10-2-5	10-2-6				
	10-1	10-1-1	10-1-2	10-1-3	10-1-4	10-1-5	10-1-6				
9	9-4	9-4-1	9-4-2	9-4-3	9-4-4	9-4-5					
	9-3	9-3-1	9-3-2								
	9-2	9-2-1	9-2-2	9-2-3	9-2-4	9-2-5	9-2-6				
	9-1	9-1-1	9-1-2	9-1-3	9-1-4	9-1-5					
8	8-3	8-3-1	8-3-2	8-3-3	8-3-4	8-3-5					
	8-2	8-2-1	8-2-2	8-2-3	8-2-4						
	8-1	8-1-1	8-1-2	8-1-3							
7	7-5	7-5-1	7-5-2	7-5-3							
	7-4	7-4-21									
		7-4-11	7-4-12	7-4-13	7-4-14	7-4-15	7-4-16	7-4-17	7-4-18	7-4-19	7-4-20
		7-4-1	7-4-2	7-4-3	7-4-4	7-4-5	7-4-6	7-4-7	7-4-8	7-4-9	7-4-10
	7-3	7-3-1	7-3-2	7-3-3	7-3-4	7-3-5	7-3-6				
	7-2	7-2-11	7-2-12	7-2-13	7-2-14	7-2-15	7-2-16	7-2-17	7-2-18		
		7-2-1	7-2-2	7-2-3	7-2-4	7-2-5	7-2-6	7-2-7	7-2-8	7-2-9	7-2-10
	7-1	7-1-11	7-1-12	7-1-13	7-1-14						
		7-1-1	7-1-2	7-1-3	7-1-4	7-1-5	7-1-6	7-1-7	7-1-8	7-1-9	7-1-10
6	6-2	6-2-1	6-2-2	6-2-3	6-2-4	6-2-5	6-2-6	6-2-7			
	6-1	6-1-1	6-1-2	6-1-3	6-1-4	6-1-5	6-1-6	6-1-7	6-1-8		
5	5-2	5-2-1	5-2-2	5-2-3	5-2-4	5-2-5	5-2-6	5-2-7	5-2-8		
	5-1	5-1-1	5-1-2	5-1-3	5-1-4	5-1-5	5-1-6	5-1-7	5-1-8	5-1-9	5-1-10
4	4-5	4-5-1	4-5-2	4-5-3	4-5-4	4-5-5	4-5-6	4-5-7	4-5-8		
	4-4	4-4-1	4-4-2	4-4-3	4-4-4	4-4-5	4-4-6	4-4-7			
	4-3	4-3-1	4-3-2	4-3-3							
	4-2	4-2-1	4-2-2	4-2-3	4-2-4	4-2-5	4-2-6	4-2-7	4-2-8	4-2-9	
	4-1	4-1-1	4-1-2	4-1-3	4-1-4						
3	3-8	3-8-1	3-8-2	3-8-3	3-8-4						
	3-7	3-7-1	3-7-2	3-7-3	3-7-4						
	3-6	3-6-1	3-6-2	3-6-3	3-6-4	3-6-5	3-6-6				
	3-5	3-5-1	3-5-2	3-5-3							
	3-4	3-4-1	3-4-2	3-4-3							
	3-3	3-3-1	3-3-2	3-3-3							
	3-2	3-2-1	3-2-2	3-2-3	3-2-4	3-2-5	3-2-6	3-2-7			
	3-1	3-1-1	3-1-2	3-1-3	3-1-4	3-1-5	3-1-6	3-1-7			
2	2-6	2-6-1	2-6-2	2-6-3							
	2-5	2-5-1	2-5-2	2-5-3							
	2-4	2-4-1	2-4-2	2-4-3	2-4-4						
	2-3	2-3-1	2-3-2	2-3-3	2-3-4	2-3-5	2-3-6				
	2-2	2-2-1	2-2-2	2-2-3	2-2-4						
	2-1	2-1-1	2-1-2	2-1-3	2-1-4	2-1-5					
1	1-2	1-2-1	1-2-2	1-2-3	1-2-4	1-2-5	1-2-6				
	1-1	1-1-1	1-1-2	1-1-3	1-1-4	1-1-5	1-1-6	1-1-7			

Figure 69. The Lean Enterprise Architecture Framework Matrix

5.3 The Lean Enterprise Transition Roadmap and its Dynamics

The Lean enterprise transformation has been decomposed into several phases: Identification, Concept, Requirements, LET Planning, Lean Workplace, Lean System, and Operational Excellence in this case. The specific components of each phase are integrated into the Lean Enterprise Transition Roadmap, as represented in Figure 70. Note that phases 5 to 7 contain the letters P, A, D, I, O and S, which identify six sub-phases: Planning, Analysis, Design, Implementation, Operation, and Sustainment respectively. Phases 1 to 4 focus on the Lean enterprise transformation as a whole. Phases 5 to 7 focus on each of the products in all product families. It is important to note that phases 6 and 7 can start only after phase 5 is completed. After phases 5 to 7 are concluded for a specific product, the transformation continues by repeating phases 5 to 7 with (an)other product(s) in the same or a different product family.

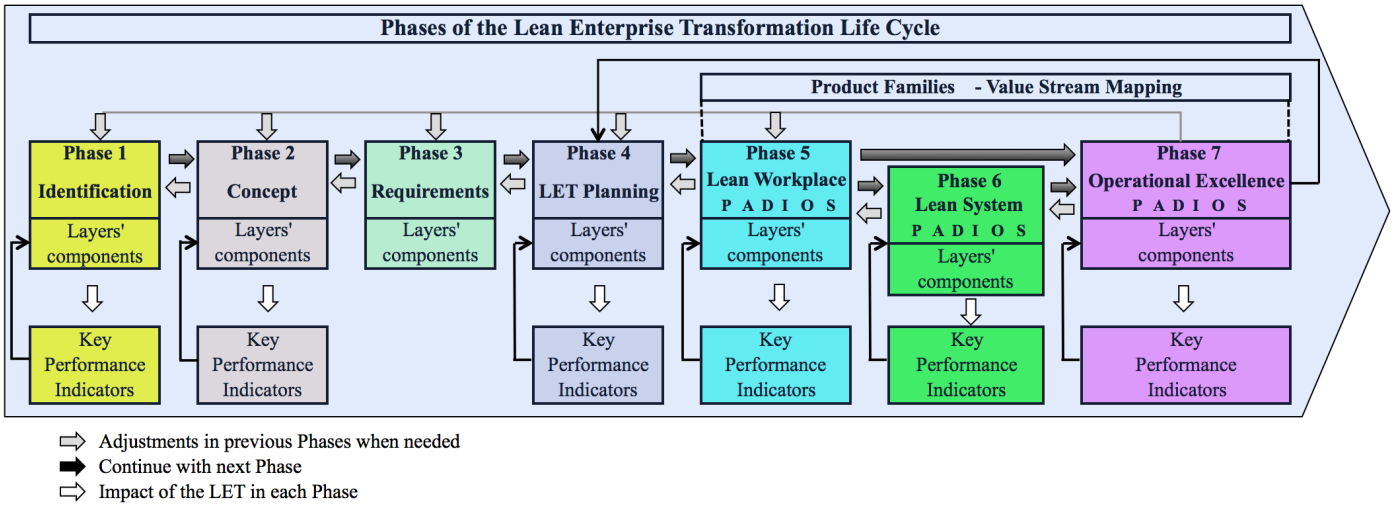

Figure 70. The Lean Enterprise Transition Roadmap

The black and gray arrows show the dynamics of the model. The gray line and gray arrows represent possible modifications throughout the phases of the LET life cycle in case something is altered affecting one or more of the components or the phases. Each phase, together with the layers' components, is linked through the white arrows to its strategic key performance

indicators. Active learning takes place during each phase, and after each phase is completed the key performance indicators are reviewed and relevant information is updated. Such updates take place continually during the Lean transformation.

Each phase of the Lean enterprise transition roadmap includes the components of the framework layer. The framework layers are listed in the first column in Figure 71. The set of components that constitute each phase of the Lean enterprise transformation, indicated as the colored columns under each phase, are shown in detail in Figures 72 to 78.

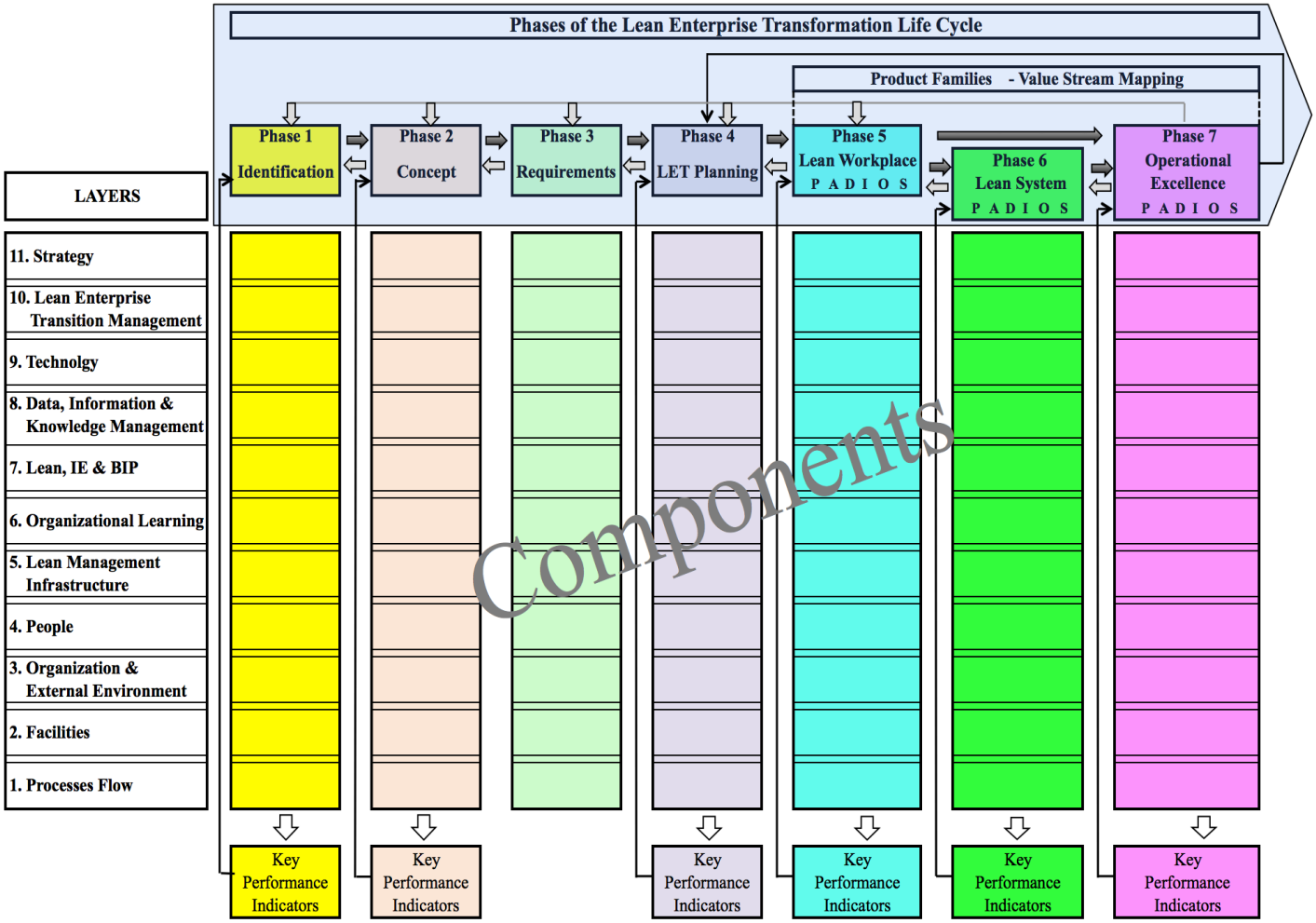

Figure 71. The Lean Enterprise Transition Roadmap

It is important to recognize that the Lean enterprise transformation uses a network of interrelated and interdependent components that work together in all phases to achieve the strategic intent of the company.

5.3.1 Rationale behind the Lean Enterprise Transition Roadmap

The enterprise architecture framework of a Lean enterprise transformation has been built based on existing Lean frameworks as well as on the most relevant excellence models recognized by the national quality awards discussed in the literature review. The first step in building the framework was to define the layers. The chief components of each layer were then determined by assessing how crucial the component was for achieving operational excellence. The answer was based on domain knowledge that considers the layers and the logic underpinning the proposed framework, as well as from the active learning gained during the testing phase of the framework and personal experience from Lean enterprise transformations. Finally, the components were grouped into similar clusters or categories using affinity diagrams based on similar attributes.

The Lean enterprise transition roadmap has been designed based on the components of each layer in the proposed framework, decomposing the Lean enterprise transformation life cycle into phases, and considering the logic underpinning the proposed framework. The life-cycle phases have been defined after analyzing the phases of existing Lean frameworks as well as the main enterprise architecture frameworks found in the literature. The possible components in each phase were determined by considering the steps in each stage towards Lean implementation also found the literature. A tree-matrix diagram was used to identify whether there is an interrelationship between the layer component and each LET life cycle phase. The decision as to which component is associated with each phase was based on the specific attributes of each

phase and by answering the following question: *Is this component interrelated to the specific attributes of this phase?*

5.3.2 Description of the Lean Enterprise Transition Roadmap Phases

The following paragraphs describe each phase of the Lean enterprise transition roadmap, which encompasses the summary of the attributes of each phase, the description of the phases and their corresponding layers' components, and the components of each phase.

5.3.2.1 Phase 1 – Identification

5.3.2.1.1 Attributes of Phase 1 – Identification

i) Boundaries and their relation to internal and external environments

ii) Identification of present and foreknown critical business problems

iii) The need for change

iv) Key elements to be considered for the Lean enterprise transformation

v) Current situation of the key performance indicators

vi) Main constraints to executing the transformation

5.3.2.1.2 Phase 1: Identification - Description and corresponding layers' components

In phase 1 the issues related to boundaries that the firm faces in the internal and external environment are identified. One of the first steps is to identify the organizational situation as well as the global environment of the company. To achieve this, the competitive environment has to be analyzed in order to envision where the company is positioned in the market. Moreover, the existing and predicted crises must be identified to understand the current and future situation of the company so as to anticipate possible decisions. Additionally, it is relevant to identify the current strategic key performance indicators (KPI's) of the company and analyze how well the company is doing regarding its customers and in comparison with its competitors.

After identifying the organizational situation, it is important to perform a corporate diagnosis. Several approaches can be used: the SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis, an organizational culture diagnosis, or a Lean assessment. There is no standard way of doing the organizational culture diagnosis and the Lean assessment. Therefore, the company has to determine what method is the most appropriate for its own organization.

At this point, the CEO has to identify the needs of the company, for example to improve competitiveness or to survive in a competitive market, and decide whether to pursue the Lean enterprise transformation (LET). This decision should be based on feasibility studies to identify the potential benefits versus the costs of implementation, based on the present and anticipated critical business problems of the firm that would be addressed during the transformation. Additionally, it is crucial to identify the resources and constraints that the company has for implementing the Lean enterprise transformation. Having all the previous components together is critical to obtaining senior management buy-in. The CEO together with the top management must determine the current strategic key performance indicators (KPI's) to understand the existing situation as well as to establish where they expect the company to be in its ideal situation.

The strategic KPI's are specific to each company, given its size, type of products or services, type of sector, and the particularities of the company. Several KPI's have been proposed in the framework in a general form, namely customer satisfaction, people, quality, safety, learning, productivity, delivery, costs, overall equipment effectiveness (OEE), and financial and market results. All of these KPI's have to be decomposed into subcategories of each KPI according the needs of the company. Moreover, it is imperative to develop a

performance report to link the components of the layers in each phase to the strategic KPI's of the company throughout the LET lifecycle.

Concerning the organization and the external environment, it is important to identify the company's organizational structure: vertical organization, product organization, horizontal organization, or a matrix organization. A good understanding of the type of organization is important in determining the key stakeholders of the Lean transformation as well as developing the thorough LET planning. Furthermore, it is essential to identify the organizational culture in the different hierarchical and functional levels, namely the executive culture, the functional culture, the leadership culture, the workers culture, the political and the organizational environment. This point is key to determining how to approach the LET and what issues have to be considered during the process.

The identification of the organizational governance is also relevant to identifying the organizational powers as well as the legal and regulatory behavior and the organizational policies and initiatives. It is vital to identify the labor-management relations, to understand employee relations and the union partnership with the company. This issue is crucial for identifying the barriers or advantages in the LET effort. Moreover, it is also necessary to identify the different organizational relations, namely the partners and shareholders relations and community support as well as distribution and transport alliances. Additionally, the LET is customer focused; therefore, it is important to listen to current customers as well as to potential customers.

The most important resource of a company is the employees. Therefore, it is fundamental to identify several features of the workforce: the workforce profile, workforce climate, and workforce capability and capacity. Furthermore, it is essential to identify the mindset and behavior of these people as well as their attitudes. All of these issues are key in identifying the

potential barriers raised by personnel as well as defining the best approach given the existing situation. It is imperative that the workforce develop the Lean concepts; thus the company needs a people-development system as well as a learning management system.

5.3.2.1.3 Components of Phase 1 – Identification

The set of components that constitute Phase 1 of the Lean enterprise transformation are shown in detail in Figure 72.

Phase 1 - Identification	
11	**Strategy**
11-1	Organizational situation
11-1-1	Gobal environment
11-1-2	Competitive environment
11-1-3	Existing / predicting crisis
11-1-4	Current strategic KPI's
11-2	Corporate Diagnosis
11-2-1	SWOT analysis
11-2-2	Organizational culture diagnosis
11-2-3	Lean Assessment
11-3	Decision to pursue the Lean enterprise transformation
11-3-1	Identify need for change
11-3-3	Feasibility studies - potential benefits vs costs of implementation
11-3-4	Obtain senior management buy-in
11-3-5	Resources & constraints
11-7	Strategic Key Performance Indicator (KPI')s
11-7-1	Costumer
11-7-2	People
11-7-3	Quality
11-7-4	Safety
11-7-5	Learning
11-7-6	Productivity
11-7-7	Delivery
11-7-8	Costs
11-7-9	Financial & market results
11-7-10	Society results
11-7-11	Performance reporting system
7	**Lean, IE & BIP**
7-1-7	Overall equipment effectiveness (OEE)
6	**Organizational Learning**
6-2-1	People development system
6-2-7	Learning management system
4	**People**
4-1-1	Workforce profile
4-1-2	Workforce climate
4-1-4	Workforce capability & capacity
4-2-3	People attitute
4-2-9	Mindset & behavior
3	**Organization & External Environment**
3-1	Organizational Structure
3-1-1	Vertical Organization
3-1-2	Product Organization
3-1-3	Horizontal Organization
3-1-4	Matrix Organization
3-2	Organizational Culture
3-2-1	Executive culture
3-2-2	Functional culture
3-2-3	Leadership culture
3-2-4	Workers culture
3-2-5	Organizational environment
3-2-7	Politics
3-4	Organizational governance
3-4-1	Organizational powers
3-4-2	Legal & regulatory behavior
3-4-3	Organizational policies & initiatives
3-5	Labor-Management Relations
3-5-1	Employee relations
3-5-2	Union partnership
3-6	Costumer focus
3-6-1	Voice of the current customer
3-6-2	Listening to potential customers
3-8	Organizational relations
3-8-1	Partners relations
3-8-2	Shareholders relations
3-8-3	Community support
3-8-4	Distribution & transport alliances

Figure 72. Phase 1 - Identification

5.3.2.2 Phase 2 – Concept

5.3.2.2.1 Attributes of Phase 2 – Concept

i) Concepts underlying the enterprise

ii) Statements describing the status of the company in terms of the nature of its products and its market

iii) Future desired state

iv) Strategic objectives

v) Policies and fundamental beliefs

5.3.2.2.2 Phase 2: Concept – Description and corresponding layers' components

Phase 2 includes the concepts underlying the enterprise and its future desired state. It encompasses the statements describing where the company is in terms of the nature of its products and its market. In this phase it is important to define the company's strategy, including the policy and the strategic objectives, and to define the policy deployment using either the Balanced Scorecard or Hoshin Kanri. It is essential to consider the LET as a part of the strategy and to define the strategic intent comprising the vision, mission, values and long-term strategy, as well as the future strategic key performance indicators (KPI's) of the company. The proposed KPI's are described in the previous section.

5.3.2.2.3 Components of Phase 2 – Concept

The set of components that constitute Phase 2 of the Lean enterprise transformation are shown in detail in Figure 73.

Phase 2 - Concept	
11	**Strategy**
11-4	Strategy
11-4-1	Policy & strategy
11-4-2	Strategic objectives
11-4-3	Policy Deployment
11-4-4	LET as a part of the strategy
11-5	Strategic Intent
11-5-1	Vision
11-5-2	Mission
11-5-3	Values
11-5-4	Policies
11-5-5	Long-term strategy
11-7	Strategic Key Performance Indicator (KPI')s
11-7-1	Customer
11-7-2	People
11-7-3	Quality
11-7-4	Safety
11-7-5	Learning
11-7-6	Productivity
11-7-7	Delivery
11-7-8	Costs
11-7-9	Financial & market results
11-7-10	Society results

Figure 73. Phase 2 - Concept

5.3.2.3 Phase 3 – Requirements

5.3.2.3.1 Attributes of Phase 3 - Requirements

i) Collection of actions

ii) Physical resources

iii) People

iv) Knowledge and similar concepts needed to accomplish the Lean enterprise transformation

5.3.2.3.2 Phase 3: Requirements – Description and corresponding layers' components

Phase 3 involves the requirements for accomplishing the Lean enterprise transformation. It includes the set of actions, physical resources, people, and knowledge, among other issues, that support the transformation process. One of the most important requirements of a successful LET implementation is the commitment and involvement of the company's CEO throughout the entire LET life cycle. Also, it is fundamental to align the enterprise resources that are related to the value stream in order to lead the people in the organization to work together towards the strategic intent. To achieve this effort, it is essential to create a Lean department, which will be in command of the Lean transition management. Another requirement for the LET is to develop a Lean culture within the organization as well as a long-term supplier relationship that involves the suppliers in the design of the product.

