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Lean and performance: an assessment on North-East Italy

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INTRODUCTION

This thesis, which focuses on manufacturing companies in north-eastern Italy, aims to establish whether, over a seven-year period, those applying Lean management perform better than those which do not.
Lean Management is an organizational approach whose ultimate aim is to create the highest possible value for the final customer by eliminating any kind of problems, the so-called wastes, from within the company.

First introduced in Japan by the automotive company Toyota, Lean is a five-principle process through which companies properly implement a wide set of techniques and tools to achieve several business improvements, not only at operational level, but also to benefit the whole firm.
Over time, Lean has been upgraded according to the principle of continuous improvement, has spread to different industries, and has been the subject matter of many academics' research. It supports a philosophy of tiny daily changes rather than one sudden overhaul. Chapter 1 clearly describes the background of this phenomenon, its tools and practices.

The second chapter contains a literature review that focuses on how this phenomenon can be gauged in one company. The first part deals with all the authors and academics that have treated this topic, albeit not many have. The second half analyzes factors that may be fundamental in implementing and gauging Lean successfully.

This analysis was carried out by downloading a list of companies from AIDA, focusing on the four regions that make up north-eastern Italy, i.e., Veneto, Emilia Romagna, Trentino Alto-Adige and Friuli Venezia Giulia. They were contacted by telephone and invited to fill in a questionnaire (see appendix) via e-mail, through the help of Survey Monkey, regardless of whether they adopt Lean Production. Then results were compared to assess the influence of Lean in these companies' performances.

Chapter 3 contains a detailed description (with tables and graphs) of the sample collected, initial data processing together with data downloaded from AIDA. This enabled me to divide companies into those that apply Lean and those that do not, making it easier to compare them. The variables that are more relevant for the final study of the population are Ebitda/Revenues, Ebitda/sales and ROA.

The fourth chapter analyzes the effect of Lean on performances over a certain period of time, focusing solely on Lean companies. Further on, a regression analysis and with couples of comoanies compares the results of both Lean and Non-Lean companies to gauge just how much Lean matters.

CHAPTER 1: LEAN MANAGEMENT: HISTORY AND PRINCIPLES

1.1 WHAT IS LEAN MANAGEMENT?

This chapter describes what lean management is, i.e., an approach that suggests how to run an organization which supports the concept of continuous improvement, a long-term *modus operandi* systematically seeking to achieve small, incremental changes in a process aimed at improving efficiency and quality.

Lean production (or just Lean) was developed in the 1950s in the automotive company Toyota which was looking for a solution to its financial crisis.
The term was coined by John Krafcik in his 1988 article "Triumph of the Lean Production System" inspired by his master's thesis. Krafcik had been a quality engineer at the Toyota-GM joint venture in California. Later, these studies prompted the international best-selling book co-authored by James P. Womack, Daniel Jones and Daniel Ross, "The Machine That Changed the World". The authors defined Lean Production (LP) as a "*an entirely new way of making things*", referring to the fact that this new method was totally different from mass production which, in the 1950s, was the most diffused system to manufacture cars due to the characteristics of the European market.

The post-war scenario in Japan, however, was very different, and implementing this system was much harder. Toyota more than any other automotive company had to come up with innovative ideas to overcome its financial distress caused by World War II. In particular, the post-war scenario in Japan presented the following characteristics (Womack *et al.,* 1990):

1. Small but domestic market for cars;
2. High employment protection and lack of temporary workers, which turned salaries into a set investment rather than a variable cost for companies;
3. Severe lack of financial capital and foreign exchange that made it both impossible to invest in new production technologies and to buy them from Western countries;
4. Great pressure from foreign competitors, which prevented Japan from expanding abroad and increased competitiveness in the Far East.

In this economic scenario, Toyota fell into a vicious circle which made the adoption of mass production no longer sustainable:

1. the Japanese market did not require large volumes and large-scale production was

unnecessary;

2. Toyota's production of small quantities was insufficient to achieve an economy of scale and cut costs;
3. Toyota's competitiveness was negatively affected by high management costs, which hindered demand growth.

Even if suitable, production in large batches had several disadvantages (Holweg, 2007). Indeed, typical mass production strengths, like huge inventory, could cause defects or rising costs. Moreover, mass production is inflexible, and Toyota was unable to meet all its customers' needs.

In this situation, Taiichi Ohno, an industrial engineer at Toyota, designed a strategy based on producing small volumes aimed at reducing costs and eliminating waste, renouncing economies of scale. This was the base for the Toyota Production System (TPS).

This is how what was later known as Lean Production was born, a philosophy that changes a company's point of view completely and focuses on customers rather than on productivity.

1.2 STARTING POINT: THE TOYOTA PRODUCTION SYSTEM

The Toyota Production System, from now on TPS, is a manufacturing method developed over a 20-year-period by Toyota in Japan. In its most simplistic definition all manufacturing activities are divided into adding value or creating waste.

The goal of TPS is to maximize value by eliminating waste. Liker and Morgan (2006) expanded its meaning to include a method to define, organize and manage operations and called it the precursor of Lean Manufacturing or, even better, "The best-known example of lean processes in action".

To represent this system scientists generally use the metaphor of a house (see Figure 1), which shows the main elements of the structure and the role each part plays within it. The house is indeed a perfect metaphor: like a house, LM needs solid foundations to be stable, and every part should be strong and coherent with the entire system. The roof of the house represents the final goal of TPS: to assemble products with the greatest quality possible while keeping costs low and minimizing lead time, the latency between initiation and execution of a process.

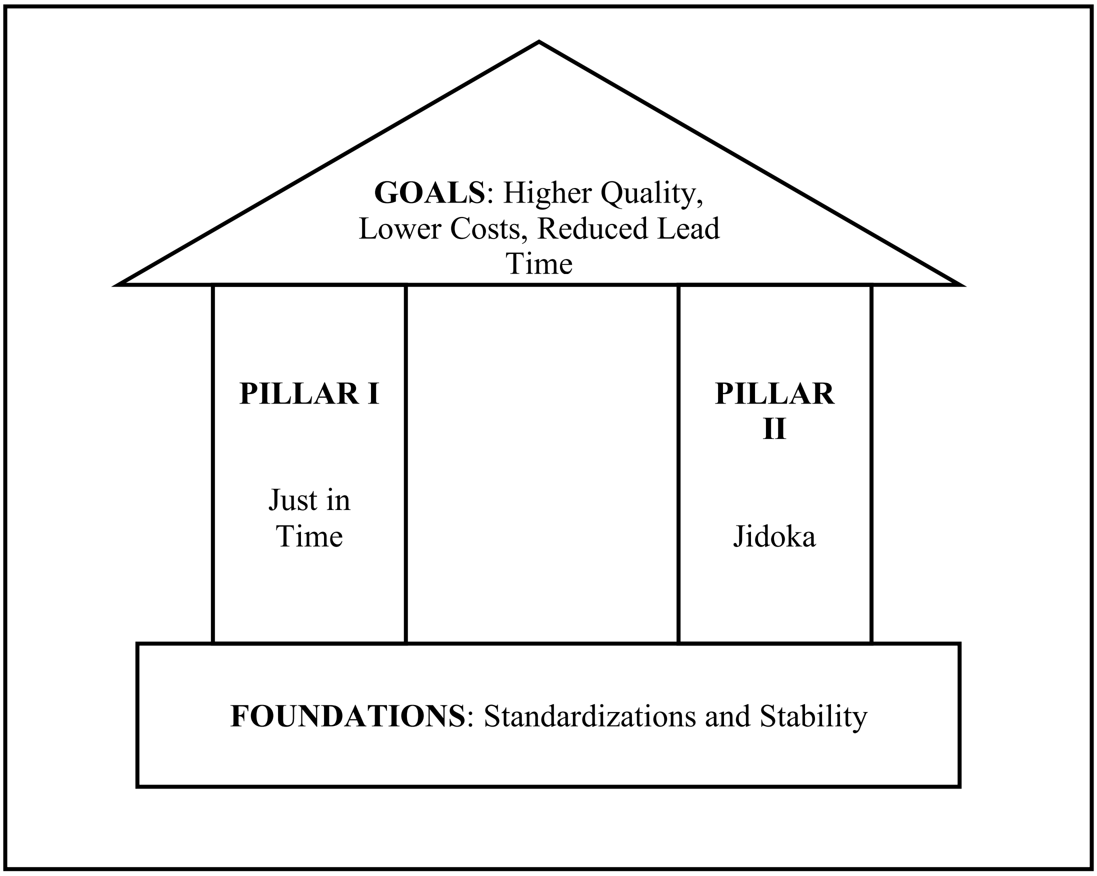

Figure 1: The TPS house

The general idea is that quality and costs are inversely proportional, but from the TPS point of view they are strictly positively correlated. In particular, high-quality working processes can significantly reduce the need of rework, cutting down both lead time and production costs, bearing in mind that although some activities may create waste, they are still necessary. Hence, in order to reach its goals, TPS implements a series of strategies based on the two pillars of the house: Just In Time (JIT) and Jidoka.

JIT is considered the TPS reply to the typical mass-production instrument, the so-called "Just In Case" (JIC). In mass production companies build up inventories of raw materials and processed and finished products to be ready in case production problems occur. In this way, the plant works tirelessly because buffers prevent any disruption. Conversely, JIT management is based on the attempt to be flexible and to respond quickly to any possible change in market trends, producing only when required and in the quantity needed (Pieńkowski, 2014).

In order to do that, workers have to be able to switch production very fast, considerably reducing set-up time, i.e. the period required to prepare a device, machine, process or system for it to be ready to function or accept a job. As a result, flexibility increases, buffers tend to decrease, and many of the disadvantages of JIC may be overcome.

Going back to our TPS house analysis, there is a second pillar, *Jidoka*. This Japanese word, which can be translated as "automation", refers to the implementation of some supervisory rather than production functions. At Toyota, this usually means that if an unexpected issue arises, the machines stop, and workers halt the production line. It is a quality control process that applies the following four principles:

1. Detect the abnormality.
2. Stop.
3. Fix or correct the immediate condition.
4. Investigate the root cause and install a countermeasure.

Automation aims to prevent the production of defective products, eliminate overproduction, focus on understanding problems, and ensuring that they do not reoccur (Sugimori *et al.*, 1977).

In particular, this pillar presupposes that machines can understand if there are unconformities in the production and stop automatically to solve the problem immediately with the intervention of the worker. In this situation, the operator first tries to understand and solve the problem by himself and, if he cannot, he calls a supervisor. The final aim is only for high-quality pieces to pass through the line.

The implementation of *Jidoka* has two important benefits, as claimed by Sugimori *et al.* (1977):

- Machines can stop automatically even when the daily number of pieces has been achieved. Indeed, *Jidoka* prevents the company from overproducing, which is one of the most important sources of waste;
- It enables continuous quality control along the production line - when a stop occurs, there is accurate intervention on the defective part and immediate corrective action to avoid further interruptions.

The whole system of the TPS, like a true house, needs strong foundations, which in this case are stability and standardization of processes in order to implement LM techniques correctly. The invested efforts on the foundations assist in the sustainability of systems. Stability and standardization ensure that work is done the right way— each and every time. This is especially important because improvements cannot occur without stable processes.

One aspect of business may be improved, and it takes just one ill-thought-out process to annul the improvement. To help with this, tools like control charts and value stream maps should be used to gain full understanding of processes, where they fail, and how they might be improved.

In this case stability of the processes means:

- *Consistent*: Operators and machines do not produce defective products and do not make systematic errors
- *Prepared*: Operators must be ready and able to work when they are asked to do so.

Stability of the processes can be reached by implementing specific tools, like for example 5S, Total Productive Maintenance, and *Heijunka*.

1.3 LEAN MANAGEMENT PHILOSOPHY AND TOOLS

As mentioned above, the final aim of LM is to eliminate organization waste and maximize the value accrued for the final customer by enforcing proper operational processes and implementing a specific set of principles and techniques.

Starting from here, LM may be defined as a philosophical movement (Bhasin and Burcher, 2006) not only based on tools and techniques but also, to be completely successful, on the transformation of organizational mindsets.

In this sense, LM transformation is thorough, it starts from management, but soon encompasses the entire company, and every dimension is equally relevant, as is the essence of this methodology. It affects companies starting from their mindset up to their daily activities and processes.

Creating value for customers is the ultimate LM goal – all principles, techniques and activities will increase the value of the final product. For instance, Womack and Jones (2003) defined value as “a capability defined by customers and provided to them at the right time and cost”.

In simple terms, value is the element that differentiates one product from its competitors and is defined by the customers' willingness to pay for it. A product will deliver more value than another to customers if and only if it is perceived as a solution to their needs and what they really want (Kotler and Armstrong, 2010).

As a consequence, a company should investigate both what people look for and what they do not want in order to create value and deliver it to the right target.

This process needs all waste to be eliminated, where waste is any human activity which absorbs resources but creates no value (Womack and Jones, 2003).

The translation of the word “waste” in Japanese is *Muda*. In particular, Muda means “futility; uselessness; wastefulness” - it represents all the activities for which customers are not willing to pay (Pieńkowski, 2014), and it is only one of the three types of wasteful activities, the other two being *Muri* and *Mura*.

There are two types of *Muda*:

- **Type I Muda**: non-value adding, but necessary for end-customers. These activities are usually harder to eliminate because while classified as non-value adding, they may still be necessary. For example, while an end-customer might not view quality inspection in car assembly as value-adding, it is necessary to ensure the car meets safety standards.

- **Type II Muda**: non-value adding and unnecessary for end-customers. These contribute to waste, incur hidden costs, and should be eliminated.

To sum up everything in a single sentence, we may say that the three MUs (Muda, Muri and Mura) are all the activities which, together, hinder a company from being efficient in its production system.

Mura means “incompatibility” and is related to the traditional industrial system, in particular when stock supplies a reserve even when production does not need it. In fact, having a reserve of spare parts makes it harder to come up with newly designed pieces based on possible new needs of final customers, so changes in the production schedule are harder and responding to changes becomes more difficult. According to the industrial strategies of Japanese factories, stocks should not exceed the real demand.

The main cause can be identified in production schedule fluctuations, and this leads to the other two Mu wastes, which is why Mura is also called the “mother” of all wastes. One solution, applied by LM, is to level production – in Japanese, *Heijunka* – as we shall see later on.

In addition, there is *Muri*, translatable as “excess” or “overburden”. It is intended as large-batch production, so when companies overload machines and workers above their optimal level or below their actual capacity.

