

International Product and Service Management

MASTER THESIS

**Integration of Knowledge Management and Change
Management to Implement Lean Manufacturing**

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Abbreviations

CM: Change Management

EPEI: Every Part Interval

JIT: Just in Time

KM: Knowledge Management

SMED: Single Minute Exchange Die

TPM: Total Productive Maintenance

TPS: Toyota Production System

VSM: Value Stream Mapping

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1. INTRODUCTION

1.1 Background

Nowadays organizations are worried about getting better and better results with fewer resources, in order to survive and overcome the high competition, globalized markets, economic downturns and cost effects that obligate them to follow this policy. In this sense, there are many proposed solutions to face those challenges (methods, strategies and techniques) available on internet portals, consulting sectors, books and many other sources. One of these is the well-known strategy “Lean Manufacturing”, a popular Japanese production method that was mainly developed in Toyota as the Toyota Production System. Many companies have tried to implement it as a whole system or have adopted a portion of the strategy, in order to improve their internal processes.

Lean Manufacturing is a way of production that achieves the challenge of getting more with less through the elimination of waste or activities that do not add value to the production process. It also increases customer satisfaction, improves the organizational performance and results in general. The Lean thinking specifies value, line up that value with the creation of actions in the best structure, conduct these activities without interruption, and perform them in a more efficient manner.

To implement this philosophy a big effort is required from the organization and its members to adapt themselves to new ways of performing, thinking and improving procedures. In this process there is a lot of knowledge sprouting out and changes provoked, and if it is not managed properly it can affect the development of Lean methodology and delay the positive results.

In that sense, there are other models that can complement the implementation of the strategy explained before; these are Knowledge and Change Management. The first one can create the mechanisms to identify, capture and share the knowledge needed to launch Lean Manufacturing and the second one make the transition from the current state to the desired future state, attacking points such as the resistance to change that comes naturally while facing any transformation environment.

According to what has been explained and based on the popularity of Lean among the organizations, we propose to integrate knowledge and change management to implement Lean Manufacturing concept.

1.2 Objectives

The main objective of this thesis is to find a common passage between lean manufacturing, knowledge and change management, integrating their tools and filling the empty holes of the first one with the strategies of the two others.

The purpose pursues to increase the interactions of the models, adapting the knowledge and change management tools to what Lean system really requires to avoid unpleasant surprises and be prepared to efficiently solve the problems that appear on the way to the journey. This will be accomplished through looking at the historical facts, the state of the art and the future challenges of this integration.

It is significant to remark that the intention of this thesis is not to provide a very deep and detailed description of the three models. It is to give an overview of the models and their supporting tools to demonstrate and establish ideas of how far they can be integrated.

1.3 Structure of the Thesis

The development of this work is split into four parts:

First part is about the theoretical characteristics and concepts of Lean Manufacturing. Here Lean Manufacturing is defined with a quick look at its history, the structure and how it is functioning. Moreover are presented the types of waste in a lean production system, Lean Principles and the toolkit that follows these principles: value stream mapping, SMED, total productive maintenance, Kanban, 5S, just in time, production leveling, standardized work, Kaizen and others.

In the second part we talk about the Knowledge Management theories that are essential in order to complement Lean. In this section the term knowledge and the methodology of Knowledge management are defined, and two types of knowledge are distinguished “the tacit and explicit knowledge”. The core process of Knowledge Management “identify-generate-storage-share-apply knowledge” is detailed with tools and strategies that support this process being described briefly.

The third part complements the integration of the three models and introduces the concepts of Change Management. The definition of change and change management are the initial step in this section. Change is divided in types “incremental and radical”. It is also presented the resistance to change as a challenge to change management process.

Finally the strategies of change management are described to face the transformation in organizations.

Part four is the basic work of the thesis. It is about the Integration of the three previous parts. It contains an overview of the model integration. Explore the coincidences, benefits and present a historical precedent for the combination of the models, as well as its state of the art. The strengths, opportunities, weaknesses and threats are analyzed in order to see the interaction level. The tools of knowledge and change management are merged with the implementation of the Lean tools, this is done in order to strengthen and complement the application of the production philosophy. Through this tools connection is shown how the models can work together. The Value Stream Mapping is presented in the integration form. Future challenges are exposed and finally some general recommendations from the change and knowledge management side are given.

At the end of the four parts some conclusions are presented to summarize and understand the objectives of this paper.

2. LEAN MANUFACTURING STRATEGY

2.1 General Characteristics of Lean Manufacturing

2.2 Definition of Lean

Lean Manufacturing is a production philosophy focused in elimination of all waste while increasing customer value. Simply, lean means adding more value for customers with fewer resources. A lean organization comprehends customer value and focuses its key processes to continuously increase it¹. This strategy takes into consideration the respect for the workers, the quality of the products and the stability of the process.

This production method changes the focus of management and directs it to the elimination of waste along entire value streams, instead of at individual points. To accomplish this creates processes that need less human effort, less space, less capital, and less time to make products and services at far less costs and with much fewer defects, compared with traditional production systems.

Lean Manufacturing was initiated by the Toyota Motor Company. The Toyota Production system is based on two concepts: Automation with human touch (Jidoka), which means that when a problem occurs the machine or process stops immediately, preventing defective products from being produced; and the other concept is “Just in time”, which means that every process produces only what is needed by the next process in a continuous flow.

This system can also be explained with the following affirmation: ²Analyzing and looking at the time line, from the moment the customer place the order to the point when the cash is collected. The time line has to be reduced by removing the non-value-adding waste.

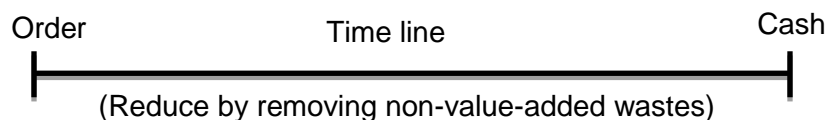


Figure 2.1: Time line of Toyota Production System³

¹ James P. Womack, <http://www.lean.org/WhatsLean/>

² & ³Productivity Press, Taiichi Ohno. 1988. Toyota Production System: Beyond Large-Scale Production. N.Y.

2.2.1 A Brief History of Lean

To talk briefly about the history of Lean, we can start from the late 19th century, when the engineers Frederick Taylor, Frank and Lillian Gilbreth, Henry Ford, and other engineers contributed to some theories and worked to eliminate waste from the manufacturing process. These and some other developments later became part of the Lean Manufacturing techniques; works such as time study and standardized work, elimination of waste, the Ford assembly line, among others. Lean is a conception that has evolved from the craft production, mass production and Fordism.

Following those contributions, Lean history is mostly based on the origins and development of the Toyota Production System (TPS) in Japan, the majority of the tools and techniques were developed in Toyota Motor Company.

The TPS which is a philosophy that looks for the total elimination of waste, as was explained in the previous topics it impregnates all aspects of production in pursuit of the most efficient methods, tracing back its roots to the automatic loom of Sakichi Toyoda, founder of Toyota. This system has evolved through many years of trial and error to improve efficiency based on the “just in time” concept.

To following figure presents a step by step evolution of this system.

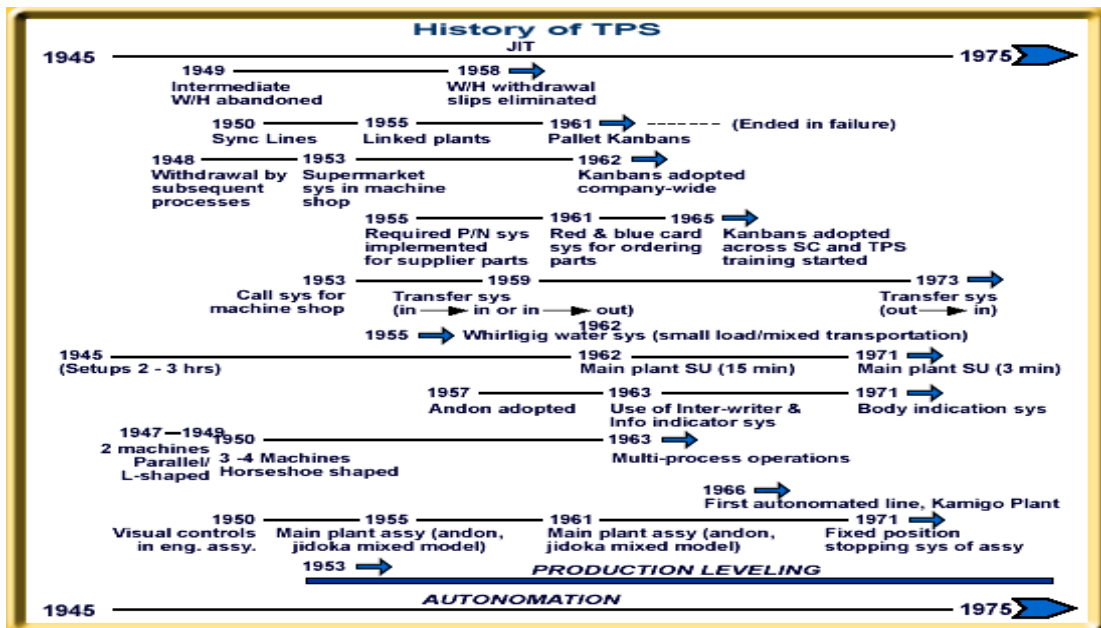


Figure 2.2: History of the Toyota Production System⁴

⁴ Productivity Press, Taiichi Ohno. 1988. Toyota Production System: Beyond Large-Scale Production. N.Y.

The contributions of the engineers Taichi Ohno and Shigeo Shingo from Toyota were very important to create many important changes in the productions system. They were able to transfer their contributions and ideas to literature, what later were used by James P. Womack, Daniel Roos, and Daniel T. Jones to recalled the concept “Lean Manufacturing” in their book “The Machine that change the World” and a subsequent work called “Lean Thinking”.

There are some other contributions that affected the creation of the Lean concept, like the one from Professor Edward Deming with his production principles and cycle process that is used in Kaizen tool. In these brief words the most relevant events that support the development of this interesting production strategy has been collected.

2.2.2 Difference between Traditional Mass Production System and TPS

Following the historical facts of the Toyota Production System, the main differences between the traditional mass production at that time and the TPS are presented in table 2.1. These factors were the key of success of Toyota and its well-known production system.

Factor	Traditional Mass Production System	Toyota Production System
Production diversity	A big amount of few products	Small amount of a big range of products
Parts to be produced	Estimated by sales forecast (push system). Make more as possible.	Driven by pull system, what means that parts are only produced when the customer place the order. Just make what customers need.
Inventory	Based on large batches	Based on one piece flow. Large batches are considered a big waste for the system.
Quality	Radom sampling	Tested at each station. Workers are integrated in quality control.
Worker participation	Normal operators have a very little participation or none.	Workers are empowered to participate in continuous improvement process.
Problems	Viewed just like problems.	Viewed as opportunities for improvement through cause and analysis (5 Why)

Table 2.1: Differences between Traditional Mass Production System and Toyota Production System

2.2.3 Structure and Function of Toyota Production System

To visualize how all the Toyota Production System is structured, it is used temple of TPS, which is a well-known diagram that has become very important in modern manufacturing. It represents the whole system and its elements, the tools that contribute to achieve the success using this methodology.

In the following figure, it can be appreciated the two pillars, Just in Time and Jidoka, sustaining and integrating the whole system, of course supporting it with strong bases to achieve the main goals placed on the roof.

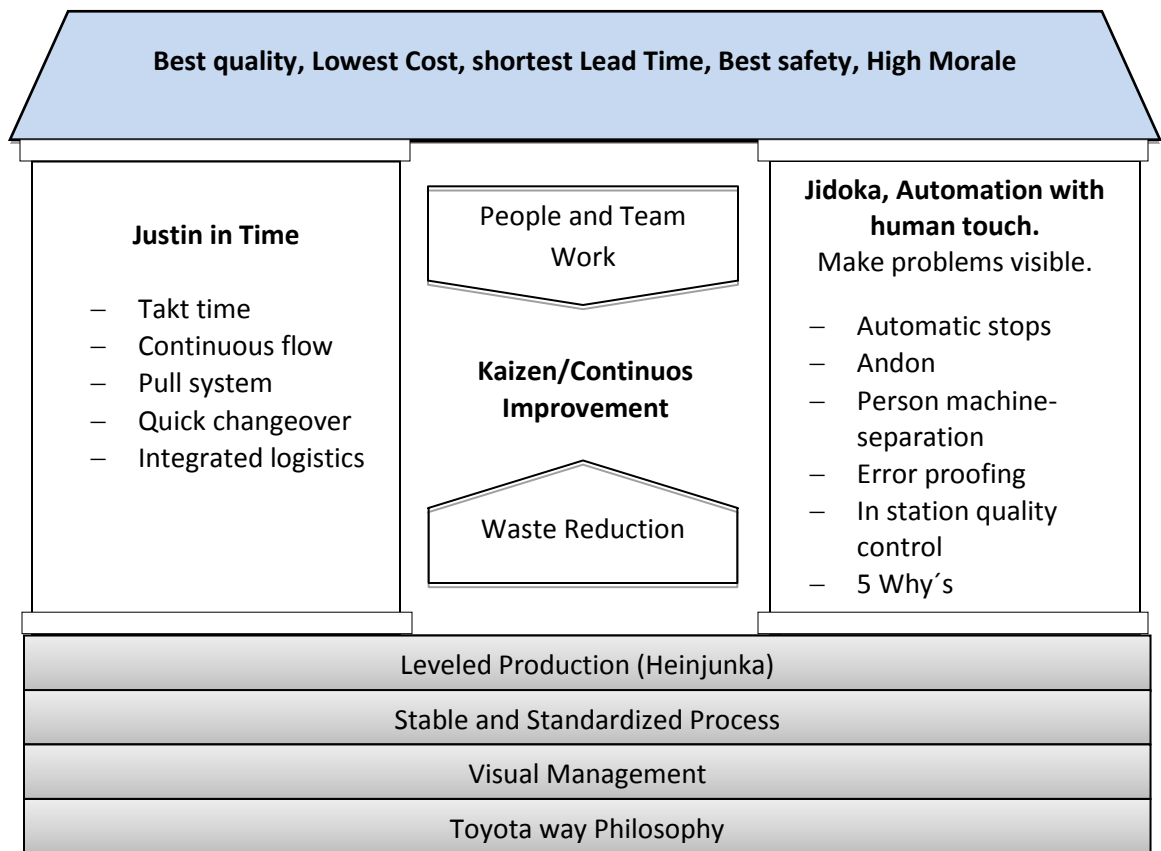


Figure 2.3: The Temple of Toyota Production System⁵

⁵ Editorial Limusa, Alberto Villaseñor and Edber Galindo. 2007. Manual de Lean Manufacturing: Guía Básica. Mexico.