An additional requisite is to focus on people through the entire Lean transformation. People development and involvement during the LET is crucial. Alignment of the job description and compensation to operational excellence as well as rewards, recognition, and care is another requirement. Furthermore, people throughout the same value stream have to work in teams in order to coordinate the efforts towards common goals. Therefore, it is critical to create cross-functional and cross-training teams. A clear communication system is required in order to transfer accurate information to all the stakeholders in the Lean transformation.

A Lean organizational culture is achieved by creating a Lean management infrastructure. Developing a Lean management culture where the CEO and top management leadership are committed and involved is crucial. Furthermore, Lean leadership needs to be practiced by all managers from all departments. The leaders have to be the role models of a culture of excellence. Moreover, they must be involved in ensuring the Lean implementation as well as involved with

the external environment. Another requirement is to develop a Lean implementation management system to support the LET, including steering committee meetings, tier meetings, visual management, standardized work audit boards, A3 format management, and standard work for leaders.

An additional requirement is to focus on organizational learning in order to develop people, teams, and leaders in the Lean concepts and tools. Therefore, the LET requires a people-development system, a structured education program, and a learning management system in order to support the continuous improvement and continuous learning throughout the entire organization. Furthermore, a knowledge management system that incorporates the key concepts and practices of the LET must be created. Moreover, it is important to have data availability and hourly production control boards as well as area information boards.

The proper technology must be used to support the organizational learning, the knowledge management system, and the Lean transition. Technology can be used for e-learning and for developing a learning management system. Furthermore, mobile devices and discrete-event simulation software can also be useful, for example, to explain how a kanban system works. Moreover, technology can be used to develop a content management system and databases as well as to transfer information from texts, articles, manuals, and directories. Additionally, the technology for the Lean transition can include time studies and Lean software, production control boards, and smart phones applications as well as a computer-integrated manufacturing system.

The Lean transition management is also a key requirement since management identifies and empowers the team leader and change agents of the LET. Furthermore, it is important to develop the scope of the Lean transformation and to create the Lean transformation plan as well

as to identify and manage the main constraints. Another requirement is to develop an infrastructure for the LET that encompasses an LET office and training material as well as the equipment for presentations and for the LET. Moreover, it requires developing courses and workshops to teach the LET concepts and tools.

5.3.2.3.3 Components of Phase 3 – Requirements

The set of components that constitute Phase 3 of the Lean enterprise transformation are shown in detail in Figure 74.

Phase 3 - Requirements	
11	**Strategy**
11-3-2	CEO commitment & involvement
10	**Lean Transition Management**
10-1	Scope of the Lean transformation
10-1-1	Create the Lean transformation plan
10-1-3	Identify & manage constraints
10-2	Develop an infrastructure for the Lean enterpise transformation
10-2-1	Identify & empower team leader & change agents
10-2-2	LET office
10-2-3	Equipment for presentations
10-2-4	Didactic material
10-2-5	Equipment for the LET
10-2-6	Develop Lean courses & workshops
9	**Technology**
9-1	Technology for learning
9-1-1	Learning management system
9-1-2	e-learning
9-1-3	Mobile devices
9-1-4	Technology-based learning
9-1-5	Discrete-event simulation software
9-2	Technology for the Lean Transition
9-2-2	Time studies & Lean software
9-2-3	Production control boards
9-2-5	Smart phones applications
9-3-1	Computer integrated manufacturing
9-4-2	Content management systems
9-4-3	Databases
9-4-4	Texts, articles, manuals,directories
8	**Data, Information & Knowledge Management**
8-1-1	Data availability
8-1-3	Hourly production control board
8-2-4	Area information boards
8-3-5	Create a knowledge management system of the LET
6	**Organizational Learning**
6-2-1	People development system
6-2-2	Structured education program
6-2-7	Develop a learning management system
5	**Lean Management Infrastructure**
5-1	Lean management culture
5-1-1	CEO & top management leadership commitment & involvement
5-1-2	Leadership by all managers
5-1-3	Leaders are role models of a culture of excellence
5-1-4	Leaders are personally involved in ensuring the Lean inplementation
5-1-5	Leaders are involve with the external environment
5-2	Lean implementation management
5-2-3	Steering committee meetings
5-2-4	Tier meetings
5-2-5	Visual Management
5-2-6	Standardized work audit board
5-2-7	A-3 Format management
5-2-8	Standard work for leaders
4	**People**
4-2-2	People involvement
4-4	Teamwork
4-4-2	Cross-functional teams
4-4-3	Cross-training
4-5	Focus on people
4-5-1	People development
4-5-2	Clear communication system
4-5-3	Rewards, recognition & care for
4-5-8	Alignment of job description & compensation to operational excellence
3	**Organization & External Environment**
3-1-6	Create a Lean Department
3-2-6	Develop a Lean culture
3-7-2	Long term supplier relationship
3-7-4	Supplier involvement in design
1	**Processes Flow**
1-1-7	Align enterprise resources to the value stream

Figure 74. Phase 3 - Requirements

5.3.2.4 Phase 4 – LET Planning

5.3.2.4.1 Attributes of Phase 4 - LET Planning

i) Actions required to plan the Lean enterprise transformation,

ii) Type of Lean strategy

iii) Activities that must be carried out to execute all phases of the transformation

5.3.2.4.2 Phase 4: LET Planning – Description and corresponding layers' components

Phase 4 comprises the actions required for planning the Lean enterprise transformation as well as the type of Lean strategy that should be followed. Furthermore, it encompasses planning the activities that must be carried out to execute all phases of the transformation. It is relevant to plan for the resources that will be available for the LET. Planning the CEO involvement is crucial throughout this phase and the entire transformation. Moreover, it is necessary to plan how to empower the team leaders and change agents in the LET department or on the LET team.

Once phases 1 to 3 have been developed, the Lean transformation strategy can be defined. According to each particular situation, the company can decide how to implement the LET from the following options: i) Implement the Lean tools Company-wide, ii) Implement Lean in a complete manufacturing process, iii) Implement a radical change (Kaikaku) including not only the manufacturing process but also the auxiliary and administrative processes, iv) Implement continuous improvement (kaizen) events, or v) a combination of the previous four options. It is important to plan how to align the LET to the strategic intent of the company. Furthermore, it is essential to plan how to link each phase of the LET to the strategic KPI's identified in previous phases as well as to develop a performance reporting system.

It is essential to create the Lean transformation plan focusing on the value stream of the products. Planning how manage the constraints that could affect the LET is key. Furthermore, it

is important to identify all key process flows, including product development and primary, and support activities.

The LET can be initiated by focusing on a specific pilot case. All products of the company have to be grouped into product families and the most important product to the company has to be chosen from one product family. The production line of this product will be used as the production line reference model before expanding it to other product families within the firm. It is relevant to understand the whole value stream in order to improve the entire system and not only its parts. Therefore, it is necessary to determine the sponsors, team leader, and team members of the team that will perform the Lean transformation throughout the production line model.

The LET team has to create the current and future state value stream map in order to build a Lean system by identifying and eliminating the waste throughout the whole system. It is important to understand what the customer holds valuable. The LET team has to develop an action plan and set the objectives, goals, and metrics of the production line model. It is key to identify and involve all stakeholders in the value stream. Furthermore, the LET team has to create a clear communication system in order to interact and communicate the updated information to the involved stakeholders. Value stream mapping can be used to develop the current and future state of the value stream. Hoshin Kanri as well as A3 thinking can be used to deploy company policies to the different hierarchical levels of the organization.

It is important to plan how the individual and team performance indicators will be measured throughout the LET as well as the career progression of the employees. Moreover, it is relevant to create a clear communication system in order to inform the people about all the LET concerns. The learning and development system is an essential component in transferring the

Lean knowledge to the whole organization. Therefore, it is important to create a system for identifying, developing, and sustaining people's knowledge and competencies. Then, a structured education program has to be developed by using a training philosophy similar to "training within industry." Furthermore, Lean courses and workshops have to be planned, as well as training material for each Lean tool. Afterwards, a learning management system has to be created in order to monitor which employees have been trained as well as in what Lean tools.

The Lean transformation has to be expanded to the whole system, implementing Lean at the office as well as with its suppliers. Value stream mapping can be used for all products. Technology plays an important role in learning, communicating, and transferring throughout the LET. Therefore, it is vital to plan what technology will be used in phases 5 to 7.

5.3.2.4.3 Components of Phase 4 - LET Planning

The set of components that constitute Phase 4 of the Lean enterprise transformation are shown in detail in Figure 75.

Phase 4 - LET Planning	
11	**Strategy**
11-3-2	CEO commitment & involvement
11-3-5	Resources & constraints
11-6	Lean Transformation Strategy
11-6-1	Implement Lean tools Company-wide
11-6-2	Implement Lean in a complete process
11-6-3	Radical Change (Kaikaku)
11-6-4	Continuous Improvement (Kaizen)
11-6-5	Alignment of LET to strategic intent
11-7	Strategic Key Performance Indicator (KPI')s
11-7-1	Customer
11-7-2	People
11-7-3	Quality
11-7-4	Safety
11-7-5	Learning
11-7-6	Productivity
11-7-7	Delivery
11-7-8	Costs
11-7-9	Financial & market results
11-7-10	Society results
11-7-11	Performance reporting system
10	**Lean Transition Management**
10-1-1	Create the Lean transformation plan
10-1-3	Identify & manage constraints
10-1-5	Comunication with all stakeholders
10-2-1	Identify & empower team leader & change agents
10-2-4	Didactic material
10-2-6	Develop Lean courses & workshops
10-3	Focus on specific pilot
10-3-1	Determine production line model
10-3-3	Determine sponsors & team leaders
10-3-5	Set objectives, goals & metrics
10-3-6	Action plan implementation
10-5	Expand to the whole system
10-5-1	VSM for all products
10-5-2	Implement Lean at the office
10-5-3	Implement Lean with suppliers
9	**Technology**
9-1	Technology for learning
9-1-1	Learning management system
9-1-2	e-learning
9-1-3	Mobile devices
9-1-4	Technology-based learning
9-1-5	Discrete-event simulation software
9-2-2	Time studies & Lean software
9-2-5	Smart phones applications
9-2-6	Social networks
8	**Data, Information & Knowledge Management**
8-3-5	Create a knowledge management system of the LET
7	**Lean, IE & BIP**
7-4-17	Project management
7-2	Lean System
7-2-2	Hoshin Kanri
7-2-4	Value Stream Mapping - current state
7-2-5	A3 Thinking
7-2-6	Value Stream Mapping - future state
6	**Organizational Learning**
6-2	Learning & development system
6-2-1	People development system
6-2-2	Structured education program
6-2-3	Training philosophy similar to Training Within Industry
6-2-6	People's knowledge & competencies are identified, developed & sustained
6-2-7	Learning management system
4	**People**
4-4-7	Team performance indicators
4-5-2	Clear communication system
4-5-4	Career progression
4-5-5	Individual performance indicators
3	**Organization & External Environment**
3-6-3	Understand customer value
1	**Processes Flow**
1-1	Focus on the value stream
1-1-1	Identify product families
1-1-2	Understand the whole value stream
1-1-3	Create a current state map
1-1-5	Develop the future state map
1-1-6	Identify & involve all stakeholders
1-2-6	Identify all key processes flow including product development, primary & support activities

Figure 75. Phase 4 - LET Planning

Phases 5, 6 and 7

Phases 5, 6 and 7 encompass the same layers' components and all the components are based on phase 4. Basically the main differences among these phases are the components that are from the Lean, Industrial Engineering (IE) and Business Improvement Programs (BIP) layer as well as the Facility layer. Additionally, phase 5 focuses on the Lean workplace, while phase 6

focuses on the Lean system and phase 7 focuses on the continual improvement and continual learning from phases 5 and 6. Once phase 5 is finished, if the company has the resources, phases 6 and 7 can be initiated at the same time. In the following section, the components of phase 5 are described in more detail (descriptions of components that are the same as those in phase 4 are not repeated). Descriptions of the components of phases 6 and 7 include only those components that have not been described in previous sections.

5.3.2.5 Phase 5 - Lean Workplace

5.3.2.5.1 Attributes of Phase 5 - Lean Workplace

i) Activities to eliminate all types of waste identified in the workplaces related to the value stream determined in Phase 4

ii) Actions needed to design or improve the workplace components

iii) Components from the framework layers useful to reduce variability, stabilize the workflow, and increase flexibility in the workplace.

5.3.2.5.2 Description of Phase 5 - Lean Workplace and its corresponding layers' components

Phase 5 encompasses the layer components in the framework useful to reduce the variability, stabilize the workflow, and increase flexibility in the workplace as well as other attributes described in section 4.7.

The CEO as well as the senior management's commitment and involvement in the Lean workplace are crucial. It is important to determine the resources and constraints for implementing Lean in each workplace of the value stream. Furthermore, it is important to

determine the strategic KPI's related to the workplace and monitor them through the Lean transformation.

Lean pursues perfection; hence, the LET effort is toward achieving this goal. In order to attain perfection it is crucial to eliminate all types of waste throughout the whole value stream as well as to reduce the complexity of the process. Furthermore, it is imperative to reduce the variability of sources as well as to build quality into each operation. It is important to embrace scientific thinking and bring to the surface the root causes of the problems. Moreover, people in the organization must focus on continual improvement in their daily work as well as continual learning and reflection.

One of the main objectives of LET is to create a continuous flow and eliminate waste in the entire enterprise. It is essential to transform the workplace into a Lean workplace before attempting to achieve a Lean system. The alignment of the enterprise resources related to the value stream of a specific product is a key factor in the Lean transformation. The LET is process-flow oriented; therefore it is crucial to create continuous process flow and develop flexible processes, as well as reduce variability along the process flows and build quality into each operation. In order to build the Lean system, the current and future state of the value stream mapping done in phase 4 has to be used to identify all the workplaces included in the value stream of the production line model. This value stream mapping is also used in phases 6 and 7. It is important to align and involve all key stakeholders in all workplaces of the value stream. Hoshin Kanri and A3 thinking can be used for the policy deployment of the company as well as the catchball process for communicating with the stakeholders.

Once the workplaces of the value stream have been identified, the elements of each workplace must be analyzed: facilities, work environment, workplace design, machines and

equipment, methods and standards, people, learning and knowledge, technology, and data and information (see section 4.2). All of these components are interrelated and have to be well synchronized and excel in their operations or functions. Each can be improved by using the proper tools and concepts of Lean, Industrial Engineering, and Business Improvement Programs.

Several factors of the work environment facilities have to be analyzed and improved, such as the illumination, noise, temperature, and humidity. Furthermore, the workplace lay out, design, illumination, organization, safety, and daily maintenance have to be studied. Other elements of the workplace that have to be examined are the machines (daily maintenance, safety, and set-up time), equipment (daily maintenance, safety, and equipment design), and tools (daily maintenance, tool order, and tool design).

The following concepts from Industrial Engineering (IE) can be used to improve the elements of the workplace: work environment design; ergonomic workplace design; ergonomic equipment and tool design; manual work design; environmental, health, and safety efforts; work systems design; work measurement systems; wage payment system; standards; and quality assurance systems.

In addition to previous IE concepts, the Lean tools can be used to create a Lean workplace by identifying and eliminating waste, workplace organization (5S), problem solving tools (5Why's), use of flexible machines, cellular manufacturing, visual workplace, overall equipment effectiveness (OEE), standard work, automation (jidoka), Mistake proofing (pokayoke), andon system, in station quality control, quick changeover (SMED), continuous improvement (kaizen) and breakthrough improvement, visual factory, Lean thinking, and ringi decision making.

Business Improvement Programs (BIP) such as the following can be useful in stabilizing the operations in the workplace through total productive maintenance (TPM), useful for maximizing the equipment effectiveness; Lean six sigma, a methodology and set of tools used to improve quality to less than 3.4 defects per million or better; and total quality management (TQM), a management system focused on customer satisfaction through continual improvement and employee participation.

If the concepts, tools, and methodologies from Lean, IE, and BIP are complementary and holistically integrated, they can be very powerful in creating a Lean workplace towards operational excellence. However, these concepts and tools of Lean, IE, and BIP are not the main focus; they are only the means that help to improve the workplaces and the systems. The focus is on people, the most important resource in the company. It is important to develop a workforce change management process in order to support the stakeholders to transitioning to the desired Lean future state. Furthermore, it is relevant to consider different human aspects such as respect for the people, people involvement, people attitude, people motivation, people engagement, people morale, people commitment, people empowerment, and mindset and behavior. Moreover, a multi-skilled workforce has to be developed to support flexible workstations. Therefore, it is necessary to have multi-skilled workers as well as job rotation and flexible job responsibilities. Additionally, the LET requires a teamwork approach, considering people alignment, cross-functional teams, cross-training, decision-making by consensus, common goals, sharing problems and exchanging ideas, and team performance indicators. A focus on people also takes into consideration people development, a clear communication system, rewards, recognition, and care for, career progression, individual performance indicators, new workforce members,

employee suggestions and improvement activities, and alignment of job description and compensation to operational excellence.

It is important to understand the organization as well as its external environment, to identify the network of stakeholders and their positions in the organizational structure as well as to acknowledge their decision level within the organization. Moreover, it is necessary to align the organization with the flow process and to listen to the voice of current customers. To develop a Lean culture, it is essential to understand first the current organizational culture and its subcultures, such as the executive culture, the functional culture, the leadership culture, the workers' culture, and the organizational environment. Furthermore, it is important to recognize the organizational governance within the organizational powers, its legal and regulatory behavior, and the organizational policies and initiatives. It is relevant that the employees and the management of the organization have a dialogue.

Organizational learning is crucial for the LET. People development in Lean thinking, Lean tools, Lean leadership and other relevant topics such as workforce and leader development, scientific thinking as a philosophy, multifunctional training, learning from continual improvement results, development of employees to support flow, transfer of lessons learned, training of trainers, and training in the job are also very important for LET. Moreover, a learning and development system is necessary to support a cross-training program and learning by doing, to identify, develop and sustain people's knowledge and competencies, and to implement a learning management system.

A Lean management infrastructure is needed in order to support the stakeholders, and to create a Lean culture within the organization. A Lean management culture is a key factor for success in the LET implementation: CEO and top management leadership, commitment and

involvement, leadership by all managers, leaders as role models of a culture of excellence, leaders personally involved in ensuring the Lean implementation, leaders involved in the external environment, leaders that motivate, support and recognize organization's people, on the job coaching, direct observation (Genchi Genbutsu), define roles of leaders, and leaders as learners and teachers.

Furthermore, Lean implementation management is key to leading the LET, to communicating with the stakeholders and to sustaining the Lean changes. It encompasses change management, cross-functional management, steering committee meetings, tier meetings, visual management, standardized work audit board, A-3 format management, and standard work for leaders.

Data, information, and knowledge management helps in keeping information updated, making decisions, and transferring knowledge throughout the LET. Data management includes data availability, data based decisions and actions, and hourly production control boards. Furthermore, the information comprises simple and visual information systems, information sharing, daily accountability, and area information boards. Knowledge management is the process of capturing, sharing, and effectively using Lean knowledge throughout the LET. It encompasses transfer of lessons learned, best practices and ideas sharing, Lean knowledge, capture and adoption of new knowledge, and creating a knowledge management system for the LET.

Technology is necessary to generate the appropriate organizational learning, to support the Lean transition as well as to manage the data, information, and knowledge of the LET phases. The components of technology for learning include learning management system, e-learning, mobile devices, and technology-based learning. Furthermore, technology for the Lean

transition comprises organizational communication, time studies and Lean software, production control boards, smart phones applications, social networks, and computer integrated manufacturing. Technology for data, information, and knowledge management encompasses knowledge transfer, content management system, databases, and texts, articles, manuals, and directories.

5.3.2.5.3 Components of Phase 5 - Lean Workplace

The set of components that constitute Phase 5 of the Lean enterprise transformation are shown in detail in Figure 76.