Muri can cause problems related to safety, for example accidents at work due to ergonomic problems, or the repetition of the same operation too many times, and perhaps in the wrong way. Analysis of *Muri* within a company is one of the processes that underlies optimization of both processes and resources; for instance, a reduction of overload referred to operators leads to fewer accidents and sick leaves. Improving these conditions means that operators do not feel exploited and produce more and better. *Muri* is also caused by *Mura*, for instance, if we consider a production system with a set workforce and constant capacity levels, a variability in production patterns will generate an overload to operators and equipment when the volume of production is higher than the capacity level. In the opposite situation both will be not operating.

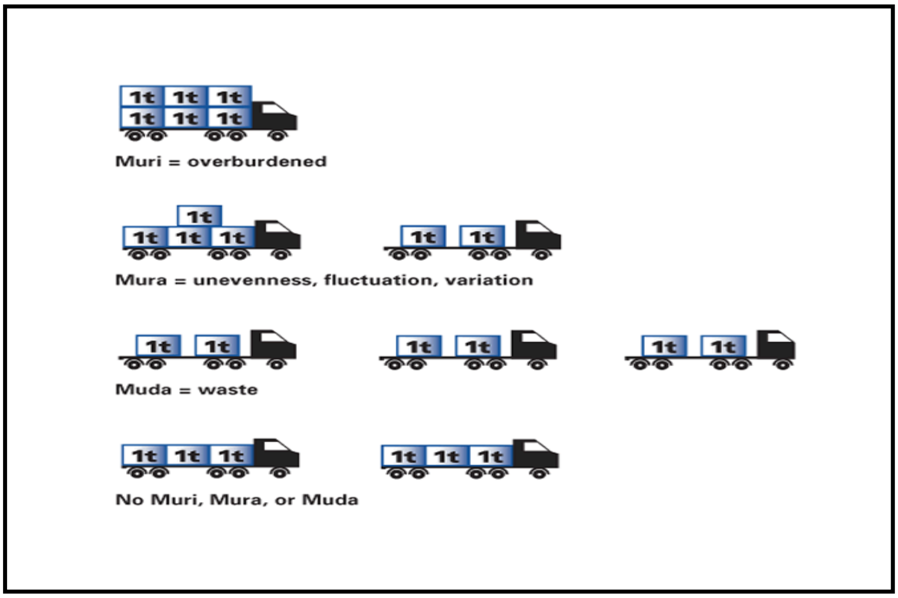

Figure 2: Representation of Mura, Muri and Muda

Lastly, *Muda* is the set of unnecessary activities that a company implements absorbing resources without adding any value for customers (Figure 2[1]).

What has been described so far already contains all 5 Lean principles: identifying what is worth ("value"), arranging the activities that create value in the right sequence, identifying the flow of value (flow of value), implementing them without interruption (flow) to move the flow when the client requests it "flow drawn", learning how to execute it in an increasingly effective way and continuous improvement ("perfection"). Traditionally, Lean Management described seven types of wastes, as recognized by Taiichi Ohno, the 'father' of TPS:

OVERPRODUCTION

Typically caused by production in large batches, a company has this waste when it is producing more than the real demand. Moreover, during the production time the customers' needs could change making products obsolete. It is in contrast with Just-In-Time production.

Lean production is lean especially because it produces only what is needed. Overproduction ties up capacity, material, time, and other resources that are not yet needed. You are actually paying today what you may have to pay a week from now. Additionally, you now have even more inventory, and hence you are losing even more money.
Overproduction has been described as the worst kind of waste.

TRANSPORTATION

The unnecessary movement of a material with the risk of damage, loss or delay cause every

[1] Imagine taken from http://leanvalley.eu

tame a waste, without adding any value.
In fact, the movement along the production line of whatever element does not create any value to the final customer, neither something they will pay for.
Continuous repositions highlight a lack in organization, or an inadequate layout, extending time of processing and increasing production costs.

INVENTORY

Inventory is always a cost, in every form it can be founded inside the plant: raw material, work in process (WIP) or finished goods.
Hence any element waiting in on ef these states it considered a waste, while the aim of Lean is to smooth flow in order to minimize wastes and costs.

Several companies still define their inventory as a fundamental element of their success, because it gives security, but in reality, it is accountable as cost for 30%-65% of its value

MOTION

Differently from transportation that refer specifically to products, motion refers to the damage and cost of production tools as for example wear and tear for equipment, repetitive strain injuries for workers.
Indeed, motion comprehend both workers and machines, tools should be close to the user in order to make faster operations and of consequence there will be less tear and wear.
It is important to arrange instruments to let move workers as little as possible.

WAITING

Typically refer to product waiting to be processed or moved (i. e. it is in a queue), usually production in batches consider that the large part of product life will be spent waiting.
Waiting refers also to people and in this case is easy to notice. Indeed, companies pay wages for workers even when they are waiting for parts, machine processes, or other workers, and this is a waste of money and disrespectful to people.
Increased utilization of machines is not a solution, the only effect produced is to increase inventory, leading to even greater waste.

OVERPROCESSING

As written before, accompany producing more than the needed by the market is making a waste, spending much more time and costs.

Over processing includes also the use of more expensive and complex machines.

Hence, designers and engineers drawing the project of a product should be aware that there are some characteristics of the product that are not relevant for the final customer.
This is common when designers and engineers fell attached with their project, but they should remember that any process that does not add value for the end-user it is a waste

DEFECTS
Having to discard or rework a product due to earlier defective work or components results in additional costs and delays.

Even if it can be reworked, it is additional effort, will consume more capacity and time, and in general will mess up your production schedule. Hence, when you do it, do it right the first time.

It is useful to remember that an eighth waste was introduced at a later time. This is unused skills and relates to the fact that often organizations underutilize all the skills their workers have or permit workers to operate in silos so that knowledge is not shared.
This was added to the original seven forms of waste, as solving this waste is a key enabler to solving the others (Pereira, 2009)

After the description of what is called the LM philosophy, it is important to shed more light on the LM principles. The LM principles are the guidelines that companies need to comply with if they want to implement lean transformation and change their organizational mindset. Although the five lean principles are easy to remember, they are not always easy to achieve.

The first step is *Defining Value,* and every lean firm should specify value from the standpoint of the end customer by product family (Womack and Jones, 2003). A company should find the answer to questions such as: What is the timeline for manufacturing and delivery? What is the price point? What are other important requirements or expectations that must be met? In fact, the final customer should be the focus of every process-from product development to the after-sales services in order to create and deliver an appreciable value for clients.

It is important to remember that the final customer is looking for the product that respond to its needs with the highest possible value that should be delivered in its entirety.

It is important to understand that this is the final goal of a company, in order to avoid a low customer rate and a lack in brand equity. Value determine how much a customer is willing to pay for the product, even more than the price. Starting from this concept it is now possible to identify and reorganize activities dividing adding value and waste activities.

After having divided all the activities, a company should maximize the first and minimize the last.

The second LM principle is *Identify Value*, whereby companies should analyze all their activities, identify which generate value, and separate them from the ones that do not add value, trying to eliminate the latter or reduce them to a minimum. So far, the most important LM concept mentioned is waste elimination, but waste definition is strictly associated with value (Mossman, 2009) – in fact, waste is identified as any action that absorbs resources without adding value.

Once a company has determined the value to achieve (end goal), the second step is to map the “value stream”, analyzing all the processes that go from the input of raw materials to the delivery of a specific product to the customer.

Value-stream mapping (VSM) is a simple technique that allows to identify all the actions a product or a service pass through in the production plant. Any process can be analyzed ad for example: design’s processes, production, procurement, HR, administration or delivery.

The VSM draws, on one page only, a sort of map of the flow of materials/products through the process. The aim is to detect which activities which step does not create value in order to eliminate it.

Activities that do not add value to the end customer are considered waste. Waste can be divided into two categories: non-value added but necessary and non-value and unnecessary. Value creating activities are the main activities in production systems and the ones that make products attractive to consumers.

Non-value added but necessary are activities impossible to be removed for their importance in the final results, but which do not add anything from the customers' point of view. Classical examples for this category are quality tests.

Finally, non-value added and unnecessary are the activities a company should eliminate because totally unnecessary or not required by the final customer.

The third concept, *Flow,* is the most important and the core of Lean.

After removing waste from the value stream, the following action is to ensure that flow of the remaining steps runs smoothly, without interruptions or delays. Some strategies to ensure that value-adding activities flow smoothly include breaking down steps, reconfiguring production steps, leveling out workload, creating cross-functional departments, and training employees to be multi-skilled and adaptive.

The strategy suggested by Toyota is one-piece flow, literally to produce one piece at a time, as opposed to the traditional view of producing in batches.

One-piece flow focuses on completing the production of one piece from start to finish with as little as possible work in process inventory between workers.

In order to implement it, plants have small and often general-purpose equipment that is arranged sequentially according to line layout. This way one single item at a time is processed, avoiding intermediate inventory between productive stations. Once one item is processed it goes directly to the next stage.

In addition, good plant organization is required. Usually organizing plants in cells - small productive units able to process a specific product or family of products each.

This layout has several advantages for the general production system, for instance,

with one-piece flow, work in process (WIP) is dramatically reduced. If there is no need to move, store, and manage piles of inventory, companies save money. And rest assured that if you are in profit business, cash is paramount.

Many of the wastes so inherent with batch and queue production (e.g. motion, transportation, waiting) are reduced with one-piece flow. As a result, productivity increases.

Through "make one, move one" processing defects are detected immediately, (usually at the next work station) forcing immediate corrective action. In contrast, when batches of material are produced, piles of scrap may result when a defect is detected downstream.

One-piece flow is faster than batch and queue. This speediness factor enables manufacturers to wait longer to schedule orders (and still deliver on time). Subsequently, it is better at responding to last-minute changes from customers. And everyone knows, no matter what industry you work in, customers love to change their mind.

Employees want to do good work. They want to see progress. They want to be involved. Implementing one-piece flow brings all these things, and more, together.

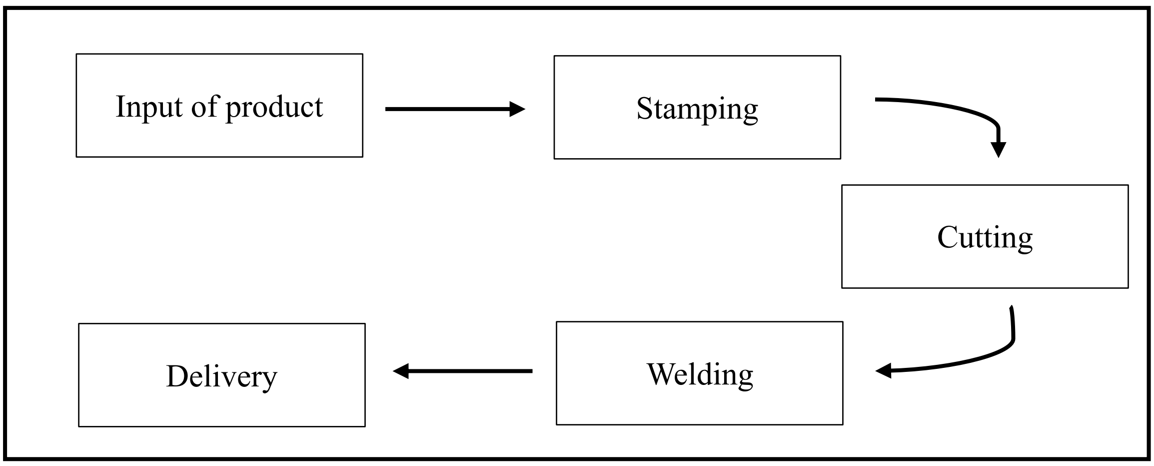

Figure 3: Example of one-piece flow production

The fourth principle of LM[2] is the *Pull approach,* which states "no-one upstream should produce a good or a service until the customer downstream asks for it" (Womack and Jones, 2003). The goal of the Pull implementation is to adjust the company production on the actual demand and not anymore on forecasts.

Once this production change is made, companies can focus on non-creating value activities in order to eliminate them. The results should be an optimization of the resources available and the reduction of inventory, one of the greatest wastes, and other wastes.

In the end a company will have improved its inventory, limited the work-in process (WIP) items, assuring that materials and also information is available for a smooth flow of work.

In other words, a pull-based system considers the implementation of Just-In-Time delivery and manufacturing, producing at the right time in the right quantities. All the system is in favor of the final customer and its perception of value, in this way companies will be able to fully satisfy it.

Traditionally companies base their production on the Push approach, in particular they refer to the Material Requirement Planning (MRP) system, a production planning, scheduling, and inventory control system used to manage manufacturing processes.

The main drawback of Push systems is that they are based on demand forecasts which cannot be totally reliable.

Pull logic, conversely, is based on the Made To Order (MTO) principle whereby production relies on actual demand and there are no forecasts. Pull-type supply chain management is based on the demand side such as Just-in-Time (JIT) and CRP (Continuous Replenishment Program) or actual demand assigned to later processes (Imaoka,2012).

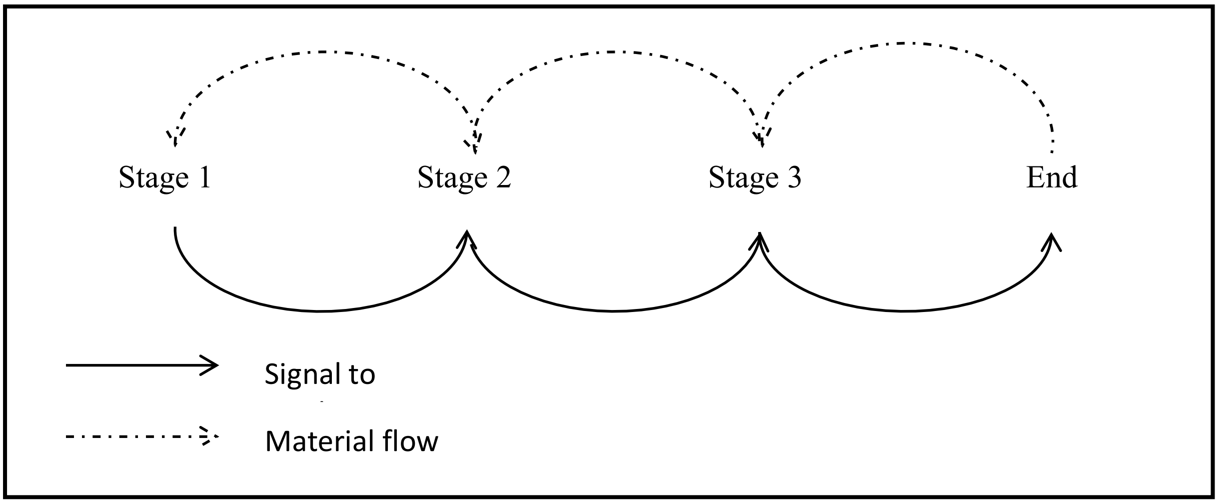

Figure 4: How Pull system works

[2] LM is the acronyms for Lean Manufacturing

Information starts from the end-customer and goes back to the production line through stages, and material automatically flows forward to the client. This path is represented in the figure below.