In the structure of the temple we had a glance of the foundation of TPS, now it is good to know how all this configuration works in the real production process at Toyota. The following figure shows the real production process of Toyota Motor, how the system flows from one process to another, and what are the requirements to make that happens.

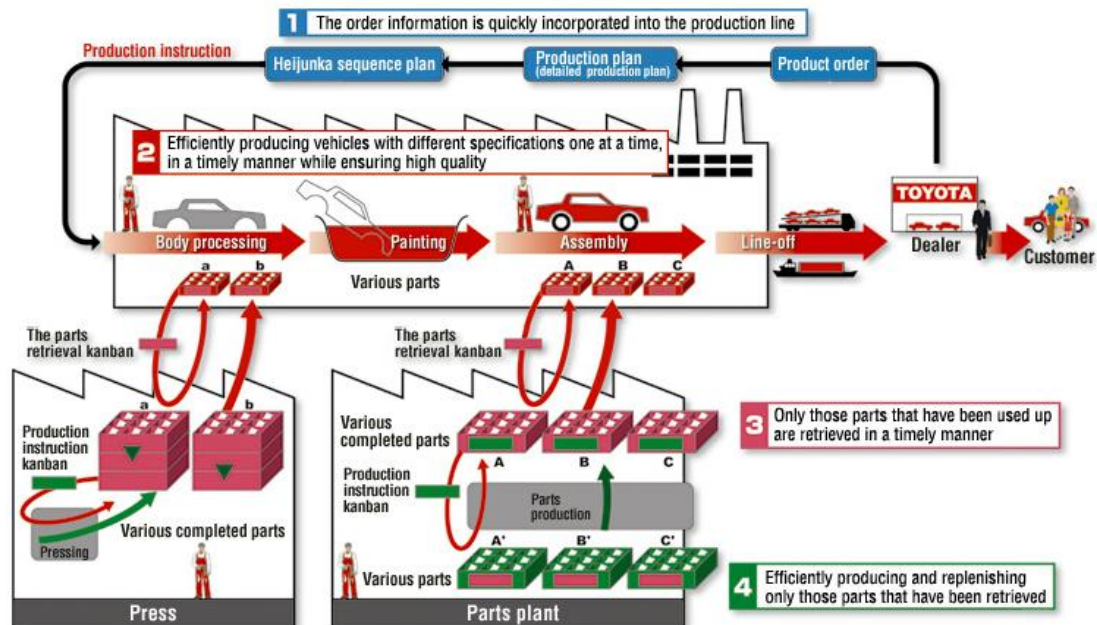


Figure 2.4: Illustration of the Toyota Production System⁶

2.2.4 The Seven Wastes: The Non-Added Value Activities in Lean Production

In order to have a clear concept of the Toyota Production System or Lean Manufacturing the term “Waste” and its nature must be understood.

In lean terminology, Waste is anything other than the minimum amount of equipment, materials, parts and working time which is absolutely essential to add value to the product⁷.

This waste is categorized in 7 types:

- **Over production:** producing items early or in greater quantities than needed by the customer. This situation generates other wastes, such as overstaffing, storage, and transportation costs because of inventory.

⁶ <http://www.toyota-global.com/company/>

⁷ Productivity Press, Taiichi Ohno. 1988. Toyota Production System: Beyond Large-Scale Production. N.Y.

- **Waiting:** It is the idle time created when materials, parts, information, people or equipment is not ready when it is required.
- **Transporting:** moving materials, parts, vehicles to and from storage or between processes.
- **Over processing:** this is about all non-value added process steps or actions taken that are not important to the customer.
- **Inventories:** It is any material, supplies, parts or products in excess of Just-in-time requirements. Inventories hide a lot of problems.
- **Moving:** unnecessary movement of people that do not add value to the product.
- **Making defective parts and products:** any defects, errors, rework or repair.

Waste elimination is one of the bases of lean philosophy. This is because the activities that add value to the product just represent 5% of efforts; the other 95% is waste.

2.2.5 The Five Principles of Lean Production

Lean thinking is based on Toyota Production System and it is a way to specify value, line up value creating actions in the best structure, conduct these activities without interruption whenever someone request them, and perform them in a more effective direction. This affirmation takes us to the five principle of lean thinking: Value, Value Stream, Flow, Pull and perfection.

- **Add Value:**

Value is defined as a “capability provided to customer at the exact time and at an right price, as established in each case by the customer⁸”. Value is the critical starting point for lean thinking, and can only be defined by the ultimate end customer.

- Value-Added: Those activities that unambiguously create value.
- Type One Waste: Activities that create no value but seem to be unavoidable with current technologies or production assets.
- Type Two Waste: Activities that create no value and are immediately avoidable.

⁸ Simon & Schuster, James Womack & Daniel Jones. 1996. Lean Thinking: Banish Waste and Create Wealth in Your Corporation. New York.

- **Value Stream Mapping**

The value stream is defined in Lean Thinking as the set of all the “specific activities required to design, order, and provide a specific product, from concept to launch, order to delivery, and raw materials into the hands of the customer⁹”. To create a value stream, describe what happens to a product at each step in its production, from design to order to raw material to delivery.

- **Production Flow**

Flow is defined as the “progressive achievement of tasks along the value stream so that a product proceeds from design to launch, order to delivery and raw materials into the hands of the customer with no stoppages, scrap or backflows”. This translates as a directive to abandon the traditional batch-and-queue mode of thinking that seems commonsense to most. Ways to foster flow include enabling quick changes of tools in manufacturing, as well as rightsizing machines and locating sequential steps adjacent to one another.

- **Pull System**

The fourth lean principle of pull is defined as a “system of cascading production and delivery instructions from downstream to upstream in which nothing is produced by the upstream supplier until the downstream customer signals a need¹⁰”. This is in contrast with pushing products through a system, which is unresponsive to the customer and results in unnecessary inventory buildup.

- **Perfection**

The fifth and final lean principle is perfection, defined as the “complete elimination of waste so that all activities along a value stream create value”. This principle makes the pursuit of lean a never-ending process, as there will always be activities that are considered waste in the value stream and the complete elimination of waste is more of a desired end-state than a truly achievable goal.

¹⁰ Simon & Schuster, James Womack & Daniel Jones. 1996. Lean Thinking: Banish Waste and Create Wealth in Your Corporation. New York.

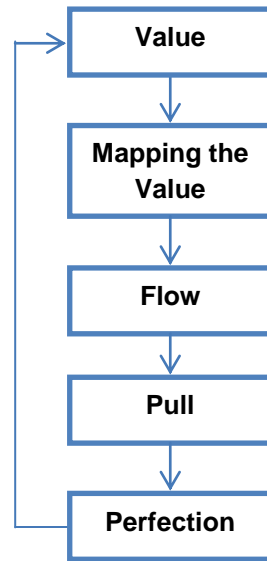


Figure 2.5: Principle of Lean Thinking¹¹

2.3 Levels to apply Lean Manufacturing

2.3.1 Overview

After looking at the five principles of Lean, this part will explain the key elements of this production philosophy. These tools can be grouped within three application levels: understanding Customer Demand, establishing a Continuous Flow and Leveling the Production.

Customer Demand: understanding customer needs for service, products, required quality, delivery time desired (Lead Time) and price.

Continuous flow: this is to make the internal and external customer receive the indicated products and materials, in the time that they need it and in the correct amount.

Leveling: this part is about distributing the work uniformly among the production system, by volume and variety, reducing the work in process and final inventory.

In the figure 2.6 is shown all the elements grouped in the three levels presented before. However just some of them will be briefly described.

¹¹ Simon & Schuster, James Womack & Daniel Jones. 1996. Lean Thinking: Banish Waste and Create Wealth in Your Corporation. New York.

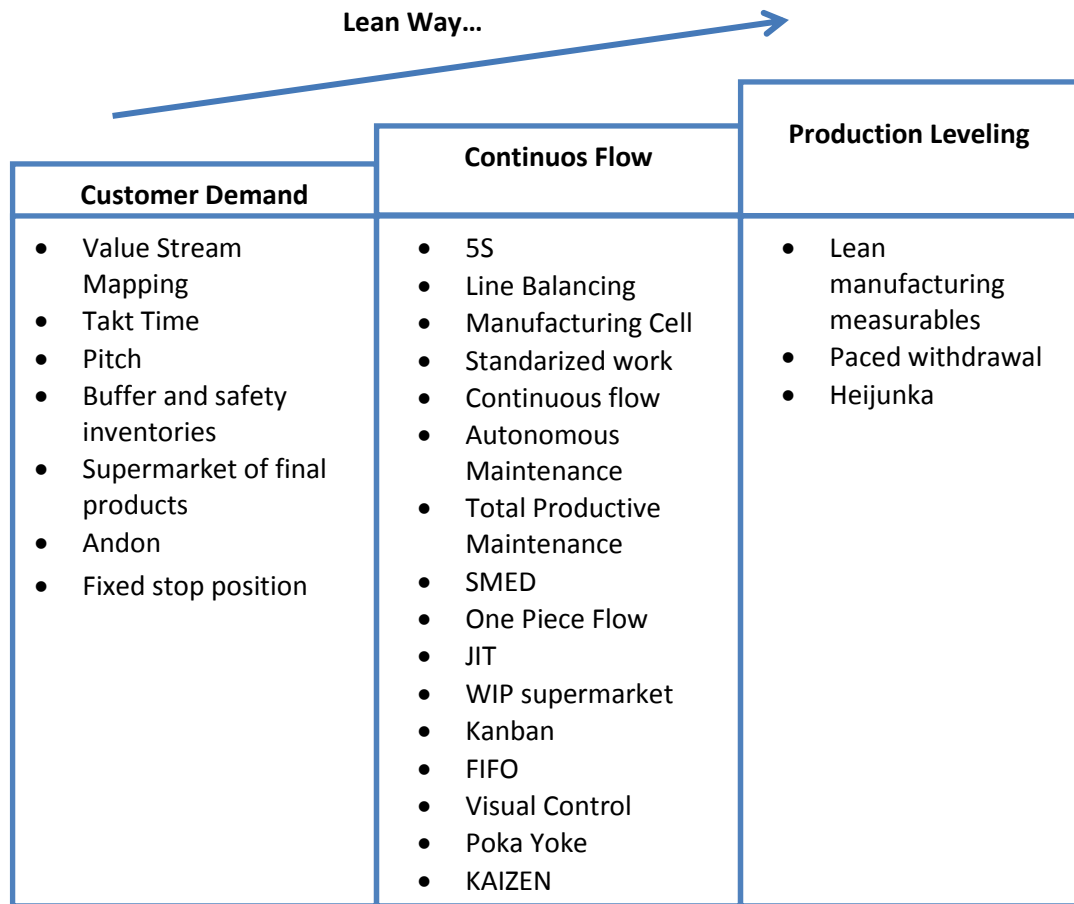


Figure 2.6: Levels for the implementation of Lean and its tools¹²

2.3.2 Understanding Customer Demand

The customer is the one that will provide the guidelines for the production rate and the desired delivery of products and services. The customer also establishes what adds value and what does not add value to the process. In order to survive as a business, it is essential to understand the customer needs, quality features, lead time and price.

For achieving the stability of customer demand and develop a system that allows the company to do it, the following tools are briefly described in the subsequent lines as an overview.

¹² Editorial Limusa, Alberto Villaseñor and Edber Galindo. 2007. Manual de Lean Manufacturing: Guia Basica. Mexico.

2.3.2.1 Calculating the Takt Time: rhythm of production and customer demand

The takt time is a range of time or the rhythm that the manufacturing plant must meet to satisfy customer demand. It is calculated by dividing production time available (or the available working time per shift) over the total required amount (customer demand).

$$\text{Takt Time} = \frac{\text{Production Time Available}}{\text{Required Amount (Customer Demand)}}$$

Producing with the takt time means that the production and sales rate are synchronized, one of the goals of Lean Manufacturing.