Phase 5 - Lean Workplace	
11	**Strategy**
11-3-2	CEO commitment & involvement
11-3-5	Resources & constraints
11-6-5	Alignment of LET to strategic intent
11-7	Strategic Key Performance Indicator (KPI')s
11-7-1	Customer
11-7-2	People
11-7-3	Quality
11-7-4	Safety
11-7-5	Learning
11-7-6	Productivity
11-7-7	Delivery
11-7-8	Costs
11-7-9	Financial & market results
11-7-10	Society results
11-7-11	Performance reporting system
11-7-12	KPI's monitoring
10	**Lean Transition Management**
10-1	Scope of the Lean transformation
10-1-2	Commit resources
10-1-3	Identify & manage constraints
10-1-4	Correlation with business results
10-1-5	Comunication with all stakeholders
10-1-6	Monitor Lean progress
10-2	Develop an infrastructure for the Lean enterpise transformation
10-2-1	Identify & empower team leader & change agents
10-2-4	Didactic material
10-2-6	Develop Lean courses & workshops
10-3	Focus on specific pilot
10-3-2	Focus on the value stream
10-3-4	Alignment & involvement of all key stakeholders of the value stream
10-3-6	Action plan implementation
10-4	Toward perfection
10-4-1	Eliminate all types of waste throughout the whole value stream
10-4-2	Reduction of variability sources
10-4-3	Reduce complexity of design & process
10-4-4	Build in quality at each operation
10-4-5	Scientific thinking
10-4-6	Surface root causes of the problems
10-4-7	Continuous improvement
10-4-8	Continuous learning and reflection
10-5	Expand to the whole system
10-5-1	VSM for all products
10-5-2	Implement Lean at the office
10-5-3	Implement Lean with suppliers
9	**Technology**
9-1	Technology for learning
9-1-1	Learning management system
9-1-2	e-learning
9-1-3	Mobile devices
9-1-4	Technology-based learning
9-2	Technology for the Lean Transition
9-2-1	Organizational communication
9-2-2	Time studies & Lean software
9-2-3	Production control boards
9-2-5	Smart phones applications
9-2-6	Social networks
9-3-1	Computer integrated manufacturing
9-4	Technology for data, information & knowledge management
9-4-1	Knowledge transfer
9-4-2	Content management systems
9-4-3	Databases
9-4-4	Texts, articles, manuals,directories
8	**Data, Information & Knowledge Management**
8-1	Data
8-1-1	Data availability
8-1-2	Data based decisions and actions
8-1-3	Hourly production control board
8-2	Information
8-2-1	Simple & visual information systems
8-2-2	Information sharing
8-2-3	Daily accountability
8-2-4	Area information boards
8-3	Knowledge Management
8-3-1	Transfer lessons learned
8-3-2	Best practice & ideas sharing
8-3-3	Lean knowledge
8-3-4	Capture & adopt new knowldege
8-3-5	Create a knowledge management system of the LET
7	**Lean, IE & BIP**
7-1	Lean Workplace
7-1-1	Eliminate waste
7-1-2	Workplace organization (5 S)
7-1-3	Problem solving tools (5 Why's)
7-1-4	Use of flexible machines
7-1-5	Cellular manufacuring
7-1-6	Visual workplace
7-1-7	Overall equipment effectiveness (OEE)
7-1-8	Standard work
7-1-9	Automation (Jidoka)
7-1-10	Mistake proofing (Pokayoke)
7-1-11	Andon system
7-1-12	In-station quality control
7-1-13	Quick changeover - SMED
7-1-14	Kaizen and breakthrough improvement
7-2	Lean System
7-2-2	Hoshin Kanri
7-2-3	Catchball process
7-2-4	Value Stream Mapping - current state
7-2-5	A3 Thinking
7-2-6	Value Stream Mapping - future state
7-2-18	Visual factory
7-3	Operational Excellence
7-3-5	Lean thinking
7-3-6	Ringi decision making
7-4	Industrial Engineering
7-4-6	Work environment design
7-4-7	Ergonomic workplace design
7-4-8	Ergonomic equipment and tools design
7-4-9	Manual work design
7-4-10	Scope of environmental, health & safety efforts
7-4-11	Work systems design
7-4-12	Work measurement systems
7-4-13	Wage payment system
7-4-14	Standards
7-4-17	Project management
7-4-18	Quality assurance system
7-5	Business Improvement Programs
7-5-1	Total Productive Maintenance - TPM
7-5-2	Total Quality Management - TQM
7-5-3	Lean Six Sigma

Figure 76. Phase 5 - Lean Workplace

Phase 5 - Lean Workplace	
6	**Organizational Learning**
6-1	People development
6-1-1	Workforce & leaders development
6-1-2	Scientific thinking as a philosophy
6-1-3	Multifunctional training
6-1-4	Learning from continuous improvement results
6-1-5	Develop people to support flow
6-1-6	Transfer lessons learned
6-1-7	Training of trainers
6-1-8	Training in the job
6-2	Learning & development system
6-2-4	Cross-training program
6-2-5	Learning by doing
6-2-6	People's knowledge & competencies are identified, developed & sustained
6-2-7	Learning management system
5	**Lean Management Infrastructure**
5-1	Lean management culture
5-1-1	CEO & top management leadership commitment & involvement
5-1-2	Leadership by all managers
5-1-3	Leaders are role models of a culture of excellence
5-1-4	Leaders are personally involved in ensuring the Lean inplementation
5-1-5	Leaders are involved with the external environment
5-1-6	Leaders motivate, support & recognize organization's people
5-1-7	On the job coaching
5-1-8	Direct observation Genchi-Genbutsu
5-1-9	Role of leaders
5-1-10	Leaders must be learners & teachers
5-2	Lean implementation management
5-2-1	Change management
5-2-2	Cross-functional management
5-2-3	Steering committee meetings
5-2-4	Tier meetings
5-2-5	Visual Management
5-2-6	Standardized work audit board
5-2-7	A-3 Format management
5-2-8	Standard work for leaders
4	**People**
4-1-3	Workforce change management
4-2	Human aspects
4-2-1	Respect for people
4-2-2	People involvement
4-2-3	People attitude
4-2-4	People motivation
4-2-5	People engagement
4-2-6	People morale
4-2-7	People commitment
4-2-8	People empowerment
4-2-9	Mindset & behavior
4-3	Multiskilled workforce
4-3-1	Multi skills workers
4-3-2	Job rotation
4-3-3	Flexible job responsibilities
4-4	Teamwork
4-4-1	People alignment
4-4-2	Cross-functional teams
4-4-3	Cross-training
4-4-4	Decision making by consensus
4-4-5	Common goals
4-4-6	Sharing problems & exchanging ideas
4-4-7	Team performance indicators
4-5	Focus on people
4-5-1	People development
4-5-2	Clear communication system
4-5-3	Rewards, recognition & care for
4-5-4	Career progression
4-5-5	Individual performance indicators
4-5-6	New workforce members
4-5-7	Employee suggestions & improvement activities
4-5-8	Alignment of job description & compensation to operational excellence
3	**Organization & External Environment**
3-1	Organizational Structure
3-1-4	Matrix Organization
3-1-5	Stakeholders network
3-1-7	Align organization with flow
3-2	Organizational Culture
3-2-1	Executive culture
3-2-2	Functional culture
3-2-3	Leadership culture
3-2-4	Workers culture
3-2-5	Organizational environment
3-2-6	Develop a Lean culture
3-3	Decision levels
3-3-1	Strategic (CEO)
3-3-2	Tactical (Managers)
3-3-3	Operational (Engineers, supervisor, workshop associates)
3-4	Organizational governance
3-4-1	Organizational powers
3-4-2	Legal & regulatory behavior
3-4-3	Organizational policies & initiatives
3-5-3	People & the organization have a dialogue
3-6-1	Voice of the current customer
2	**Facilities**
2-2	Work Environment
2-2-1	Ilumination
2-2-2	Noise
2-2-3	Temperature
2-2-4	Humidity
2-3	Workplace
2-3-1	Workplace lay-out
2-3-2	Workplace design
2-3-3	Ilumination
2-3-4	Work place organization
2-3-5	Workplace safety
2-3-6	Daily maintenance
2-4	Machines
2-4-1	Daily maintenance
2-4-2	Preventive maintenance
2-4-3	Safety
2-4-4	Set-up time
2-5	Equipment
2-5-1	Daily maintenance
2-5-2	Safety
2-5-3	Equipment design
2-6	Tools
2-6-1	Daily maintenance
2-6-2	Tools order
2-6-3	Tools design
1	**Processes Flow**
1-1	Focus on the value stream
1-1-4	Continuous flow and eliminating waste in the entire enterprise
1-1-7	Align enterprise resources
1-2	Processes flow oriented
1-2-1	Create continuous process flow
1-2-2	Develop flexible processes
1-2-3	Reduce variability along processes flow
1-2-4	Build in quality at each operation of the process

Figure 76. Phase 5 - Lean Workplace (Continued)

5.3.2.6 Phase 6 – Lean System

5.3.2.6.1 Attributes of Phase 6 - Lean System

i) Actions to synchronize the entire process flow

ii) Activities to visualize the whole system by understanding the components' interconnections and their relationships

iii) Activities to understand the sequence of operations and flow of activities

iv) Activities to eliminate all types of waste identified through the process flow as well as to reduce its variability and increase flexibility

5.3.2.6.2 Phase 6: Lean System – Description and corresponding layers' components

The Lean system phase encompasses the actions to synchronize the entire process flow. Furthermore, it includes the activities to eliminate all types of waste identified through the process flow as well as to reduce its variability and increase flexibility. This phase has components similar to those in phase 5. However, phase 5 focuses on the Lean workplace and phase 6 on the Lean system. The components of phase 6 that are not included in phase 5 are continuous flow, just-in-time (JIT), level production (heijunka), pull system, takt time and pitch time, one piece flow, supermarket, kanban, automatic guided vehicle, visual devices and systems, synchronization, production process preparation (3P), and visual factory. These Lean components can be implemented in the value stream after the Lean workplace phase is completed. Concepts from IE that can be used to improve the facility's components in order to design the Lean system are facility layout design for flow, cellular layout design, warehouses design for flow, storage and retrieval systems design for flow, material handling systems design for flow, line balancing, and resource management systems design.

Other components that are relevant to designing the Lean system but are not included in phase 5 are discrete event simulation software (which is useful to show the dynamics of the system and can be used for learning as well as for supporting the Lean transition), operations planning and control software, distribution and transport alliances, and reduction of product and process complexity.

5.3.2.6.3 Components of Phase 6 - Lean System

The set of components that constitute Phase 6 of the Lean enterprise transformation are shown in detail in Figure 77.

Phase 6 - Lean System	
11	**Strategy**
11-3-2	CEO commitment & involvement
11-3-5	Resources & constraints
11-6-5	Alignment of LET to strategic intent
11-7	Strategic Key Performance Indicator (KPI')s
11-7-1	Customer
11-7-2	People
11-7-3	Quality
11-7-4	Safety
11-7-5	Learning
11-7-6	Productivity
11-7-7	Delivery
11-7-8	Costs
11-7-9	Financial & market results
11-7-10	Society results
11-7-11	Performance reporting system
11-7-12	KPI's monitoring
10	**Lean Transition Management**
10-1	Scope of the Lean transformation
10-1-2	Commit resources
10-1-3	Identify & manage constraints
10-1-4	Correlation with business results
10-1-5	Comunication with all stakeholders
10-1-6	Monitor Lean progress
10-2	Develop an infrastructure for the Lean enterpise transformation
10-2-1	Identify & empower team leader & change agents
10-2-4	Didactic material
10-2-6	Develop Lean courses & workshops
10-3	Focus on specific pilot
10-3-2	Focus on the value stream
10-3-4	Alignment &involvement of all key stakeholders of the value stream
10-3-6	Action plan implementation
10-4	Toward perfection
10-4-1	Eliminate all types of waste throughout the whole value stream
10-4-2	Reduction of variability sources
10-4-3	Reduce complexity of design & process
10-4-4	Build in quality at each operation
10-4-5	Scientific thinking
10-4-6	Surface root causes of the problems
10-4-7	Continuous improvement
10-4-8	Continuous learning and reflection
10-5	Expand to the whole system
10-5-1	VSM for all products
10-5-2	Implement Lean at the office
10-5-3	Implement Lean with suppliers
9	**Technology**
9-1	Technology for learning
9-1-1	Learning management system
9-1-2	e-learning
9-1-3	Mobile devices
9-1-4	Technology-based learning
9-1-5	Discrete-event simulation software
9-2	Technology for the Lean Transition
9-2-1	Organizational communication
9-2-2	Time studies & Lean software
9-2-3	Production control boards
9-2-4	Discrete-event simulation software
9-2-5	Smart phones applications
9-2-6	Social networks
9-3-1	Computer integrated manufacturing
9-4	Technology for data, information & knowledge management
9-4-1	Knowledge transfer
9-4-2	Content management systems
9-4-3	Databases
9-4-4	Texts, articles, manuals, directories
9-4-5	Operations planning and control
8	**Data, Information & Knowledge Management**
8-1	Data
8-1-1	Data availability
8-1-2	Data based decisions and actions
8-1-3	Hourly production control board
8-2	Information
8-2-1	Simple & visual information systems
8-2-2	Information sharing
8-2-3	Daily accountability
8-2-4	Area information boards
8-3	Knowledge Management
8-3-1	Transfer lessons learned
8-3-2	Best practice & ideas sharing
8-3-3	Lean knowledge
8-3-4	Capture & adopt new knowldege
8-3-5	Create a knowledge management system of the LET
7	**Lean, IE & BIP**
7-1	Lean Workplace
7-1-1	Eliminate waste
7-1-3	Problem solving tools (5 Why's)
7-1-5	Cellular manufacuring
7-1-6	Visual workplace
7-1-8	Standard work
7-2	Lean System
7-2-1	Continuous flow
7-2-2	Hoshin Kanri- Policy deployment
7-2-3	Catchball process
7-2-4	Value Stream Mapping - current state
7-2-5	A3 Thinking
7-2-6	Value Stream Mapping - future state
7-2-7	Just-In-Time
7-2-8	Level production (Heijunka)
7-2-9	Pull system
7-2-10	Takt time and pitch time
7-2-11	One piece flow
7-2-12	Supermarket
7-2-13	Kanban
7-2-14	Automatic guided vehicle
7-2-15	Visual devices and systems
7-2-16	Synchronization
7-2-17	Production Process Preparation (3P)
7-2-18	Visual factory
7-3	Operational Excellence
7-3-4	Product & process simplification
7-3-5	Lean thinking
7-3-6	Ringi decision making
7-4	Industrial Engineering
7-4-1	Facility layout design for flow
7-4-2	Cellular layout design
7-4-3	Warehouses design for flow
7-4-4	Storage & retrieval systems design for flow
7-4-5	Matrial handling systems design for flow
7-4-6	Work environment design
7-4-10	Scope of environmental, health & safety efforts
7-4-11	Work systems design
7-4-15	Line Balancing
7-4-16	Resource management systems design
7-4-17	Project management

Figure 77. Phase 6 – Lean System

Phase 6 - Lean System	
7-4-19	Management systems of the organization
7-4-20	Understanding demand & capacity, material planning & scheduling
7-4-21	Discrete-event simulation systems
7-5	Business Improvement Programs
7-5-2	Total Quality Management - TQM
7-5-3	Lean Six Sigma
6	**Organizational Learning**
6-1	People development
6-1-1	Workforce & leaders development
6-1-2	Scientific thinking as a philosophy
6-1-3	Multifunctional training
6-1-4	Learning from continuous improvement results
6-1-5	Develop people to support flow
6-1-6	Transfer lessons learned
6-1-7	Training of trainers
6-1-8	Training in the job
6-2	Learning & development system
6-2-4	Cross-training program
6-2-5	Learning by doing
6-2-6	People's knowledge & competencies are identified, developed & sustained
6-2-7	Learning management system
5	**Lean Management Infrastructure**
5-1	Lean management culture
5-1-1	CEO & top management leadership commitment & involvement
5-1-2	Leadership by all managers
5-1-3	Leaders are role models of a culture of excellence
5-1-4	Leaders are personally involved in ensuring the Lean inplementation
5-1-5	Leaders are involved with the external environment
5-1-6	Leaders motivate, support & recognize organization's people
5-1-7	On the job coaching
5-1-8	Direct observation Genchi-Genbutsu
5-1-9	Role of leaders
5-1-10	Leaders must be learners & teachers
5-2	Lean implementation management
5-2-1	Change management
5-2-2	Cross-functional management
5-2-3	Steering committee meetings
5-2-4	Tier meetings
5-2-5	Visual Management
5-2-6	Standardized work audit board
5-2-7	A-3 Format management
5-2-8	Standard work for leaders
4	**People**
4-1-3	Workforce change management
4-2	Human aspects
4-2-1	Respect for people
4-2-2	People involvement
4-2-3	People attitude
4-2-4	People motivation
4-2-5	People engagement
4-2-6	People morale
4-2-7	People commitment
4-2-8	People empowerment
4-2-9	Mindset & behavior
4-4	Teamwork
4-4-1	People alignment
4-4-2	Cross-functional teams
4-4-3	Cross-training
4-4-4	Decision making by consensus
4-4-5	Common goals
4-4-6	Sharing problems & exchanging ideas
4-4-7	Team performance indicators
4-5	Focus on people
4-5-1	People development
4-5-2	Clear communication system
4-5-3	Rewards, recognition & care for
4-5-4	Career progression
4-5-5	Individual performance indicators
4-5-6	New workforce members
4-5-7	Employee suggestions & improvement activities
4-5-8	Alignment of job description & compensation to operational excellence
3	**Organization & External Environment**
3-1	Organizational Structure
3-1-4	Matrix Organization
3-1-5	Stakeholders network
3-1-7	Align organization with flow
3-2	Organizational Culture
3-2-1	Executive culture
3-2-2	Functional culture
3-2-3	Leadership culture
3-2-4	Workers culture
3-2-5	Organizational environment
3-2-6	Develop a Lean culture
3-3	Decision levels
3-3-1	Strategic (CEO)
3-3-2	Tactical (Managers)
3-3-3	Operational (Engineers, supervisor, workshop associates)
3-4	Organizational governance
3-4-1	Organizational powers
3-4-2	Legal & regulatory behavior
3-4-3	Organizational policies & initiatives
3-5-3	People & the organization have a dialogue
3-6-1	Voice of the current customer
3-8-4	Distribution & transport alliances
2	**Facilities**
2-1	Facility lay-out
2-1-1	Facility layout
2-1-2	Cellular layout
2-1-3	Warehouses
2-1-4	Storage & retrieval systems
2-1-5	Matrial handling systems
2-2	Work Environment
2-2-1	Ilumination
2-2-2	Noise
2-2-3	Temperature
2-2-4	Humidity
1	**Processes Flow**
1-1	Focus on the value stream
1-1-4	Continuous flow and eliminating waste in the entire enterprise
1-1-7	Align enterprise resources
1-2	Processes flow oriented
1-2-1	Create continuous process flow
1-2-2	Develop flexible processes
1-2-3	Reduce variability along processes flow
1-2-5	Reduce product and process complexity

Figure 77. Phase 6 – Lean System (Continued)

5.3.2.7 Phase 7 - Operational Excellence

5.3.2.7.1 Attributes of Phase 7 - Operational Excellence

i) Activities to improve operations and process flow involved in the value stream determined in Phase 4

ii) Activities for continual improvements and continual learning based on Phase 5 and Phase 6

5.3.2.7.2 Phase 7: Operational Excellence - Description and corresponding layers' components

The aim of phase 7 is to seek operational excellence. It comprises the activities for continual improvements and continual learning based on phases 5 and 6. This phase includes the same components as the two previous phases. Additional components that are implemented in this phase are kaizen events, a suggestion system (teian system), and continual improvement and innovation. The LET is customer-focused; therefore in its design, it is relevant to consider customer support, customer engagement, and customer involvement. Moreover, it is essential to develop good relations with suppliers such as respect, long term relationships, supplier training and development, and supplier development. Additionally, it is also vital to establish respectful organizational relations such as partner relations, shareholders relations, and community support.

Phase 7 has no end. Every stakeholder involved in the same value stream has to be aligned and included in the ongoing process of working together towards operational excellence, applying continual improvement and continual learning in a consistent manner on a daily basis. The components of each phase of the Lean transition roadmap are holistically integrated to support this Lean journey.

5.3.2.7.3 Components of Phase 7 - Operational Excellence

The set of components that constitute Phase 7 of the Lean enterprise transformation are shown in detail in Figure 78.