It is very difficult to harmonize an entire production line to respond to demand changes quickly, but Pull implements some inventory-controlling systems, like Supermarket for example. The name comes from the typical retail supermarket.

In manufacturing, a supermarket is a series of parallel FIFO (First-In, First-Out) lanes sorted by product. The key of a supermarket (both retailing and manufacturing) is that removing any part or product issues a signal to replenish this part (a so-called Kanban). Hence, a supermarket also aims to keep all parts in stock, while at the same time avoiding overproduction. Compared to a FIFO lane, a supermarket takes more effort to set up and manage.

This method gives importance to the final customer, because it provides the input to activate Flow, pulling the product through the production line.

Last but not least, there is *Perfection*, based on the concept that companies need to improve in every aspect. Waste is prevented by accomplishing the first four steps: 1) identifying value, 2) mapping value stream, 3) creating flow, and 4) adopting a pull system. However, the fifth step of pursuing perfection is the most important of them all. It makes Lean thinking and continuous process improvement a part of the organizational culture. Every employee should strive towards perfection while delivering products based on customer needs. The company should be a learning organization and always find ways to get a little better each and every day.
Lean experts often say that a process is not truly lean until it has been through value-stream mapping at least half a dozen times.
As Womack and Jones (2003) defined, the first step to start a Lean transformation is to identify that several problems are present in the company and that the application of the first four Lean principle should solve them.
Then, after the clarification of the purpose of the transformation, an organization can begin to work generating a higher quality service or product.
Changes should be small initially in order to avoid the overwhelming of some activities and also it makes easier to understand for workers the situation. That is why the effort needed can be defined as continuous improvement, because they are small and continuous over time in any part of the production.
In order to create processes able to produce high-quality, high-value services and products the

improvement teams should adopt some techniques that will be described later on in this chapter. Strive for perfection, Lean practitioners will infantize the aim presented before of the TPS house roof: reduce complexity, eliminate wasteful activities, and reduce costs, with no effect on quality.

Following this operational circle, performances may always be improved at every step, enabling lean companies to strive for perfection, exerting all their effort in implementing lean principles.

This continuous search for perfection is defined in lean with the Japanese word *Kaizen*, that literally means "continuous improvement". It is important to notice that, even if this is considered the most important principle of lean, total perfection is an impossible target to achieve.

Lean Principles	Remarks
Define Value	Specify value from the customer point of view
Identify Value	Identify which activities create value and eliminate the one that do not provide it
Flow	Manage the processes to ensure that value flow smoothly and continuously
Pull	Production is based on actual demand, not on forecasts
Perfection	Lean companies should strive for perfection enhancing their ability in implementing lean principles

Table 2: 5 Lean principles

Indeed, just as it is not realistic to believe that customers maintain views, beliefs and preferences unchanged over time, so the complete achievement of this goal is clearly unrealistic (Bicheno and Holweg, 2008).
The next step of LM is the enforcement of all these principles, and Lean tools and techniques are fundamental elements to fully transform a company into a lean one.
Indeed, while lean principles prescribe the path to follow to reach the maximum value for consumers, lean tools represent the practical implementation of those principles (Mostafa, Dumrak and Soltan, 2013) and techniques are the materialization of LM theories.
The Table below lists some of the main and most common lean tools, regrouped according to their purpose and described in greater detail.

Objective	Tools
Identify Value along the Value stream	• Value Stream Mapping
Give Stability to processes	• 5S • Total Productive Maintenance • Visual Management
Implement Just In Time	• Heijunka • Layout • Kanban • Single Minute Exchange of Dies
Control defects	• Andon • Poka Yoke
Continuously Improve	• Kaizen • PDCA logic • Lean Six Sigma • A3

Table 3: Major Lean tools and corresponding objectives

Value Stream Mapping (VSM) is a lean-management method to analyze the current state and design a future state for the series of events that take a product or service from its beginning through to the customer with reduced lean waste than that of the current map. A value stream focuses on areas of a company that add value to a product or service, whereas a value chain refers to all of the activities within a company. At Toyota, it is known as "material- and information-flow mapping".
In a build-to-the-standard form, Shigeo Shingo suggests that the value-adding steps be drawn across the center of the map and the non–value-adding steps be represented in vertical lines at

right angles to the value stream. Thus, the activities become easily separated into the value stream, which is the focus of one type of attention, and the 'waste' steps, another type. He calls the value stream the process and the non-value streams the operations. The thinking here is that the non–value-adding steps are often preparatory or tidying up to the value-adding step and are closely associated with the person or machine/workstation that executes that value-adding step. Therefore, each vertical line is the 'story' of a person or workstation whilst the horizontal line represents the 'story' of the product being created. The map is directly drawn while visiting the plant, the so called Gemba "the place where value is created".

Two are the peculiarities of this process mapping:

- **Current State Map**: It describes the present situation of the product in the value flow. This map provides a screenshot of how activities are currently organized (Singh *et al.*, 2010) in order to identify any loss in value.
  Mapping of the information flow issues the definition of Time Line in the form of a line drawn under the process boxes and under the inventory triangles to define the production Lead Time, i.e. the time taken by the piece to cross the factory. It also allows you to establish the connections between customer areas, suppliers, production processes, production planning and production supervision of the entire company system.

After this analysis, managers can plan changes and modifications to fix some situations that will be shown on the future state map.

- **Future State Map**: It is a representation of how the plant should look after removing all the negative situations found. The ultimate aim of this process is to have a tense and balanced flow that can meet the needs of end customers with great speed and efficiency without penalizing company production and turnover. At the end of this process, a company should build an ideal state of operations complying with Lean principles and perspectives.

The value flow mapping is the first, and perhaps the most important, Lean tool.
It is the first to be used timewise, because it indicates where the others should be applied, and it is fundamental for successful implementation, because it builds a solid and comprehensive action plan.

A second, widely-used technique is called *5S*, a method to organize the workplace and standardize the workers' performance. Its aim is to reduce variability in the workers' operative

processes, and to reduce waste (Bicheno and Holweg, 2008).
Two major frameworks to understand and apply 5S to business environments have arisen, one proposed by Osada, the other by Hirano. Hirano provided a structure to improve programs with a series of identifiable steps, each building on its predecessor. As noted by John Bicheno, Toyota's adoption of the Hirano approach was '4S', with Seiton and Seiso combined. In particular, these are the five concepts at the basis of this tool:

1. **Seiri** (or Sort)
   Seiri is sorting through all items in a location and removing all unnecessary items from it. Correct application of this point reduces problems and interferences in the workflow, provides better product quality and increases productivity. For example, items used more than twice a week must be kept near the work space, while others are stored away.

2. **Seiton** (or Straighten)
   Seiton is to arrange all necessary items in the optimal place for them to fulfil their function in the workplace. This is very important as it prevents wasting time in the performance of production activities. Arrangement and organization issue greater flow and linearity in production activities; this concept is central to standardization. Standardization is the development of a system that enables companies to complete procedures and tasks in an appropriate manner. The workstations must be tidy, as this is the only way standardization can be carried out efficiently. To develop the second principle, the 5S map is used. This is an instrument that evaluates the current location of templates, tools, bolts, equipment and machinery, and then enables us to decide how to best arrange them according to the two sets of principles described above.
   Once object arrangement has been decided, the second step is to identify its location.
   To identify where to place certain objects and in which quantity, two strategies are suggested, the painting technique (indication of the paths to follow on the floor) and signals.
   Two other strategies used to identify the exact location of objects are color-based codes and the contour method.

3. **Seiso** (or Shine)
   Seiso is sweeping or cleaning and inspecting the workplace, tools and machinery on a regular basis. This activity requires everything to be neat and clean, so that all objects / tools are always available and ready to use. When this third principle is not applied, a

number of problems can occur, including reduction of workers' morale, health risks, breakage of objects / tools, and increase in the number of defective products. It is fundamental to understand the concept that the responsibility for cleaning and for the workstation rely on all its occupants.

4. **Seiketsu** (or Standardize)
   Seiketsu is to standardize the processes used to sort, order and clean the workplace. The main purpose of standardization is to avoid the failure to apply the three previous processes, in order to make them a daily habit, and to ensure that they are maintained and improved over time.

5. **Shitsuke** (or Sustain)
   Shitsuke or sustain the developed processes by self-discipline of the workers. It also translates as "do without being told". It does not matter how well the first four procedures have been applied, but the system cannot work for a long time if the last maintenance does not apply.

Total Productive Maintenance (TPM) is a system of maintaining and improving the integrity of production and quality systems through the machines, equipment, processes and employees that add business value to an organization. TPM focuses on keeping all equipment in top working condition to avoid breakdowns and delays in manufacturing processes. Given that LM implementation cannot be successful with a high level of breakdowns (Bicheno and Holweg, 2008) TPM has the objective of reducing to a minimum machine failures and emergency maintenance. One of the main objectives of TPM is to increase the productivity of a factory and its equipment with little maintenance investments. Total quality management (TQM) and total productive maintenance (TPM) are considered the key operational activities of the quality management system. In order for TPM to be effective, the full support of the total workforce is required – from top management to grassroots (Chan *et al.*,2005). This should result in accomplishing the goal of TPM: "Enhance the volume of production, employee morale and job satisfaction." The main objective of TPM is to increase the Overall Equipment Effectiveness (OEE) of plant equipment. TPM addresses the causes of accelerated deterioration while creating the correct environment between operators and equipment to create ownership. According to Nicholas (1998), the steering committee should consist of production, maintenance, and engineering managers. The committee should formulate TPM policies and strategies and give advice. This committee should be led by a top-level executive. Also, a TPM program team must rise, this program team has oversight and coordination of implementation activities.

Advancing in the description of Lean tools and techniques there is *Visual Management* (VM) defined by Tezel *et al.* (2016) as "the strategy of increasing pervasive information availability, […] removing blockages in the information flows". VM groups several concepts of Lean Management focused on visual perception. The goal is to shape information and its context to make work and decision-making clear. Visual aids can convey messages quicker and elicit more interest than written information. And this also means exposing defects and problems to be addressed sooner.

Bicheno and Holweg (2008) argue that operation visibility represents the core element of LM with the purpose to gather as much information as possible while passing through the Gemba or without recurring to IT systems and databases.

Hence, the implementation of the VM method to share information and communication occurs in the workspace, directly coordinated through the use of proper practice by workers. Two of the most popular and significant VM tools are: *Poka Yoke* and *Andon*, which are described in depth below.

Poka yoke is a Japanese term that means "mistake-proofing" or "inadvertent error prevention". The often-omitted key word in the second translation is "inadvertent". There is no *poka-yoke* solution that protects against an operator's sabotage, but sabotage is a rare behavior among people. A *poka-yoke* is any mechanism in a lean manufacturing process that helps an equipment operator avoid (*yokeru*) mistakes (*poka*). Its purpose is to eliminate product defects by preventing, correcting, or drawing attention to human errors as they occur. The concept was formalized, and the term adopted, by Shigeo Shingo as part of the Toyota Production System. It was originally described as *baka-yoke*, but as this means "fool-proofing" (or "idiot-proofing"), so the name was changed to the milder *poka-yoke*.

Poka-yoke can be implemented at any step of a manufacturing process where something may go wrong, or an error can be made. For example, a fixture that holds pieces for processing might be modified only to allow pieces to be held in the correct orientation, or a digital counter might track the number of spot welds on each piece to ensure that the worker executes the correct number of welds. Shigeo Shingo recognized three types of *poka-yoke* to detect and prevent errors in a mass production system:

The *contact* method identifies product defects by testing product shape, size, color, and other physical attributes.

The *fixed-value* (or *constant number*) method alerts the operator if a certain number of movements is not made.

The *motion-step* (or *sequence*) method determines whether the prescribed steps of the process have been made.

Either the operator is alerted when a mistake is about to be made, or the *poka-yoke* device prevents the mistake from being made. In Shingo's lexicon, the former implementation would be called a *warning* poka-yoke, while the latter would be referred to as a *control* poka-yoke.

The second VM tool is *Andon*, a manufacturing term referring to a system notifying management, maintenance, and other workers of a quality or process problem. The centerpiece is a device incorporating signal lights to indicate which workstation has the problem. The alert can be activated manually by a worker using a pullcord or button, or may be activated automatically by the production equipment itself. The system may include a means to stop production, so the issue can be corrected. Some modern alert systems incorporate audio alarms, text, or other displays. Usually it is based on two elements: the Andon board and the Andon line.

An Andon System is one of the main elements of the Jidoka quality-control method pioneered by Toyota as part of the Toyota Production System and therefore now part of the Lean approach. It gives the worker the ability, and moreover the empowerment, to stop production when a defect is found, and immediately call for assistance. Common reasons for manual activation of the *Andon* are part shortage, defect created or found, tool malfunction, or the existence of a safety problem. Work is stopped until a solution has been found. The alerts may be logged onto a database so that they can be analyzed as part of a continuous-improvement program.

The system typically indicates where the alert was generated and may also provide a description of the trouble. So, when operators identify a problem, they can give a signal pushing the button or pulling a cord. In case of more serious problems workers can also stop the line and ask for the help of supervisors. This activates the alarm on the *Andon* board – a yellow or red light – highlighting the existence of a problem and which workstation is experiencing it.

Once the problem is fixed, the alert signal turns off and production starts again, while the lights on the *Andon* board switch back to green.

Previously, when speaking about *Mura*, the risk of problems caused by high variability and

incompatibility was highlighted. A possible solution, only mentioned before, is *Heijunka*, the process of leveling production minimizing variability.
The main elements of *Heijunka* production are (Slack *et al.*, 2013):

- ❖ Leveling of production volume - Every day the systems should produce the same amounts of certain items to reduce set-up time.
- ❖ Smoothing of production mix - Products are manufactured according to a specific sequence to reduce lot size and produce all items every day.