2.3.2.2 Value Stream Mapping: Mapping the value

Mapping the value is one of the principles of Lean and it is the basis for beginning this journey. This tool is a standardized instrument for assessment integrated flows of material and information. It looks at all aspects of the value-adding chain from customer to supplier; the value stream focuses on the details and interaction within the process chain. Value Stream Mapping aims to:

- Visualize the material and information flow
- Reveal causes of waste
- Create improved flow
- Develop a consistent and structured method in a multi-functional team.

The process of value stream mapping is as follows:

- a. Select the product family to be mapped and analyzed.
 - Collect part numbers information, customer demand, frequency, type, and fluctuation of demand within family.
 - Group the products that are manufactured in the same or similar production process and equipment.
 - Identify and select Product Family
 - When a complex product mix appears use matrix or diagrams to visualize it.
- b. Draw the current state of the flow of material and information
 - Revise all the information available regarding the production process.

- Communicate to all areas their purpose and activities
- Tour the plant to identify and map the main processes. Collect the current attributes of the process such as cycle time, changeovers, work in process, line capacity, machinery, number of operators among other relevant production data.
- Utilize icons to do the mapping (see Appendix 1)
- Fill out data boxes, count inventory and map inventory locations. Cycle time, process time, change over time and utilization rate.
- Draw material flow and process interaction.
- Draw supplier information
- Draw information flow
- Calculate lead time and process time

c. Map the future State

Repeat the process of drawing the icons that represent the customer, suppliers and production control, but instead base it on the improvements made to the current state of the mapping. This has to be focused on the customer demand, establishment of an efficient production flow, and a leveled production. (See Appendix 2)

d. Implement

Apply all the changes made in the Future State in order to improve the current state of the production process.

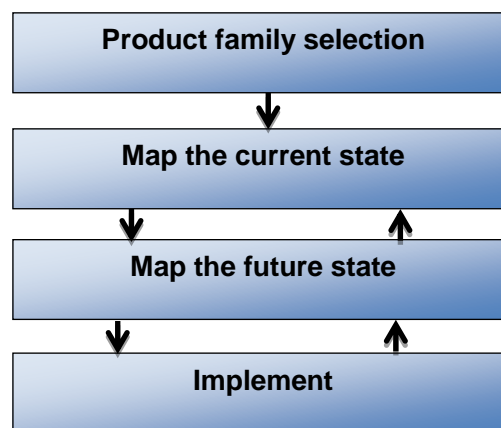


Figure 2.7: VSM process

2.3.3 Establishing the flow

The word Flow means that work must be done toward receiving the correct parts, in the indicated time and doing the activities that are required. In a more structured scheme, flow can be defined as the progressive improvement of the activities through the entire value chain, from the design procedures to the product launch, from order to delivery, and from raw material to the customer's hands without any stoppages and waste¹³.

The tools presented in this topic are considered the relevant ones to achieve the definition in previous paragraph.

2.3.3.1 Continuous flow: Make one, Move one.

The continuous flow is based on the statement: "make one, move one" or "make one small batch, move one small batch". A piece of small batch will be produced by the operations just when is moved or pulled.

The continuous flow allows the system to produce or transport products according three key factors:

- Only what is needed,
- When it is required,
- And in the exact amount.

Some of the advantages of using continuous flow are: short lead times, reduction of work in process (inventory), identifying and immediately solving problems that may occur.

The continuous flow is possible due to a manufacturing cell. This is a system where the equipment and workstations are placed in an efficient sequence that allows continuous and smooth movement of inventories and materials. The objective is to produce products from start to finish in a single process flow, while incurring minimal transport or waiting time, or any delay that matter, or other waste in general.

¹³ Simon & Schuster, James Womack & Daniel Jones. 1996. Lean Thinking: Banish Waste and Create Wealth in Your Corporation. New York.

2.3.3.2 Standardized Work: Documenting what has to be done

The standard work will effectively combine materials, workers, and machines to produce a product¹⁴. By documenting the current best practice, standardized work forms the baseline for continuous improvement.

The three elements of the standard work procedure are:

- *Cycle Time*, which is the time allotted to make one piece or unit.
- *Work sequence* refers to the sequence of operation, or the order of operations in which a worker processes items: for example transporting, mounting, and removing them from machines.
- *Standard inventory* is about the minimum intra-process work-in-process needed for operations to proceed.

Normally the standard work procedures are contained in a sheet placed in each work station. Using this visual control the worker can understand the process and always keep in mind what they have to do, what they need in the process and in what amount.

2.3.3.3 SMED: Reducing changeover time

SMED is the acronym of “Single Minute Exchange Die”. This concept was developed by Shingeo Shingo in Toyota Motor Company, and implies the actions when the operator stop producing one product and have to change the tooling of the machine in order to start producing another product in the same line. The purpose of the SMED is to reduce and/or eliminate downtime due to setups and changeovers in the production and simultaneously create a simple, safe and reliable preparation.

The concept promotes the idea of single minute, one digit of minutes; it means less than ten minutes. The exchange time is unproductive, shorter interval is better.

The reduction of the exchange rate has two objectives:

- Increase the Overall Equipment Effectiveness (OEE)
- To reduce the work in progress

¹⁴ Productivity Press, Taiichi Ohno. 1988. Toyota Production System: Beyond Large-Scale Production. N.Y.

These objectives represent the elimination of waste, which is one of the main goals of Lean methodology. In modern manufacturing the flexibility of the operations, increases productivity, decreases lead time and generates an environment to achieve zero stored products with SMED applications.

There are two types of operations in SMED¹⁵: *Internal Operations*, related to how to mount or dismount the dies, and this can be done when the machine is stopped. And the *external operations*, how dies are transported to or from the warehouse, this can be done while the machine is operating.

2.3.3.4 Total Productive Maintenance: Keeping equipment in perfect conditions

When lean production is mentioned what should come to our minds are the words flow, rhythm, stability, consistency and reliability. If it is desired to achieve this in a manufacturing environment, the first thing is to ensure that the equipment that the production process relies on is available when it is needed. It is unacceptable any surprise, stoppages such as a machine breakdown or broken tools. This is what it means to achieve with Total Productive Maintenance (TPM).

TPM is a logical, structured method of monitoring, inspecting, cleaning and evaluating the present and future equipment by using the resources that are available as effectively as possible.

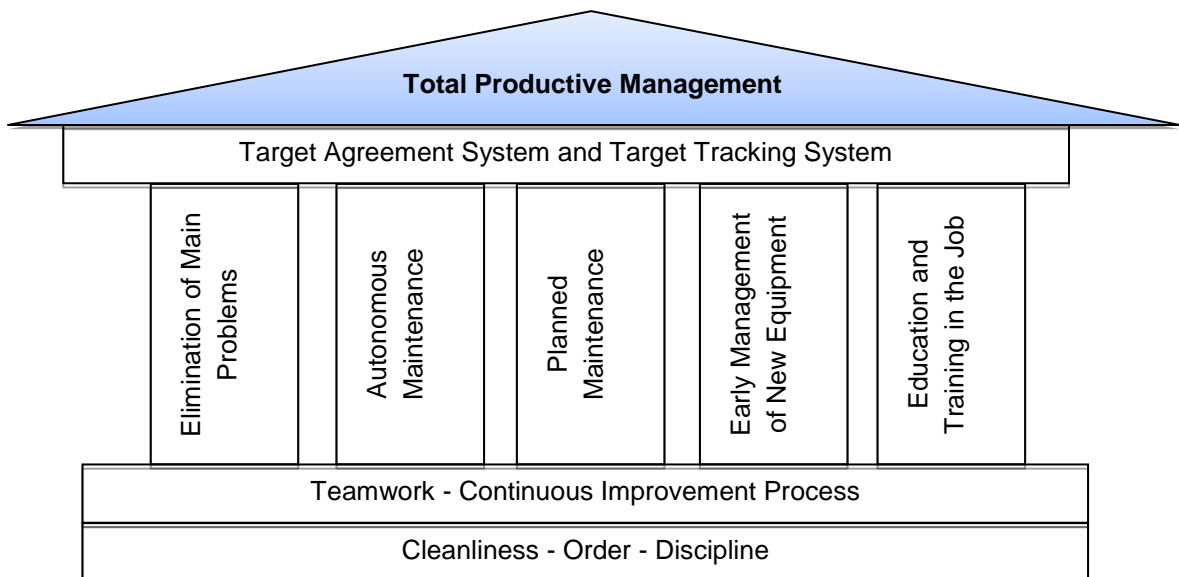


Figure 2.8: House of the Total Productive Management ¹⁶

¹⁵ ¹⁶ Productivity Press, Shigeo Shingo. 1989. A Study of the Toyota Production System from an Industrial Engineering Viewpoint. Portland, Oregon.

2.3.3.5 Jidoka: Automation with human touch

The term "jido" is applied to equipment with a built-in device for making judgments. Jidoka refers to "automation with a human touch," as opposed to a machine that simply moves under the monitoring and supervision of an operator. This lean concept can be appreciated in the following figure:

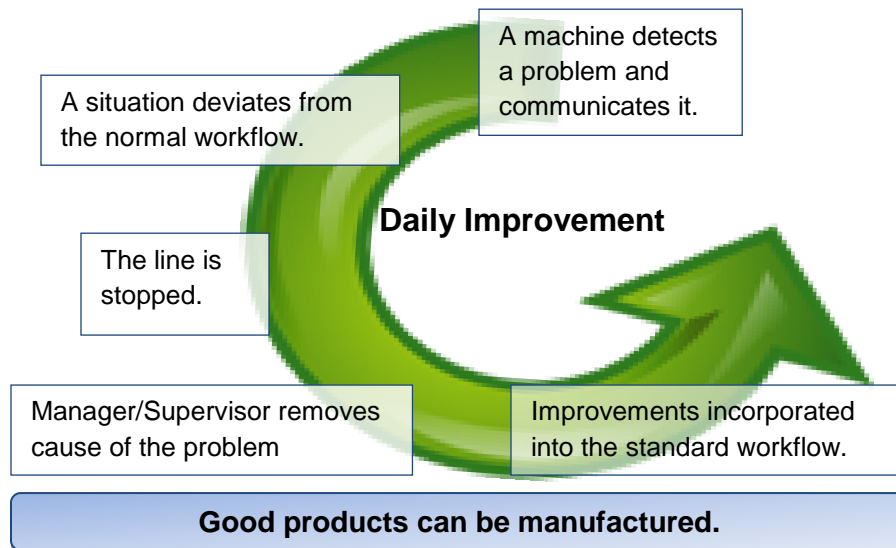


Figure 2.9: Concept of Jidoka¹⁷

2.3.3.6 Just in Time (JIT): What, when and how much is required

Just-in-Time means making only what is needed, when it is needed, and in the amount that is needed. This can eliminate waste, irregularities, and unreasonable requirements, resulting in improved productivity.

Just in time is a group of principle, tools and techniques that allows companies to produce and deliver products in small quantities and with short lead times, in order to satisfy the customer needs.

JIT have three basic elements to change the production system of company: *Continuous flow*, where is used the concept of manufacturing cell to allow materials to flow in the process and improve the communication among operators. *Takt time*, this marks the production rate within the process. And the *Pull System*, which allows the flowing of materials/products without any stock, or within a minimum range of work in progress.

¹⁷ http://www.toyota-global.com/company/vision_philosophy/toyota_production_system/images/p_3_4.gif

2.3.3.7 Kanban: the system that pulls the production

It is one of the most important tools in Lean Manufacturing. It is the heart of the pull system. Taichi Ohno established in his book¹⁸, that the Kanban is the operating method of the Toyota Production System.

A Kanban control system uses signaling device to regulate Just in Time flows. Kanban means “sign” or “instruction” in Japanese. When a production system has an inventory, it uses a card which acts as a signal to indicate what amount is required. In this way the system just counts on what is needed in exact amounts.

The kanban are cards attached to containers of small batches, which carries pick up transfer and production information. The Kanban carries the information vertically and laterally within the lean production system itself and between the company and the cooperating firms. The card could be printed, written or in an electronic form that contains barcode, RFID, among other electronic technology.

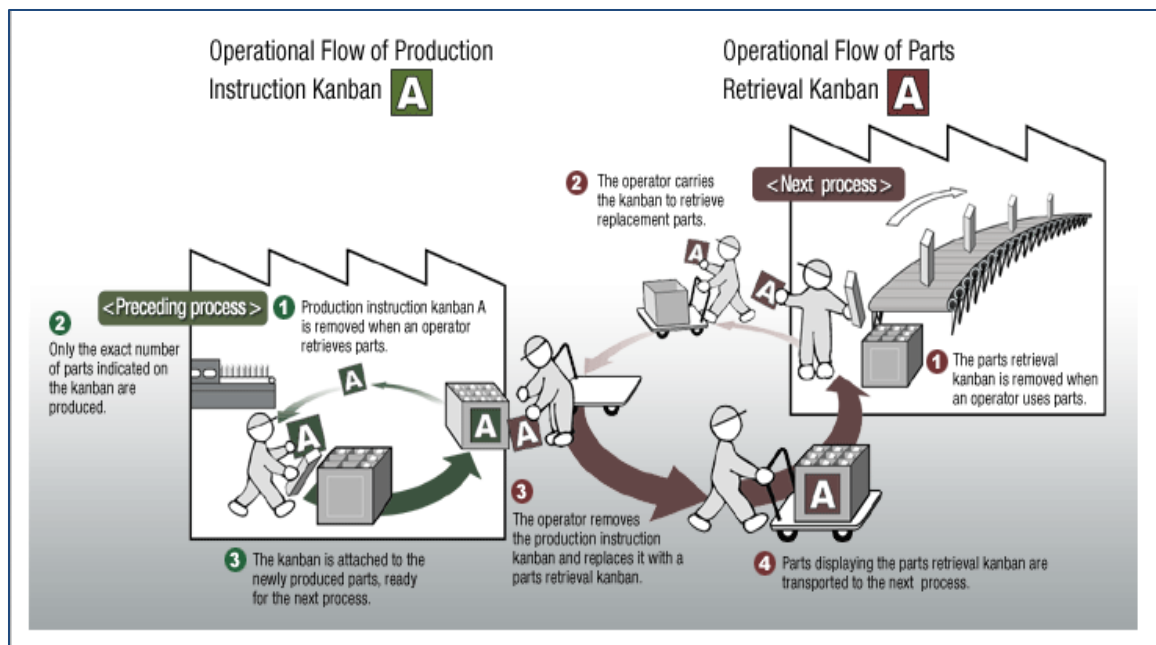


Figure 2.10: Conceptual diagram of the Kanban System¹⁹

The figure 2.11 is an example of the information that a kanban card contains. Information regarding the quantity required, lead time, where is going to be used, place of storage among other shown in the following figure. In modern times the kanban card has evolved and it is more common to use cards containing barcode or other electronic methods.