Phase 7 - Operational Excellence	
11	**Strategy**
11-3-2	CEO commitment & involvement
11-3-5	Resources & constraints
11-6-5	Alignment of LET to strategic intent
11-7	Strategic Key Performance Indicator (KPI')s
11-7-1	Customer
11-7-2	People
11-7-3	Quality
11-7-4	Safety
11-7-5	Learning
11-7-6	Productivity
11-7-7	Delivery
11-7-8	Costs
11-7-9	Financial & market results
11-7-10	Society results
11-7-11	Performance reporting system
11-7-12	KPI's monitoring
10	**Lean Transition Management**
10-1	Scope of the Lean transformation
10-1-2	Commit resources
10-1-3	Identify & manage constraints
10-1-4	Correlation with business results
10-1-5	Comunication with all stakeholders
10-1-6	Monitor Lean progress
10-2	Develop an infrastructure for the Lean enterpise transformation
10-2-1	Identify & empower team leader & change agents
10-2-4	Didactic material
10-2-6	Develop Lean courses & workshops
10-3	Focus on specific pilot
10-3-2	Focus on the value stream
10-3-4	Alignment & involvement of all key stakeholders of the value stream
10-3-6	Action plan implementation
10-4	Toward perfection
10-4-1	Eliminate all types of waste throughout the whole value stream
10-4-2	Reduction of variability sources
10-4-3	Reduce complexity of design & process
10-4-4	Build in quality at each operation
10-4-5	Scientific thinking
10-4-6	Surface root causes of the problems
10-4-7	Continuous improvement
10-4-8	Continuous learning and reflection
10-5	Expand to the whole system
10-5-1	VSM for all products
10-5-2	Implement Lean at the office
10-5-3	Implement Lean with suppliers
9	**Technology**
9-1	Technology for learning
9-1-1	Learning management system
9-1-2	e-learning
9-1-3	Mobile devices
9-1-4	Technology-based learning
9-2	Technology for the Lean Transition
9-2-1	Organizational communication
9-2-2	Time studies & Lean software
9-2-3	Production control boards
9-2-4	Discrete-event simulation software
9-2-5	Smart phones applications
9-2-6	Social networks
9-3-1	Computer integrated manufacturing
9-4	Technology for data, information & knowledge management
9-4-1	Knowledge transfer
9-4-2	Content management systems
9-4-3	Databases
9-4-4	Texts, articles, manuals, directories
9-4-5	Operations planning and control
8	**Data, Information & Knowledge Management**
8-1	Data
8-1-1	Data availability
8-1-2	Data based decisions and actions
8-1-3	Hourly production control board
8-2	Information
8-2-1	Simple & visual information systems
8-2-2	Information sharing
8-2-3	Daily accountability
8-2-4	Area information boards
8-3	Knowledge Management
8-3-1	Transfer lessons learned
8-3-2	Best practice & ideas sharing
8-3-3	Lean knowledge
8-3-4	Capture & adopt new knowldege
8-3-5	Create a knowledge management system of the LET
7	**Lean, IE & BIP**
7-1	Lean Workplace
7-1-1	Eliminate waste
7-1-3	Problem solving tools (5 Why's)
7-1-6	Visual workplace
7-1-8	Standard work
7-3	Operational Excellence
7-3-1	Kaizen events
7-3-2	Suggestions System (Teian System)
7-3-3	Continuous improvement and innovation
7-3-4	Product & process simplification
7-3-5	Lean thinking
7-3-6	Ringi decision making
7-4	Industrial Engineering
7-4-10	Scope of environmental, health & safety efforts
7-4-17	Project management
7-5	Business Improvement Programs
7-5-1	Total Productive Maintenance - TPM
7-5-2	Total Quality Management - TQM
7-5-3	Lean Six Sigma
6	**Organizational Learning**
6-1	People development
6-1-1	Workforce & leaders development
6-1-2	Scientific thinking as a philosophy
6-1-3	Multifunctional training
6-1-4	Learning from continuous improvement results
6-1-5	Develop people to support flow
6-1-6	Transfer lessons learned
6-1-7	Training of trainers
6-1-8	Training in the job
6-2	Learning & development system
6-2-4	Cross-training program
6-2-5	Learning by doing
6-2-6	People's knowledge & competencies are identified, developed & sustained
6-2-7	Learning management system

Figure 78. Phase 7 – Operational Excellence

Phase 7 - Operational Excellence	
5	**Lean Management Infrastructure**
5-1	Lean management culture
5-1-1	CEO & top management leadership commitment & involvement
5-1-2	Leadership by all managers
5-1-3	Leaders are role models of a culture of excellence
5-1-4	Leaders are personally involved in ensuring the Lean inplementation
5-1-5	Leaders are involved with the external environment
5-1-6	Leaders motivate, support & recognize organization's people
5-1-7	On the job coaching
5-1-8	Direct observation Genchi-Genbutsu
5-1-9	Role of leaders
5-1-10	Leaders must be learners & teachers
5-2	Lean implementation management
5-2-1	Change management
5-2-2	Cross-functional management
5-2-3	Steering committee meetings
5-2-4	Tier meetings
5-2-5	Visual Management
5-2-6	Standardized work audit board
5-2-7	A-3 Format management
5-2-8	Standard work for leaders
4	**People**
4-1-3	Workforce change management
4-2	Human aspects
4-2-1	Respect for people
4-2-2	People involvement
4-2-3	People attitude
4-2-4	People motivation
4-2-5	People engagement
4-2-6	People morale
4-2-7	People commitment
4-2-8	People empowerment
4-2-9	Mindset & behavior
4-4	Teamwork
4-4-1	People alignment
4-4-2	Cross-functional teams
4-4-3	Cross-training
4-4-4	Decision making by consensus
4-4-5	Common goals
4-4-6	Sharing problems & exchanging ideas
4-4-7	Team performance indicators
4-5	Focus on people
4-5-1	People development
4-5-2	Clear communication system
4-5-3	Rewards, recognition & care for
4-5-4	Career progression
4-5-5	Individual performance indicators
4-5-7	Employee suggestions & improvement activities
4-5-8	Alignment of job description & compensation to operational excellence
3	**Organization & External Environment**
3-1	Organizational Structure
3-1-4	Matrix Organization
3-1-5	Stakeholders network
3-1-7	Align organization with flow
3-2	Organizational Culture
3-2-1	Executive culture
3-2-2	Functional culture
3-2-3	Leadership culture
3-2-4	Workers culture
3-2-5	Organizational environment
3-2-6	Develop a Lean culture
3-3	Decision levels
3-3-1	Strategic (CEO)
3-3-2	Tactical (Managers)
3-3-3	Operational (Engineers, supervisor, workshop associates)
3-4	Organizational governance
3-4-1	Organizational powers
3-4-2	Legal & regulatory behavior
3-4-3	Organizational policies & initiatives
3-5-3	People & the organization have a dialogue
3-6-1	Voice of the current customer
3-6	Customer focus
3-6-4	Customer support
3-6-5	Customer engagement
3-6-6	Customer involvement in design
3-7	Supplier relations
3-7-1	Respect for suppliers
3-7-2	Long term supplier relationship
3-7-3	Supplier training & development
3-7-4	Supplier involvement in design
3-8	Organizational relations
3-8-1	Partners relations
3-8-2	Shareholders relations
3-8-3	Community support
3-8-4	Distribution & transport alliances
1	**Processes Flow**
1-1	Focus on the value stream
1-1-4	Continuous flow and eliminating waste in the entire enterprise
1-1-7	Align enterprise resources
1-2	Processes flow oriented
1-2-1	Create continuous process flow
1-2-2	Develop flexible processes
1-2-3	Reduce variability along processes flow
1-2-4	Build in quality at each operation of the process
1-2-5	Reduce product and process complexity

Figure 78. Phase 7 – Operational Excellence (Continued)

5.4 Comparison of Existing Lean Frameworks with the Proposed Framework

This section compares existing Lean frameworks and the proposed framework in a number of ways. Even though the existing Lean frameworks provide significant information about Lean, the type of framework and the components outlined in the various frameworks are completely different. A set of relevant criteria has been considered in order to compare these frameworks with the proposed framework as shown in Table 16.

The review of existing Lean frameworks showed that there are "conceptual frameworks" and "implementation frameworks." The conceptual frameworks (all except 5, 8, and 12), emphasize "what" constitutes Lean manufacturing or a Lean enterprise, providing a set of concepts, principles, techniques, or tools. Most of these frameworks describe a set of Lean components, but they are not comprehensive. Some frameworks are comprehensive, namely 2, 5, 7, 12, 14, and 15. The most complete framework found in the literature review is Anand and Kodali (2010) (i.e., framework 7), which lists 65 Lean manufacturing components. However, this framework focuses only on the Lean tools and Lean principles; it does not consider other key components. On the other hand, the implementation frameworks, 5, 8, 12, and 15, focus on "how" to implement Lean in a company. These frameworks provide a sequence for implementing the Lean and other key components throughout the Lean enterprise transformation. Table 16 shows which of the existing Lean frameworks are conceptual in nature and which are implementation frameworks.

The proposed framework, on the other hand, is a comprehensive framework that provides a complete list of Lean components and Lean principles as well as other key components useful to achieving operational excellence. This framework is a conceptual framework that provides "what" components constitute the Lean enterprise transformation, as shown in the Enterprise

Architecture Framework of a Lean Enterprise Transformation and the Lean Enterprise Architecture Framework Matrix (Figures 68 and 69 respectively); however the proposed framework also encompasses implementation ("how"), which is reflected in the Lean Enterprise Transition Roadmap (Figure 70). This Roadmap suggests a sequence for implementing the Lean components as well as other key components in each phase of the Lean transformation. In comparison with other frameworks, the proposed framework is unique in that it provides a complete set of Lean principles and Lean components as well as other key components and includes sequence for how to implement the Lean enterprise transformation.

A comparison across fifteen models regarding different criteria is shown in Table 16. In principle, the proposed framework (15) is the most complete since it contains aspects related to integration of tools and concepts of Lean, IE, and BIP; incorporates concepts of the most recognized excellence models underpinning the national quality awards; and codifies components to track the maturity of LET and the impact on KPI's in the LET phases.

Only the Lean enterprise model from MIT (5) and the proposed framework (15) consider a Lean management infrastructure to lead and sustain Lean improvements. Furthermore, the proposed framework includes a holistic approach, a Lean enterprise transition management, and has the flexibility to change layers, groups, and components. Only two of the existing frameworks include the aforementioned criteria, i.e. the proposed framework (15) and the Shingo model (14).

Criteria	Existing Lean Frameworks													
	Five Principles of Lean thinking for Creating a Lean Enterprise (Womack and Jones, 2003)	Fourteen principles of the Toyota Production System (Liker, 2004)	Seven principles of a Lean Enterprise Transformation (Nightingale & Srinivasan, 2011)	Seven Disciplines of enterprise engineering (Martin,1995)	Lean Enterprise Model - LAI / MIT (Nightingale & Mize, 2002)	The Lean House (Liker, 2004)	Framework for Lean Manufacturing based on the Lean house structure(Anand & Kodali, 2010)	Lean Enterprise Architecture (Mathaisel, 2008)	A conceptual framework for JIT implementation (Wafa & Yasin, 1998)	Model for Continuous Improvement (Kaye & Anderson, 1999)	Business Process Change Framework (Motwani, 2003)	A proposed dynamic model for a Lean roadmap (Anvari et al.,2011)	The Flow Framework (Mackle , 2012)	The Shingo for Operational Excellence Model (USU,2010)	*Proposed Framework*
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Comprehensive framework		x			x		x					x		x	x
Conceptual framework	x	x	x	x		x	x		x	x	x		x	x	x
Implementation framework					x			x				x			x
Lean Principles	x	x	x		x	x	x	x						x	x
Complete set of Lean tools		x				x	x					x		x	x
Integration of tools and concepts of Lean, IE & BIP															x
Concepts of most recognized excellence models underpinning the national quality awards															x
Codification of components to track maturity of LET															x
Lean management infrastructure to lead and sustain Lean improvements					x										x
Holistic approach					x									x	x
Lean Enterprise Transition Management					x						x				x
Flexibility to change layers, groups, and components in framework							x							x	x
Systems thinking	x				x			x						x	x
Lean transformation effort across entire enterprise	x		x		x	x		x				x		x	x
Focus on flow of value stream	x		x	x	x	x		x				x	x	x	x
Involvement of all stakeholders related to value stream		x			x									x	x
Alignment of resources in value stream towards the strategic intent				x									x	x	x
Tracking the key performance indicators (KPI's)	x	x			x	x						x	x	x	x
Integration of Lean, Lean six sigma, TPM, TQM, Kaizen in framework														x	x
Lean Six Sigma														x	x
TPM						x	x							x	x
TQM				x			x							x	x
Kaizen				x		x								x	x
Lean enterprise transition roadmap					x			x				x			x
Dynamic model					x				x	x	x	x			x
Phases of the Lean enterprise transformation life cycle								x				x			x
Holistic integration of the Lean tools and other key components in each phase of LET												x			x
Phases of the LET linked to KPI's												x			x
Lean enterprise assessment tool					x									x	

Table 16. Comparison of the Proposed Framework with Existing Lean Frameworks

Comprehensive framework	Framework which covers broadly the Lean manufacturing principles, concepts and elements helping understand what constitutes Lean
Conceptual framework	Framework that provides different number of Lean manufacturing elements but does not specify precisely what constitute Lean manufacturing (Anand & Kodali, 2010)
Implementation framework	Framework which describes the sequence to implement each and every element of Lean manufacturing (Anand & Kodali, 2010)
Holistic approach	The approach concerned with complete systems rather than the individual parts, relating the nature, functions, properties of the components, their interactions, and their relationships to the whole
Alignment of resources in value stream towards the strategic intent	Linking all type of the company resources (people, machine, equipment, technology, information…) that are directly or indirectly involved in the value stream of a product towards the strategic intent
Lean six sigma	A methodology and set of tools used to improve quality to less than 3.4 defects per million or better
TPM	Total productive maintenance aims at maximizing equipment effectiveness and uptime throughout the entire life of the equipment.
TQM	Total quality management
Kaizen	The Japanese word for "change for the better" or "improvement". Kaizen is a system of incremental continuous improvement in which instances of waste are eliminated one by one at minimal cost

Table 17: Definitions

Frameworks 1, 5, 8, 14, and 15 encompass systems thinking. Frameworks 1, 3, 4, 5, 6, 8, 12, 13, 14, and 15 focus on the value stream of the company's products. Frameworks 2, 5, 14, and 15 involve all the stakeholders. Based on this analysis, frameworks 5, 14, and 15 are the most comprehensive in these terms. Lean transformation efforts across the entire enterprise are covered in frameworks 1, 3, 5, 6, 8, 12, 14, and 15, and alignment of resources towards the

strategic intent is specifically part of frameworks 4, 13, 14, and 15. Also, tracking the key performance indicators is specifically part of frameworks 1, 2, 5, 6, 12, 13, 14, and 15. As can be seen, the proposed framework (i.e. 15), includes all of these criteria as well. Frameworks 4, 6, 7, 14, and 15 consider one or more of the following business improvement programs: Lean six sigma, TPM, TQM, and Kaizen. Only the Shingo model (14) and the proposed framework (15) integrate all of these programs in the same framework.

The proposed framework comprises a Lean enterprise transition roadmap. This roadmap is a dynamic model that allows doing modifications throughout the phases of the LET life cycle in case something needs to be changed or improved. Each phase of the LET encompasses a holistic integration of the Lean tools as well as other key components. Moreover, each phase is linked to the key performance indicators. The proposed dynamic model for a Lean roadmap from Anvari et al. (2011), namely framework 12, is the most complete existing framework that includes similar criteria as the proposed framework. Frameworks 5 and 8 have some elements of these criteria.

The Lean enterprise model from MIT (5) and the Shingo for operational excellence model (14) are the only frameworks that include a Lean enterprise assessment tool. The proposed framework (15) does not include such tool.

The main shortcomings of the existing frameworks are that most are not holistic, (except frameworks 5, 14, and 15) and that they do not have a complete list of Lean components or other key components. Furthermore, just a few Lean frameworks focus on the Lean implementation. They include some of the criteria mentioned above but not all of them in an integrated way, while the proposed framework includes all of them except the Lean enterprise assessment tool.

In addition to the previous criteria comparison, additional components were proposed in section 4.5. These unique components are not in any other existing Lean framework and are shown in Figures 46 to 56 as the non-highlighted components. These additional components, valuable to the overall success of the LET, are listed below in the corresponding layers and groups:

1. Processes Flow layer:

1-1 Focus on the value stream

1-1-1 Understand the whole value stream

1-1-6 Align the enterprise resources

1-2 Process flow oriented

1-2-3 Reduce variability along processes flow

1-2-6 Identify all key processes flow including product development, primary and support activities

2. Facilities layer:

2-1 Facility layout

2-1-3 Warehouses

2-1-4 Storage and retrieval systems

2-1-5 Material handling systems

2-2 Work environment

2-2-1 Illumination

2-2-2 Noise

2-2-3 Temperature

2-2-4 Humidity

2-3 Workplace

2-3-1 Workplace layout

2-3-2 Workplace design

2-3-3 Illumination

2-3-5 Workplace safety

2-3-6 Daily maintenance

2-4 Machines

2-4-1 Daily maintenance

2-4-2 Preventive maintenance

2-4-3 Safety

2-4-4 Set-up time

2-5 Equipment

2-5-1 Daily maintenance

2-5-2 Safety

2-6 Tools

2-6-1 Daily maintenance

2-6-2 Tools orders

2-6-3 Tools design

3. Organization and External Environment layer

3-1 Organizational structure

3-1-1 Vertical organization

3-1-2 Product organization

3-1-3 Horizontal organization

3-1-4 Matrix organization

3-1-5 Stakeholders network

3-1-6 Lean department

3-2 Organizational culture

3-2-1 Executive culture

3-2-2 Functional culture

3-2-3 Leadership culture

3-2-4 Workers culture

3-2-6 Develop a Lean culture

3-2-7 Politics

4. People layer

4-2 Human aspects

4-2-9 Mindset and behavior

4-4 Teamwork

4-4-1 People alignment

4-4-7 Team performance indicators

4-5 Focus on people

4-5-2 Clear communication system

5. Lean Management Infrastructure layer

5-1 Lean management culture

5-1-10 Leaders must be learners and teachers

5-2 Lean implementation management

5-2-3 Steering committee meetings

5-2-4 Tier meetings

5-2-6 Standardized work audit board

5-2-8 Standard work for leaders

6. Organizational Learning layer

6-1 People development

6-1-7 Training of trainers

6-1-8 Training in the job

6-2 Learning and development system

6-2-1 People development system

6-2-5 Learning by doing

6-2-7 Learning management system

7. Lean, Industrial Engineering and Business Improvement Programs layer

7-1 Lean workplace

7-1-7 Overall equipment effectiveness (OEE)

7-2 Lean system

7-2-3 Catchball system

7-2-18 Visual factory

7-3 Operational excellence

7-3-2 Suggestions system (Teian system)

7-4 Industrial engineering

7-4-3 Warehouses design for flow

7-4-4 Storage and retrieval systems design

7-4-5 Material handling design for flow

7-4-6 Work environment design

7-4-7 Ergonomic workplace design

7-4-8 Ergonomic equipment and tools design

7-4-9 Manual work design

7-4-12 Work measurement systems

7-4-13 Wage payment system

7-4-14 Standards

7-4-15 Line balancing

7-4-16 Resource management systems design

7-4-17 Project management

7-4-19 Management systems of the organization

8. Data, Information and Knowledge Management layer

8-1 Data

8-1-3 Hourly production control board

8-2 Information

8-2-3 Daily accountability

8-2-4 Area information boards

8-3 Knowledge Management

8-3-1 Transfer lessons learned

8-3-4 Capture and adopt new knowledge

8-3-5 Create a knowledge management system of the LET

9. Technology layer

9-1 Technology for learning

9-1-1 Learning management system

9-1-2 e-learning

9-1-3 Mobile devices

9-1-4 Technology-based learning

9-2 Technology for Lean transition

9-2-1 Organizational communication

9-2-2 Time studies and Lean software

9-2-3 Production control boards

9-2-4 Discrete-event simulation software

9-2-5 Smart phones applications

9-2-6 Social networks

9-4 Technology for data, information and knowledge management

9-4-1 Knowledge transfer

9-4-2 Content management system

9-4-3 Databases

9-4-4 Texts, articles, manuals, directories

9-4-5 Operations planning and control

10. Lean Transition Management layer

10-1 Scope of the Lean transformation

10-1-1 Create the Lean transformation plan

10-1-3 Identify and manage constraints

10-1-5 Communication with all stakeholders

10-2 Develop an infrastructure for the Lean enterprise transformation

10-2-2 LET office

10-2-3 Equipment for presentation

10-2-4 Training material

10-2-5 Equipment for the LET

10-2-6 Develop Lean courses and workshops

10-3 Focus on specific pilot

10-3-1 Determine production line model

10-3-3 Determine sponsors and team leaders

10-3-6 Action plan implementation

11. Strategy layer

11-2 Corporate diagnosis

11-2-1 SWOT analysis

11-2-2 Organizational culture diagnosis

11-2-3 Lean assessment

11-3 Decision to pursue the Lean enterprise transformation

11-3-3 Feasibility studies – potential benefits vs. cost of implementation

11-3-5 Resources and constraints

11-6 Lean transformation strategy

11-6-1 Implement Lean tools company-wide

11-6-3 Radical change (Kaikaku)

11-6-5 Alignment of LET to strategic intent

11-7 Strategic key performance indicators (KPI's)

11-7-5 Learning

11-7-12 KPI's monitoring

There are, however, some important drawbacks of the proposed framework. First, the process of LET implementation takes a long time and the results are only seen after Phase 4. Furthermore, it is necessary to have a Lean expert within the company or an external expert in Lean enterprise transformation. Such an expert will help others understand and implement the Lean enterprise transition roadmap and will develop the Lean team and guide the entire transformation process.

5.5 Summary

The results derived from the previous sections have been described in this chapter. The most representative Lean principles under the Lean frameworks and the excellence models were selected. A set of additional principles has been proposed as a result of designing the framework. The Lean enterprise architecture framework matrix provides a frontal view of the framework. Moreover, the layer components and phases have been integrated into a coherent whole: "the Lean Enterprise Transition Roadmap." Finally, a comparison of all the frameworks, the one developed here and others, is done to put their attributes into perspective. The following chapter describes the conclusions of the study.

CHAPTER 6: CONCLUSIONS AND FUTURE RESEARCH

This chapter draws conclusions from the work developed in this dissertation, the research contributions, and future research directions. It is divided into these three sections. It is important to highlight that the framework depicted in this study is ongoing work that is certainly perfectible as additional case studies and experiences are included.

6.1 Conclusions

The purpose of this dissertation was to design an Enterprise Architecture Framework of a Lean enterprise transformation to guide a company towards operational excellence. Several specific objectives have been accomplished in order to achieve this goal as described in the following sections.

Basic concepts have been covered in order to understand what an enterprise architecture framework is as well as what a Lean enterprise transformation implies. Additionally, the origins of Lean and the principles and tools that underlie Lean have been considered. Moreover, several Lean frameworks were identified and the most important for this project were selected. Furthermore, the most well-known national quality awards models for operational excellence were considered as well as the main architecture frameworks for enterprise integration. These concepts contributed to the design and understanding of the enterprise architecture framework.

The methodology used was developmental research, using a qualitative research design approach that encompasses inductive logic to develop the framework and deductive logic to test it. The design of the study was useful in determining the qualitative data categories and identifying the core components together with a pattern coding. The qualitative data were analyzed by comparing existing frameworks, affinity, tree, and tree-matrix diagrams, all of which helped determine the chief components of a Lean enterprise transformation.