Color Cord	Condition	Action
Green	Production is normal or smooth	Proceeds to next level
Yellow	Problem appeared	Operator takes help of concerned authority to fix the problem
Red	Production Stopped	When problem is not identified and needs further investigation

Table 4: Example of Andon board

"Leveled production volume" is given by the uniform distribution of production over a given period of time. Leveled production volume depends on "level production variety", which is the uniform distribution of the production mix / variety over a given period of time.

Heijunka production control ensures uniform distribution of labor, materials and movements. With leveled scheduling, the production is based on smaller batches that are completed every day without accumulating inventory. This technique allows to improve process regularity and enhance flexibility.

An important concept related to Heijunka is Changeover, that is the time it takes to go from the last good part of one product run to the first good part of the next. Quick changeover is critical to Lean. It provides the flexibility to match the product mix to actual demand. In turn, this prevents the accumulation of inventory that can add costs and substantial waste to a value stream. Ohno immediately realized the importance of minimizing set-up delays, and modified changeover procedures to make them simpler and quicker (Holweg,2007; Womack *et al.*, 1990). Later in the 1950s, Shingo developed the Single-Minute Exchange of Dies (SMED) system, which brought the concept to a higher level (Holweg, 2007).

An important element of the SMED system is the distinction between changeover work that occurs while the machine is not running, called **Internal Setup**, and preparatory work that occurs while the machine is running, called **External Setup**. At the point in time when SMED was developed, almost all changeover work was performed while the machine (press) was down.
The fundamental point of SMED, after distinguishing internal from external activities, is to transform Internal operations into Externals, which is SMED's main principle.

A core element in LM is *Layout* defined as the one which "sets the framework for every lean transformation" (Bicheno and Holweg, 2008). It is important to place machinery and equipment in the proper way along the production line to prevent waste and to improve continual flow. Traditionally, the production system is batch and queue, in which more than one piece of an item is produced, then moved forward to the next operation, before they are all actually needed there. Batching and queuing tend to drive up inventory and lead time and create inefficiency in an operation. They also increase the space needed for production. As Bicheno and Holweg (2008) highlight, the layout connected with batch production is a source of waste, and has several drawbacks, for example transportation, long lead time, recurring bottlenecks and hard-to-detect defects on time. Instead, LM implements one-piece flow production, which relies more on product layout systems where the work stations and equipment are located along the line of production, like in assembly lines. A good place to start when reviewing layout is to trace the movement of a component or material from the moment it enters a factory all the way through, before leaving as part of a finished product. Do this on a paper layout of the factory plan. The route will highlight the overall length of the journey, together with how many times it crisscrosses back and forth across its own path. The waste of transportation will be illustrated very clearly. Ideally the layout should be rearranged (as far as is practical) to dramatically shorten the journey of most parts and materials. This will require some thought and careful consideration. But the aim will be to minimize the route. Once the shortest route has been planned, machines and workstations should be moved as close together as is practical. Machines, trolleys and crates should be mounted on wheels to enable more flexible movement and easier cleaning. Housekeeping and maintenance also require access around equipment.

Production cells should facilitate one-piece flow. A 'U' shape is desirable, where the work piece comes in at one end, is worked on at different stations, moving around the 'U' space, before leaving at the other end. Ensure the ergonomics are correct with tools, workpieces and the bench set up for comfortable operation by an employee of average size. Instructions or data should be easily visible as they work. Seating or standing positions should be checked, lighting should be to satisfactory minimum and the operator should not have to overstretch. A U-shaped layout of work cells has several advantages:

- The IN and OUT are close, allowing visual control and management, according to the production takt, a single person can handle both the cell feeding input and output
- Shorter distances enable work-sharing and transportation waste reduction
- These layouts provide convenient foundations for one-piece flow
- Communication among cell team mates is easier
- The work is done within the “U”, supplies stay outside
- Machines and tables are usually on rollers (if possible) for quick reconfiguration
- The floor space is generally smaller with a “U” cell than in a stretched line (including inventories and supplies), walk distances are also reduced, as they are Muda.

In order to fully implement the third principle, Pull, LM suggest using the *Kanban* system which is a scheduling system for lean and just-in-time manufacturing (JIT).

Taiichi Ohno developed Kanban to improve manufacturing efficiency. *Kanban* is one method to achieve JIT. The system takes its name from the cards that track production within a factory. For many in the automotive sector, *Kanban* is known as the "Toyota nameplate system" and as such the term is not used by any other automaker.
Kan (看) means "visual", Ban (板) means "signal". The *Kanban* is based on physical cards that agree to the production, purchase or handling of materials.
The aim of the *Kanban* is to avoid overproduction, which is the most impacting waste on a production system performance.
Kanban is an operational method for circulating information systematically within the company and possibly between company and suppliers eliminating the need for complex production planning systems. The *Kanban* is configured as a square card that contains the information necessary to produce, purchase or move components and materials in the production system. As a result, the *Kanban* is the driving force behind the company's operations, automatically managing the daily work orders, allowing managers to deal with problems and develop system improvements.

The Kanban can be divided into two main types:

- ❖ **Withdrawal Kanban** used to specify the kind and quantity of components and materials to move down the production process;

- ❖ **Production Kanban** that represents real production orders by which the upstream process is authorized to produce a certain component for a downstream process.

Kanban tags are placed on a container that contains a fixed quantity of a component. Only after this material is consumed the card is passed to the supplier who can restore the consumed components. The flow of materials in *Kanban* production is therefore defined as "pulled" because the production of a component is authorized only by actual consumption.

Kaizen = Continuous Improvement by Everybody! Everyday! Everywhere!
"Improvements in lean production companies should, in fact, come much faster – that is, learning curves should be much steeper – than in mass-production companies because of kaizen, the continuous incremental improvement in the production process" as we can read in the book "The machine that changed the world – the story of lean production".

Kaizen is the practice of continuous improvement. It was originally introduced into the West by Masaaki Imai in his book "Kaizen: The Key to Japan's Competitive Success" in 1986. Today *kaizen* is recognized worldwide as an important pillar of an organization's long-term competitive strategy. *Kaizen* is continuous improvement based on certain guiding principles:

- Good processes bring good results
- Go see for yourself to grasp the current situation
- Speak with data, manage by facts
- Act to contain and correct root causes of problems
- Work as a team
- Kaizen is everybody's business

One of the most notable features of kaizen is that big results come from many small changes accumulated over time. However, this has been misunderstood to mean that kaizen equals small changes. In fact, kaizen means everyone involved in making improvements. While most changes may be small, the greatest impact may be kaizens that are led by senior management as transformational projects, or by cross-functional teams as kaizen events (Bicheno and Holweg, 2008).

Kaizen Events (KE) usually last from 3 to 5 days of full work, may stop production, and involve both internal members of the organization and external managers called to help solve complex issues.

Bicheno and Holweg (2008) also sustain that KEs are a compromise between individual and greater improvements, such as value stream improvement, which entails the involvement of the whole line, making improvements, and fostering communication among people. The authors also suggest following a sequence of activities to prepare a KE: Before the beginning of the event, the company should select the area targeted for the improvement; during the event the team should identify the aim and the background of the event, observing processes, formulating hypotheses, trying to implement possible solutions and then checking results; at the end of the event a review session should be performed on a routine basis.

KAI = CHANGE 改

ZEN = GOOD 善

Within the logic of Kaizen, it is important to describe the PDCA (Plan Do Check Act) method, a key instrument to address problem-solving in a Continuous Improvement perspective.

The PDCA cycle encourages commitment to continuous improvement. PDCA, sometimes called the "Deming Wheel," "Deming Cycle," or PDSA was developed by the renowned management consultant Dr William Edwards Deming in the 1950s. Deming himself called it the "Shewhart Cycle," as his model was based on an idea from his mentor, Walter Shewhart.

Deming wanted to come up with a way to identify what caused products to fail to meet customers' expectations. His solution helps businesses develop hypotheses about what needs to change, and then tests them in a continuous feedback loop. (Tague, 2005)

The four phases are:

- PLAN: Identify and analyze the problem or opportunity, develop hypotheses about what the issues may be, and decide which one to test.
- DO: Test the potential solution, ideally on a small scale, and measure the results.
- CHECK/STUDY: Study the result, measure effectiveness, and decide whether the hypothesis is supported or not.
- ACT: If the solution is successful, implement it.

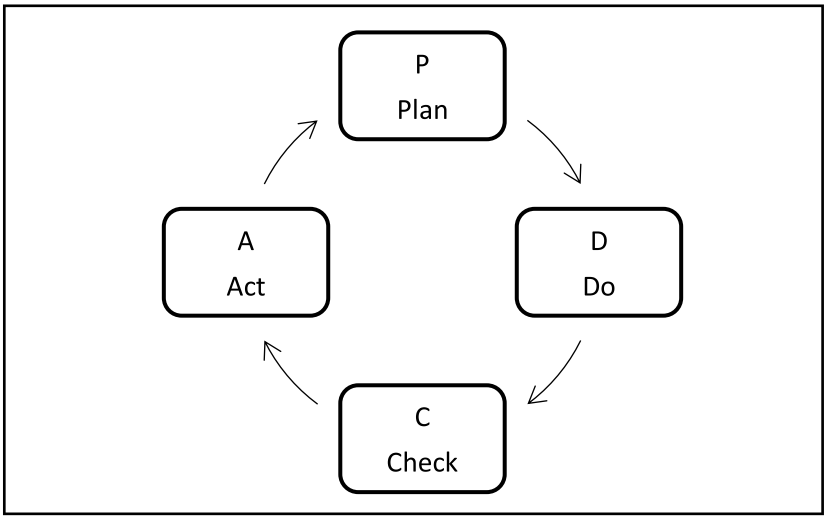

Figure 5: Representation of the PDCA cycle

The PDCA/PDSA framework can improve any process or product by breaking it into smaller steps. It is particularly effective to:

- Help implement Total Quality Management or Six Sigma initiatives and improve processes.
- Explore a range of solutions to problems, and pilot them in a controlled way before selecting one for implementation.

- Avoid wastage of resources by rolling out an ineffective solution on a wide scale.

The model can be used in all sorts of business environments, from new product development, project and change management, to product lifecycle and supply chain management.

A3 problem solving is a structured problem-solving and continuous-improvement approach, first employed at Toyota and typically used by lean manufacturing practitioners. It provides a simple and strict procedure that guides problem-solving by workers based on the PDCA principles just mentioned. The approach typically uses a single sheet of ISO A3-size paper, which gives it its name.

On this sheet, workers should identify different aspects and fill in the corresponding areas on the sheet:

- ❖ The first aspect is **Background**, identification of the context details, highlighting the relevance of the problem;

- ❖ The second is **Current conditions**, a brief description of the issue;

- ❖ The third is **Goals**, a description of expected results;

- ❖ **Analysis** is the fourth and is related to the identification of the root-cause of the problem;

- ❖ The fifth is **Purposed countermeasures**, workers should formulate possible solutions for all the problems identified and also plan their implementation;

- ❖ **Effect of confirmation** is assessment of the effectiveness of countermeasures;

- ❖ The last one is **Follow-up**, to schedule periodic reviews of the issues, record improvements and communicate them to the rest of the organization.

The ultimate goal of the *A3* technique is to ensure transparency in problem-solving processes, enhancing people's involvement through a standard sequence of activities to address these issues (Shook, 2008).

Lean *Six Sigma* is a method that relies on team effort to improve performance by systematically removing waste and reducing variation. It combines lean manufacturing/lean enterprise and Six Sigma to eliminate waste.

What *Six Sigma* provides, however, is not a statistical method to photograph the quality of processes; the most interesting applications are associated with process improvement. Starting from an analysis of the status quo ("what is Sigma today?") and applying an adequate method of Structured Problem Solving, companies that have introduced this approach launched a campaign of improvement projects aimed at increasing the sigma value, i.e. an exponential reduction in the number of defects. In short, simplified processes, by eliminating activities that add bureaucracy and non-value from the customers' point of view, increase speed and significantly reduce errors.
The term Six Sigma refers to the statistical value of Sigma = s, representing the standard deviation around a target and indicating the concentration of the data collected around its average value.
n = 6 number of times the sigma is contained in T / 2.
Working under contract conditions of "Six Sigma" means setting the contractual specification limits to ± 6 sigma for which the value that sigma must assume is contractually established equal to 1/6 of the specified tolerance.
Lean Six Sigma not only increases revenue and reduces costs, it positively affects people by engaging them in improving the way they work. Since employees are closest to the actual work (production of a product or delivery of a service) of any organization, they become the best resources to understand how to improve the efficiency and effectiveness of business processes.

Level of Sigma in processes	Number of defects/ million	Quality cost estimated
2	308.537	Not available
3	66.807	25-40% of turnover
4	6210	15-25% of turnover
5	233	5-10% of turnover
6	3.4	< 1% of turnover

Table 5: Correlation between Sigma, Defectiveness and Quality costs

By participating in successful Lean Six Sigma projects, employees can build confidence and become your business's most important assets. Studies show that when employees feel that they have a positive effect on the organization, they perform better, are more accountable and live happier lives. And once employees get comfortable with Lean Six Sigma skills, they can continue to find and remove problems and waste in an organization. Lean Six Sigma is simply an effective method used to fix a problem. It is based on common sense practices and is completed in five phases:

1. *Define*
   Identify the problem that needs to be solved or the activity to be improved

2. *Measure*
   First, the team must establish the current state, or the "baseline" of the process before making any changes. The baseline becomes the standard against which any improvement is measured.

3. *Analyze*
   After creating, verifying and examining detailed process maps created in the Measure Phase, the team will be able to list concerns or pain points within the process.

4. *Improve*
   The team's efforts at this stage are to produce as many ideas as possible based on the idea that from Quantity comes Quality.

5. *Control*
   The team has been building a form of infrastructure throughout the life of the project, and during the Control Phase it begins to document exactly how it wants to pass that structure on to the employees who work within the process.

In general, Lean Six Sigma may be defined as the combination of key LM principles and the Six Sigma approach with the purpose of eliminating waste, optimizing the use of resources, working areas and productive cycles to ensure great productive quality and better processes management.

In the following Chapter, a literary review helps define how all these techniques and tools can be measured and explains the overall level of implementation of LM at one company.