¹⁸ Productivity Press, Taichi Ohno. 1988. Toyota Production System: Beyond Large-Scale Production. N.Y.

¹⁹ <http://www.toyota-global.com/company/>


Stockroom INFO Card			
Part: XX-XXXXXXXX			
Description:		Supplier:	
Location:	Shelf Position:	Lead Time:	Parts ordering Kanban
Minimum Inventory	Reorder Point	Used in:	

Figure 2.11: Example of a Kanban Card

2.3.3.8 5S: a strategy to improve work environment conditions

The 5S is lean methodology created with the objective of maintaining the workplace ordered, cleaned and safe. With these features in an environment processes can be accomplished with high level of performance and minimal waste.

English Term	Japanese Term	Purpose
Sort	Seiri (整理)	Throw away all unnecessary and unrelated things in the workplace. The idea is that everything surrounding the workplace is related to work.
Set in Order	Seiton (整頓)	Having all the necessary things in the workplace, this S is about putting everything in an assigned place in order to have easy and quick access to it. When all workers have quick access to the tools or any material, the workflow becomes efficient and workers become more productive.
Shine	Seiso (清掃)	The workplace must be cleaned for maintaining a high performance in the work environment.
Standardized	Seiketsu (清潔)	Eliminate the causes that affect the equilibrium of the cleanliness and order. Create a standard of the three first S's.
Sustain	Shitsuke (躰)	It is about maintaining the standards, to guarantee that the system can have prevalence in the time and not going back to bad practices of the past.

Table 2.2: 5S strategy

2.3.3.9 Visual Control: Signaling the work environment

It is a tool that transmits information through controls and visual devices. The permanent visualization of work flow, minimum and maximum graphs, pictures of things place in order, all the signals in the plant, delimitation of the shop floor, and other visual tools are part of the visual control.

The objective is to create a visual language that everybody can understand; conditioning the behavior of every person in the plant and making them act in a more efficient way.

2.3.3.10 Kaizen: The Continuous Improvement Process

Kaizen is a Japanese term that stands for “Continuous improvement” and it is the process to do improvements incrementally, small improvement ideas or breakthrough improvements, and achieve the goals of Lean Manufacturing of eliminating all waste that generates no added value. Kaizen involved everybody in the plant, from low ranking workers to high ranking managers.

This system pursues the improvement of the process with the available resources; it means that the creativity prevailed over the investment. The achievement of the objectives is possible through the use of the Deming Cycle, Plan-Do-Check-Act.

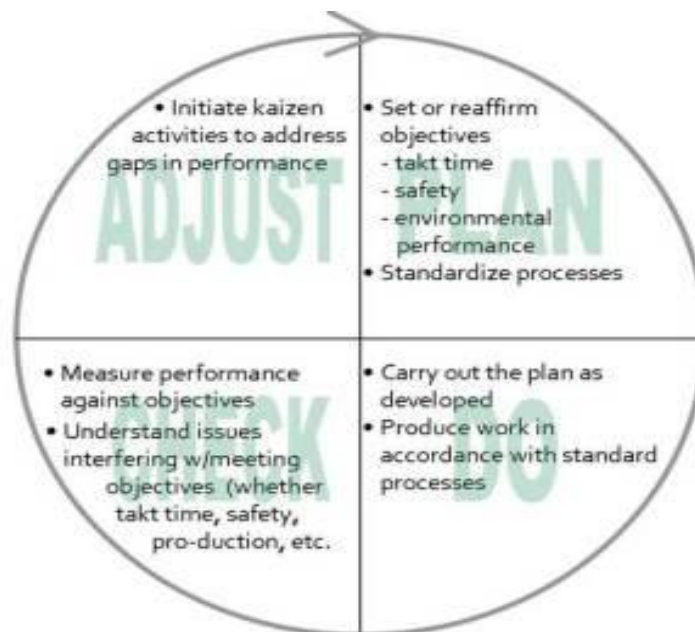


Figure 2.12: Deming Cycle²⁰

²⁰<http://www.leadingtransformation.wordpress.com>

2.3.4 Leveling the Production: Heijunka

After determining the customer demand and establishing the continuous flow within the production process. Now it is time to highlight the production leveling or *Heijunka* in Japanese language.

The objective of production leveling is to distribute the work load per shift, day or week in order to satisfy customer demand. Said in other words, the purpose of production leveling is to separate the supplier from the customer in such a way as to ensure regularity of types, intervals and quantities of production.

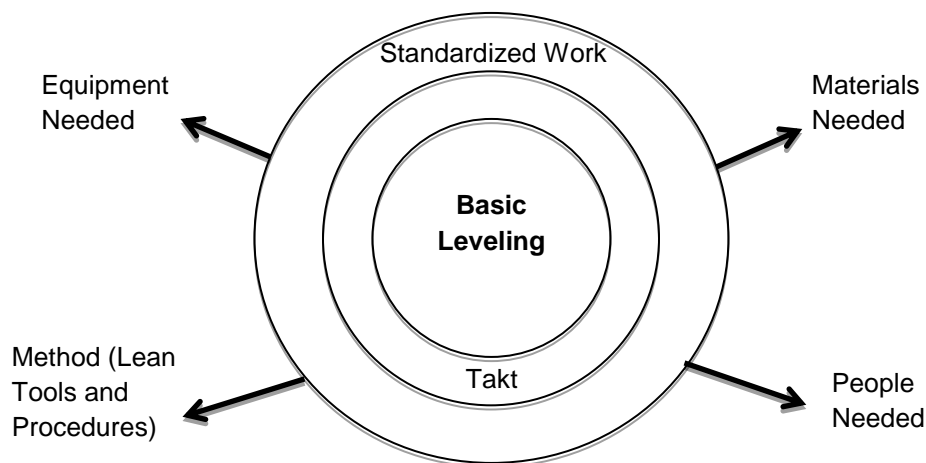


Figure 2.13: Basic leveling in the core for all resource planning²¹

There are some important steps that need to be followed when implementing production leveling:

- Analysis of the current customer ordering behavior.
- Analysis of the part spectrum.
- Definition of the shift model.
- Selection of the pacemaker process.
- Capacity calculation.
- Development of the EPEI (Every Part Every Interval). EPEI represents the frequency that different parts are produced within a fixed repeating schedule.
- Calculation of the production lot sizes.
- Development of the leveled plan.

²¹ McGraw-Hill, Jeffrey K. Liker. David Meier. 2006. The Toyota Way Fieldbook: A practical Guide for Implementing Toyota's 4P. New York.

- Calculation of the Kanbans and layout of the respective supermarkets.
- Layout of leveled plan represented on the Heijunka board.

2.3.4.1 Heijunka Box: The box to level the production

In the previous topic it was explained that the Japanese term Heijunka stands for leveling, which means that Heijunka Box is a “Leveling Box”. It is a tool used to level the mix and volume of production by distributing kanban within a facility at fixed intervals.

The Heijunka box consistently levels demand by short time increments (instead of releasing a shift, day, or week’s worth of demand to the floor) and levels demand by mix.

The following illustration shows a common Heijunka Box, each horizontal row is for one type of product (one part number) and each vertical column represents identical time intervals for paced withdrawal of kanban. The slots represent the material and information flow timing, the Kanban in the slots each represent one pitch of production for one product type.

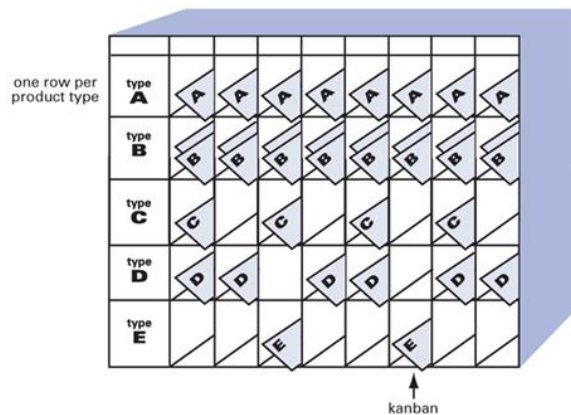


Figure 2.14: Heijunka Box²²

2.3.4.2 Paced Withdrawal

The paced Withdrawal is a system that moves small quantities of products from one operation or process to another. This tool levels the production dividing the total requirements by shifts or days into same lots. In the figure below, the material handler circulates through the entire path with an established frequency. It starts by taking

²² <http://www.lean.org>

production kanban from a heijunka box, and then delivers the instructions to a production process where there is a signal to manufacture new products.

The handler picks up finished goods from the production process and takes these to the supermarket. There the handler picks up production kanban from the collection box, inserts them to the heijunka box for insertion in the box, and withdraws the next increment of instruction from the appropriate column in the box as the cycle starts again.

The following figure explain the concept of paced withdrawal and at same time shows how this tool serves to prevent overproduction and quickly alerts managers, if there is a production problem.

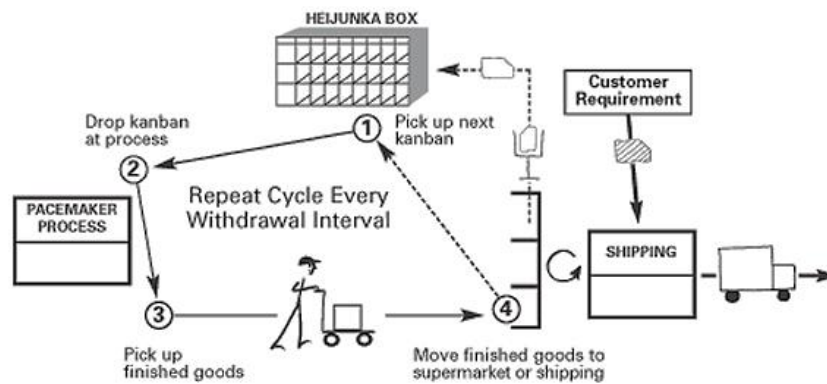


Figure 2.15: Paced Withdrawal concept²³

²³ <http://www.lean.org>

3. KNOWLEDGE MANAGEMENT CONCEPT

3.1 Defining Knowledge and Knowledge Management

While implementing Lean a lot of knowledge sprouts and it is needed to successfully complete the required activities. This knowledge can be tracked in external and internal sources and in individuals or teams. The knowledge is factor that has a very relevant sense in Lean strategy and it is indispensable to manage it.

Before talking about knowledge management it is important to define the key word in this field, “Knowledge”.

Knowledge comprises all cognitive expectancies —observations that have been meaningfully organized, accumulated and embedded in a context through experience, communication, or interface— that an individual or organizational actor uses to interpret situations and to generate activities, behavior and solutions no matter whether these expectancies are rational or used intentionally²⁴.

Knowledge management (KM) is the process of capturing, distributing, and effectively using knowledge. In more detailed words, KM is a discipline that promotes an integrated approach to identify, capture, evaluate, retrieve, and share all of an enterprise's information assets. These resources may include databases, documents, policies, procedures, and previously un-captured expertise and experience in individual workers.

3.2 Differences between Data, Information and Knowledge

A useful way of arriving at a definition of what knowledge is can be achieved by differentiating it from what it is not. One of the most common distinctions in contemporary knowledge literature is between knowledge, information and data.

Data can be defined as a raw number, images, words or sounds which are derived from observation or measurement. For example data could be raw numbers coming out from the production process.

Information, in comparison, represents data arranged in a meaningful pattern, data where some intellectual input has been added. For example, where the raw data from the production process has been analyzed using graphs and techniques, to produce some structured results.

²⁴ Springer, Ronald Maier. 2004. Knowledge Management Systems. 2nd Edition. Berlin.

Finally, *Knowledge* can be understood to emerge from the application, analysis, and productive use of a data and/or information. In other words, knowledge can be seen as data or information with a further layer of intellectual analysis added, where it is interpreted, meaning is attached, and is structured and linked with existing systems of beliefs and bodies of knowledge. Knowledge therefore, provides the means to analyze and understand data/information, provides beliefs about the causality of events/actions, and provides the basis to guide meaningful action/thought.