The enterprise architecture framework was designed using an analytical, logical and systematic approach, based on a three-dimensional thinking scheme. It comprises layers, which represent the enterprise views. Each layer is divided into groups and each group is broken down into components of the same category. The logic underpinning the design of the enterprise architecture framework is based on the generic enterprise model, the dynamics of the enterprise system, and the structure of the work place, including its main components. The layers, groups, components, and elements of the framework have been codified using a logical notation with the aim of identifying the components of each group/layer as well as the relationships among them. Furthermore, this codification gives a clear understanding of the Lean transition path.

The Purdue Enterprise Reference Architecture has been adapted to enhance the robustness of the proposed framework. To reduce the complexity of the Lean enterprise transformation, it has been decomposed into several phases. The PERA, in addition to other enterprise reference architectures and Lean frameworks, was used to define the phases of the Lean enterprise transformation life cycle. Both layer components and phases have been integrated into a coherent whole forming the Lean enterprise transition roadmap. The roadmap is decomposed into seven phases and phases 5, 6, and 7 have been broken down into sub-phases. Each phase encompasses a set of components associated with the layers of the framework.

The most representative Lean principles under the Lean frameworks were selected and a set of additional principles was proposed as a result of designing the framework. Furthermore, a Lean enterprise architecture framework matrix has been built in order to have a frontal view of the framework. Moreover, a particular product process within a German firm was used to pilot test the model. However, only phases 1 to 4 were tested.

Overall, the real power of a Lean Enterprise Transformation is to align and integrate the related components that must be involved in each phase of the transformation. In addition, it is essential to develop a Lean management infrastructure and engage all the stakeholders in the transformation phases to sustain the changes. The employees and managers from all departments have to work together toward common goals and practice Lean thinking consistently and every day. Furthermore, it is critical to have an infrastructure for capability building in the Lean enterprise transformation. The Lean tools and principles must be applied as a systemic change and not as local or silo initiatives. Moreover, it is important to build a lean learning organization, focusing on continuous improvement and continuous learning. The Lean culture must become a part of the organizational culture.

All the Lean enterprise transformations are different and there is no one “silver bullet” methodology to follow. However, the enterprise architecture framework presented here can be useful as a guide to support the whole organization in its Lean journey to transform the company into a more productive system. The framework integrates in a holistic way the main components that are crucial to transforming a traditional enterprise into a Lean Enterprise. The roadmap of the framework display all the phases of a Lean enterprise transformation life cycle and shows the components to consider in each phase.

As a final conclusion, to have a successful Lean Enterprise Transformation it is imperative to have a holistic view of the transformation itself. What is outlined in this dissertation is a network of interrelated and interdependent components that work together in all of the LET phases to achieve the strategic intent of the company. However, each organization has to transform its company into a Lean enterprise by its own way of doing business. Being a Lean enterprise has no end; it is an ongoing journey.

6.2 Research Contributions

The main contribution of this research is the enterprise architecture framework of a Lean enterprise transformation that can be used to guide an organization in transforming a current Enterprise into a Lean Enterprise that is moving toward operational excellence.

The proposed framework is unique in that it:

1. Designs a generic framework that holistically integrates the chief components that are crucial to transform a traditional firm into a Lean Enterprise
2. Provides a holistic Lean transition roadmap that can take a company from its current situation to its own future vision by showing what components to consider and how to integrate them in each phase of the Lean enterprise transformation life-cycle
3. Aligns and integrates the network of interrelated and interdependent components that work together in all of the Lean transformation phases in order to achieve the strategic intent of the company
4. Integrates the main tools and principles of Lean Manufacturing as well as Business Improvement Programs and Industrial Engineering

5. Expands the framework from two-dimensional thinking into three-dimensional (3D) thinking to visualize and carry out the Lean enterprise transformation, by using layers to represent the whole enterprise views as well as developing a codification system for each layer component
6. Provides a codification system using a logical notation with the aim of identifying the components of each group/layer as well as identifying the relationships among them, leading to a clear understanding of the Lean transition path
7. Supports the whole organization in its Lean journey to transform the company into a more productive system
8. Aligns all the resources of the company towards the strategic intent of focusing on the value streams
9. Considers a holistic view instead of the functional silos of the organization
10. Tracks the maturity level of the Lean enterprise transformation in each phase as well as links each phase to the strategic KPI's of the company
11. Applies to manufacturing companies but may be reproduced in other types of companies and in different sectors, once it is adapted to the specific characteristics of the company and to the particular type of sector

6.3 Future Research

This research has provided a holistic and integrated enterprise architecture framework to guide an organization in how to transform a current Enterprise into a Lean Enterprise towards operational excellence. Future lines of research can be developed as described in the following sections.

First, the pilot study is an on-going implementation; therefore, phases 5 to 7 have yet to be tested in the same company. Second, additional applications of the framework with other types of manufacturing companies must be carried out in order to validate the framework. Third, a structural equation model can be developed in order to know the impact on the key performance indicators of the company as a result of implementing the Lean enterprise transformation and using the proposed framework. Finally, this framework may be reproduced in the service sector such as hospitals.

On the other hand, the framework comprises layers that represent a high level viewpoint of the enterprise. Each layer and the Lean enterprise transition roadmap can be divided into activities and sub-activities. The Integration Definition for Function Modeling (IDEF0) methodology can be used to model the Lean enterprise transformation process. Moreover, a guide for the Lean transformation planning and implementation can be developed. This guide can adapt the concept of the "Handbook for Master Planning and Implementation for Enterprise Integration," based on the PERA architecture. Additionally, a performance measurement system can be developed in order to have a standard for tracking the maturity level of the Lean enterprise transformation in each phase, as well as linking each phase to the strategic KPI's of the company. Furthermore, a mathematical representation of the framework as well as its transition roadmap may be developed, to have a better understanding of the logic of the Lean enterprise transformation process.

The framework was pilot-tested on a particular product process within a German firm. Seven steps were followed within phases 1 through 4 of the Lean enterprise architecture transition roadmap: planning, analysis, design, implementation, active learning from the implementation, design improvement, and synthesis (described in Section 3.3). Phase 5 was

partially tested and the remaining phases have not been tested because of time limitations and firm constraints.

Glossary[1]

A3 Report: An "A3" sized (11 inches x 17 inches) form is used at Toyota as a one-sheet problem evaluation, root cause analysis, and corrective action-planning tool. It often includes sketches, graphics, flow maps or other visual means of summarizing the process current condition and future state of the process. It is evidence of A3 thinking.

Andon: A type of visual control that displays the current state of work (i.e., abnormal conditions, work instructions, and job progress information). It is one of the main tools of Jidoka.

Andon Board: A visual control device in a work area (in a manufacturing environment, typically a lighted overhead display), providing the current status of the process system and alerting team members to emerging problems.

Autonomation: Stopping a line automatically when a defective part is detected. Machines are given "human intelligence" and are able to detect and prevent defects. Machines stop autonomously when defects are made, asking for help. Autonomation was pioneered by Sakichi Toyoda with the invention of automatic looms that stopped when a thread broke, allowing an operator to manage many looms without risk of producing large amounts of defective cloth. Autonomation is a pillar of the Toyota Production System.

Balanced Scorecard: The Balanced Scorecard is a strategic management system used to drive performance and accountability throughout the organization. The scorecard balances traditional performance and/or financial measures with more forward-looking indicators in four key

[1] The source of this glossary is **(www.maine.gov/dhhs/btc/training-material/)**

dimensions: Finances, Integration/Operational Excellence, Employees, and Customers. It is an organizational framework for implementing and managing strategy at all levels of an enterprise by linking objectives, initiatives, and measures to an organization's strategy. The scorecard provides an enterprise view of an organization's overall performance. It integrates financial measures with other key performance indicators around customer perspectives, internal business processes, and organizational growth, learning, and innovation. The *balanced scorecard* was created by Dr. Robert Kaplan & Dr. David Norton in the early 1990s.

Catchball: A process used in Hoshin Planning to communicate vertically to obtain consensus on the Means that will be used to attain each Breakthrough Objective. A catchball is a series of discussions between managers and their employees during which data, ideas, and analysis are thrown like a ball-back, forth, up, down, and horizontally across the organization. This process opens a productive dialogue throughout the entire organization.

Cellular Manufacturing: An alignment of processes and equipment in correct process sequence, where operators work within the cell and materials are presented to them from the outside of the cell. Often, cellular manufacturing has not taken into account waste elimination or Standard Work principles, and therefore greater savings have not been realized.

Change Agent: Someone who will lead the organization and its staff from the traditional mentality to becoming a Lean Organization -- who leads the cultural change in an organization. Someone whose objective is to help cause the transformation from Current State (traditional processing, e.g. push, batch and queue) to Future State (Lean Enterprise). The catalytic force moving organizations and value streams out of the world of inward-looking batch-and-queue.

Change Management: The process of planning, preparing, educating, resource allocating, and implementing of a cultural change in an organization.

Changeover: The time from when the last good piece comes off a machine or process until the first good piece of the next product is made. Changeover time includes set up, warm up, trial run, adjustment, and first piece inspection: *preparation* (getting ready to make the change), *replacement* (removing and replacing files, program, etc.), *positioning* (placing the materials in the correct location for use for the task/step), and *adjustment* (first-item inspection, materials/equipment tweaking, trial runs).

Constraint: Anything that limits a system from achieving higher performance or throughput. Alternate: That bottleneck which most severely limits the organization's ability to achieve higher performance relative to its purpose/goal.

Continuous Flow: Each step/process (in the office or plant setting) makes or completes only the one piece that the next step/process needs, and the batch size is one, single-piece flow or one-piece flow. This process is the opposite of batch-and-queue.

Continuous Improvement: The never-ending pursuit of waste elimination by continually creating a better workplace, better products, and greater value to society. The process is never perfect; as the name implies, with continuous improvement even the improvement can be improved.

The purpose of continuous improvement is to institutionalize the practice of making many small improvements every day to improve overall efficiency. It refers to the idea that a large number of small improvements in processes are easier to implement than a few major improvements and the small improvements have a large cumulative effect.

Customer: Customers are the requestors/receivers of or the "payers" for the service/output of the process. Customers can include clients, providers, payers, community, and other staff. Customers can be internal (staff, programs) to the organization or external (clients, their families,

contractors, etc.) and both are key to the success of organizational change/improvement.

Cycle Time: Cycle time is the time it takes to do one complete repetition of any particular task/step. Cycle time can be categorized into 1) manual cycle time, 2) machine cycle time, and 3) auto cycle time. It is also referred to as *touch time* or *hands-on time*. If the cycle time for every step/operation in a complete process can be reduced to equal *Takt* Time, the service/product can be made in a Single-Piece Flow.

Error-Proofing: Also called Mistake-Proofing or Poka-Yoke. A system that addresses both the work/product and the processes to detect errors before they become defects.

External Set-Up: All set-up tasks that can be done while equipment is still running. Examples are collecting tools and preparing the next piece of material or fixtures. Moving set-up activities from internal to external in order to reduce down time is a central activity of set-up reduction and SMED.

Five S (5S): The five terms, all beginning with *S,* are derived from the Japanese words seiri, seiton, seiso, seiketsu, and shitsuke. In English the 5S are sort, set in order, shine, standardize, and sustain (explained below). 5S is a systematic process for applying the principle of waste elimination through workplace organization. Discipline, simplicity, pride, standardization, and repeatability, as emphasized in the *5S*, are critical to the Lean enterprise in general and flow implementations specifically.

Sort: Evaluate and eliminate everything not required for the current work, keeping only the bare essentials.

Set in order: Arrange items in a way that they are easily visible and accessible.

Shine: Inspect, refine, and clean everything and find ways to keep it clean. Make this a part of your everyday work.

Standardize: Create rules and procedures by which the first 3S are maintained. Document.

Sustain: Keep the other 4S activities from unraveling.

Five Whys: A very simple but effective method of analyzing and solving problems by asking "why?" five times (or as many times as needed) to get to the root cause of the problem. There can be more than one root cause, and in an organizational setting, usually a team carries out a root cause analysis for a problem. No special technique is required for this technique.

Flow: In its purest form, continuous flow means that items are processed and moved directly to the next process one piece at a time. Each processing step completes its work just before the next process needs the item, and the transfer batch is one. Also known as "one-piece flow" and "make one, move one."

Flow Production: A way of doing things in small quantities in sequential steps, rather than in large batches or lots, or mass processing. Product (or service) moves (flows) from process to process in the smallest, quickest possible increment (one piece). Only acceptable quality products or services are accepted by the downstream customer.

Functional Layout: The practice of grouping activities/functions or machines by type of operation performed, for example, service request-entry and copiers and shredders.

Genchi Genbutsu: Go see; go to the real place and see what is actually happening. Go see the problem. This term reflects the belief that practical experience is valued over only theoretical knowledge. You must see the problem to know the problem. (On Site, With the Actual Things)

Hoshin Kanri (Policy deployment): A method of policy deployment and strategic decision-making that focuses and aligns the organization on a few vital "breakthrough" improvements. The objectives and the means to achieve the objectives are cascaded down through the entire organization using a series of linked matrices. The process is self-correcting and encourages

organizational learning and continuous improvement of the planning process itself. It is the selection of goals, projects to achieve the goals, designation of people and resources for project completion, and establishment of project metrics: Developed in Japan in the 1960's.

In Hoshin Kanri, organizational leadership identifies critical (3-5) breakthrough objectives/goals and subordinates all other goals or projects to achieving those objectives. Then a process called *catchball* is used to assure that these objectives are SMART (Simple, Measurable, Attainable, Realistic, Time-based) and, most important, that resources are available. This *catchball* process goes on, back and forth among different levels of the organization, until there is alignment and agreement that the breakthrough goals are not out of sight.

Inventory: A major cost for most organizations/businesses. Inventory is all raw materials, purchased parts, work-in-process components, and finished products that are not yet provided/sold to a customer. Inventory may also include "consumable" goods used in the process/production itself.

Jidoka: Stopping a process automatically when a defective product is detected. Automatically stopping when there are abnormalities and immediately notifying the worker. The idea is to build in quality by preventing any error from going to the next step/process. Exceptions are handled in real time. Examples include the *andon* and *pokayoke* -- also known as "autonomation with a human touch." It is one of the two main pillars of TPS.

Just-In-Time (JIT): A system to make what the customer needs when the customer needs it in the quantity the customer needs, using minimal resources of manpower, material, and machinery – No More, No Less. The three elements to making Just-in-Time possible are Takt Time, Flow production, and the pull system, as well as standard work. The opposite of Just-In- Time is "Just-In-Case."

JIT requires waste elimination, process simplification, set-up and batch-size reduction, parallel (rather than sequential) processing, and layout redesign. Just-In-Time approaches Just-On- Time when upstream activities occur minutes or seconds before down-stream activities, so that single-piece flow is possible. Just-In-Time is one of the two main pillars of TPS.

Kaikaku: Radical improvements or reforms that affect the future value stream. Often these are changes in the business practices of the systems. Usually applied only once within a Value Stream.

Kaizen: The Japanese word for "change for the 'better" or "improvement." Kaizen is an improvement: continual improvement in personal life, home life, social life, and working life. In the workplace, Kaizen means continuing improvement involving everyone regardless of position. It is a business philosophy of continuous cost reduction, reduced quality problems, and delivery time reduction through rapid, team-based improvement activity. Continuous improvement through incremental improvements. Kaizen implies more than improvement in basic processes. Kaizen represents a philosophy within which an organization, and the individuals within it, undertake continual improvements of all aspects of organizational life. The key to successful Kaizen is going to the worksite, working with the actual product/process, and getting the facts.

Kaizen is a system of incremental continuous improvement in which instances of waste (Muda) are eliminated one by one at minimal cost. This system applies to all employees rather than by just specialists. [Same as *Process Kaizen*]

Kanban: A Japanese word for "sign," Kanbans are typically a card or other visual method of triggering the pull system based on actual usage of material. It is a central element of a Just in Time system. Kanbans are attached to the actual work/item/product, at the point of use. Kanbans are cards that have information about the parts (name, part number, quantity, source, destination,

etc.) but carts, boxes, and electronic signals are also used. Squares painted on the floor to indicate storage or incoming areas are frequently, but mistakenly, referred to as kanbans.

Lead-Time: The total time a customer must wait to receive a product or service after placing the request. When a scheduling and production system is running at or below capacity, Lead Time and Throughput Time are the same. When demand exceeds the capacity of a system, there is additional waiting time and Lead Time exceeds Throughput Time.

Lean: *Lean* is simply a thought process or approach, not a tool, used to look at a business, whether it is service, manufacturing, or any other activity, that has a supplier and a customer/receiver. The key thought processes within Lean are identifying "waste" from the customer perspective and then determining how to eliminate it. Waste is defined as the activity or activities that a customer would not want to "pay" for and/or that add no value to the product or service from the customer's perspective. Once waste has been identified in the Current State, a plan is formulated to reach the Future State in an effective manner that encompasses the entire system.

Lean Manufacturing: A business practice characterized by the endless pursuit of waste elimination. A manufacturer that is lean uses the minimum amounts of manpower, materials, money, machines, space etc. to get the job done on time.

Lean Enterprise: A Lean Enterprise is an organization that is engaged in the endless pursuit of waste elimination. A Lean Enterprise has a culture that does not tolerate waste of any kind.

Lean Transformation: Developing a culture that is intolerant to waste in all of its forms. A successful Lean Transformation should result in a Lean Enterprise, an organization that is engaged in the endless pursuit of waste elimination.

Leveling: Smoothing out the production schedule by averaging out both the volume and mix of

products. Production leveling allows a consistent workflow, reducing the fluctuation of customer demand with the eventual goal of being able to produce any product any day.

OEE: Overall Equipment Effectiveness. OEE is calculated based on Availability x Performance x Quality to determine how much of the time a piece of equipment is being used while it is actually making good parts at an appropriate speed. OEE is one of the 5 pillars of TPM.

One-Piece Flow: Moving the work/product through each step/operation as a single part, never handled in batches. One-piece flow processing occurs when the work/item/product is made one at a time and passed on to the next process. Among the benefits of one-piece flow are 1) the quick detection of defects to prevent a large batch of defects, 2) short lead-times of processing, 3) reduced material and inventory costs, and 4) workstations and equipment of the right size and design. It forces near-perfect balance and coordination.

Performance Management: Using a set of tools and approaches to measure, improve, monitor and sustain the key indicators of a business.

Poka-Yoke: Japanese for "mistake-proofing." Mistake-proofing and fool-proofing devices made by designing parts, processes, or procedures so that mistakes physically or procedurally cannot happen. These are low-cost, highly reliable devices, used in the jidoka system that will stop processes in order to prevent the production of defective parts.

Policy Deployment (Hoshin Kanri): The selection of goals, projects to achieve the goals, designation of people, and resources for project completion, and establishment of project metrics.

Problem: Problems in a process are the discrepancies between actual and desired performance. For example, a client has to wait too long for a service to be provided, work has to be done over again, work is reviewed multiple times at various stages of the process, services do not match or

meet the needs of the client/customer, etc. Problems are solved by making changes that close these discrepancies.

Process: The flow of material in time and space. The accumulation of sub-processes or operations that transform material from raw material/input to finished products. Processes are the series of action steps taken to convert inputs into outcomes. All processes have inputs, steps, and outcomes. Measurements can be made, data collected, and changes made and tested for improvements.

Organizations exist to serve customers. Customers are served by processes. The overwhelming majority of problems that organizations experience in serving clients are caused by their processes. Therefore, if the organization is to improve its client service, it must solve the problems in its processes.

Production Preparation Process (3P): Rapidly designing production processes and equipment to ensure capability, built-in quality, productivity, and Takt-Flow-Pull. The Production Preparation Process minimizes resources needed such as capital, tooling, space, inventory, and time.

Pull System: To produce or process an item only when the customer needs it and has requested it: Use One; Make One. The customer can be internal or external. An essential part of any *Build-To-Order* strategy. Having set up the framework for *Flow*, the next step is to only produce what the customer needs. *Pull* means that no one upstream should produce goods or services until the customer downstream asks for it. Contrast this concept to *Push*. One of the 3 Elements of *Just-In-Time*. The pull system enables the production of what is needed, based on a signal of what has just been "sold." The downstream process takes the product it needs and "pulls" it from the producer. This "customer pull" is a signal to the producer that the product is sold. The pull

system links accurate information with the process to minimizes overproduction.

Push System: To produce or process an item without any real demand from the customer – usually creates inventory and all other "wastes." In contrast to the *Pull* system, the service/product is pushed into a process, regardless of whether it is needed at that time. The pushed product goes into inventory, and lacking a pull signal from the customer indicating that it has been used/bought, more of the same service/product could be overproduced and put in inventory. In a *Push* System, creating/producing more of an item or service is based on the anticipation of its use. A Push system attempts to predict when the item/service/material will be needed and will launch its processing in anticipation of this need.

Quick Changeover: The ability to change tooling and fixtures rapidly (usually minutes), so multiple products can be run on the same machine.

Seven New Tools: Problem-solving tools used for Kaizen and Hoshin Kanri activities: 1) matrix diagram, 2) relationship diagrams, 3) process decision program charts, 4) activity network diagrams, 5) radar charts, 6) tree diagrams, and 7) affinity diagrams.

Seven Wastes: Taiichi Ohno's original enumeration of the wastes commonly found in physical production. These are *overproduction* ahead of demand, *waiting* for the next processing stop, unnecessary *transport* of materials (for example, between functional areas of facilities), *over-processing* of parts due to poor tool and product design, *inventories* more than the absolute minimum, unnecessary *movement* by employees during the course of their work (looking for parts, tools, prints, help, etc.), and production of *defective parts*.