CHAPTER 2: LEANNESS MEASUREMENT METHODS: LITERATURE REVIEW

2.1 LITERATURE REVIEW OUTLINE

Since its first implementation in companies of different industries, both businesses and academics strove to come up with ways to measure the degree of LM adoption in a process, or even better, in an entire company. Indeed, the organizational paradigm was not limited to the automotive sector (Womack, 2006), and lean principles were applied in service and manufacturing companies, healthcare and public administration and even in accounting, marketing and finance departments (Brian H. Maskell and Bruce L. Baggaley, 2006).

As most researchers focus on the effect of LM implementation on business performances and results (Jasti and Kodali, 2015; Negrão *et al.*, 2017), there is no thorough research or analysis on Lean measuring methods (Lucato *et al.*, 2014) and this chapter aims at summarizing some of the most discussed ones. This study was prompted by the need to analyze different points of view about Lean adoption and different ways of implementing it. Moreover, this paper may be used by companies as an internal instrument for their own improvement and perhaps to bring about changes within their businesses. Its aim is to make everybody inside and outside companies aware that they are working well if they comply with one of the most important Lean principles - continuous improvement. This chapter compares different methods, from fuzzy approaches to more basic examinations of key success factors in processes.

Schonberger (2011) first distinguished lean **efficiency** from lean **effectiveness**. With **efficiency** the author refers to local acts that, for example, reduce storage time for a working piece or the turnover of a final product. That kind of time-based efficiency is central to most lean activities. Hence, the metric proposed is **time in queue**. Although this is one of lean's priorities because of customer sensitivity, it has disadvantages when compared to **number in queue**; another possible deficiency of this metric is the lack of **in-place visibility**.

Effectiveness defines a long-term variable that can be judged reliably. For its enduring role, a great amount of information is required. The metric the author deems suitable for lean effectiveness is **inventory turnover**. Inventory turnover, computed as the cost of goods sold from the income statement divided by the value of inventory from the balance sheet, generates a numbered value. Furthermore, thanks to Little’s law, it is also a function of lead time, flow time, throughput time or cycle time.

In the following literature review dealing with the extent of LM adoption at company level, we shall speak about leanness to identify different methods and techniques.

The structure adopted is:

- Identification of metrics and elements that determine LM implementation;
- Methods and measuring techniques to assess a company's leanness degree;
- Definition and degree of leanness for a company.

The chosen structure shows different methods that start from similar bases, have the same purpose, and offer a sort of path to guide readers through several empirical analyses. As a result, in Chapter 3 the implementation of the methods described will be tested in an empirical analysis on companies in north-eastern Italy. After deciding which methods are more reliable and appropriate in this particular situation, the thesis analyzes in depth LM adoption in the samples, identifies the elements that seem to be more correlated in the implementation of future and more complex techniques, and discusses possible effects of these processes in the final results of a company.

2.2 DIFFERENT LEANNESS MEASUREMENT METHODS

The topic of this chapter is to analyze which direction some of the most famous authors suggest evaluating company leanness. As mentioned above, identification of measurement indices is essential not only for academics and researchers, but also to help companies carry out internal inspections on their LM level of implementation and success. What is really surprising in this analysis is not so much the lack of literature, rather that the topic “assessment” has not yet stimulated any discussion. In fact, some of the authors analyzed do not elaborate on Lean implications and avoid any argument regarding leanness and the hypothesis of any kind of measurement (Wan and Chen, 2008). In addition, some of the following case studies are focused on the principle of efficiency as “produce more using less”, which is closely associated with the principle of waste reduction, without considering the application of any LM techniques, which are the true instruments through which results are achieved.

The various studies, each of which with different methods, parameters and indicators speak for the lacking literature. For instance, Soriano-Meier and Forrester (2002) provide a method based on surveys given to managers and employees. There were two types of surveys: one, addressed to production and operations managers, was used to gauge the extent of adoption of lean production principles; the second one, for managers and managing directors/CEOs, was used to measure the level of management commitment to lean production. The “degree of adoption of lean production principles" (DOA), was measured by asking the respondents to rate the degree of adoption of lean production principles on a list of nine principles. The respondents rated their answers on a seven-point scale with scores ranging from 1 (No adoption) to 7 (Total adoption), with a score of 4 (Partial adoption) as the middle point of the scale. The mean and standard deviations were computed with the scores of these nine answers. The mean is the value of the dependent variable DOA. The “degree of leanness" (DOL), was measured as the mean value of the nine separate variables in the model developed and tested by Karlsson and Åhlström (1996): waste elimination, Continuous Improvement; Zero Defects; JIT deliveries; Pull of materials, Multifunctional teams, Decentralization, Integration of functions and Vertical Information System. The paper shows that there is a close relationship between managerial commitment to JIT/ TQM and investments in the supporting manufacturing infrastructure; there is a correlation between the companies' claims they adopted lean production and the actual changes made in this direction; and there is a positive relationship between investments in SMI and actual changes towards lean principles and performance.

Doolen and Hacker (2005) also studied a measuring method on multiple dimensions integrated within a lean enterprise system, using a survey to gather data. They identified six impact areas

– Workforce management, Customer relations, Supplier management, Manufacturing equipment and processes, Shop floor management and New product development – attributing each of them a set of secondary activities. The evaluation scale went from 0 to 5 according to how frequently each practice was used, and then the average score of the practices represents the corresponding average level of implementation of each area.

A widespread method is the use of fuzzy logic, a form of many-valued logic in which the true value of variables may be any real number between 0 and 1. It is employed to handle the concept of partial truth, where the truth value may range between completely true and completely false. For instance, Seyed Mahmod Zanjirchi *et al.* (2010) performed a measurement using this technique. The purpose of the authors was to identify a method that could weigh the inexact human assessment for measuring organization leanness. It starts from the definition of lean attributes, so to define a common reliable scale for every person to judge. The second step is to define linguistic attributes that correspond to a specific value in the scale to grasp what people really think. Here, it is important to create a common viewpoint on concepts between researchers and experts called to verify. The authors continue the discussion introducing **enablers**, factors inside the company that help the implementation and operation of LM techniques. Hence, though fuzzy logic and a particular algorithm, they calculate the Fuzzy Leanness Index.

Bhim Singh, S.K. Garg and S.K. Sharma (2010) rearranged fuzzy logic to discuss the concept of leanness and provide an efficient measurement method for leanness in manufacturing companies. The method is based on the judgment and evaluation given by a leanness measurement team (LMT) on various leanness parameters such as supplier's issues, investment priorities, lean practices, and various waste addressed by lean and customers' issues. Further, fuzzy set theory is introduced to remove the bias of human judgment, and finally defuzzification is done and results are presented as leanness index (see Figure 6). This method is assumed to have a history of 40 points and goal of 80 points on a 100-point scale for all parameters. A team of five experts in lean implementation is selected for the study and asked to rate the said parameters according to the goal and history of the measurement method, so each evaluator awards scores between 40 and 80 points.

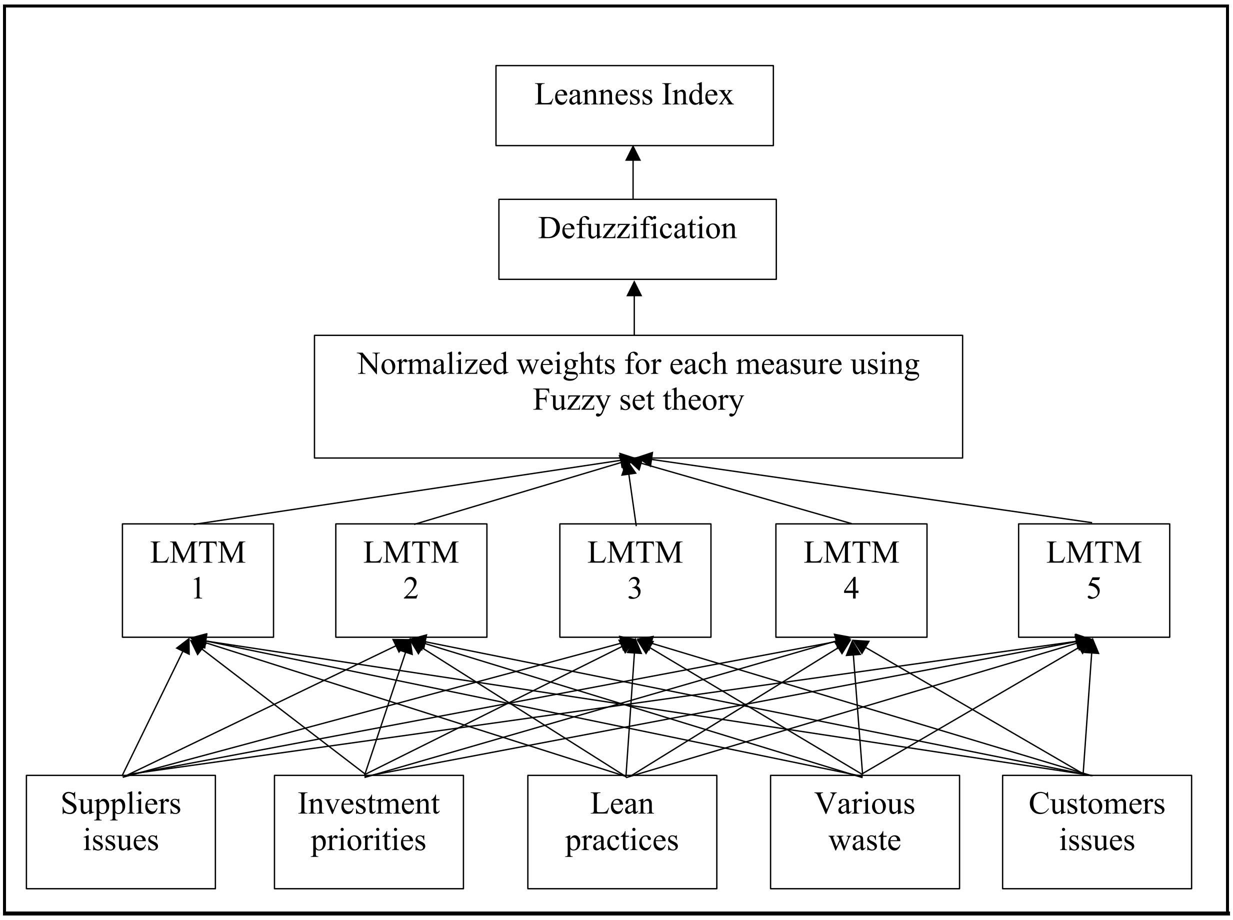

Figure 6: Representation of measurement model by Bhim Singh *et al.* (2010).

Similarly, Chan and Qi (2003) applied fuzzy logic to their research. The authors referred to parameters like supplying, inbound logistics, core manufacturing, outbound logistics and marketing and sales; they revealed the key issue in existing performance measurement methods, especially in the Supply Chain Management context, and also proposed a cross-organizational performance measurement method.

The same logic was applied by Chew *et al.* (2004), who use fuzzy logic on 28 parameters that affect the technical evaluation score for curtain walls and cladding facades. They developed a technical evaluation index attributing the following relative weightages of 37.8 percent to design, 3.6 percent to construction, 14.5 percent to customer satisfaction, 41.6 percent maintenance and 2.5 percent to environment factors.

As previously said, Lean manufacturing principles are based on the assumption that a company is at its best when it minimizes physical waste and maximizes its available resources. Implementing lean manufacturing policies and procedures is a great way to increase company productivity and operational efficiency, as well as to save money. To ensure that lean practices are correctly used throughout your business, a lean audit is usually necessary. Several methods can be applied to conduct an informative lean audit.

Sanjay Bhasin (2011) focused precisely on Lean audits. Indeed, existing audits fail to fully encapsulate the complexities of an organization's value chain and the significance of culture and change to the success of Lean. His paper developed an extensive audit that could establish the juncture of an organizations' Lean journey. It was piloted within 20 manufacturing organizations in the UK. A total of 104 separate indices were used, grouped in 12 distinctive categories. In this framework, Lean could be viewed as a journey consisting of seven stages; Table 6 summarizes the indicative characteristics that an organization should display at each stage. Organizations at the final stage will have experienced every one of the preceding six stages. Most organizations fail to reach the top stage, and this is reinforced by the lack of successful Lean implementations.

Among the authors that discussed Lean audits, Saurin *et al.* (2011) studied the applications of Lean practices in a manufacturing automotive company. This study presented a framework to assess the use of Lean Production with two innovative characteristics as

- it focuses on assessing the extent to which LP practices are used at cell level, unlike previous methods of lean assessment that focused on lean principles and/or outputs in the plant as a whole;
- It includes a model of the relationships between lean practices, which helps to put into practice the so-called need to understand LP from a systemic viewpoint.

Stages of Lean journey	
Seven stages	Indicative organizational characteristics
Planning	No implementation; benefits evident but no infrastructure and no organizational decisions have been implemented.
Developmental	Implementation started; pilot area selected, and work commenced; no roll out; few tools with little subsequent commitment; may have been implemented in other areas; importance of culture not recognized.
Mechanical	Pilot progressing well; few tools embedded within internal organization but largely within manufacturing only; tools are implemented in a piecemeal fashion with little consideration of correlations; importance of culture not recognized.
Enhanced	Pilot proven successful; roll out program progressing in other key areas within the internal organization; predominantly manufacturing based; recognition that culture and the organizational practices need addressing but few tangible signs visible towards accomplishing this.
Holistic	Roll-out program on track; internal organization nearly incorporated; suppliers embraced and signs towards integration of the whole value chain; organizational and cultural developments still in their infancy.
Innovative	Lean principles applied across the whole internal organization; good progress towards integrating across the whole value chain; some cultural and organizational development issues fully implemented but further progress required; ingrained as a strategy.
Ideological	Lean tools, culture and organizational practices alongside the ideology implemented across every component of the value chain; recognized as a combination of value streams, Lean viewed as the way of working with a quest for perfection apparent.

Table 6: Seven stages of Lean journey defined by Bhasin (2011)

Moreover, the framework includes guidelines to define practices and attributes, and devises relationship models to make future framework adaptations to LP theory evolution and practice easier. Since these guidelines are explicit, they add conceptual precision and generalizability to the model, once possible adaptations are guided by well-defined principles. Indeed, such guidelines might be useful to adapt the framework to other sectors.