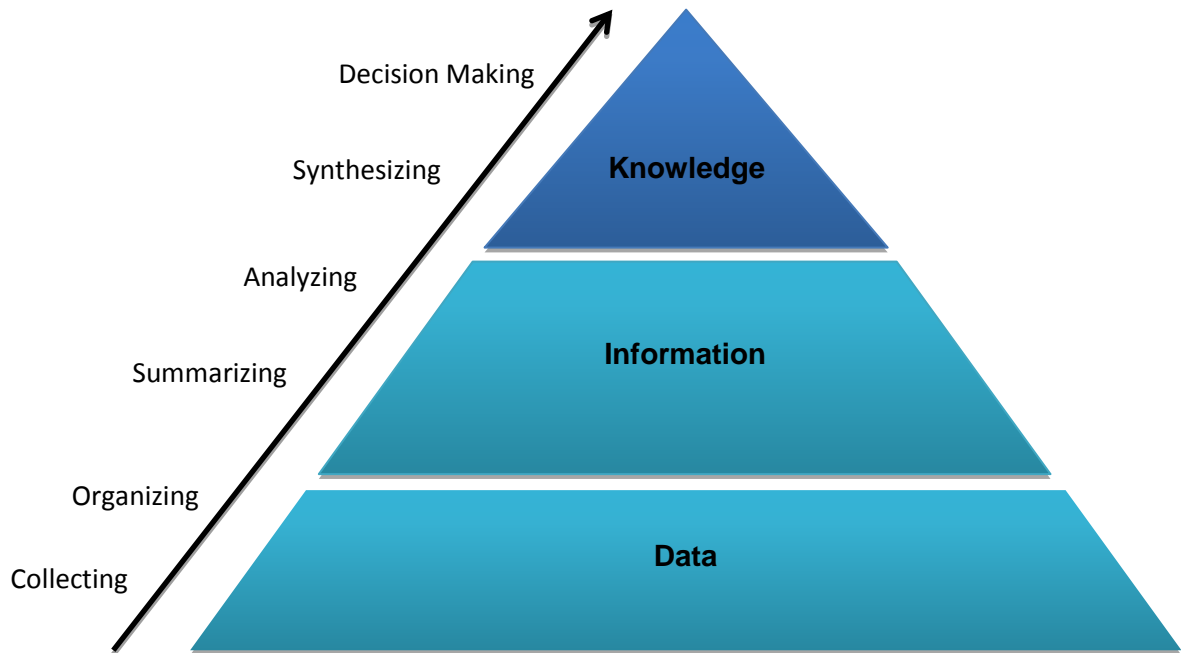


Figure 3.1: Difference between Data, Information and Knowledge²⁵

In the previous figure “data, information and knowledge” can be interrelated in a hierarchical structure represented with this pyramid, where the relationship is primarily unidirectional, with data supporting the generation of information, which is in turn used to generate knowledge. It is very important to highlight that the interrelationship between these elements is more complicated than this. While data and information can provide the building blocks of knowledge, equally knowledge can be used to generate data and information; therefore the relationship between them is dynamic and interactive, rather than simply unidirectional²⁶.

²⁵ <http://www.infostory.com/2012/03/28/data-information-knowledge-web/>

²⁶ Oxford University Press, Donald Hislop. 2005. Knowledge Management in Organization: A critical Introduction. New York.

3.3 Types of Knowledge: Tacit and Explicit Knowledge

One of the most common differentiations of knowledge is between “tacit and explicit knowledge”.

The Tacit Knowledge is based on experiences, best practices, wisdom and intelligence that live within individuals and teams. It represents knowledge that people possess, but which is inexpressible. It incorporates both physical/cognitive skills, and cognitive frameworks. The main characteristics of tacit knowledge are that it is personal, and is extremely difficult to operationally set out in tangible form, if not impossible to disembody and codify²⁷.

The Explicit Knowledge is regarded as objective, standing above and separate from both individual and social value systems and secondly that it can be codified into a tangible form. To understand more these two interesting characterization of knowledge is presented the following table, comparing both types of knowledge.

Tacit Knowledge	Explicit Knowledge
Inexpressible in a codifiable form	Codifiable
Subjective	Objective
Personal	Impersonal
Context Specific	Context independent
Difficult to share	Easy to share

Table 3.1: Characteristics of Tacit and Explicit Knowledge²⁸.

Establishing a difference between tacit and explicit knowledge is an essential step in the Knowledge Management process. The conversion of first one into the second one is a critical objective to be pursued.

²⁷ ²⁶ Oxford University Press, Donald Hislop. 2005. Knowledge Management in Organization: A critical Introduction. New York.

3.4 Knowledge Management Process: Identifying, Generating, Storage, Sharing and Applying Knowledge.

To transform knowledge into a valuable organizational asset, knowledge, experience, and expertise must be identified, created, distributed, shared, and applied. These actions represent the core activities of the knowledge management process.

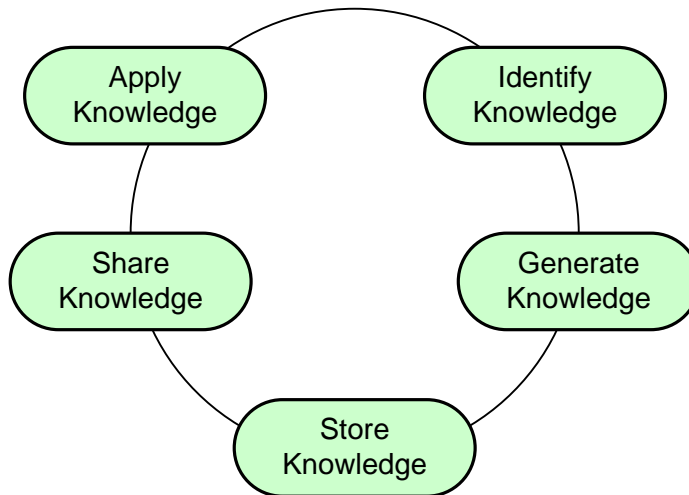


Figure 3.2: Core Process of Knowledge Management²⁹

Identifying Knowledge

To identify the knowledge is the main basis for every knowledge management process. The objective is to find out what organizational knowledge is available, who has the critical knowledge, and where this knowledge is stored. The source of knowledge can be found internally and externally with suppliers, customers, or in research institutions.

The organization must be clear of what is pursued and the knowledge that is required for that purpose. The information coming from this analysis is crucial for decision making, and can be obtained through brainstorming, knowledge mapping, customer feedback, and experience from previous projects, data bases, web and other that tools that will be explained in the following topics.

²⁹ Springer, Kai Mertins, Peter Heisig and Jens Vorbeck. 2001. Knowledge Management: Best Practices in Europe. Berlin.

Creating knowledge

The organizational knowledge primarily depends on people. It is usually stored in routines, documents, corporate culture, and thus in the behavior of the organization. But, the creation of new knowledge cannot take place without the participation of the individual members of the organization. This is because organizational knowledge originates from organizational process of learning. The process of creating knowledge requires the identification of both of available knowledge and of knowledge that is necessary for the success of the company³⁰.

The creation of new knowledge can occur at different levels: in reproduction through achievement, by solving problems and completing task. Existing knowledge and experience is used in these processes that always include learning procedures.

Storing knowledge

To make people able to access important information when it is needed, the information has to be stored on different data carriers within the organization. This ability to store knowledge effectively in electronic or paper way allows:

- A quick search for information
- Access to information for other employees
- The directing of colleagues to specific information
- The effective sharing of knowledge as it is easily stored for everyone's use.

The knowledge accessibility to others must be done with unified use of indices so that everyone can reproduce storage procedures. With the help of directional signals, everyone who is looking for information can find what they want or be directed to a specific document. Also the information needs to be kept up to date.

Sharing knowledge

The objective of this phase is to transfer the knowledge wherever it is necessary, at the right time and with the required quality. The knowledge must be available to other people and in this way they can add value to the different processes they are involved in.

In this step team work represent a very important figure, because supports the knowledge sharing through following common goals.

³⁰ Springer, Kai Mertins, Peter Heisig and Jens Vorbeck. 2001. Knowledge Management: Best Practices in Europe. Berlin.

To share knowledge the internet, e-learning experiences, web-conferences, workshops, teleconference, email, blogs, WebPages, group experience and data bases are used.

Applying knowledge

The goal of Knowledge management is to apply the relevant knowledge that has been identified, created, store and shared. The application of new knowledge also allows new learning experiences and perception. It is possible to create more knowledge as a result of the implementation of knowledge, which then closes the circle of the cycle of knowledge management process.

3.5 Tools and Methods of Knowledge Management

There is a variety of tools and techniques that help the core process of knowledge management. These instruments can be applied or are found in different ways, such as paper form, information technology, direct contact, web conferences and teleconferences or in some virtual spaces. Here you will find what is considered relevant to complement the implementation of Lean Manufacturing.

- **Brain Storming** is a group technique to generate new and creative ideas. It is useful when there is a need to generate a relatively large number of options or ideas. The dynamic is that a moderator takes every idea from the group in a short version, gathers it and builds ideas on the same basis through a consensus of the team.
- **Knowledge repositories** are computerized systems that systematically capture, organize and categorize an organization's knowledge. The repository can be searched and data can be quickly retrieved. Very good examples of this are the data bases and bookmarking engines.
- **Learning Review** is a method used by a project team to aid groups and individual learning during the work process. The objective is to make that the team members learn continuously while carrying out a project.
- **After action reviews** is a tool to evaluate and captured lessons learned. The main objective is to evaluate what, why and how things occurred during in a specific project according to what was planned. It is important to improve things that went wrong.

- **Community of practice** is a network of individuals with common problems or interest who get together to exploring ways of working, identifying common solutions and sharing good practices and ideas.
- **Peer Assist** is a technique used by a project team to ask for assistance from peers and subject matter experts regarding a significant issue the team is facing. Peer assist is learning before doing, for example gathering knowledge before embarking on a project or piece of work. The purpose of this tool is to shorten the learning curve of the project team³¹.
- **Knowledge Cafe** is about gathering a group of people to have an open exchange of ideas of a topic of mutual interest in order to surface their collective knowledge, sharing perspectives to deeply understand the issues involved and decision making. This group discussion can be in a normal business meeting or technical workshop.
- **Taxonomy** is a method that provides the structure to set in order information, documents and documentation in general in a consistent way. This technique can be considered as a classification system and assist people to navigate, store and retrieve data and information. Making easy the construction of a good knowledge structure.
- **Document Libraries** Maintaining a document repository with good categorization and/or taxonomy is paramount to filing and, subsequently, searching and finding the right information at the right time. This is the objective of documenting libraries.
- **Knowledge Base** is a special database for the collection, organization, sharing and usage of knowledge that pertains to a specific topic or subject of interest. As example of this tool it can be mentioned the answers to frequently asked questions, detailed procedures and tutorials. Knowledge bases may also offer user manuals or articles on a specific subject.
- **Social Network Services** is a group of people that share common points of interest. This a online system that support social networking in times that people pay much attention to social networks and its interactions. To find people with similar interest, grouping that people and facilitating the communication among

³¹ Asian Productivity Organization, Dr. Ronald Young. 2010. Knowledge Management Tools and Techniques Manual. Tokyo

between them through sharing contents, are part of the objectives of this interesting tool.

- **Expertise Locator** is a tool to know who owns the information and who need the information. It enables effective and efficient use and/or share of existing knowledge by connecting the stakeholders of the knowledge.
- **Knowledge Mapping** is a graph that represents the flow of knowledge and its roots. It maps where the knowledge is located, including people, media, organizational units or sources of knowledge outside the organization; and also the access, distribution, and learning. Knowledge mapping creates an inventory of knowledge and is the base to develop new knowledge systems or to improve to current one³².
- **KM Maturity Model** helps an organization assess its relative progress in KM implementation at a more detailed level through its different phases: initial, repeat, define, manage and optimize. It can be described as a structured collection of elements that describes the different stages of Knowledge Management maturity that an organization can expect to pass.
- **Mentor/Mentee** is a tool that contributes to the knowledge sharing. It creates the relationship between an experienced senior and junior organizational member with an intended program designed to transfer experience and learning.

³² Asian Productivity Organization, Dr. Ronald Young. 2010. Knowledge Management Tools and Techniques Manual. Tokyo

4. CHANGE MANAGEMENT PHILOSOPHY

4.1 Understanding Change and Change Management

Lean Production is constant transformation itself, many changes in the environment take place and must be managed it to avoid unpleasant surprises that affect the development and progress of the organization that is reducing waste in this production scheme.

To start describing this interesting model it must be defined what change is and how affects the production system and organization in general. The term Change can be considered as any modification that could impact the stability or responsiveness of a process or the whole organization culture. The change can be provoked by internal or external forces that surround the organization environment.

Following with previous definition and linking it to different literatures, Change Management can be defined as the capacity or the ability that organizations have to adopt and define corporate strategies, procedures, structures and technologies to deal with organizational change. This model can also be defined as the process of transitioning individuals, teams, and organizations from a current state to a desired future state with application of knowledge, tools and resources, taking into consideration the negatives effects of the change and counter measures to face it.

Many changes occur in an organization, they affect people, processes and organization culture. That is why Change Management has a relevant importance, helping to reduce the negative effects of these transformations and increasing the positive outcomes through the implementation of its tools and strategies.

4.2 Types of Changes: Radical and Incremental Change

In Change Management strategy it can be identified two main types of change, one that radically transform the process and the other that do it incrementally.

Radical Change or Business Process Re-engineering is a strategy focused on the study and design of workflows and processes within an organization, helping them to analyze and understand the way they are working in order to dramatically restructure their environments. Re-engineering is also known as redesign, business transformation, or business process change management. Many organizations that begin to implement Lean decide to start everything from zero, in other words they radically change or re-engineering

their production process. This change is characterized by having a dramatic or radical transformation in one fell jump; it is fast and probably would require some pressure.