Six Sigma: A methodology and set of tools used to improve quality to less than 3.4 defects per million or better. Six Sigma is a statistical term that equates to 3.4 defects per one million opportunities. Typical organizations/manufacturers operate at around three sigma, or 67,000

defects per million. Applying Six Sigma can achieve dramatic improvement in business performance through a precise understanding of customer requirements and the elimination of defects from existing processes, products, and services. Key tenets of Six Sigma are Define, Measure, Analyze, Improve, Control. To fully embrace Six Sigma, an organization must work intimately with all internal disciplines in addition to external suppliers and customers.

SMED: (Single Minute Exchange of Dies.) A system of a series of techniques pioneered and developed by Shigeo Shingo for set-up time reduction and quick changeovers. The long-term objective is always Zero Setup, in which changeovers are instantaneous and do not interfere in any way with continuous flow.

Standards: Standards involve comparison with accepted norms, such as are set by regulatory bodies. Examples include the standards for road/highway development and repair, for program and individual licensure, for conducting health and environmental tests, etc.

Standard Work: Specifying tasks to the best way to get the job done in the amount of time available while ensuring the job is done right the first time, every time. Standard Work is the most efficient, optimum combination of man, machine, and material. The three elements of standard work are 1) Takt Time, 2) Work Sequence, and 3) Stand Work-in-Process. Performing standard work allows for a clear and visible “standard” operation. Deviation from standard work indicates an abnormality, which is then an opportunity for improvement. Standardized work is organized around human motion and creates an efficient production sequence without any waste.

Standard Work In Process: Also Standard WIP, or SWIP. The minimum work-in- process needed to maintain standard work. Standard WIP parts are 1) parts completed and in the machine after the auto cycle, 2) parts placed in equipment with cycle times exceeding Takt time, and 3) the parts currently being worked on or handled by the operators performing standard work.

Stop-The-Line Authority: When workers are able stop the line to indicate a problem, this is stop-the-line authority. The production line or machine remains stopped until the supervisor, manager, engineer, maintenance personnel, support staff or president has identified the problem and taken corrective action.

Strategic Planning: Developing short and long-term competitive strategies using tools such as SWOT Analysis to assess the current situation, develop missions and goals, and create an implementation plan.

Suggestion System: In a suggestion, system workers are encouraged to identify waste, safety, and environmental concerns and submit improvement ideas formally. Rewards are given for suggestions resulting in cost savings. These rewards are typically shared among the production line or by the kaizen team.

Supermarket: A supermarket is a tightly managed amount of inventory within the value stream to allow for a pull system. It is a tool of the pull system that helps signal demand for the product. In a supermarket, a fixed amount of raw material, work in process, or finished material is kept as a buffer to schedule variability. A supermarket is typically located at the end of a production line (or the entrance of a u-shaped flow line).

Takt Time: Takt time is the total net daily available "operating" time divided by the total daily customer demand. Takt time is not how long it takes to perform a task; it is the pace at which the customer is buying a particular product or service. Takt time cannot be reduced or increased except by changes in production demand or available time to work. The concept is used in Lean as the rhythm of the process. Takt is a German word for "pace," "beat," or "rhythm". Takt time is one of the 3 Elements of JIT.

Toyota Production System (TPS): A methodology that resulted from over 50 years of Kaizen

at Toyota, one of the most successful companies in the world. TPS is built on a foundation of Leveling, with the supporting pillars of Just-in-Time and Jidoka.

Total Productive Maintenance (TPM): Total productive maintenance aims at maximizing equipment effectiveness and uptime throughout the entire life of the equipment. It is an integrated set of activities aimed at maximizing equipment effectiveness by involving everyone in all departments at all levels, typically through small group activities. TPM usually entails implementing the 5 S System, measuring the six big losses, prioritizing problems, and applying problem-solving with the goal of achieving Zero breakdowns. It is a series of methods, originally pioneered by Nippondenso (a member of the Toyota group), to ensure that every piece of equipment in a process is always able to perform its required tasks so that processing/work is never interrupted.

Value: A product or service's capability provided to a customer at the right time, at an appropriate cost/price, as defined in each case by the customer. What does and does not create value is to be specified from the customer's perspective and not from the perspective of individual organizations, functions, and departments.

Value-Added Work: Activities or work essential to ensure a product or service meets the needs of the customer -- work that the customer is willing to pay for. A transformation of the shape or function of the material/information in a way that the customer will pay for. Activities or actions taken that add real value to the product or service. [See *Non-Value-Added*]

Value Stream: All activities, both value-added and non-value-added, required to bring a product or service from request/order to the hands of the customer, and a design from concept to launch to production to delivery. By locating the value-creating processes next to one another and by processing one unit of work at a time, work flows smoothly from one step to another and finally

to the customer. This chain of value-creating processes is called a value stream. A value stream is simply all the things done to create value for the customer. It is a series of all actions required to fulfill a customer's request, both value-added and not.

Value Stream Mapping (VSM): A VSM is a Lean tool used to visualize the value stream of a process, department, or organization. Creating a picture of the complete material and information flow from customer request through order fulfillment for an operation. Value Stream Mapping can be done at an enterprise level (showing customer-supplier relationships as well as distributors), a door to door level showing the flow of material and information primarily within a factory, office, or hospital operation, and a process level map with a narrower scope and more detail. The 'Current State' is how the process works today and the 'Future State' map shows improvements towards a long-term 'ideal state'. It is a hands-on, pencil-and-paper tool used a) to follow a product or information (or both) activity path from beginning to end and draw a visual representation of every process (value and non-value) in the material and information flow, b) to design a future state map which has waste removed and creates more flow, and c) to end up with a detailed implementation plan for the future state.

Visual Controls: Displays of the status of an activity so every employee can see it and take appropriate action. It is the placement in plain view of all tools, parts, processing activities, and indicators of process system performance, so everyone involved can understand the status of the system at a glance. Various tools for visual management are color-coding, charts, andons, schedule boards, labels and markings on the floor. Used synonymously with Transparency.

Visual Management: When the normal state and abnormal state can be clearly and visually defined, visual management is possible. In visual management, simple visual tools are used to identify the target state, and any deviance is met with corrective action.

Waste: Anything that uses resources, but does not add real value to the product or service in the eyes of the customer. An activity customer would not want to pay for if they knew it was happening.

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APPENDICES

APPENDIX A: LEAN PRINCIPLES

Lean Manufacturing (Womack & Jones, 2003)
Specify value accurately by specific product
Identify the value stream for each product
Make value flow without interruptions
Let the customer pull value from the producer
Pursue perfection
Toyota Production System (Liker, 2004)
Long-term philosophy
Create continuous process flow
Use pull systems
Level out the workload
Build a culture to get quality right the first time
Standardized tasks
Use visual control so no problem are hidden
Use only reliable technology
Grow leaders with the lean management philosophy
Develop exceptional people and teams
Respect the extended network of partners & suppliers
Go and see yourself to thoroughly understand the situation
Make decisions slowly by consensus, implement decisions rapidly
Become a learning organization through reflection & continuous improvement
Framework for Lean Manufacturing based on the Lean house structured (Anand & Kodali, 2010)
Elimination of waste
Supplier partnership
Order based production
Visual management
Respect to humanity
Zero defects
Customer focus
Continuous improvement
Lean Enterprise Transformation (Nightingale & Srinivasan, 2011)
Adopt a holistic approach to enterprise transformation
Secure leadership commitment to drive enterprise behaviors
Identify relevant stakeholders & determine their value propositions
Focus on enterprise effectivenes before efficiency
Address internal & external enterprise interdependencies
Ensure stability & flow within & across the enterprise
Emphasize organizational learning

Table A.1: Lean Principles

The Shingo Orinciples of Operational Excellence (USU,2010)		
Dimension	**Guiding principles**	**Supporting principles**
Dimension 1		
Cultural enablers (People)		
	Respect every individual	Nurture long term relationships
	Lead with humility	Empower & involve everyone
		Develop people
		Asure a safe environment
Dimension 2		
Continuous process improvement (Processes)		
	Focus on process	Stabilize processes
	Embrace scientific thinking	Rely on data
	Flow & pull value	Standardize processes
	Assure quality at the source	Insist on direct observation
	Seek perfection	Focus on value stream
		Keep it simple & visual
		Identify and eliminate waste
		Integrate improvement with work
Dimension 3		
Enterprise alignment (Alignment)		
	Create constancy of purpose	See reality
	Think systematically	Focus on long term
		Align systems
		Align strategy
Dimension 4		
Results	Create value for the customer	Measure what matters
		Align behaviors with performance
		Identify cause & effect relationships

Table A.1: Lean Principles (Continued)

APPENDIX B: LEAN FRAMEWORKS / COMPONENTS

	Frameworks
	Seven Disciplines of enterprise engineering (Martin,1995)
1	Strategy visioning
2	Enterprise redesign
3	Value stream reinvention
4	Procedure redesign
5	TQM, Kaizen
6	Information technology development
7	Organization & culture development
	Lean Enterprise Model - LAI / MIT (Nightingale & Mize, 2002)
8	**Enterprise strategic planning**
9	- Decision to pursue enterprise transformation
10	**Adopt Lean paradigm**
11	- Build vision
12	- Convey urgency
13	- Foster Lean learning
14	- Make the commitment
15	- Obtain senior management buy-in
16	**Focus on the value stream**
17	- Map value stream
18	- Internalize vision
19	- Set goals and metrics
20	- Itentify and involve key stakeholders
21	**Develop Lean structure & behavior**
22	- Organize for Lean implementation
23	- Identify and empower change agents
24	- Align incentives
25	- Adapt structure and systems
26	**Create & refine transformation plan**
27	- Identify & prioritize activities
28	- Commit resources
29	- Provide education & training
30	**Implement Lean initiatives**
31	- Develop detailed plans
32	- Implement Lean activities
33	- Outcomes on enterprise metrics
34	**Focus on continuous improvements**
35	- Monitor Lean progress
36	- Nurture the process
37	- Refine the plan
38	- Capture & adopt new knowledge

Table B.1: Lean Frameworks / Components

	The Lean House (Liker, 2004)
39	**Toyota way philosophy**
40	**Visual management**
41	**Stable and standardized processes**
42	**Level production (heijunka)**
43	**Waste reduction**
44	- Genchi Genbutsu
45	- 5 Why's
46	- Eye's for waste
47	- Problem solving
48	**Continuous improvement**
49	**People & teamwork**
50	- Selection
51	- Common goals
52	- Ringi decision making
53	- Cross trained
54	**Just-in-time**
55	- Takt time planning
56	- Continuous flow
57	- Quick changeover
58	- Integrated logistics
59	**Jidoka**
60	- Automatic stops
61	- Andon
62	- Person-machine separation
63	- Error proofing
64	- In-station quality control
65	- Solve root cause of problems
66	**Results**
67	- Best quality
68	- Lowest cost
69	- Shortest lead time
70	- Best safety
71	- High morale
	Framework for Lean Manufacturing based on the Lean house structure (Anand & Kodali, 2010)
72	**Foundation**
73	- Leadership/ managers & executives
74	- Human aspects / attitude, motivation, ownership etc.
75	- Culture / social & organizational
76	- Commitment / employees & management
77	**Strategic decision level - CEO / President**
78	Value stream mapping
79	Focused factory production
80	Communication between employees
81	Flat organization structure
82	Long term employment
83	Rewards & recognition
84	Supplier involvemnt in design
85	Sole sourcing or supplier reduction
86	Long term supplier relationship
87	New process or equipment technologies
88	Cellular manufacuring
89	Total productive maintenance

Table B.1: Lean Frameworks / Components (Continued)

	Framework for Lean Manufacturing based on the Lean house structure (Anand & Kodali, 2010)
90	Total quality management
91	Computer integrated manufacturing
92	Maintain spare capacity
93	Concurrent engineering
94	**Tactical decision level - Managers**
95	Use of flexible machines
96	Production smoothing (load leveling)
97	Mixed model manufacturing / scheduling
98	Kanban system
99	Small lot production
100	Pull production
101	One piece flow
102	Automation
103	Group technology
104	Commonolization & standardization of parts
105	Design for manufacturing
106	Supplier proximity
107	Information sharing with suppliers
108	Supplier traing & development
109	Use of electronic data interchange with suppliers
110	Quality certification (suppliers & self)
111	Rolling production plan
112	**Tactical decision level - Engineers, supervisor**
113	- Multi-functional training
114	- Cross-functional teams
115	- Multi-skilled workforce
116	- Cycle time & lead time reduction
117	- Standardized containers
118	- Job rotation or flexible job responsibilities
119	- Elimination of buffers
120	- Mistake proofing(Pokayoke)
121	- WIP reduction
122	- Storage space reduction
123	- Quality circles
124	- Job enlargement
125	- Synchronization
126	- Safety improvement programs
127	- Product & process simplifacation
128	- Layout change or U shaped cell
129	- Workload or line balancing
130	- Just in time delivery
131	- Statistical process control
132	- Single minute exchange of dies
133	**Operational decision level - Shop floor associates**
134	- Problem solving tools
135	- 5'S
136	- Employee empowerment
137	- Employee participation
138	- Andon
139	- Jidoka
140	- Defect at source
141	- Successive checking
142	- Work standardization
143	- Process sharing
144	- Takt time
145	- Suggestion schemes

Table B.1: Lean Frameworks / Components (Continued)

	Lean Enterprise Architecture (Mathaisel, 2008)
146	**Need**
147	**Conceptual design**
148	- Defining MRO strategy
149	- Product analysis
150	- Production volume
151	- Job-shop, flow-shop
152	- Trade-off analysis
153	- Make-buy
154	- Benchmarking
155	- Lean principles
156	**Preliminary design**
157	- Ideal function layout
158	- Rough scale simulation
159	- Human resource planning
160	- Production sequence
161	- Facility planning
162	- Cellular design
163	- Lean principles
164	**Detailed design**
165	- Equipment design
166	- Flow analysis
167	- Simulation
168	- Detailed floor layout
169	- Work organization
170	- Benchmarking
171	- Lean principles
172	**Implementation**
173	- Equipment selection
174	- Quick Setup Time
175	- Installing equipment
176	- Training
177	- Testing
178	- Adjusting
179	- Benchmarking
180	- Lean practices
181	**Operation**
182	- Leadership
183	- Innovation
184	- Monitoring
185	- Planning & control
186	- Continuous improvement
187	- Stabilization
188	- Engineering change management
189	- Best Lean / cllular practices
	A conceptual framework for JIT implementation (Wafa & Yasin, 1998)
190	Global environment
191	Organization as an open system
192	Competitive strategic advantage
193	Factors facilitating JIT
194	- Management
195	- Workers
196	- Process
197	- Suppliers
198	JIT implementation

Table B.1: Lean Frameworks / Components (Continued)

	Model for Continuous Improvement (Kaye & Anderson, 1999)
199	**Drivers**
200	**Management**
201	- Role of senior management
202	- Leadership by all managers
203	Stakeholders focus
204	Measurement & feedback
205	Learning from C.I. results
206	**Enablers**
207	Culture for C.I. & innovation
208	Employee focus
209	Focus on critical processes
210	Standardize best practices
211	Quality management system
212	Integration of C.I. activities
213	**Results**
214	Organizational results
215	Team results
216	Individual results
	Business Process Change Framework (Motwani, 2003)
217	**Change environment**
218	- Cultural readiness
219	- Learning capacity
220	- Relationship balancing
221	- IT leveraging & knowledge capability
222	- Strategic initiatives
223	**Lean manufacturing implementation management**
224	- Process management
225	- Change management
226	**Lean manufacturing outcome**

Table B.1: Lean Frameworks / Components (Continued)

	A proposed dynamic model for a Lean roadmap (Anvari et al.,2011)
227	**Initial investigation**
228	- Existing/predicting crisis
229	- Change agent
230	- Lean knowledge
231	**Preparation**
232	- Strategic Planning
233	Hoshin Kanri / BSC
234	- Lean knowledge
235	Lean promotion office
236	People
237	Lean experts
238	- Analyze the whole system
239	Organizational structure
240	Resources
241	Limitation & delimitation
242	- Determing: value, product family, procedures, metrics, feedback system, and VSM managers
243	**Focus on specific pilot**
244	- VSM "door to door" sample (current & future)
245	- Implementing based on future VSM
246	- Continuous flow
247	5S
248	Kanban
249	Automatic guided vehicle
250	Eliminate muda
251	Flexible work systems (group technology & cellular manufacturing
252	- Stability
253	Standard work
254	5S
255	TPM
256	Jidoka / autonomation
257	Pokayoke
258	Self controlling
259	Visual management
260	- Flexibility
261	Multi skills workers
262	SMED
263	Heijunka
264	- Pull system
265	Takt time
266	Pace maker
267	One piece flow
268	Fifo Line
269	Supermarket
270	Fit for use of pulling
271	**Expand to the whole system**
272	- VSM "door to door" for all products (current & future)
273	- Implementing Lean "door to door" value streams
274	- Spread Lean to the office
275	- Spread Lean to the whole value stream / suppliers & customers
276	**Perfection**
277	- Measurement performance, based on : indicators & maturity matrix
278	- Focus on continuous improvement by Lean learning, Lean thinking and Lean enterprise self assessment tool
279	- Toward perfection

Table B.1: Lean Frameworks / Components (Continued)

	The Flow Framework (Mackle , 2012)
280	**Create vision & guide flow**
281	Administrative & office flow
282	Design for flow
283	Supply for flow
284	**Create flow**
285	- Tools for understanding demand & capacity, material planning & scheduling
286	- Understand customer value
287	- Align production with demand
288	- Manage the constraint
289	- Manage the inventory
290	- Organize material flow by pull
291	- Compress lead time
292	**Maintain flow**
293	- Tools for availability improvement &variability reduction
294	- Surface root causes of problems
295	- Reduce variation, mistakes, complexity
296	- TPM
297	- Sustain operations
298	- Develop flexible processes
299	- Develop capable processes
300	**Organize for flow**
301	- Tools for standardization, communication & problem solving
302	- Align organization with flow
303	- Visual management
304	- Continuously improve
305	- Workplace organization and 5S
306	- Standard work / Standard operating procedures (SOP's)
307	- Lau-out for flow
308	**Measures & accounts for flow**
309	- Tools for definingmeasures linked to the overall company goal
310	- Flow accounting for financial information
311	**Develop people to support flow**
312	**Distribute for flow**

Table B.1: Lean Frameworks / Components (Continued)

	Baldrige framework criteria categories and subcategories (NIST, 2011)
313	**P. Organizational profile**
314	**P.1. Organizational description**
315	**a. Organziational environmnet**
316	Product offerings
317	Vision and mission
318	Workforce profile
319	Assets
320	Regulatory requirements
321	**b. Organizational relationships**
322	Organizational structure
323	Customers and stakeholders
324	Suppliers and partners
325	**P.2. Organizational situation**
326	**a. Competitive environment**
327	Competitive position
328	Competitiveness changes
329	Comparative data
330	**b. Strategic context**
331	**c. Performance improvement systems**
332	**1. Leadership**
333	**1.1 Senior leadership**
334	**a. Vision, values and mission**
335	Vision and values
336	Promoting legal and ethical behavior
337	Creating a sustainable organization
338	**b. Communication and organizational performance**
339	Communication
340	Focus on action
341	**1.2 Governace and societal responsibilities**
342	**a. Organizational governance**
343	Governance system
344	Performance evaluation
345	**b. Legal and ethical behavior**
346	Legal and regulatory behavior
347	Ethical behavior
348	**c. Societal responsibilities and support of key coomunities**
349	Societal well-being
350	Commnutity support
351	**2. Strategic planning**
352	**2.1 Strategic development**
353	**a. Strategy development process**
354	Strategic planning process
355	Strategy considerations
356	**b. Strategic objectives**
357	Key strategic objectives
358	Strategic objective considerations
359	**2.2 Strategy implementation**
360	**a. Action plan development and deployment**
361	Action plan development
362	Action plan implementation
363	Resource allocation
364	Workforce plans
365	Performance measures
366	Action plan modification
367	**b. Performance projections**

Table B.1: Lean Frameworks / Components (Continued)

368	**3. Customer focus**
369	**3.1 Voice of the customer**
370	**a. Customer listening**
371	Listening to current customers
372	Listening to potential customers
373	**b. Determination of customer satisfaction and engagement**
374	Satisfaction and engagement
375	Satisfaction relative to competitors
376	Dissatisfaction
377	**3.2 Customer engagement**
378	**a. Product offerings and customer support**
379	Product offerings
380	Customer support
381	Customer segmentation
382	Customer data use
383	**b. Building customer relationships**
384	Relationship management
385	Complaint management
386	**4. Measurement, analysis, and knowledge management**
387	**4.1 Measurement, analysis, and improvement of organizational performance**
388	**a. Performance measurement**
389	Performance measures
390	Comparative data
391	Customer data
392	Measurement agility
393	**b. Performance analysis and review**
394	**c. Performance improvement**
395	Best practice sharing
396	Future performance
397	Continuous improvement and innovation
398	**4.2 Management of information, knowledge, and information technology**
399	**a. Data, information, and knowledge management**
400	Properties
401	Data and information availability
402	Knowledge management
403	**b. Management of information resources and technology**
404	Hardware and software properties
405	Emergency availability
406	**5. Workforce focus**
407	**5.1 Workforce environment**
408	**a. Workforce capability and capacity**
409	Capability and capacity
410	New workforce members
411	Work accomplisment
412	Workforce change management
413	**b. Workforce climate**
414	Workplace environment
415	Workforce policies and benefits
416	**5.2 Workforce engagement**
417	**a. Workforce performance**
418	Elements of engagement
419	Organizational culture
420	Performance management
421	**b. Assessment of workforce engagement**
422	Assessment of engagement
423	Correlation with business results