The paper written by Wan and Chen (2008) is based on a self-assessment perspective, in particular the authors suggest adopting a dynamic Self-Benchmarking approach based on Data Envelopment Analysis (DEA). In particular, this elaborates data through the Charnes-Cooper-Rhodes (CCR) model, a fractional program that compares the input/output variables of a set of decision-making units (DMU) to identify the best practices among them, which determine the benchmark for the efficiency score. The score is included between 0 and 1 considering their leanness level represented by the input/output ratio. If the production unit gets 1 it means that it is working at efficiency level, linked with the total absence of non-value-adding time and costs in the process. This can be called the ideal unit, and it represents the benchmark for comparing all other activities. The average of the scores totaled by all the productive units is considered the overall leanness of the production system. Apparently, the advantage of model proposed is to make readers easily understand the final result which is expressed on a scale from 0 to 1; it is also easily adaptable to any other production type.

Conversely, Taj's (2008) paper "Lean manufacturing performance in China: assessment of 65 manufacturing plants" is based on a study previously developed by Lee (2004) on overall leanness measurement. The purpose is to investigate the adaptation of lean production and assess its current state of practice in selected plants of several industries in China. More specifically, it is used as an assessment tool to evaluate actual manufacturing practices related to nine key areas of inventory: quality; processes; maintenance; control; suppliers; setups; team approach; layout/handling and scheduling. Manufacturing executives at manufacturing plants answered 40 questions in the assessment. Each response scores from 0 to 4 and a total score for each plant is recorded by adding average scores in all areas. Finally, the overall Lean Index is computed on the sum of nine section scores and on the specific weight of each section. The findings give some insight on Chinese industries. The oil industry leads in LM implementation followed by the computer, telecommunication/wireless and electronics industries. The findings from lean production system design-related questions show low scores in layout design, volume/mix flexibility, setup, visual factory, and point-of-use delivery. However, plants earn high scores in material flow, scheduling/control, on-time delivery of finished goods, and overall defect rate. The results cannot be considered exhaustive given the small number of companies analyzed.

Among the papers taken into account there are also those who failed to obtain satisfactory results, as is the case of Shan and Ward (2007) who used a method to assess the correlation between different interconnected lean factors without achieving an aggregate leanness measure for the whole company.

Lastly, a quick list of secondary methods that include Brill and Mandelbaum (1990), who suggest a mathematical model based on a set of tasks, their relative importance and machine performance. They provide a measure of machine adaptivity in terms of flexibility related to the previous parameters.

Kuhnle (2001) investigated a model without any mathematical formula. He demonstrated a model that supports change management by measuring the reconfigurability of manufacturing areas focusing on time consumption for reconfigurability. Its parameters were lead time, quality, budget, personnel capacity, personnel flexibility and machine flexibility.

Sharma and Bhagwat (2007) developed a balanced scorecard (BSC) using finance, customer, internal business, process and learning growth as indicators. The BSC gave a SCM evaluation and proposed a method to prioritize the different performance levels in any organization using an analytical hierarchy process approach.

To sum up, considering the literature and the analysis of measuring methods, although there is no perfect and tested instrument for the assessment of overall company leanness, there are some fundamental criteria to comply with:

- ❖ the method must be simple and easy to understand for readers (e.g. expressed in numbers from 0 to 1 or in percentages);
- ❖ it has to consider the actual implementation of LM practices;
- ❖ it has to be flexible and easy to adapt to different situations;
- ❖ it must measure the diffusion and actual efficiency of practices, considering the department involved.

The effective use of some models and the implications they have – and therefore the search of a right method to identify the "Leanness Index" – are deeply indagated in Chapter 4 - the analysis over the sample collected.

Authors, Year	Overall Leanness Assessment	Practices-based	Formula used	Remarks
Soriano-Meier and Forrester (2002)	X	X	Hypothesis testing	Developed and tested the model that can evaluate the degree of leanness possessed by manufacturing firms.
Doolen and Hacker (2005)	Missing	X	Data survey analysis	Elaborate a measuring method on multiple dimensions integrated with lean enterprise system.
Zanjirchi et al. (2010)	X	X	Fuzzy logic	Method that weight the human assessment for measuring overall leanness in organizations.
Singh et al. (2010)	X	X	Fuzzy logic	The leanness measurement team (LTM) judge various leanness parameters.
Bhasin (2011)	X	X	Audit examination	Developed an audit able to establish correlation of lean in the whole company.
Saurin et al. (2011)	X	X	Audit examination	Build an innovative method based on use of practices at the cell level and a relationship among lean practices.
Wan and Chen (2008)	X	Missing	Data envelop analysis	Use the model of Charnes-Cooper-Rhodes comparing input and output in decision-making units.
Taj (2008)	X	X	Hypothesis testing	Tested the lean performances in China manufacturing plants.
Shah and Ward (2007)	Missing	X	Data envelop analysis	Elaborate a model to assess the correlation between interconnections among different lean factors.

Table 7: Summary of overall leanness measurement reviewed in the paragraph

2.3 LEAN MANAGEMENT IMPLEMENTATION ENABLERS

As previously anticipated, several authors tried to create a reliable method to measure lean implementation and improvement, each of them starting from different hypotheses and emphasizing different Lean principles and techniques. This is why the key performance factors, or the common **enablers** should be highlighted and analyzed to implement a Lean strategy correctly, and to measure it easily. The following paragraphs focus on what these factors are and why they are so important. It must be borne in mind that the studies presented so far come from different economic backgrounds, such as distinct industries (Doolen and Hacker, 2005), geographical areas (Marodin, 2016; Taj, 2008), company sizes (Negrão *et al.*,2017) and government policies. These assessing activities should improve five areas - elimination of waste; continuous improvement; continuous flow and pull-driven systems; multifunctional teams and information systems.

- Waste is anything in the final product that does not add value for the customer, like inventories, machine setups, machine downtime, movement of parts and scrap.
- Continuous improvement is the conviction that improvement efforts are never over, and it is consistency that maintains the discipline for improvement in place.
- One-piece flow and Pull-driven systems - the ability to forego batch mentality and adjust processes to accept smoother movement of products through the line. Products are going to be triggered by the pull of customers in each process.
- Multifunctional teams - In Lean implementations, teams have more responsibility and autonomy, so improvement and problem-solving can happen closer to the source. Also, to make flexibility in the line feasible, a multi-skilled workforce is required.
- Information systems - reduction of vertical levels in the structure, and the autonomous operation that teams have to reach requires employees to have timely access to better information to enable problem solving and decision making. It does not necessarily mean, but it certainly does not exclude, computerized information systems.

It is necessary to show progress and to assess the effectiveness of the different changes, tools and techniques that are implemented. For each of the improvement dimensions, several indicators and metrics can show progress (see Table 8).

General dimension	Metrics and Indicators
Elimination of waste	• Work in process (WIP): Value of WIP in the line. • Setup time: Time spent in setups/ total productive time (percentage). • Machine downtime: Hours-machine lost due to malfunction/Total machine hours scheduled (percentage). • Transportation: Number of parts (trips) transported and distance. • Space Utilization: How much area does the line need, including its WIP and tools.
Continuous improvement	• Number of suggestions per employee per year. • Percentage of suggestions that get implemented. • Scrap: % of the products that need to be scrapped. • Rework: % of the units that need to be sent to rework.
Continuous flow and Pull-driven systems	• Lot sizes: Average lot size for each product. • Order flow time: Time an order spends being processed in the shop floor. • Order lead time: Average time from the placement of an order (by a customer) to its delivery. • Pulling Processes: Percentage of the line processes that pull their inputs from their predecessors. • Pull Value: % of the total annual value or throughput of the system that is scheduled through pull mechanisms.
Multifunctional teams	• Autonomous control: % of quality inspection carried out by the team. • Work team Task Content: % of the tasks required to make the product performed by the team. • Cross training: Average over team members of Number of skills a team member possesses/Number of skills needed in a team. • Number of employees capable of assignment rotation.
Information systems	• Frequency with which information is given to employees. • Percentage of procedures that are documented in the company. • Frequency with which the line or cell progress boards are updated.

Table 8: Enablers for Lean implementation measurement by Vienazindiene and Ciarniene (2013)

For instance, Fullerton *et al.* (2003) suggest investigating the positive impact of a high degree of Just-In-Time in terms of performances measuring the implemented practices. The authors identify 10 practices: total quality control, quality circles, JIT purchasing, Kanban, uniform workload, multi-function employees, total productive maintenance, focused factory, group technology reduced setup times. Each practice is evaluated on a Likert scale that goes from 1 (No implementation) to 6 (Fully implemented).

In their study Viagi *et al.* (2017) investigate the enablers of lean implementation in Brazilian SMES, and the factors identified are knowledge and sponsorship of senior management; Focus on continuous improvement; Employee development fostered by the company; Company orientation process; Industry with great competitive focus on reducing operating costs and Industry with great spread of lean practices. The authors highlight that the main factor in successful Lean implementation and measurement is awareness of benefits by the senior management. This commitment not only reflects and promotes the strategic importance of each Lean Transformation initiative within an organization, but also supports and encourages the commitment of resources involved, it motivates and focuses on the results of the changing process. The second aspect, which should not be underestimated, is the culture oriented towards continuous improvement, a constant drive to process betterment that is key for a successful organization. Empowering all team members within an organization to continuously seek opportunities for improvement is what leads to a strong company. This concept is closely associated with the third factor, employee development fostered by the company.

Similarly, Vinod and Chintha (2011) base their model on a multi-grade fuzzy approach. Their system is divided into three levels. The first level is made up of five leanness enablers; the second level has 20 lean criteria; and the third level has several lean attributes. The authors want to review the overall system from various perspectives. For example, the management responsibility enabler can be explained following two perspectives, i.e. organizational structure and nature of management as shown in Table 9.

Enabler	Criteria	Attributes
Management responsibility leanness	Organizational structure	• Smooth information flow • Team management for decision making • Interchange-ability of personnel
	Nature of management	• Clearly know management goal • Management involvement • Transparency in information sharing
Manufacturing management leanness	Customer response adoption	• Prevalence of continuous improvement culture • Empowerment of personnel to resolve customer problems
	Change in business and technical processes	• Employee's attitude tuned to accept the changes • Conduct of pilot study on new • Production/business processes
	JIT flow	• Pull production system • Produce small lot sizes • JIT delivery to customer • Optimization of processing sequence and flow in shop flor
	Supplier development	• Providing technological assistance to suppliers • Provide training in quality issues to the supplier personnel • Providing financial assistance to the suppliers
	Streamlining of processes	• Adoption of value stream mapping • Quantification of seven deadly wastes
	Cellular manufacturing	• Focused factory production system • Organization of manufacturing operations around similar product families • Utilization of manufacturing cells
Workforce leanness	Employee status	• Flexible workforce to accept the adoption of new technologies • Multi-skilled personnel • Implementation of job rotation system
	Employee involvement	• Strong employee spirit and cooperation • Employee empowerment
Technology leanness	Manufacturing set-ups	• Flexible set-ups • Less time for changing the machine set-ups • Usage of automated tools used to enhance the production • Active policy to help keep work areas clean, tidy and uncluttered
	Productive service	• Product designed for easy serviceability • Service centers well equipped with spares

	Integrated product design	• Usage of DFMA principles • Practice job rotation between design and manufacturing engineering • Usage of product data management (PDM) systems • New ways of coordination of design and manufacturing issues
	In-house technology	• Design and development of proprietary items for own use • Improve present equipment before considering new equipment • Develop dedicated technologies for specific product use
	Production methodology	• Management's interest towards investment on FMS concepts • Application of lean manufacturing principles for waste elimination • IT application to exercise better vendor and supplier management
	Manufacturing planning	• Utilization of advanced MRPII systems • Usage of ERP systems • Execution of short-range planning • Company's procurement policy based on time schedule • Strategic network in SCM to exercise zero inventory system
Manufacturing strategy leanness	Status of quality	• Product exceeding the customers' expectations • Conduct of survey/studies to ensure quality status • Usage of TMQ tools
	Status of productivity	• Productivity linked to the personnel prosperity • Reduction of non-value-adding costs • Quality is not infused at the cost of productivity • Application of totality concepts in achieving productivity
	Cost management	• Kaizen method of product pricing • Costing system focusing on the identification of value adding and non-value adding activities
	Time management	• Scheduled activities • IT based communication system

Table 9: Conceptual model for leanness measurement by Vinodh and Chintha (2011)

Organizational structure criteria are attributes like smooth information flow, team management for decision making and personnel interchangeability, while the nature of management criteria is based on the clear knowledge of management objectives, management involvement and transparent sharing of information.

Vinod, together with Balaji, also authored a paper (2011) that presents a completely different index for leanness assessment always based on fuzzy logic. In particular, the paper designs a decision-support system, called FLBLA-DSS (decision support system for fuzzy logic-based leanness assessment) that calculates the Euclidean distance and identifies the weaker areas which need improvement. Like in the previous model, enablers are divided into five perspectives made up of 20 leanness criteria which are defined through 59 leanness attributes.

The tests listed in the last paragraph suggest that application of the same techniques might differ among companies, according to the area in which they are diffused. Consequently, the implementation of LM practices could create a misunderstanding in data analysis and in the measurement of the overall leanness degree of one company. In particular, if we analyze a company that implements several tolls but focuses exclusively on a few departments, and another firm using fewer tolls, but diffusing them all over the entire organization, the general degree of leanness will be higher in the former company, simply by considering the number of techniques adopted.

In addition to all the enablers and variables mentioned so far, internal diffusion must be considered to calculate the leanness degree of a company completely and correctly. The main concept this Chapter wants to emphasize is that LM is not a simple set of tools, practices and principles that companies can just implement as mere operating instruments, they are actually mandatory elements of a more complex, well-oiled machine, a basic part of the total system.

CHAPTER 3: RESEARCH AND DESCRIPTION OF THE SAMPLE

3.1 DATA COLLECTION

As the goal of the third chapter is to assess the effect of Lean on company performance indicators, research was carried out with the following indications: an online database called AIDA[3] provided a list of companies selected by grouping both financial and non-financial data from the 200,000 best-performing companies in north-eastern Italy; some of these companies were contacted via telephone and e-mail and asked to fill out a questionnaire with more specific data than those available in the database, in particular about Lean practices and industry 4.0 adopted by their companies. The questionnaire was written in Italian.

About 3,000 e-mails were sent and 250 complete questionnaires were collected, providing valuable information to be used for analysis in addition to that collected by the online database.

The questionnaire was drawn up on the online platform Survey Monkey and sent through a link that automatically collects data from replies and creates an Excel file.