Incremental Change is about adding change inputs little by little to the transformation process. It means many small incremental variations instead of a few big change configurations. Normally takes place when the organization is evolving and developing their activities in a slow, extensively planned and inclusive way.

4.3 Resistance to Change: A Change Management Challenge to deal with.

In the application of Lean or let's say in every environment where a change is taking place, most of the time there are forces that opposes to those organizational transformations. The organizations and people present resistance to change and this can be an obstacle to adapt or progress to the new situation. In the other hand can be a challenge that generates a discussion and as result brings benefits to the idea of change and decision making.

The resistance to change is not coming out in identical forms; it can be open, implicit, instant or differed when appears. For management it is better that resistance be as open and instant as possible, thus they can manage it efficiently. An implicit and differed resistance to change can affect the change process with negative points, such as demotivation. The last two are one of the challenges of Change Management.

Resistance to change occurs in different levels and to individuals, groups or the whole organization. This phenomenon can provoke a state of friction and rigidity and also confusion, immediate critic, denial, sabotage, hypocrisy, distraction and other negative effects. To avoid these bad results explained before, there are some measures or points recommended to deal with confrontation:

- Make people participate in change process, involve them and establish communication.
- It is necessary to understand the why and who present the resistance, get to know the nature of resistance.
- Identify the blind spots that generate the resistance to change. Blind points can be due to implicit process, tacit knowledge or just because of the efforts are concentrated on creating the new idea or project.

- Management has the responsibility to motivate and adapt the mind set of people in order to face the new challenge of the organization.

4.4 Getting to know the Tools and Strategies of Change Management

There are many tools and strategies around the concept of change management, additional to that some organizations have developed or adapted their own theories, philosophies or strategic tools. Here it is grouped some of what we consider most popular and that can be easily adapted while implementing Lean Manufacturing or that can be merged with the knowledge management strategies.

- **Change Curve** is a method that is used to describe the four phases that most people experiment while they involved in changing situation. The objective of this tool is to reduce the negative impact of the change scenario and support people to adapt more quickly to the transformation, and as consequence help the management to have more control of the situation. In the following illustration is shown how the behavior is changing from one stage to another, from the first shock impression to the commitment.

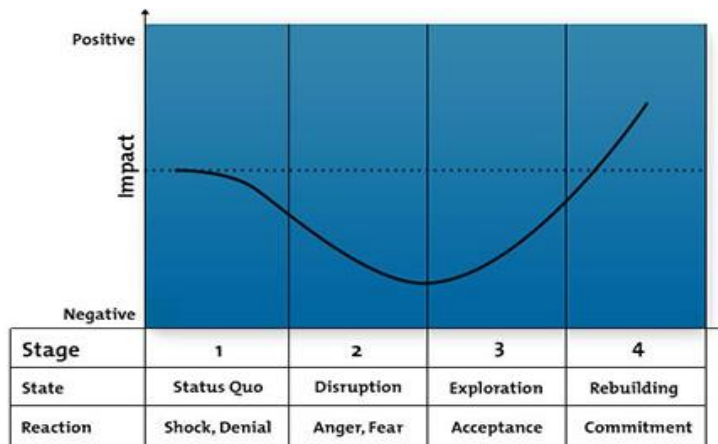


Figure 4.1: The Change Curve³³

- **Lewin's Change Management Model** is a strategy of change management developed by Kurt Lewin to understand the change management process through its three phases: unfreeze-transition-freeze. This theory start with changing mind set of people and preparing to the coming changes (unfreezing); in the transition new structure is created to change the actions and attitudes, this is the bridge from

³³ http://www.mindtools.com/pages/article/newPPM_87.htm

old method to new one. And finally in freeze state everything is done to achieve the fully adaptation to the transformation. The whole process will break up with current status and will prepare the organization for the next stage.

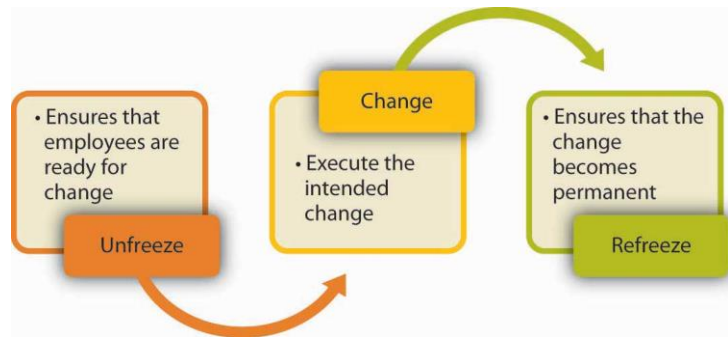


Figure 4.2: Lewin's Change Management Model³⁴

- **Change Impact Analysis** is a tool that faces the unexpected negative impacts while implementing a change in an organization. The objective is to create a structure from all the effects of a decision of change and manage those consequences.
- **The Burke-Litwin model** gives you an idea about the different key drivers of change and ranks them in terms of importance. The model is expressed diagrammatically, with the most important variables placed at the top. The lower layers become gradually less important. The model argues that all of the factors are integrated (to greater or lesser levels). The result after using this tool is that you will be able to know which variables have to be changed and why make this transformation.
- **McKinsey 7S Framework** is a tool that pursues almost the same objective of Burke-Litwin Model; this technique helps the change managers to understand the relationship between seven hard and soft aspects of organizations: strategy, structure, system, skills, staff, style and shared values³⁵. Analyzing the consequences of an organization that is about to experiment a future change.
- **SIPOC Diagrams** stands for suppliers, inputs, process, outputs, and customers and it is a tool used in other models such as Lean and Six Sigma. From the Change management view allows you to see a picture before and after the change is implemented. These diagrams show a general view of the change process

³⁴ <http://www.web-books.com>

³⁵ http://www.mindtools.com/pages/article/newPPM_87.htm

involved and helps change managers to achieve the expected outcomes oriented for the right people, and from the beginning of the process.

- **Kotter Model: the 8-Step Process for Leading Change** is a holistic approach to see through, analyze and do the change in an organization³⁶. This theory established the following eight steps to lead the change in a successful way:
 - (1) Establishing a Sense of Urgency: motivate people to push forward, make objectives real and relevant.
 - (2) Creating the Guiding Coalition: get the appropriate people in place with the right emotional commitment, and the right mix of skills and levels.
 - (3) Developing a Change Vision: establish a simple vision and strategy focus on emotional and creative aspects necessities.
 - (4) Communicating the vision for buy-in: involve as many individuals as possible in the process, communicate the essentials things in simply way, and respond to people's requirements.
 - (5) Empowering Broad-based Action: eliminate obstacles, enable constructive feedback and support from leaders.
 - (6) Generating Short-term Wins: plan for achievements that can easily be made visible, follow-through with those achievements and recognize and reward employees who were involved in the change process.
 - (7) Never Letting Up: use increased reliability to change systems, structures, and policies that don't fit the vision. Promote and develop employees who can implement the vision.
 - (8) Incorporating Changes into the Culture: reinforce the value of successful change via recruitment, promotion, new change leaders. Weave change into culture.

- **Stakeholder Analysis** is the procedure used to identify the key people who have to be involved to get the desired or better results in a change management situation. Stakeholder analysis is a process of systematically gathering and analyzing qualitative information to determine whose interests should be taken into account when developing and/or implementing a policy or program.

³⁶ <http://www.kotterinternational.com/our-principles/changesteps>

5. INTEGRATION OF KNOWLEDGE MANAGEMENT AND CHANGE MANAGEMENT TO IMPLEMENT LEAN MANUFACTURING

5.1 Overview

The three models are already presented and now it is time to put the common points in the table and mix it to help organizations get better results. Lean is a philosophy that is focused clearly on knowledge creation and through this new knowledge brings new changes in workplace and in the way that work is done. In Lean production the changes are supported by the knowledge and vice versa.

Knowledge Management (KM) is utilized for improving processes, customer relations, decisions making, the work place, performance and other aspects. A well-established knowledge management system will strengthen the expertise of the Lean Organization and put together as much useful information as possible in a strategic way.

The previous affirmation fits in one of the cornerstone of Lean, the respect for people, and the consideration to them providing one of the most powerful tools in modern era "the knowledge". This includes all information, data and knowledge available that will help the organization performance. Most of the lean tools are based on KM.

Lean is a strategy of constantly change, an example of that is the KAIZEN or continuous improvement processes and the Value Stream Design applied in to the Production System. The Change Management process can prepare the ground to receive those changes: identifying, implementing, managing and evaluating it. These transformations will be supported by knowledge to overcome the shock, fear and resistance presented by the stakeholders, and achieves the acceptance and commitment by the people involved.

It is relevant to mention that over the past couple of decades traditional change management studies show a 70% failure rate in change projects³⁷. They cite "lack of a structured change process" and "un-predicable nature of people" as the reasons. That is mean change management process plays a supporting role in lean implementation.

Lean, as a single system, creates knowledge and makes important changes in the production process and in the organization in general, but before, during and after the model is implemented, there are missing some important aspects that can be accompanied and strengthened by the knowledge and Change Management. This the reason why the integration of these concepts has a relevant sense.

³⁷ <http://www.leanchange.org/>

5.2 Coincidences between Lean Manufacturing, Knowledge Management and Change Management

To understand better the integration and how it will work effectively, it is necessary to have a look at the common points where these models converged. In the next lines are presented some of these factors.

- Lean, KM and change management are oriented to people, process and technology.
- Top management must be very involved in the three models.
- The information system plays a very important role.
- All are strategic and have a long term vision.
- Knowledge is the base of Lean philosophy, knowledge is managed to improve the process and the implementation of Lean tools, and also support the change activities and transformation process.
- Lean can be used as an approach to identify changes and knowledge required, and provides its tools to make the transition.
- Flexibility and adaptability to change and new knowledge continuously.
- Learning and training are key factors to apply lean, to manage knowledge and to overcome the changes in an organization.
- Strong Leadership and everyone participation is crucial.

5.3 Historical combination of Lean Manufacturing, Knowledge Management and Change Management

In the Craft Production era the main factors of production were land and labor, and the changes were rarely; later on, this era evolved to mass production where the labor and the capital prevailed, and change had more presence. In Lean production times the knowledge

became the first factor of production, and the changes were very constant because of technology evolution, customer requirements, and other important factors.

In the book “Beyond Large-Scale Production”, Taichi Ohno tell us how he followed the step by step process to achieve Toyota Production System, later call Lean Production, and presented some facts that can also be linked to the knowledge and change management, relating them with some tools and measure that were applied. It is important to highlight that this process took Toyota some years and some of them decades.

The objective pursued was to look at the time line, since the customer place the order till the moment the cash was received, and make it shorter. To achieve this there were new knowledge and severe changes involved.

The oil crisis, the need to increase competitiveness or the catch up with America, the post second world war period and Korean War, just were some of the changing facts or scenarios that brought as consequences “The Toyota Production System (TPS) ³⁹”. To accomplish this, Ohno and his collaborators developed on the way an ability to manage and adapt the organizational change. This was to overcome the resistance to change from employees, management, suppliers and other stakeholders, while implementing TPS. These abilities of managing change and knowledge can be taken into account as a precedent of the activities of Lean Production and change management.

In the other side to change the paradigm, the mass production (American style), was necessary to identify, create, store, share and apply the knowledge related with all the tools and methods that were implemented.

When Toyota start implementing Just in Time, they struggled with changing the traditional production flow, from an early process to a later process, then they go in the reverse direction in order to provide the right parts needed, at the time they are needed and in the amount they are needed⁴⁰. People had to learn a complete new model and information system through the implementation of Kanban, a system that pull production with cards.

In the same way the intelligence to the machine was given and the second pillar was implemented with many changes in the workplace and the worker behavior. The process passed from a non-stop operation to stoppable operation. An automatic stopping device was attached to the machines and the operator was able to stop the process when it was

³⁹ Productivity Press, Taichi Ohno. 1988. Toyota Production System: Beyond Large-Scale Production. N.Y.

required, to avoid defective products. As consequence of this other change was that one worker has to attend several machines. To do this the operators needed to have the adequate knowledge to know the exact moment when to stop the machine and also multipurpose knowledge to manage different machines.

Another example is when they were establishing the production flow; it was not easy to break the machine-shop tradition in which operators were fixed to jobs also to radically change the line production layout. In this new scheme one worker had to operate three or four machines along the processing route.

In all these changing processes, there was a strong resistance to change from the traditional model to the proposed one. For example there was a big resistance from production workers to change from one operator- one machine to be multi-skilled worker. They had to receive a lot of new knowledge through trainings for the new operations that were assigned to them. Motivation, commitment with the society and the company and the fact that they do not have to work more extra hour were the key of the success.

Despite this knowledge and change management applied on the way contribute to success of Toyota Production System at that time, at present the situation is different because knowledge sources has changed with the technology and changes are faster. Lean System must be implemented securing the implementation of changes in a controlled manner to minimize the risk of interruptions that can appear and setting a very structured knowledge system.

5.4 State of the Art of the Integration

At present time a lot of companies have had contact with Lean concepts and tools, implementing it or trying to introduce it to their production system. It can be said so for Knowledge and Change Management but in a small scale. In some organizations that Lean is implemented, the knowledge management or Change management models are applied separately from first one.