Table B.1: Lean Frameworks / Components (Continued)

424	**c. Workforce and leader development**
425	Learning and development system
426	Learning and development effectiveness
427	Career progression
428	**6. Operation focus**
429	**6.1 Work systems**
430	**a. Work system design**
431	Design concepts
432	Work system requirements
433	**b. Work system management**
434	Work system implementation
435	Cost control
436	**c. Emergency readiness**
437	**6.2 Work processes**
438	**a. Work process design**
439	Design concepts
440	Work process requirements
441	**b. Work process management**
442	Key work process implementation
443	Supply-chain management
444	Process improvement
445	**7. Results**
446	**7.1 Product and process outcomes**
447	**a. Customer-focused product and process results**
448	**b. Operational process efectivenes results**
449	Operational effectiveness
450	Emergency preparedness
451	**c. Strategy implementation results**
452	**7.2 Customer-focused outcomes**
453	**a. Customer-focused results**
454	Customer satisfaction
455	Customer engagement
456	**7.3 Customer-focused outcomes**
457	**a. Workforce results**
458	Workforce capability and capacity
459	Workforce climate
460	Workforce engagement
461	Workforce development
462	**7.4 Leadership and governace outcomes**
463	**a. Leadership, governance & societal responsibility results**
464	Leadership
465	Governance
466	Law and regulation
467	Ethics
468	Society
469	**7.5 Financia and market outcomes**
470	**a. Financial and market results**
471	Financial performance
472	Marketplace performance

Table B.1: Lean Frameworks / Components (Continued)

	Deming Prize (2000) set of criteria (Khoo & Tan, 2003, p.15)
473	1.0 Top management leadership, vision and strategies
474	1.1 Top management leadership
475	1.2 Organizational vision and strategies
476	2.0 TQM frameworks
477	2.1 Organizational structure and its operations
478	2.2 Daily management
479	2.3 Policy management
480	2.4 Relationships to ISO 9000 and ISO 14000
481	2.5 Relationships to other management improvement program
482	2.6 TQM promotion and operation
483	3.0 Quality assurance system
484	3.1 Quality assurance system
485	3.2 New product and new technology development
486	3.3 Process control
487	3.4 Test, quality evaluation and quality audits
488	3.5 Activities covering the whole life cycle
489	3.6 Purchasing, subcontracting and distribution management
490	4.0 Management systems for business elements
491	4.1 Cross-functional management and its operations
492	4.2 Quality/delivery management
493	4.3 Cost management
494	4.4 Environmental management
495	4.5 Safety, hygiene and work environmental management
496	5.0 Human resource development
497	5.1 Positioning of people in management
498	5.2 Education and training
499	5.3 Respect for people's dignity
500	6.0 Effective utilization of information
501	6.1 Positioning of information in management
502	6.2 Information systems
503	6.3 Support for analysis and decision making
504	6.4 Standardization and configuration management
505	7.0 TQM concepts and values
506	7.1 Quality
507	7.2 Maintenance and improvement
508	7.3 Respect for humanity
509	8.0 Scientific methods
510	8.1 Understanding and utilization of methods
511	8.2 Understanding and utilization of problem-solving methods
512	9.0 Organizational powers
513	9.1 Core technology
514	9.2 Speed
515	9.3 Vitality
516	10.0 Contribution to realization of corporate objectives
517	10.1 Customer relations
518	10.2 Employee relations
519	10.3 Social relations
520	10.4 Supplier relations
521	10.5 Shareholder relations
522	10.6 Realization of corporate mission
523	10.7 Continuously securing profits
524	10.8 TQM features (shining example)

Table B.1: Lean Frameworks / Components (Continued)

	European Foundation for Quality Management Excellence Model (EFQM,2010)
525	**1 Leadership**
526	a Leaders develop the mission, vision & values and are role models of a culture of excellence
527	b Leaders are personally involved in ensuring the organisation's management system is developed,implemented & continuously improved
528	c Leaders are involved with customers, partners & representatives of society
529	d Leaders motivate, support & recognise the organisation's people
530	**2 Policy & Strategy**
531	a Policy & strategy are based on the present & future needs & expectations of stakeholders
532	b Policy & strategy are based on information from performance measurement, research, learning and creativity related activities
533	c Policy & strategy are developed, reviewed & updated
534	d Policy & strategy are deployed through a framework of key processes
535	e Policy & strategy are communicated & implemented
536	**3 People**
537	a People resources are planned, managed & improved
538	b People's knowledge & competencies are identified, developed & sustained
539	c People are involved & empowered
540	d People & the organisation have a dialogue
541	e People are rewarded, recognised & cared for
542	**4 Partnerships & Resources**
543	a External partnerships are managed
544	b Finances are managed
545	c Buildings, equipment & materials are managed
546	d Technology is managed
547	e Information & knowledge are managed
548	**5 Processes**
549	a Processes are systematically designed & managed
550	b Processes are improved, as needed, using innovation in order to fully satisfy & generate increasing value for customers & other stakeholders
551	c Products & services are designed & developed based on customer needs & expectations
552	d Products & services are produced, delivered & serviced
553	e Customer relationships are managed & enhanced
554	**6 Customer Results**
555	a Perception measures
556	b Performance indicators
557	**7 People Results**
558	a Perception measures
559	b Performance indicators
560	**8 Society Results**
561	a Perception measures
562	b Performance indicators
563	**9 Key Performance Results**
564	a Key performance outcomes
565	b Key performance indicators

Table B.1: Lean Frameworks / Components (Continued)

	The Shingo Orinciples of Operational Excellence (USU,2010)
	Suggested systems, tools and activities
566	**Dimension 1 - Cultural enablers (People)**
567	Individual development plans
568	On-the-job coaching
569	Structured education programs
570	Formal systems for capturing & transfering lessons learned
571	The use of standardized work procedures
572	Specific training philosophy similar to Training Within Industry
573	Employee suggestions and improvement activities
574	Sharing problems and exchanging ideas
575	Recruitment and succession planning system
576	Initiatives regarding environmental issues
577	Scope of environmental, health, and safety efforts
578	Cross-training program
579	Job rotation
580	Clearly communicated hiring and promotion standards
581	Alignment of job descriptions and compensation to excellence
582	Union partnership including collaborative work arrengements
583	Communication of the measurement system
584	Personnel commitment to eliminate the waste
585	Proactive systems to maintain an ergonomic, clean, and safe work environment
586	Education, awareness, and practices aimed at employee health and wellness
587	**Dimension 2 - Continuous process improvement (Processes)**
588	Voice of the customer
589	Customer-facing process
590	Quality function deployment, concurrent engineering for product development
591	Variety reduction
592	Involve suppliers & customers in product / service design
593	Flow and Pull
594	Value Stream Mapping
595	Value Analysis
596	Time-based or just-in-time manufacturing
597	Total productive, preventive, or predicive maintenance -TPM
598	Quick changeover or setup reductions (SMED)
599	Zero defects through Poka-yoke
600	Cellular layout
601	Kaizen and breackthrough improvement
602	Emphasis on direct observation (go and see)
603	Distribute work intellegentlyand efficiently or level-loading
604	Theory of constraints - managing bottlenecks
605	Benchmarking processes
606	A3 Thinking
607	5S, visual workplace, visual displays, and visual management
608	Right-sized equipment and facilities
609	Six-sigma, statistical process control, design of experiments
610	Tools of quality
611	Production Process Preparation (3P)
612	Integration of the company and its suppliers
613	Distribution and transport alliances
614	Respect for suppliers
615	Commitment to supplier development
616	Alignment and integration of administration functions
617	Data-based decisions and actions
618	Visula devices and systems

Table B.1: Lean Frameworks / Components (Continued)

619	**Dimension 3 - Enterprise alignment (Alignment)**
620	A system for creating reporting requirements
621	Common management & reporting systems across the enterprise
622	A financial reporting system embraces Lean accounting practices
623	Continuous flow and eliminating waste in the entire enterprise
624	Simple and visual information systems
625	Scientific thinking as a philosophy
626	The use of knowledge management systems & ideas sharing
627	A planning system for establishing and deploying the strategy
628	A system for aligning objectives and projects
629	Assessment system to check reality
630	A system to align tools, systems, and principles to values, mission, and vision
631	A business assessment system that evaluates performance
632	Systems to develop and sustain ethical behavior
633	**Dimension 4 - Results**
634	Quality: finished product first-pass yield, rework, unplanned scrap rate, overall cost of quality, process variation measures
635	Cost / productivity: labor productivity, asset productivity, inventory turns, materials, energy productivity, resource utilization
636	Delivery: total lead time, on-time delivery, time from supplier to receipt of materials,mis-shipments, reorder rate, system availability
637	Customer satisfaction:internal & external, lead time, flexibility, synchronized processes, customer audits, surveys & awards
638	Morale; employee survey, participation in activities, number of ideas per employee, grievances, referrals for work
639	**Scope of transformation**
640	**Business & management processes**
641	Customer relations
642	Product / service development
643	Operations
644	Supply
645	Management

Table B.1: Lean Frameworks / Components (Continued)

APPENDIX C: COMPARATIVE ANALYSIS OF EXISTING LEAN FRAMEWORKS TO IDENTIFY LEAN COMPONENTS

Nr.	Frameworks
1	Seven Disciplines of Enterprise Engineering (Martin,1995)
2	Lean Enterprise Model - LAI / MIT (Nightingale & Mize, 2002)
3	The Lean House (Liker, 2004)
4	Framework for Lean Manufacturing based on the Lean house structure (Anand & Kodali, 2010)
5	Lean Enterprise Architecture (Mathaisel, 2008)
6	A conceptual framework for JIT implementation (Wafa & Yasin, 1998)
7	Model for Continuous Improvement (Kaye & Anderson, 1999)
8	Business Process Change Framework (Motwani, 2003)
9	A proposed dynamic model for a Lean roadmap (Anvari et al.,2011)
10	The Flow Framework (Mackle , 2012)
11	Baldrige Criteria for Performance Excellence Framework (NIST, 2011)
12	Deming Prize Criteria (Khoo & Tan, 2003)
13	European Foundation for Quality Management Excellence Model (EFQM, 2010)
14	The Shingo for Operational Excellence Model (USU,2010)
F	Frequency
Σ F	Total Frequency
%	Weight
Σ %	Total weight per group

Table C.1: Comparative analysis of existing Lean frameworks to identify Lean components

	Components	1	2	3	4	5	6	7	8	9	10	11	12	13	14	F	ΣF	%	Σ%
	Data, Information and Knowledge Management (D)																		
1	Data, information, and knowledge management											1				1		0	
2	Data and information availability											1				1		0	
3	Process sharing				1											1		0	
4	Management of information, knowledge, and information technology											1				1		0	
5	Properties											1				1		0	
6	Knowledge management											1				1		0	
7	Effective utilization of information												1			1		0	
8	Positioning of information in management												1			1		0	
9	Information systems												1			1		0	
10	Support for analysis and decision making												1			1		0	
11	Standardization and configuration management												1			1		0	
12	Information & knowledge are managed													1		1		0	
13	Simple and visual information systems -Dimension														1	1		0	
14	The use of knowledge management systems & ideas sharing														1	1		0	
15	Information sharing with suppliers				1											1		0	
16	Best practice sharing											1				1		0	
17	Measurement, analysis, and knowledge management											1				1		0	
	Total components																17		0.027
	Industrial Engineering (E)																		
18	Enterprise redesign	1			1											2		0	
19	Maintain spare capacity				1											1		0	
20	Concurrent engineering				1											1		0	
21	Mixed model manufacturing / scheduling				1											1		0	
22	Design for manufacturing				1											1		0	
23	Rolling production plan				1											1		0	
24	Workload or line balancing				1											1		0	
25	Product analysis					1										1		0	
26	Production volume					1										1		0	
27	Job-shop, flow-shop					1										1		0	
28	Trade-off analysis					1										1		0	
29	Rough scale simulation					1										1		0	
30	Quality assurance system												1			1		0	
31	New product and new technology development												1			1		0	
32	Process control												1			1		0	
33	Test, quality evaluation and quality audits												1			1		0	
34	Activities covering the whole life cycle												1			1		0	
35	Purchasing, subcontracting and distribution management												1			1		0	
36	Operation focus											1				1		0	
37	Work systems											1				1		0	
38	Work system design											1				1		0	
39	Design concepts											1				1		0	
40	Work system requirements											1				1		0	
41	Emergency readiness											1				1		0	
42	Work processes											1				1		0	
43	Work process design											1				1		0	
44	Design concepts											1				1		0	
45	Work process requirements											1				1		0	
46	Work process management											1				1		0	
47	Key work process implementation											1				1		0	
48	Supply-chain management											1				1		0	
49	Process improvement											1				1		0	
50	Quality function deployment, concurrent engineering for product development														1	1		0	
51	Value Analysis														1	1		0	
52	Distribute work intellegently and efficiently or level-loading														1	1		0	
53	Operations														1	1		0	
54	Product / service development														1	1		0	
	Total components																38		0.060

Table C.1: Comparative analysis of existing Lean frameworks to identify Lean components (Continued)

	Components	1	2	3	4	5	6	7	8	9	10	11	12	13	14	F	Σ F	%	Σ %
	External Environment (X)																		
55	Supplier involvement in design				1											1		0.002	
56	Sole sourcing or supplier reduction				1											1		0.002	
57	Long term supplier relationship				1											1		0.002	
58	Supplier proximity				1											1		0.002	
59	Supplier training & development				1											1		0.002	
60	Quality certification (suppliers & self)				1											1		0.002	
61	Suppliers				1											1		0.002	
62	Customer focus											1				1		0.002	
63	Voice of the customer											1			1	2		0.003	
64	Customer listening											1				1		0.002	
65	Listening to current customers											1				1		0.002	
66	Listening to potential customers											1				1		0.002	
67	Determination of customer satisfaction and engagement											1				1		0.002	
68	Satisfaction and engagement											1				1		0.002	
69	Satisfaction relative to competitors											1				1		0.002	
70	Dissatisfaction											1				1		0.002	
71	Customer engagement											1				1		0.002	
72	Product offerings and customer support											1				1		0.002	
73	Product offerings											1				1		0.002	
74	Customer support											1				1		0.002	
75	Customer segmentation											1				1		0.002	
76	Customer data use											1				1		0.002	
77	Building customer relationships											1				1		0.002	
78	Relationship management											1				1		0.002	
79	Complaint management											1				1		0.002	
80	Understand customer value										1	1				2		0.003	
81	External partnerships are managed - 4 Partnerships & Resources											1				1		0.002	
82	Customer relationships are managed & enhanced											1				1		0.002	
83	Customer-facing process														1	1		0.002	
84	Involve suppliers & customers in product / service design														1	1		0.002	
85	Integration of the company and its suppliers														1	1		0.002	
86	Distribution and transport alliances														1	1		0.002	
87	Respect for suppliers														1	1		0.002	
88	Commitment to supplier development														1	1		0.002	
89	Benchmarking processes														1	1		0.002	
90	Supply														1	1		0.002	
91	Customer relations														1	1		0.002	
	Total components																39		0.061
	Processes Flow (F)																		
92	Flow analysis					1										1		0.002	
93	Process						1									1		0.002	
94	Focus on critical processes							1								1		0.002	
95	Administrative & office flow										1					1		0.002	
96	Design for flow										1					1		0.002	
97	Supply for flow										1					1		0.002	
98	Create flow										1					1		0.002	
99	Align production with demand										1					1		0.002	
100	Manage the constraint										1					1		0.002	
101	Manage the inventory										1					1		0.002	
102	Organize material flow by pull										1					1		0.002	
103	Compress lead time										1					1		0.002	
104	Maintain flow										1					1		0.002	
105	Distribute for flow										1					1		0.002	
106	Processes													1		1		0.002	
107	Processes are systematically designed & managed													1		1		0.002	
108	Processes are improved, as needed, using innovation in order to fully satisfy & generate increasing value for customers & other stakeholders													1		1		0.002	
109	Products & services are designed & developed based on customer needs & expectations													1		1		0.002	
110	Products & services are produced, delivered & serviced													1		1		0.002	
111	Continuous process improvement (Processes)													1		1		0.002	
112	Production sequence					1								1		2		0.003	
113	Flow-shop					1								1		2		0.003	
114	Planning & control					1										1		0.002	
115	Tools for understanding demand & capacity, material planning & scheduling										1					1		0.002	
116	Develop flexible processes										1					1		0.002	
117	Develop capable processes										1					1		0.002	
	Total components																28		0.044

Table C.1: Comparative analysis of existing Lean frameworks to identify Lean components (Continued)

	Components	1	2	3	4	5	6	7	8	9	10	11	12	13	14	F	Σ F	%	Σ %
	Lean & Business Improvement Programs (L)																		
118	Procedure redesign	1														1		0.002	
119	TQM, Kaizen	1														1		0.002	
120	Toyota way philosophy			1												1		0.002	
121	Stable and standardized processes			1												1		0.002	
122	Level production (heijunka) Production smoothing (load leveling)			1						1						2		0.003	
123	Waste reduction			1												1		0.002	
124	- 5 Why's			1												1		0.002	
125	- Eye's for waste			1												1		0.002	
126	- Problem solving (Problem solving tools			1												1		0.002	
127	Just-in-time			1												1		0.002	
128	- Takt time planning			1												1		0.002	
129	- Continuous flow			1												1		0.002	
130	- Integrated logistics			1												1		0.002	
131	Jidoka			1												1		0.002	
132	- Automatic stops (Automation)			1												1		0.002	
133	- Andon			1												1		0.002	
134	- Person-machine separation			1												1		0.002	
135	- Error proofing (Mistake proofing - Pokayoke)			1												1		0.002	
136	- In-station quality control (Defect at source)			1												1		0.002	
137	- Solve root cause of problems			1												1		0.002	
138	Cellular manufacuring				1											1		0.002	
139	Total productive maintenance				1					1	1					3		0.005	
140	Total quality management				1											1		0.002	
141	Use of flexible machines				1											1		0.002	
142	Small lot production				1											1		0.002	
143	Pull production				1											1		0.002	
144	One piece flow				1											1		0.002	
145	Commonolization & standardization of parts				1											1		0.002	
146	- Cycle time & lead time reduction				1											1		0.002	
147	- Standardized containers				1											1		0.002	
148	- Elimination of buffers				1											1		0.002	
149	- WIP reduction				1											1		0.002	
150	- Storage space reduction				1											1		0.002	
151	- Quality circles				1											1		0.002	
152	- Synchronization				1											1		0.002	
153	- Safety improvement programs				1											1		0.002	
154	- Product & process simplification				1											1		0.002	
155	- Layout change or U shaped cell				1											1		0.002	
156	- Statistical process control				1											1		0.002	
157	- Successive checking				1											1		0.002	
158	- Work standardization				1											1		0.002	
159	- Lean principles					1										1		0.002	
160	- Cellular design					1										1		0.002	
161	- Lean principles					1										1		0.002	
162	- Testing					1										1		0.002	
163	- Adjusting					1										1		0.002	
164	- Continuous improvement - Continuously improve					1					1					2		0.003	
165	- Stabilization					1										1		0.002	
166	- Best Lean / cellular practices					1										1		0.002	
167	Factors facilitating JIT						1									1		0.002	
168	JIT implementation						1									1		0.002	
169	Standardize best practices							1								1		0.002	
170	Quality management system							1								1		0.002	
171	Integration of C.I. activities							1								1		0.002	
172	- Lean knowledge									1						1		0.002	
173	- Determine: value, product family, procedures, metrics, feedback system, and VSM managers									1						1		0.002	
174	- VSM "door to door" sample (current & future)									1					1	2		0.003	
175	- Implementing based on future VSM									1						1		0.002	
176	- Continuous flow									1						1		0.002	
177	Kanban				1					1						2		0.003	
178	Automatic guided vehicle									1						1		0.002	
179	Eliminate muda									1						1		0.002	
180	Flexible work systems (group technology & cellular manufacturing)									1						1		0.002	
181	- Stability									1						1		0.002	
182	Standard work									1						1		0.002	
183	5S				1					2	1				1	5		0.008	
184	Zero defects through Poka-yoke									1					1	2		0.003	
185	Self controlling									1						1		0.002	
186	Visual management			1						1	1				1	4		0.006	

Table C.1: Comparative analysis of existing Lean frameworks to identify Lean components (Continued)