The questionnaire was divided into three parts: the first concerned general data of the companies, for example their name, number and percentage of turnover abroad, province of activity, if they have any plants abroad, their main market and so on. Some data (turnover, number of employees and date of foundation) were asked in order to check the data provided by AIDA.

In the second part of the questionnaire, questions focused on technical aspects of the company production systems, like job rotation and its percentage, the portfolio of products sold, the layout adopted, and if they apply industry 4.0 techniques.

The last part of the questionnaire concerned Lean, and only companies that applied Lean were invited to continue the questionnaire.

The questions started with general topics, like the first year of implementation, the reasons why they decided to apply Lean Manufacturing, and then moved on to more specific ones, like the actual techniques implemented, in which department of the company, the people involved (internal or external) in Lean transformation, if they trained their employees and their level of

[3] AIDA is an online bank of data for Italian companies (“Analisi Infromatizzata delle Aziende Italiane”).

investment.

3.2 SAMPLE DESCRIPTION

The list of companies was downloaded following these three criteria:

- First, companies were selected from four Italian regions (Veneto, Emilia Romagna, Trentino Alto Adige and Friuli Venezia Giulia) in north-eastern Italy;
- Second, the companies contacted had more than thirty employees, which excluded small and medium enterprises;
- Third, only manufacturing companies with an ATECO 2007 code between 10 and 32 were selected.

Companies that went into liquidation were eliminated, which issued a list of 15,626 companies, 250 of which successfully submitted and completed the questionnaire.

In order to fully assess the impact of Lean, two analyses will be carried out: the first one focuses on the performance of only Lean companies over a period of seven years, while the second uses a diff-in-diff methodology among pairs of similar companies, one implementing Lean and one not.

For the first analysis, only companies that implemented Lean practices were chosen, regardless of their location, from 2008 to 2016, due to the fact that AIDA provides data from 2008 to 2017. In this case the sample shrank from 250 to 73.

The second part, the analysis uses the methodology called difference in differences (DID), in which all the population of the sample is compared in order to assess performances of Lean companies as opposed to Non-Lean ones.

To better understand the sample collected, companies may be divided according to different criteria: size represented in number of employees, distribution of data by province and turnover. All this information was then added to the one collected through the questionnaire.

SIZE (number of employees)

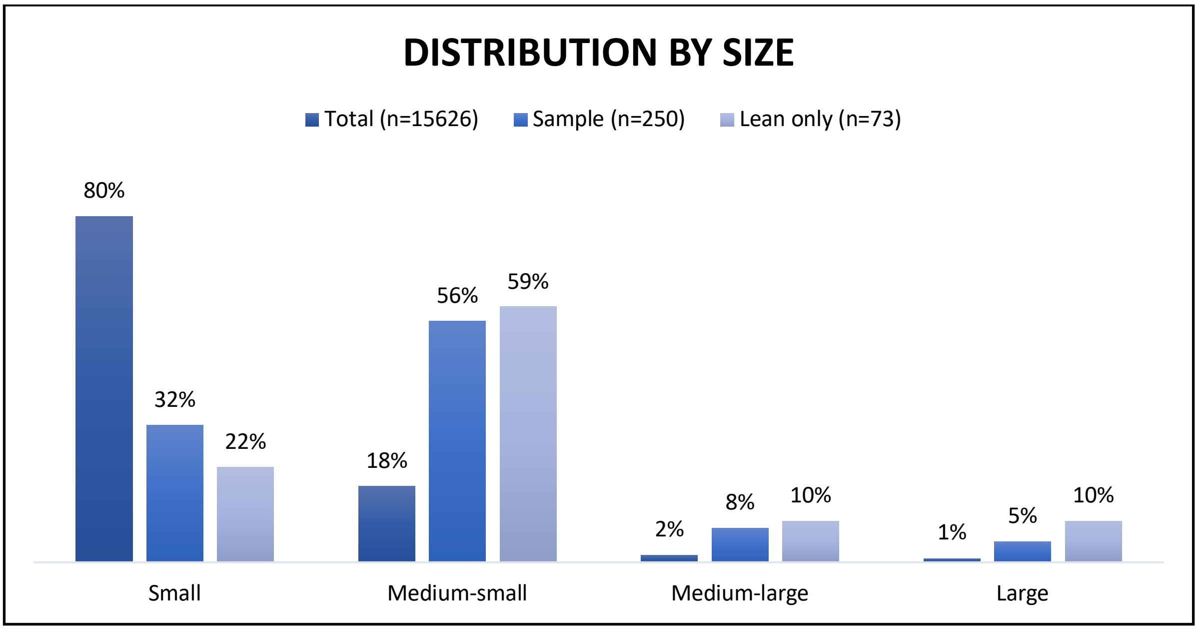

Figure 7: Division by size and samples

Companies divided by size, as shown in the above figure (Fig. 7), comparing the total list with the sample of 250 analysed in the survey and the 73 companies that will be used in the further analysis.

In Italy, most companies are SMEs (Small Medium Enterprises). In particular, in the regions selected, 80% are small companies, and among the companies that responded, the highest percentage is small-medium-enterprises (56%), which also corresponds to those that have implemented Lean (59%).

Companies were divided into categories using the following table about numbers of employees:

	Categories of employees	**Employees in the total list**	**Employees in the sample**	**Employees in Lean companies**
Small	From 10 to 49	12458	79	16
Medium-small	From 50 to 249	2735	139	43
Medium-large	From 250 to 499	282	20	7
Large	Higher than 500	151	12	7
Total		15626	250	73

Table 10: Criteria for distribution by size

Due to the fact that micro enterprises were excluded, there are no companies with fewer than 10 employees, while the highest number is 7100 employees, with an average number of 174 employees per company.

DISTRIBUTION OF DATA BY PROVINCE AND REGION

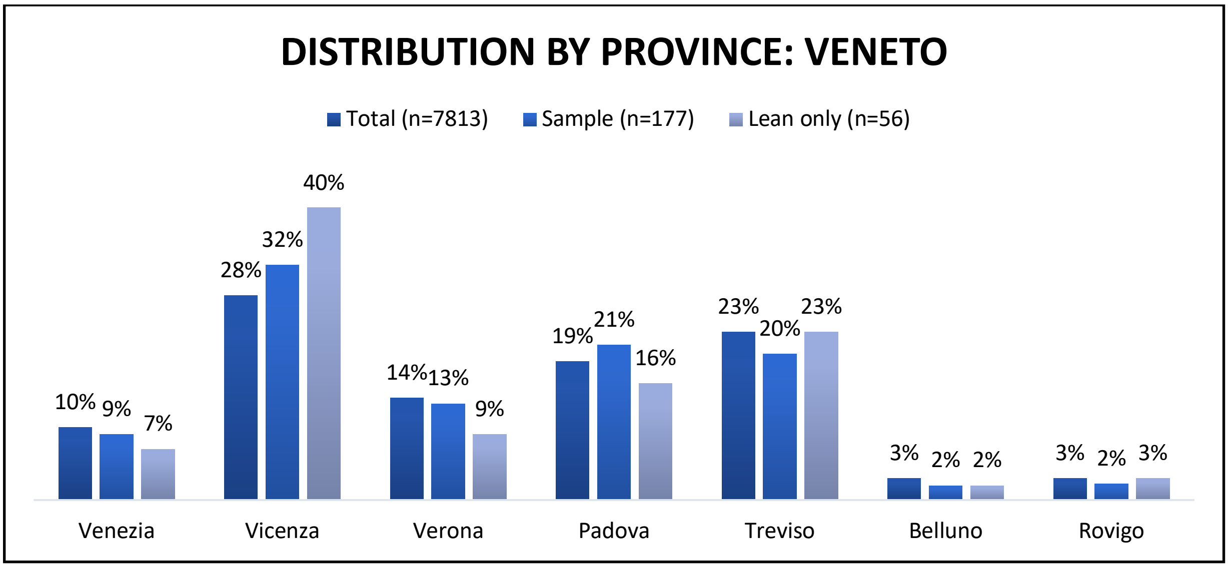

Figure 8: Distribution of data by province (Veneto)

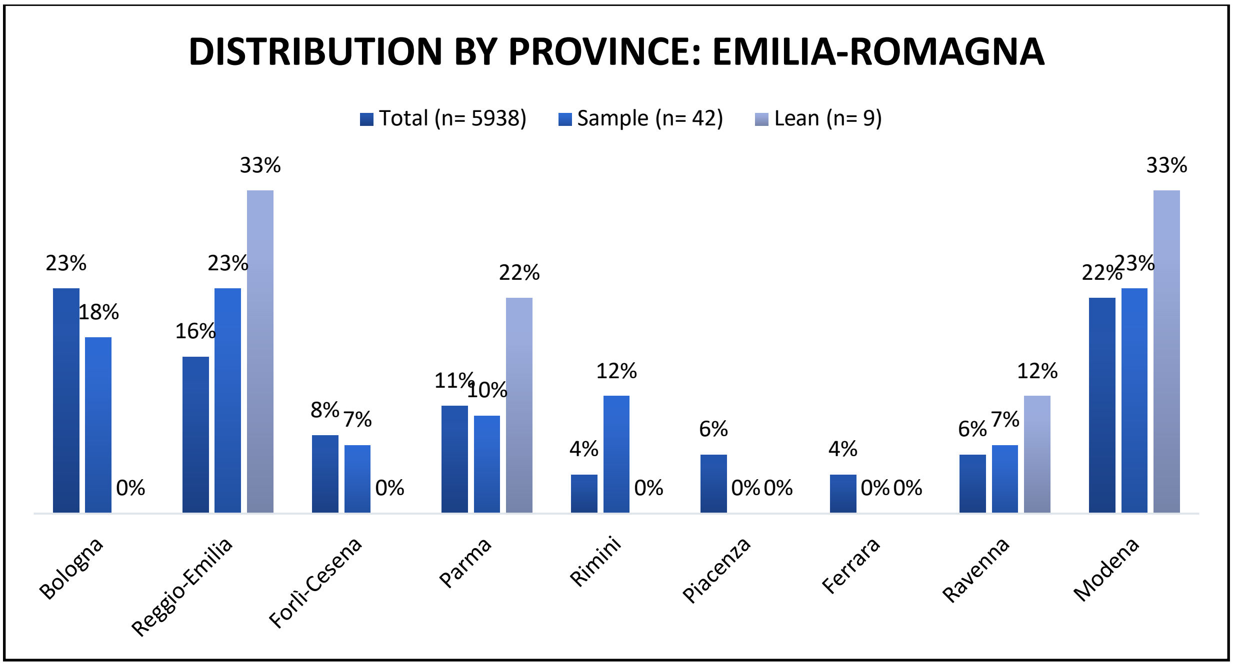

Figure 9: Distribution of data by province (Emilia Romagna)

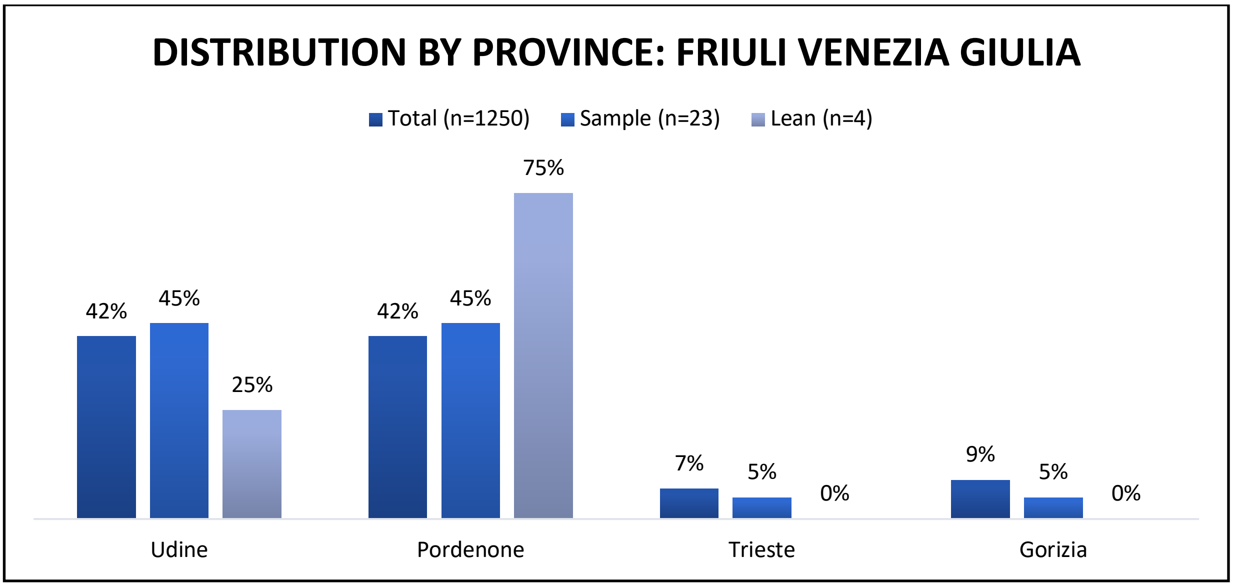

Figure 10: Distribution of data by province (Friuli Venezia Giulia)

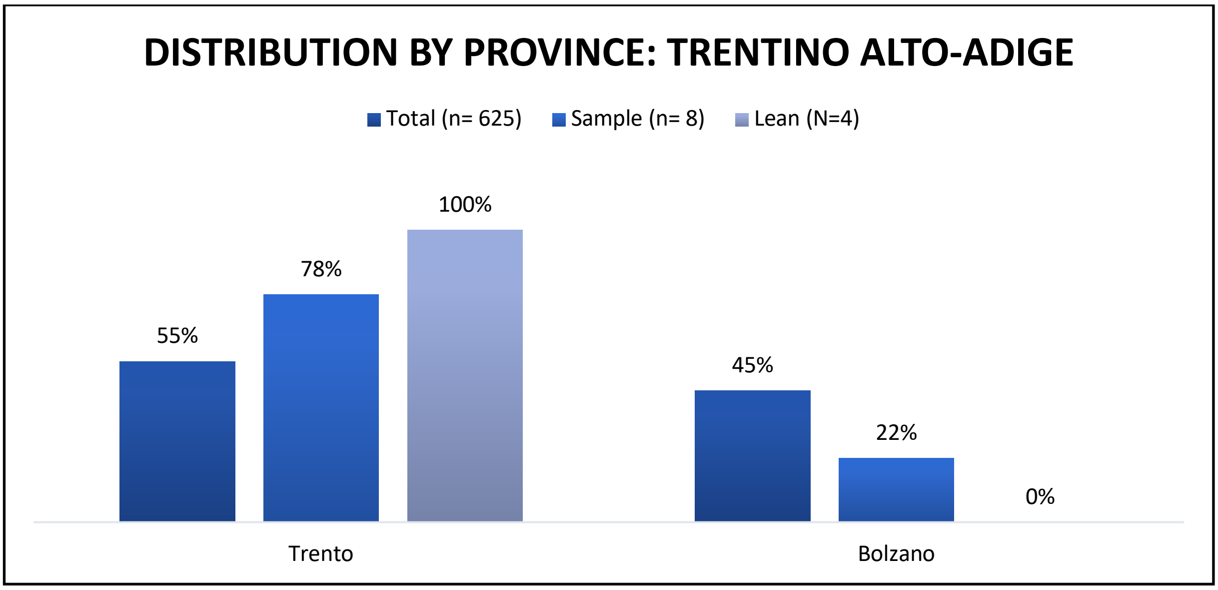

Figure 11: Distribution of data by province (Trentino Alto-Adige)