Other firms that are advanced in the field are talking about Lean Knowledge or Lean Change Management, but as separate models. This means that there are a lot of opportunities to keep working on the integration and the adaptation to the organizations needs in this knowledge society and constant change environments.

5.5 Analyzing the Strengths, Weaknesses, Opportunities and Threats when integrating the models (SWOT Analysis)

This analysis gives an understanding of the positives and negative points of the integration as it is shown in the Table 5.1. The strengths and opportunities are seen as a factor to overcome the weaknesses and threats.

Strengths	Weaknesses
<ul style="list-style-type: none"> ▪ The three models have a lot of common points. ▪ The integration is not difficult, taking into account that Lean System generates knowledge and provokes changes. ▪ It exist precedents of this combination and in some Lean organizations implement the models separately. ▪ Knowledge and Change Management complement the implementation of Lean in all the steps of the process. ▪ Technology facilitates the integration through data and information easy access while implementing Lean and preparation to change organizational culture. 	<ul style="list-style-type: none"> ▪ Team efforts have to be greater than implementing just Lean. ▪ Team has to be more flexible and open to new knowledge and changes. ▪ Preparation work takes more time, with the fact that is an integration of 3 models.
Opportunities	Threats
<ul style="list-style-type: none"> ▪ Establish a very structure Lean System complemented by all the knowledge needed to improve through the Knowledge Management, to guarantee the best results, securing all changes and possible future states through Change Management. Increasing the performance and obtaining better results. ▪ To adapt the organization culture according to the synergy or the results given by the integration. 	<ul style="list-style-type: none"> ▪ Evolution of production technology and information technology. ▪ Resistance to integrate the models.

Table 5.1: SWOT Analysis⁴¹

⁴¹ Author elaboration.

5.6 Overview of Lean Manufacturing tools integrated to Knowledge Management and change management methods

In the following table are presented some of the most important Lean tools and the knowledge and change involved in each one of them.

Lean Tool	Tool Objective	Knowledge Involved	Change involved
5S	Keep the workplace ordered and clean	It is required the tacit knowledge from people and knowledge from work station to select what is needed, order it, clean and standardized.	Mindset of the people and the dynamic of the workplace most be transformed (Necessary things now order more logical and easy to find and put it back)
KAIZEN	Continuous improvement in performance, cost and quality of process.	Data, information and knowledge coming from the different processes or from the people and department related with the improvement. External and internal knowledge. Tacit and explicit.	Small and big changes around the process are the key of this tool. Looking at the word Kaizen, "Kai" means Change and "Zen" improve. Continuous improvement tool, continuous change.
Kanban	Signs and cards to regulate Just in Time flows.	Customer demand, frequency, production flows, takt time, tacit knowledge of worker in the stream.	The biggest change is to follow the signals and accept that know cards will mark the rhythm of the production.

TPM	Monitoring, inspecting, cleaning and evaluating the present and future equipment.	Equipment information, maintenance frequency and knowhow, autonomous maintenance. Tacit tips from the operators.	Operator pass from just operate the machine to be responsible for the machine and work station.
SMED	Reduce and/or eliminate downtime due to setups and changeovers in the production. Create a simple, safe and reliable preparation.	Changeover operations (internal and external) knowledge.	The internal and external operations will change in order to make it faster. Dies must be change faster and work in progress move continuously.
Production Leveling	Distribute the work load per shift, day or week in order to satisfy customer demand	Understand Customer behavior, takt time, kanban.	The workload will pass from being fixed to be adapted to customer demand. In this way lines will be loaded according to capacity, time available, operators, etc.

Table 5.2: Knowledge and Change involved in Lean Tools⁴²

⁴² Author elaboration.

Revising the knowledge and changes involved while applying lean tools it can be realized that to integrate the models the tacit knowledge must be converted into explicit knowledge and the changes must be analyzed, for this purposes it is provided the table 5.2, in order to integrate the application of Lean Tools with the simultaneous implementation of KM and CM tools.

It seems to be difficult to integrate the change and knowledge management tools into lean ones. To have an idea in the table 5.3 there is an approach to make the knowledge and changes involved (presented in table 5.2) more manageable. In this table can be appreciated that the integration needs more efforts of KM and CM tools in the Value Stream Mapping and in Kaizen (perfection), because the first one is the basis of Lean and the second one the way to update the lean system.

The tools considered appropriate for the integration are marked in yellow. For example is recommendable to use in any step the “change curve” to understand the behavior of people during all lean process. The “Lewin’s model” will break the lean procedures in three phases (unfreeze-change-freeze) and it is useful to utilize the “Kotter’s 8 step change model”, to structure all changes surrounding lean principle and its tools. This will be supported by the knowledge management strategies presented in the first part of the table.

		Lean Tools													
		Value	Mapping Value	Flow						Pull		Perfection			
		Identifying Value, Waste	Value Stream Mapping	Continuous Flow	Standardized Work	SMED	TPM	Jidoka	JIT	5S	Visual Control	Kanban	Production Leveling (Heijunka)	Kaizen	
Knowledge Management Process	KM Tools and Techniques														
Identifying Knowledge (5, 6, 10, 12, 13, 14) ↓ Creating Knowledge (1, 3, 4, 5, 6, 9, 10, 14) ↓ Storing Knowledge (3, 4, 5, 6, 7, 8, 9, 10) ↓ Sharing Knowledge (2, 3, 4, 5, 6, 8, 9, 10, 11, 14) ↓ Applying Knowledge (3, 5, 6, 7, 8, 10, 14)	1. Brainstorming		X		X	X	X		X		X	X	X	X	
	2. Peer Assist	X	X	X	X	X	X	X	X	X		X	X	X	
	3. Learning Reviews		X		X	X	X	X				X	X	X	
	4. After Action Reviews		X	X	X	X	X	X		X	X	X	X	X	
	5. Knowledge Cafes	X	X		X				X	X	X	X	X	X	
	6. Communities of Practice	X	X		X	X	X	X	X					X	
	7. Taxonomy		X		X						X	X	X	X	
	8. Document Libraries		X	X	X	X	X	X	X	X	X			X	
	9. Knowledge Bases (Wikis)	X	X		X		X	X	X	X	X	X	X	X	X
	10. Expert Locator		X	X	X	X	X	X		X		X	X	X	
	11. Social Network Services	X	X											X	
	12. Knowledge Mapping	X	X		X	X	X	X						X	
	13. KM Maturity Model		X		X		X						X	X	
	14. Mentor/Mentee	X	X	X	X	X	X	X			X	X	X	X	
Change Management Process	Change Management Tools														
Understanding Change	The Change Curve		X	X	X	X	X	X	X	X	X	X	X	X	
	Lewin's Change Management Model		X	X	X	X	X	X	X	X	X	X	X	X	
Planning Change	Change Impact Analysis		X	X	X	X	X	X	X	X	X	X	X	X	
	Burke-Litwin Change Model		X	X	X	X	X	X	X	X	X	X	X	X	
	McKinsey 7S Framework		X	X	X	X	X	X	X	X	X	X	X	X	
	SIPOC Diagrams		X	X	X	X	X	X	X	X	X	X	X	X	
Implementing Change	Kotter's 8-Step Change Model		X	X	X	X	X	X	X	X	X	X	X	X	
Evaluating and Communicating Change	Stakeholder Analysis		X	X	X	X	X	X	X	X	X	X	X	X	

Table 5.3: Integration of the Lean Tools with KM and CM Strategies⁴³.

This table is an extended model of the figure 5.1 presented at the beginning of this chapter. It is a representation of how the models can be integrated and how they can complement each other.

⁴³ **Author elaboration** supported by [10] (Dr. Ronald Young, 2010), [7] (Villaseñor & Galindo, 2007) & [20] (http://www.mindtools.com/pages/article/newPPM_87.htm)

5.7 A Glance on Applying Value Stream Mapping with knowledge management and Change Management

Once described some of the more important tools of Lean integrated to Change Management and Knowledge Management, Value Stream Mapping (VSM) was reserved to break it down into single steps and to see clear where Knowledge and Change management can strengthen it, as well as pointing it out as reference for the models integration. It was chosen because this tool is the initial footstep in the conception of a Lean Production System, being a main method used to eliminate waste, creates and share knowledge and future states (changes).

As it was describe in theoretical part, VSM is the set of all the specific activities required to design, order, and provide a specific product, from concept to launch, order to delivery, and raw materials into the hands of the customer.

Before starting to develop the value stream mapping integrated with Knowledge and Change Management, the following activities must be accomplished:

- The top management must be committed with the Lean Philosophy, Knowledge and change management.
- A manager has to assume the responsibility for the entire value stream, which can drive changes across the internal organization. This manager will be the communication contact with top management and also it is responsible to identify together with the team the data and information, create the knowledge needed, storage it, share it and implement it using programs and project to achieve the future state design.
- A selected team has to accompany the manager in the data and information collection and decision making. This group of people should add representatives from all relevant areas of the organization. All make up the team that will gather all the relevant information and plan the future changes.

The Value Stream Mapping process is framed and adapted to the general integration model presented in the figure 5.1, as it is shown in the next illustration.

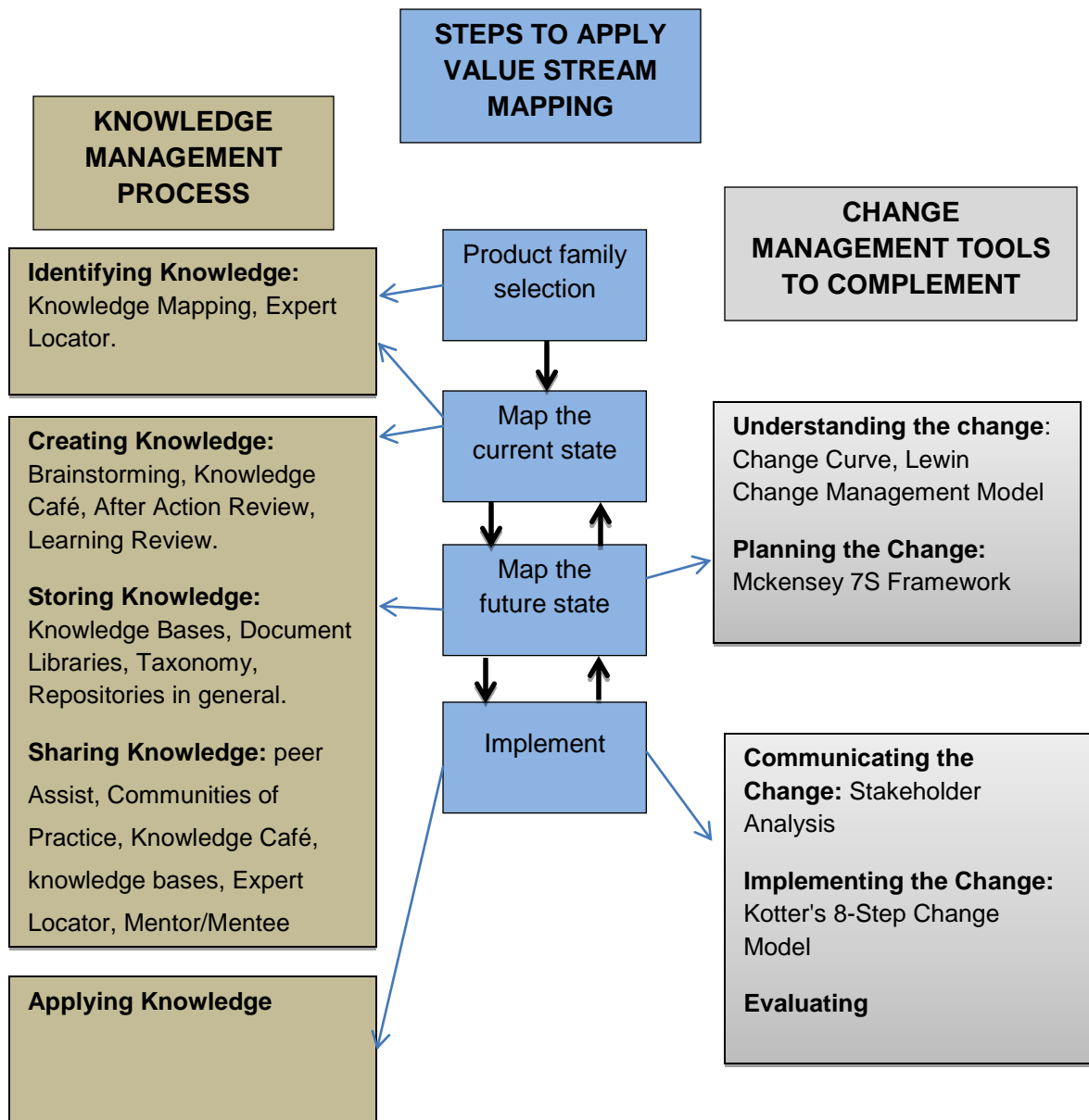


Figure 5.2: Integration of Knowledge and Change Management Strategies implementing VSM⁴⁴

In the figure is shown how the knowledge management process is an essential part of the first steps of the Value Stream Mapping, especially when drawing the current state, this to get the right knowledge and addressed to the right people in the right moment. Meanwhile the Change Management process focus once the knowledge is developed and focused on the steps where the future states are visualized and change has to be managed. To analyze the graphic in a more detailed way is presented the following table.

⁴⁴ Author elaboration.