	Components	1	2	3	4	5	6	7	8	9	10	11	12	13	14	F	Σ F	%	Σ %
	Lean & Business Improvement Programs (L)																		
187	- Flexibility									1						1		0.002	
188	SMED- Quick changeover or setup reductions (Single minute exchange of dies			1						1					1	3		0.005	
189	- Pull system									1						1		0.002	
190	Takt time									1						1		0.002	
191	Pace maker									1						1		0.002	
192	One piece flow									1						1		0.002	
193	Fifo Line									1						1		0.002	
194	Supermarket									1						1		0.002	
195	Fit for use of pulling									1						1		0.002	
196	Expand to the whole system									1						1		0.002	
197	- VSM "door to door" for all products (current & future)									1						1		0.002	
198	- Implementing Lean "door to door" value streams									1						1		0.002	
199	- Spread Lean to the office									1						1		0.002	
200	- Spread Lean to the whole value stream / suppliers & customers									1						1		0.002	
201	Perfection									1						1		0.002	
202	- Measurement performance, based on : indicators & maturity matrix									1						1		0.002	
203	- Focus on continuous improvement by Lean learning, Lean thinking and Lean enterprise self assessment tool									1						1		0.002	
204	- Toward perfection									1						1		0.002	
205	- Tools for availability improvement & variability reduction										1					1		0.002	
206	- Surface root causes of problems										1					1		0.002	
207	- Reduce variation, mistakes, complexity										1					1		0.002	
208	- Sustain operations										1					1		0.002	
209	- Tools for standardization, communication & problem solving										1					1		0.002	
210	- Workplace organization										1					1		0.002	
211	- Standard work / Standard operating procedures (SOP's)										1					1		0.002	
212	Performance improvement systems											1				1		0.002	
213	TQM frameworks												1			1		0.002	
214	Relationships to ISO 9000 and ISO 14000												1			1		0.002	
215	Relationships to other management improvement program												1			1		0.002	
216	TQM promotion and operation												1			1		0.002	
217	TQM concepts and values												1			1		0.002	
218	Quality												1			1		0.002	
219	Maintenance and improvement												1			1		0.002	
220	Scientific methods												1			1		0.002	
221	Understanding and utilization of methods												1			1		0.002	
222	Understanding and utilization of problem-solving methods												1			1		0.002	
223	Continuous flow and eliminating waste in the entire enterprise														1	1		0.002	
224	Assessment system to check reality														1	1		0.002	
225	Flow and Pull														1	1		0.002	
226	Time-based or just-in-time manufacturing														1	1		0.002	
227	Total productive, preventive, or predicive maintenance -TPM														1	1		0.002	
228	Cellular layout														1	1		0.002	
229	Kaizen and breackthrough improvement														1	1		0.002	
230	Theory of constraints - managing bottlenecks														1	1		0.002	
231	A3 Thinking														1	1		0.002	
232	Visual workplace, visual displays														1	1		0.002	
233	Six-sigma, statistical process control, design of experiments														1	1		0.002	
234	Tools of quality														1	1		0.002	
235	Production Process Preparation (3P)														1	1		0.002	
236	Variety reduction														1	1		0.002	
237	Visual devices and systems														1	1		0.002	
238	Continuous improvement and innovation											1				1		0.002	
	Total components																137		0.216

Table C.1: Comparative analysis of existing Lean frameworks to identify Lean components (Continued)

	Components	1	2	3	4	5	6	7	8	9	10	11	12	13	14	F	Σ F	%	Σ %
	Lean Management Infrastructure (M)																		
239	Leadership/ managers & executives / Senior leadership /Top management leadership				1	1						1	1			4		0.006	
240	Management						1	1								2		0.003	
241	Role of senior management							1								1		0.002	
242	Leadership by all managers							1								1		0.002	
243	Lean manufacturing implementation management								1							1		0.002	
244	- Process management								1							1		0.002	
245	- Change management								1							1		0.002	
246	Promoting legal and ethical behavior											1				1		0.002	
247	Creating a sustainable organization											1				1		0.002	
248	Focus on action											1				1		0.002	
249	Ethical behavior											1				1		0.002	
250	Action plan implementation											1				1		0.002	
251	Performance management											1				1		0.002	
252	Top management leadership												1			1		0.002	
253	Daily management												1			1		0.002	
254	Management systems for business elements												1			1		0.002	
255	Cross-functional management and its operations												1			1		0.002	
256	Quality/delivery management												1			1		0.002	
257	Cost management												1			1		0.002	
258	Environmental management												1			1		0.002	
259	Safety, hygiene and work environmental management												1			1		0.002	
260	Leadership													1		1		0.002	
261	Leaders develop the mission, vision & values and are role models of a culture of excellence													1		1		0.002	
262	Leaders are personally involved in ensuring the organization's management system is developed,implemented & continuously improved													1		1		0.002	
263	Leaders are involved with customers, partners & representatives of society													1		1		0.002	
264	Leaders motivate, support & recognize the organization's people													1		1		0.002	
265	Management														1	1		0.002	
266	Genchi Genbutsu - Emphasis on direct observation (go and see)			1											1	2		0.003	
	Total components																33		0.052
	Technology (N)																		
267	New process or equipment technologies				1											1		0.002	
268	Computer integrated manufacturing				1											1		0.002	
269	Group technology				1											1		0.002	
270	Use of electronic data interchange with suppliers				1											1		0.002	
271	Management of information resources and technology											1				1		0.002	
272	Hardware and software properties											1				1		0.002	
273	Emergency availability											1				1		0.002	
274	Data-based decisions and actions														1	1		0.002	
275	Information technology development	1														1		0.002	
276	Core technology											1				1		0.002	
277	Technology is managed												1			1		0.002	
	Total components																11		0.017

Table C.1: Comparative analysis of existing Lean frameworks to identify Lean components (Continued)

Components	1	2	3	4	5	6	7	8	9	10	11	12	13	14	F	Σ F	%	Σ %
Organization (O)																		
278 Organization & culture development	1														1		0.002	
279 Culture / social & organizational				1											1		0.002	
280 Flat organization structure				1											1		0.002	
281 Long term employment				1											1		0.002	
282 Stakeholders focus							1								1		0.002	
283 Culture for C.I. & innovation							1								1		0.002	
284 Cultural readiness								1							1		0.002	
285 Organize for flow										1					1		0.002	
286 Align organization with flow										1					1		0.002	
287 Organizational profile											1				1		0.002	
288 Organizational description											1				1		0.002	
289 Organzational environment											1				1		0.002	
290 Product offerings											1				1		0.002	
291 Organizational relationships											1				1		0.002	
292 Organizational structure											1				1		0.002	
293 Customers and stakeholders											1				1		0.002	
294 Suppliers and partners											1				1		0.002	
295 Communication and organizational performance											1				1		0.002	
296 Communication											1				1		0.002	
297 Governance and societal responsibilities											1				1		0.002	
298 Organizational governance											1				1		0.002	
299 Governance system											1				1		0.002	
300 Performance evaluation											1				1		0.002	
301 Legal and ethical behavior											1				1		0.002	
302 Legal and regulatory behavior											1				1		0.002	
303 Societal responsibilities and support of key communities											1				1		0.002	
304 Societal well-being											1				1		0.002	
305 Community support											1				1		0.002	
306 Organizational culture											1				1		0.002	
307 Work system management											1				1		0.002	
308 Work system implementation											1				1		0.002	
309 Cost control											1				1		0.002	
310 Organizational structure and its operations												1			1		0.002	
311 Organizational powers												1			1		0.002	
312 - Speed												1			1		0.002	
313 - Vitality												1			1		0.002	
314 Contribution to realization of corporate objectives												1			1		0.002	
315 Customer relations												1			1		0.002	
316 Employee relations												1			1		0.002	
317 Social relations												1			1		0.002	
318 Supplier relations												1			1		0.002	
319 Shareholder relations												1			1		0.002	
320 Realization of corporate mission												1			1		0.002	
321 Continuously securing profits												1			1		0.002	
322 TQM features (shining example)												1			1		0.002	
323 Enterprise alignment														1	1		0.002	
324 A system for creating reporting requirements														1	1		0.002	
325 Common management & reporting systems across the enterprise														1	1		0.002	
326 A financial reporting system embraces Lean accounting practices														1	1		0.002	
327 A system for aligning objectives and projects														1	1		0.002	
328 A business assessment system that evaluates performance														1	1		0.002	
329 Systems to develop and sustain ethical behavior														1	1		0.002	
330 Human resource planning					1										1		0.002	
331 Finances are managed													1		1		0.002	
332 Alignment and integration of administration functions														1	1		0.002	
333 Business & management processes														1	1		0.002	
Total components																56		0.088
Facilities (A)																		
334 Ideal function layout					1										1		0.002	
335 Facility planning					1										1		0.002	
336 Equipment design					1										1		0.002	
337 Simulation					1										1		0.002	
338 Detailed floor layout					1										1		0.002	
339 Work organization					1										1		0.002	
340 Equipment selection					1										1		0.002	
341 Installing equipment					1										1		0.002	
342 Lay-out for flow										1					1		0.002	
343 Buildings, equipment & materials are managed													1		1		0.002	
344 Right-sized equipment and facilities														1	1		0.002	
Total components																11		0.017

Table C.1: Comparative analysis of existing Lean frameworks to identify Lean components (Continued)

	Components	1	2	3	4	5	6	7	8	9	10	11	12	13	14	F	Σ F	%	Σ %
	People (P)																		
345	People & teamwork			1												1		0.002	
346	- Selection			1												1		0.002	
347	- Common goals			1												1		0.002	
348	- Ringi decision making			1												1		0.002	
349	People & teamwork- Cross trained			1												1		0.002	
350	Human aspects / attitude, motivation, ownership etc.				1											1		0.002	
351	Commitment / employees & management				1											1		0.002	
352	Rewards & recognition				1											1		0.002	
353	Cross-functional teams				1											1		0.002	
354	Multi-skilled workforce / Multi skills workers				1					1						2		0.003	
355	Job rotation or flexible job responsibilities				1											1		0.002	
356	Job enlargement				1											1		0.002	
357	Employee empowerment				1											1		0.002	
358	Employee participation				1											1		0.002	
359	Suggestion schemes				1											1		0.002	
360	Innovation					1										1		0.002	
361	Relationship balancing								1							1		0.002	
362	Workforce profile											1				1		0.002	
363	Workforce plans											1				1		0.002	
364	Workforce focus / Employee focus / Workers						1	1				1				3		0.005	
365	Workforce environment											1				1		0.002	
366	Workforce capability and capacity											1				1		0.002	
367	Capability and capacity											1				1		0.002	
368	New workforce members											1				1		0.002	
369	Work accomplishment											1				1		0.002	
370	Workforce climate											1				1		0.002	
371	Workplace environment											1				1		0.002	
372	Workforce policies and benefits											1				1		0.002	
373	Workforce engagement											1				1		0.002	
374	Workforce performance											1				1		0.002	
375	Elements of engagement											1				1		0.002	
376	Assessment of workforce engagement											1				1		0.002	
377	Assessment of engagement											1				1		0.002	
378	Correlation with business results											1				1		0.002	
379	Workforce and leader development											1				1		0.002	
380	Learning and development effectiveness											1				1		0.002	
381	Career progression											1				1		0.002	
382	Human resource development												1			1		0.002	
383	Positioning of people in management												1			1		0.002	
384	Education and training												1			1		0.002	
385	Respect for people's dignity / Respect for humanity												2			2		0.003	
386	People													1		1		0.002	
387	People resources are planned, managed & improved													1		1		0.002	
388	People are involved & empowered													1		1		0.002	
389	People & the organization have a dialogue													1		1		0.002	
390	People are rewarded, recognized & cared for													1		1		0.002	
391	Partnerships & Resources													1		1		0.002	
392	Cultural enablers (People)														1	1		0.002	
393	Individual development plans														1	1		0.002	
394	Employee suggestions and improvement activities														1	1		0.002	
395	Sharing problems and exchanging ideas														1	1		0.002	
396	Recruitment and succession planning system														1	1		0.002	
397	Initiatives regarding environmental issues														1	1		0.002	
398	Scope of environmental, health, and safety efforts														1	1		0.002	
399	Job rotation														1	1		0.002	
400	Clearly communicated hiring and promotion standards														1	1		0.002	
401	Alignment of job descriptions and compensation to excellence														1	1		0.002	
402	Union partnership including collaborative work arrangements														1	1		0.002	
403	Communication of the measurement system														1	1		0.002	
404	Personnel commitment to eliminate the waste														1	1		0.002	
405	Proactive systems to maintain an ergonomic, clean, and safe work environment														1	1		0.002	
406	Education, awareness, and practices aimed at employee health and wellness															1		0.002	
	Total components																66		0.104

Table C.1: Comparative analysis of existing Lean frameworks to identify Lean components (Continued)

Components	1	2	3	4	5	6	7	8	9	10	11	12	13	14	F	Σ F	%	Σ %
Organizational Learning (L)																		
407 Training					1										1		0.002	
408 Learning from C.I. results							1								1		0.002	
409 Learning capacity								1							1		0.002	
410 People (Lean knowledge)									1						1		0.002	
411 Structured education programs														1	1		0.002	
412 Formal systems for capturing & transferring lessons learned														1	1		0.002	
413 The use of standardized work procedures														1	1		0.002	
414 Specific training philosophy similar to Training Within Industry														1	1		0.002	
415 Cross-training program														1	1		0.002	
416 On-the-job coaching														1	1		0.002	
People's knowledge & competencies are identified, developed &																		
417 sustained													1		1		0.002	
418 Learning and development system											1				1		0.002	
419 Develop people to support flow										1					1		0.002	
420 Multi-functional training				1											1		0.002	
421 People & teamwork- Cross trained			1												1		0.002	
Total components																15		0.024

Strategy (S)																		
422 Enterprise strategic planning / Strategic initiatives / Strategies		1			1			1	1		1	1			6		0.009	
423 - Decision to pursue enterprise transformation		1													1		0.002	
424 Adopt Lean paradigm		1													1		0.002	
425 - Build vision / Vision / Organizational vision and strategies		1									1	1			3		0.005	
426 - Convey urgency		1													1		0.002	
427 - Foster Lean learning		1													1		0.002	
428 - Make the commitment		1													1		0.002	
429 - Obtain senior management buy-in / - Make-buy		1			1										2		0.003	
430 Results			1								1				2		0.003	
431 - Best quality			1												1		0.002	
432 - Lowest cost			1												1		0.002	
433 - Shortest lead time			1												1		0.002	
434 - Best safety			1												1		0.002	
435 - High morale			1												1		0.002	
436 Focused factory production				1											1		0.002	
437 Benchmarking					1										1		0.002	
438 Organization as an open system						1									1		0.002	
439 Competitive strategic advantage						1									1		0.002	
440 Measurement & feedback							1								1		0.002	
441 Organizational results							1								1		0.002	
442 Team results							1								1		0.002	
443 Individual results							1								1		0.002	
444 Lean manufacturing outcome								1							1		0.002	
445 Existing/predicting crisis									1						1		0.002	
446 Hoshin Kanri / BSC									1						1		0.002	
447 Create vision & guide flow										1					1		0.002	
448 Measures & accounts for flow										1					1		0.002	
449 Tools for defining measures linked to the overall company goal										1					1		0.002	
450 Flow accounting for financial information										1					1		0.002	
451 Mission											1				1		0.002	
452 Assets											1				1		0.002	
453 Regulatory requirements											1				1		0.002	
454 Organizational situation											1				1		0.002	
455 Competitive environment											1				1		0.002	
456 Competitive position											1				1		0.002	
457 Competitiveness changes											1				1		0.002	
458 Comparative data											1				1		0.002	
459 Strategic context											1				1		0.002	
460 Values											1				1		0.002	
461 Strategic development											1				1		0.002	
462 Strategic planning process											1				1		0.002	
463 Strategy considerations											1				1		0.002	
464 Strategic objectives											1				1		0.002	
465 Key strategic objectives											1				1		0.002	
466 Strategic objective considerations											1				1		0.002	
467 Strategy implementation											1				1		0.002	
468 Action plan development and deployment											1				1		0.002	
469 Action plan development											1				1		0.002	
470 Resource allocation											1				1		0.002	

Table C.1: Comparative analysis of existing Lean frameworks to identify Lean components (Continued)

	Strategy (S)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	F	Σ F	%	Σ %
471	Performance measures											1				1		0	
472	Performance projections											1				1		0	
473	Measurement, analysis, and improvement of organizational performance											1				1		0	
474	Performance measurement											1				1		0	
475	Performance measures											1				1		0	
476	Comparative data											1				1		0	
477	Customer data											1				1		0	
478	Measurement agility											1				1		0	
479	Performance analysis and review											1				1		0	
480	Performance improvement											1				1		0	
481	Future performance											1				1		0	
482	Product and process outcomes											1				1		0	
483	Customer-focused product and process results											1				1		0	
484	Operational process effectiveness results											1				1		0	
485	Operational effectiveness											1				1		0	
486	Emergency preparedness											1				1		0	
487	Strategy implementation results											1				1		0	
488	Customer-focused outcomes											1				1		0	
489	Customer-focused results											1				1		0	
490	Customer satisfaction											1				1		0	
491	Customer engagement											1				1		0	
492	Customer-focused outcomes											1				1		0	
493	Workforce results											1				1		0	
494	Workforce capability and capacity											1				1		0	
495	Workforce climate											1				1		0	
496	Workforce engagement											1				1		0	
497	Workforce development											1				1		0	
498	Leadership and governance outcomes											1				1		0	
499	Leadership, governance & societal responsibility results											1				1		0	
500	Leadership											1				1		0	
501	Governance											1				1		0	
502	Law and regulation											1				1		0	
503	Ethics											1				1		0	
504	Society											1				1		0	
505	Financial and market outcomes											1				1		0	
506	Financial and market results											1				1		0	
507	Financial performance											1				1		0	
508	Marketplace performance											1				1		0	
509	Policy management												1			1		0	
510	Policy & Strategy												1			1		0	
511	Policy & strategy are based on the present & future needs & expectations of stakeholders													1		1		0	
512	Policy & strategy are based on information from performance measurement, research, learning and creativity related activities													1		1		0	
513	Policy & strategy are developed, reviewed & updated													1		1		0	
514	Policy & strategy are deployed through a framework of key processes													1		1		0	
515	Policy & strategy are communicated & implemented													1		1		0	
516	Customer Results													1		1		0	
517	Perception measures													1		1		0	
518	Performance indicators													1		1		0	
519	7 People Results													1		1		0	
520	Perception measures													1		1		0	
521	Performance indicators													1		1		0	
522	8 Society Results													1		1		0	
523	Perception measures													1		1		0	
524	Performance indicators													1		1		0	
525	Key Performance Results													1		1		0	
526	Key performance outcomes													1		1		0	
527	Key performance indicators													1		1		0	
528	Results													1		1		0	
529	Quality: finished product first-pass yield, rework, unplanned scrap, rate, overall cost of quality, process variation measures														1	1		0	
530	Cost / productivity: labor productivity, asset productivity, inventory, turns, materials, energy productivity, resource utilization														1	1		0	
531	Delivery: total lead time, on-time delivery, time from supplier to receipt of materials, miss-shipments, reorder rate, system availability														1	1		0	
532	Customer satisfaction: internal & external, lead time, flexibility, synchronized processes, customer audits, surveys & awards														1	1		0	
533	Morale; employee survey, participation in activities, number of ideas per employee, grievances, referrals for work														1	1		0	
534	A planning system for establishing and deploying the strategy														1	1		0	
535	A system to align tools, systems, and principles to values, mission, vision														1	1		0	
	Total components																123		0.194

Table C.1: Comparative analysis of existing Lean frameworks to identify Lean components (Continued)

	Lean Enterprise Transition Management (T)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	F	Σ F	%	Σ %
536	Focus on the value stream	1														1		0	
537	- Map value stream		1													1		0	
538	Future Value Stream (Value stream reinvention)		1													1		0	
539	- Internalize vision		1													1		0	
540	- Set goals and metrics		1													1		0	
541	- Identify and involve key stakeholders		1													1		0	
542	Develop Lean structure & behavior		1													1		0	
543	- Organize for Lean implementation		1													1		0	
544	- Identify and empower change agents		1													1		0	
545	- Align incentives		1													1		0	
546	- Adapt structure and systems		1													1		0	
547	Create & refine transformation plan		1													1		0	
548	- Identify & prioritize activities		1													1		0	
549	- Commit resources		1													1		0	
550	- Provide education & training		1													1		0	
551	Implement Lean initiatives		1													1		0	
552	- Develop detailed plans		1													1		0	
553	- Implement Lean activities		1													1		0	
554	- Outcomes on enterprise metrics		1													1		0	
555	Focus on continuous improvements		1													1		0	
556	- Monitor Lean progress		1													1		0	
557	- Nurture the process		1													1		0	
558	- Refine the plan		1													1		0	
559	- Capture & adopt new knowledge		1													1		0	
560	Communication between employees		1													1		0	
561	- Monitoring				1											1		0	
562	- Engineering change management					1										1		0	
563	Change environment					1										1		0	
564	- IT leveraging & knowledge capability								1							1		0	
565	- Change agent								1							1		0	
566	Lean promotion office (Lean knowledge)									1						1		0	
567	Lean experts (Lean knowledge)									1						1		0	
568	- Analyze the whole system									1						1		0	
569	Organizational structure (Analyze the whole system)									1						1		0	
570	Resources (Analyze the whole system)									1						1		0	
571	Limitation & delimitation (Analyze the whole system)									1						1		0	
572	Action plan modification									1						1		0	
573	Workforce change management											1				1		0	
574	Organizational powers											1				1		0	
575	Partnerships & Resources												1			1		0	
576	Scientific thinking as a philosophy													1		1		0	
577	Scope of transformation														1	1		0	
578	Foundation														1	1		0	
579	Need				1											1		0	
580	Conceptual design					1										1		0	
581	Preliminary design					1										1		0	
582	Detailed design					1										1		0	
583	Implementation					1										1		0	
584	Lean practices					1										1		0	
585	Operation					1										1		0	
586	Global environment					1										1		0	
587	Drivers						1									1		0	
588	Enablers							1								1		0	
589	Results							1								1		0	
590	Initial investigation							1								1		0	
591	Preparation									1						1		0	
592	Focus on specific pilot									1						1		0	
593	Strategic decision level (CEO / President)				1											1		0	
594	Tactical decision level (Managers)				1											1		0	
595	Operational decision level - Engineers, supervisor				1											1		0	
596	Operational decision level - Shop floor associates				1											1		0	
																	61		0.096
	Total components	15	50	60	101	86	62	81	82	131	124	261	162	160	205	635	635	1	1

Table C.1: Comparative analysis of existing Lean frameworks to identify Lean components (Continued)

VITA

Gustavo Perez

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Doctor of Philosophy

Dissertation: AN ENTERPRISE ARCHITECTURE FRAMEWORK OF A LEAN ENTERPRISE TRANSFORMATION

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