Value Stream Mapping Process	Detailed activities of the VSM	Knowledge Management Tools	Change Management Strategies
Select a Product Family	<p>Group of products that are manufactured in the same or similar production process and equipment.</p> <ul style="list-style-type: none"> - Identify Product Family - Collect part numbers, customer demand, Frequency and type, fluctuation of demand within family. - When a complex product mix appears use matrix or diagrams to visualize it. - 	Identifying Knowledge: Knowledge Mapping, Expert Locator.	
Drawing the current state	<ul style="list-style-type: none"> - Revise all the information available regarding the production process. - Communicate to all areas the purpose and the activities - Tour the plant to identify and map the main processes. Collect the current attributes of the process such as cycle time, changeovers, work in process, line capacity, machinery, number of operators among other relevant production data. - Utilize icons to do the mapping - Fill out data boxes, count inventory and map inventory locations. Cycle time, process time, change over time, utilization rate. - Draw material flow. Process interaction. 	<p>Identifying Knowledge: Knowledge Mapping, Expert Locator.</p> <p>Creating Knowledge: Brainstorming, Knowledge Café, After Action Review, Learning Review.</p> <p>Storing Knowledge: Knowledge Bases, Document Libraries, Taxonomy, and Repositories in general.</p> <p>Sharing Knowledge: peer Assist, Communities of Practice, Knowledge Café, knowledge bases, Expert Locator, Mentor/Mentee</p>	

	<ul style="list-style-type: none"> - Draw supplier information - Draw information flow - Calculate lead time and process time 		
Map the future state	Draw the icons that represent the customer, suppliers and production control based on the improvements made to the current state of the mapping. This has to be focused on the customer demand, establishment of an efficient production flow, and a leveled production.	Applying Knowledge	<p>Here enters the change management the focus is on the wider impacts of change, particularly on people and how they, as individuals and teams, move from the current situation to the new one.</p> <p>Understanding the change: Change Curve, Lewin Change Management Model</p> <p>Planning the Change: Mckensey 7S Framework</p>
Implement	Apply all the changes made in the Future State in order to improve the current state of the production process. Take into account all the knowledge and changes involved, complemented with the columns in the right.	Applying Knowledge	<p>Communicating the Change: Stakeholder Analysis</p> <p>Implementing the Change: Kotter's 8-Step Change Model</p> <p>Evaluating</p>

Table 5.4: VSM integrated with KM and CM⁴⁵

⁴⁵ Author elaboration.

5.8 Benefits of integration

More than saying that to apply Lean with Knowledge and Change Management can reduce waste, increase efficiency and ensure that things are going toward successful transformation with the right knowledge, or that the knowledge available is complete, accurate and in the amount necessary to implement Lean strategy and the future states effectively; in this work the benefits are linked to the synergy theory, so the interaction of the models together will produce a more positive effect than the sum of their individual effects.

It has been shown the integration of the different tools in the previous parts, where Knowledge and Change Management can complement and cover the empty holes of the implementation of Lean Manufacturing in order to increase the performance, customer satisfaction and better results. For example the conversion process of data and information into knowledge, and this knowledge from tacit to explicit will allow lean organization to react quickly to problems and future recurrence. Also it will prepare the team leading the process to the future state, analyzing with the change curve method the reactions of the organization making the transition with the Kotter's 8-Step Change.

In the case of Value Stream Mapping the benefits will be reflected in the ability provide from the knowledge management core process of identifying, creating, storing, sharing and applying all knowledge and wisdom to map the current state and future state in a more accurate manner, fast and going deep into details. Everybody involved in the project will be able to speak the same language and will be awarded of the coming changes, and then the activities will flow in a dynamical way. We could say that one of the benefits is that this model will let people know what to do and what to expect in a systematic way.

5.9 Future Challenges of the Integration

In the SWOT analysis (table 5.1) it is mentioned that one of the threats of the integration of Lean, KM and CM is the new development of the ways of doing things and how these are going to be managed through the information technology. As an example it can be cited a project that has been developed in Germany in the last decade, the Industry 4.0.

The Industry 4.0 is a project that has evolved from the three past industrial revolutions and proposes the creation of intelligent factories that connect every part of the production chain with next generation wireless automation. This intelligence will be made possible by the utilization of much reduced processors, storage units, sensors, and transmitters that will be embedded in nearly all conceivable types of machines, unfinished products, and materials, as well as smart tools and new software for structuring data flows. All of these innovations will enable products and machines to communicate with one another and exchange commands. In other words, the factories of the future will optimize and control their manufacturing processes largely by themselves⁴⁶.

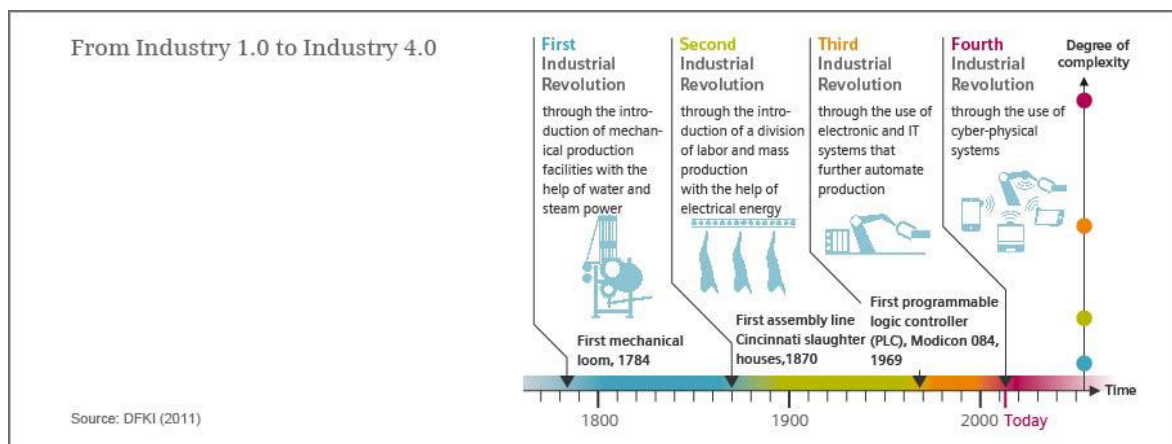


Figure 5.3: Evolution of the production process by revolutions⁴⁷

Even though this will take a very long time to arrive to that position, according to the experts, it is significant to highlight it as an issue that organizations must work on. One of the challenges of the integration of Lean, KM and CM is to be up to date and understand the transition from what we have presented as historical precedent to the scenario visualized in the future state proposed in the Industry 4.0.

This virtual scenario will affect the integration in the following way:

⁴⁶ ³⁸ http://www.siemens.com/innovation/apps/pof_microsite/_pof-spring-2013/_html_en/industry-40.html

Lean Process will change its structure, for example in Kanban system the production will be pulled by making a click or sending a message in Smartphone instead of the traditional Kanban cards. In the Kaizen improvements will be recognized and apply to the system automatically, this does not mean the human touch will be exclude it totally.

Knowledge management process will change with the Lean process. The creation of knowledge, storage and sharing will be attached to softwares that will structure the information data and information flow. In this part the human aspect need to be more prepared in the information technology to interact successfully with this new challenge.

To support the transition of the transformation in Lean and knowledge management, the change management needs to be the bridge between the actual state and this virtual state.

5.10 General Recommendations from Knowledge and Change Management view while implementing Lean with Change

The integration of the given recommendations will help the production system with the transition phase and with the usage of the knowledge required in the lean dimensions.

From the ***Knowledge Management view*** we have the following recommendations.

- Select responsible team for managing the Knowledge that will complement Lean Strategy.
- Establish what knowledge will be needed in the Lean way. Before starting the Lean journey is necessary to know the knowledge that will affect the process and will be important to the organization to own it. In this way the right knowledge is given to the right people and in the right doses.
- Identify the sources of Knowledge. The relevant data, information, knowledge and wisdom that will contribute with the reduction of waste, will come from the customer, supplier, managers, process experts, operators and shop floor in general. So the right knowledge must be located in order to manage it with tools presented in the previous topics. It can be used the Knowledge Mapping tool.

- Convert the tacit Knowledge into Explicit Knowledge. Once located the sources it is realized that most of the knowledge is found in tacit forms, so must be converted in standards for lean transformation. One of the challenges of this point is make people change the mindset from an isolated knowledge point to a sharing position, many people think that distributing the knowledge that they possess make them less powerful. This part can be supported by Change Management strategies and other to get people commitment and change the mindset.

- Capture and store the knowledge generated. The previous steps make appear a broad spectrum of knowledge, for example how to map the value stream in the current and future state, the procedures of Kaizen, the standards of 5S, and others. A well storage system will allow people the access to knowledge when they need it in the implementation of the Toyota Production System. Repositories are good measure to achieve this point.

- Establish knowledge sharing environments. Workshops, regular meetings, knowledge café and follow the tools presented before to achieve this part. Sharing knowledge update Lean production, the more knowledge people have the more is possible to eliminate waste and react to lean challenges. This will convert individual knowledge in collective knowledge.

- Follow the Knowledge management process: identify knowledge according to the lean organization needs; create the knowledge identified for lean people, store it in logical forms systems, share the knowledge and applied in the Lean scheme.

In ***Change Management side*** is recommended to answer the following questions before start the Lean transformation.

- What kind of change Lean brings?
The answer of this question will clarify the nature of the change, if it is incremental or radical, if it fast or slow. For this part it is need it to identify what is going and need to be changed, for example people mindset, shop floor environment, process flow or a technological change. This will give you the visualization of the lean change process.

- Who is responsible to make those changes take place?
In change management the leadership is a very important factor. This question is addressed to the individual or team that will be in charge of the change process to make pass from the current state to the future lean conception. This team will provide the direction of the change, decision making and evaluation of the progress that lean presents.
- What knowledge is needed to support the change?
This question can be supported with previous recommendation in Knowledge Management process.
- How can we handle the transformations that Leans brings?
This a good question, and in the first questions we have been following a process to deal with change while establishing Lean and its tools. Once the lean transformations are identified, the team is selected and prepared with the right knowledge, this things need to be visualize in a structure to achieve the objectives, what will be answer in the next question.
- What structure should be followed in order to manage the change and execute proper actions that help the process in the transition?
To structure the change we presented some tools that will support Lean implementation in achieving with fewer obstacles the objectives of reduction of waste and customer satisfaction, and the commitment of the people.
 - Lewin's Change Management Model
 - Change Impact Analysis
 - The Burke-Litwin model
 - McKinsey 7S Framework
 - SIPOC Diagrams
 - Kotter Model: the 8-Step Process for Leading Change
 - Stakeholder Analysis
- Is everybody committed or presenting some resistance to change?
As we explained the resistance to change is one of the natural attitudes that people adapt when is facing a changing situation. When implementing Lean many

transformations happen: the production is driven by different way with the Kanban pulling system, the things are ordered in a new form through the 5S strategy and continuous improvement becomes part of the culture of the company. Some people can present opposing forces to accept the new way of doing things. To face that problem, this people and groups must be identified in order to involve them in the change process. The change curve model is good tool to tackle this aspect.

- How change process has to finish?
Evaluating the results of the implementation of the change and taking measures that support the futures actions of Lean production.

6. CONCLUSIONS

Through this thesis work we have proposed the integration of Lean Manufacturing with Knowledge and Change Management, the last two concepts complement the implementation of the first one and vice versa.

We find that Lean strategy creates knowledge and makes transformations in the production process and in the organizational culture in general, but there are some important aspects that can be fully strengthened by the knowledge and Change Management process, that is why the integration of these concepts has a relevant sense. While implementing Lean Tools, Knowledge and Change Management Tools and strategies can be deployed to maximize the Lean objectives.

The three models shared enough common points, what can be considered a strength that facilitates the integration. In the other hand, this process needs more efforts from the team involved in implementation what can result as weakness compared to the single implementation of Lean.

When Toyota Motor Company was implementing what is now called the Lean Production, it was created a lot of knowledge and provoked many changes in the traditional system at that time; main actors involved make resistance to the transformations and the new knowledge they had to acquire, but on the way to Toyota Production System they overcome and made a successful system. This can be taken as precedent of the combination of the models, but for a future integration taking the best practices of this experience and adding some special tools from the complementary models as it is shown in this work.

Many organizations have applied Lean in their production processes, some other at least have tried to implement its tools and there are advanced one that are talking about Lean Change or Lean Knowledge, but there are a few of them that are integrating Lean, knowledge and Change Management.

The benefits of the integration are under the synergy concept. The integration will generates more positive results than Lean as single model. The reason of that is the high complementing level that the three models have. Lean creates knowledge and provokes changes, while knowledge management helps to handle the knowledge around and look for new one and change management creates the transition of the current and future scenarios.

Observing the tools integration it can be realized that the biggest efforts need to be done when the value is mapped through value Stream Mapping and when the whole structure is subject to continuous improvement through KAIZEN, because the first one is the basis of Lean and second one is the update of the elimination of waste.

The future challenges of Lean are linked to evolution of the production processes and the information technology. In the future production will evolved to the Industry 4.0 and things will be manage with virtual interactions, what will change the lean procedures, the way of knowledge management and transformation will be faster. To tackle this, the model integration has to be up to date with the new developments in production field.

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8. HONOR DECLARATION

I declare that the work in this assignment is completely my own work. No part of this assignment is taken from other people's work without giving them credit. All references have been clearly cited.

Place, Date

Heisor Vicente Arias Diaz

9. APPENDIX

9.1 Appendix 1: Symbols to map the value stream

9.2 Appendix 2: Example of the current state and future state mapped with VSM