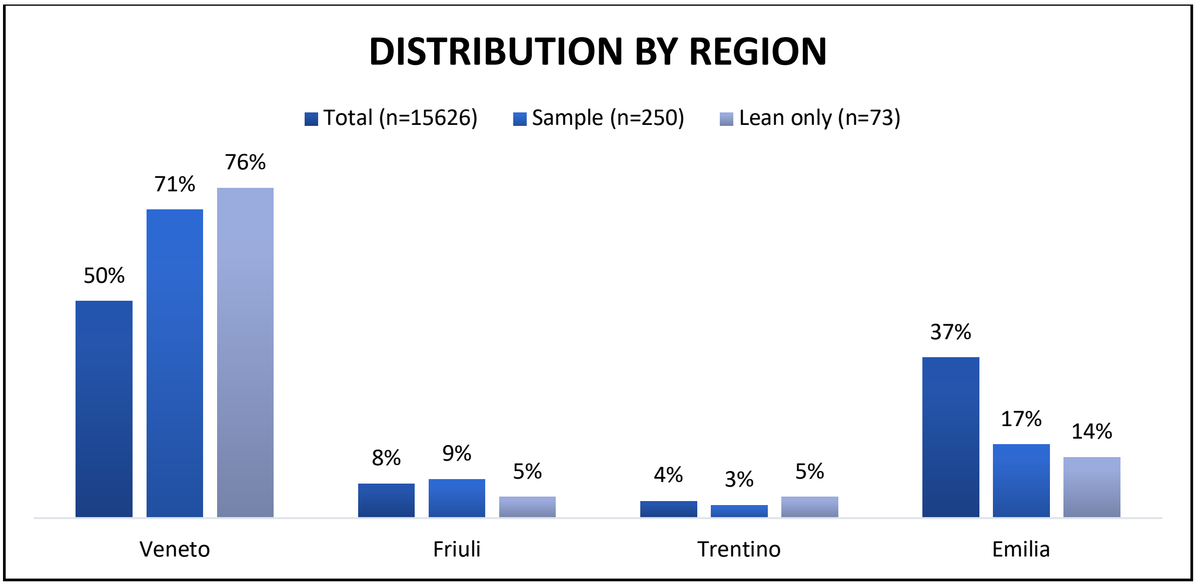

Figure 12: Distribution of data by region

The distribution of data by province is represented in figures 8 to 12: the aim is to determine if the data collected issue a good representation of the total list.

The graphs and similar percentages show that there is a good representation of all regions and provinces both in the sample collected and the one analysed.

More than half of the manufacturing companies sampled are in the Veneto region. At 16%, the second most represented region is Emilia Romagna, while there are small percentages of companies in Friuli Venezia Giulia and in Trentino Alto Adige, but this is also due to their size.

TURNOVER

The 2016 turnover is one of the financial data downloaded by the online database AIDA; most of the firms had revenues of less than 20 million (52%), a good percentage of companies in the sample had revenues between 20 and 50 million (24%).

The lowest number registered in the sample is 1.25 million, while the highest is 1.8 billion, and the average value of the sample is 53.8 million.

If we consider the sample of companies implementing Lean from 2008 to 2016, the highest percentage is companies with revenues under 20 million (38%) and the rest of the companies are equally divided between 20 and 50 and more than 50 million (30%).

The lower number registered in the sample is of 1.25 million while the highest is of 1,8 billion, and the average value of the sample is 53.8 million.

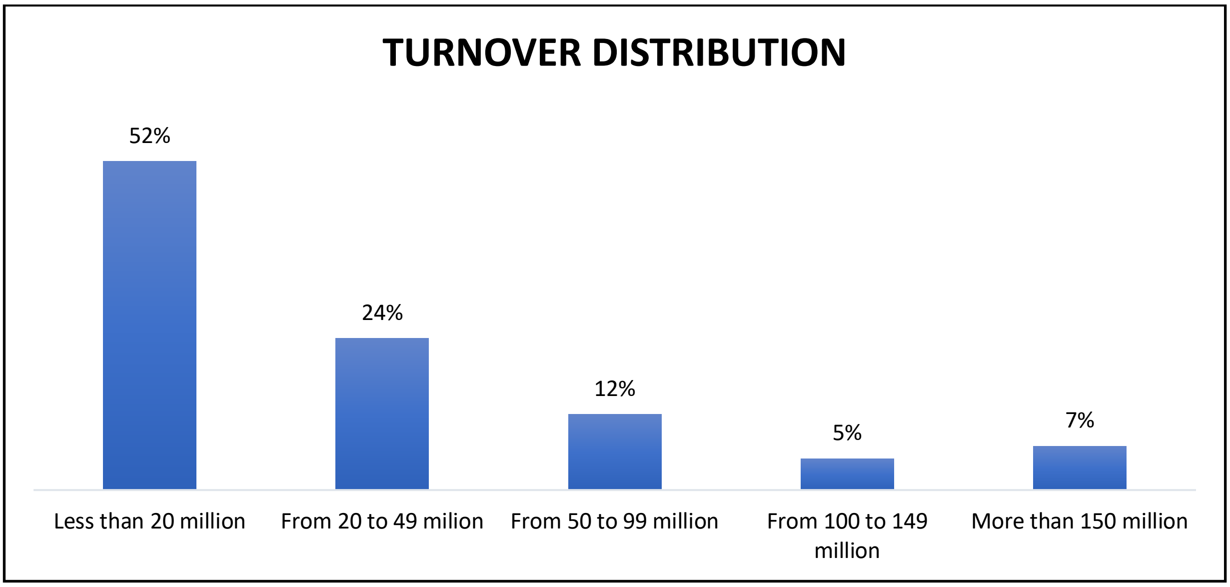

Figure 13: Division by turnover of the sample

The lowest number among Lean companies is 1.8 million, meanwhile the highest is 700 million; in this case the average value is 82.1 million, that is considerably higher than the average of the sample of 250.

All the information represented so far was collected on the AIDA online platform, and now all the data communicated by companies directly through the questionnaire are presented.

FAMILY BUSINESS

Family businesses are directed and controlled (at least 30% of the ownership) by a family group with a relevant number of family members within. In Italy, most companies are considered family businesses, around 85% of all businesses in the whole country.

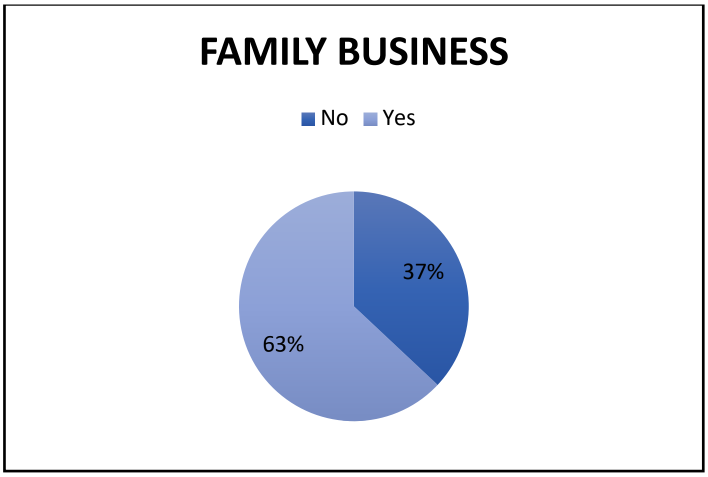

Figure 14: Family business percentage

The sample collected mirrors this datum, as 64% of the companies considered are family businesses, 66% of which implemented Lean in the period of time that is analysed here.

INDUSTRY 4.0

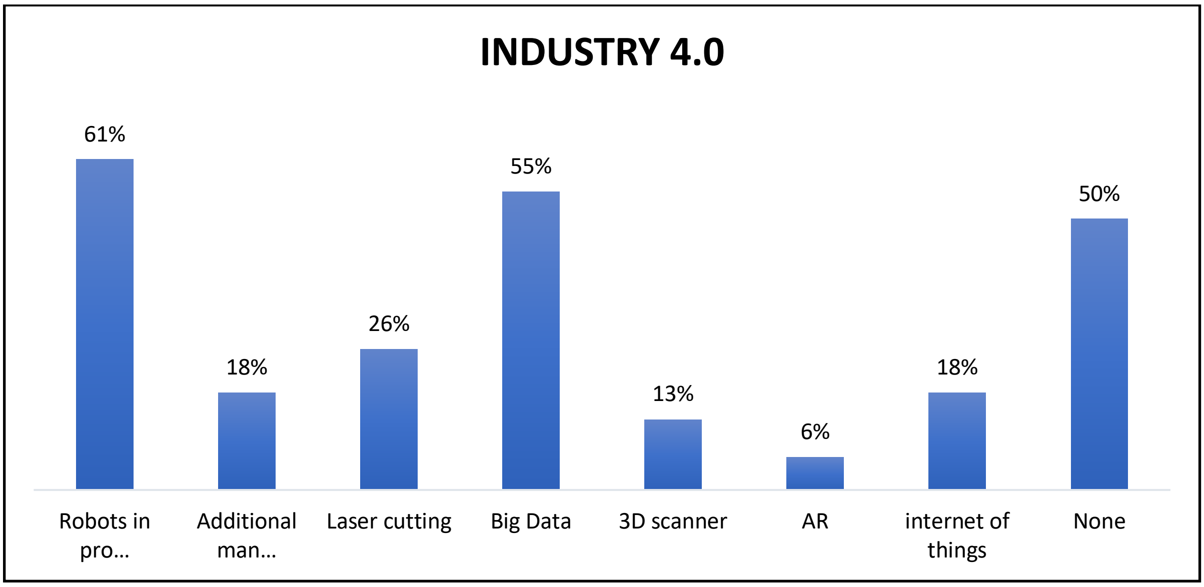

Figure 15: Elements of the Industry 4.0

The concept of Industry 4.0 is associated with the increasing company trend to achieve automation inside plants to improve labor conditions for workers, higher equipment quality and productivity through the use of new technologies - the question was whether they used any of the following techniques: robots in production, additional manufacturing (for example 3D print), laser cutting, big data[4], 3D scanner, AR[5], internet of things [6]or none of them.

As the figures reveal, Industry 4.0 is still not diffused in most of the companies interviewed, in fact 33% of the sampled companies did not implement any technique, and only 6% used it, considering only the companies that implemented Lean between 2008 and 2016. It is useful to highlight that a great number of companies did not answer this question.

Among the technologies mentioned the most used are robots in the production plant and the help of big data, 32% and 26%, respectively.

LEAN COMPANIES

As mentioned above, the third part of the questionnaire regarded Lean, as this is the main topic of this thesis. Only companies adopting Lean Manufacturing, so answering "Yes" to the question "Do you apply any Lean technique?" were asked more specific and technical questions.

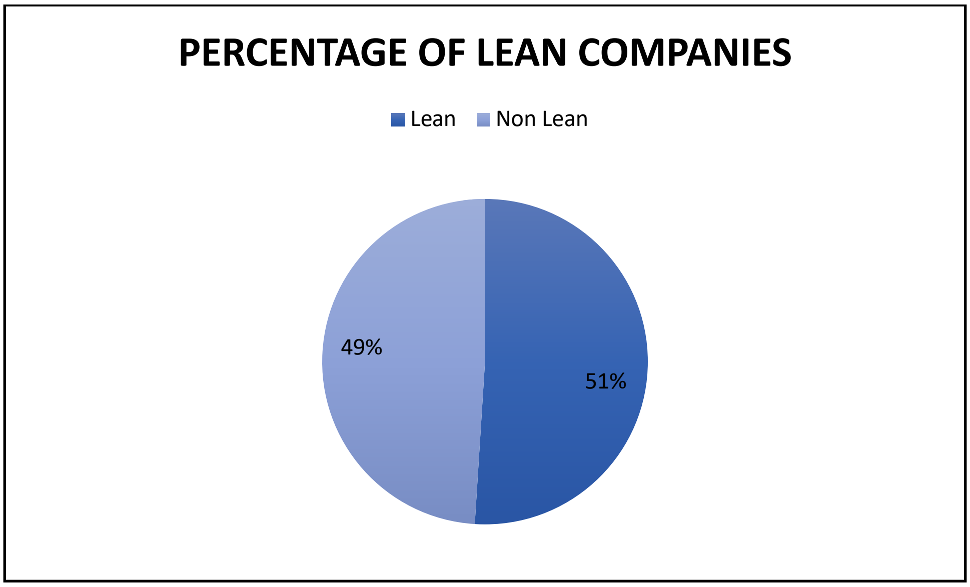

Figure 16: Presence in percentage of Lean companies in the sample

[4] Big data is a set of techniques and methods of analysis of massive data used for predictive analytics, user behavior analytics or other advanced analysis of a big amount of heterogenous data to find a connection between different phenomena.
[5] Augmented reality transforms the digital word in to real one to improve perceptions of workers and providing a different display of data.
[6] Internet of things refer to the connection of productions machineries and equipment with internet, in order to quicker reveal error and collect data.

In the sample of 250 companies, those implementing Lean were 51%, and for the analysis in chapter 4, only 73 are relevant.

More in-depth analysis (Figure 16) reveals that most companies applying LM are classified as medium-small (58%,) according to the criterion on the number of employees described before (from 50 to 249 employees).

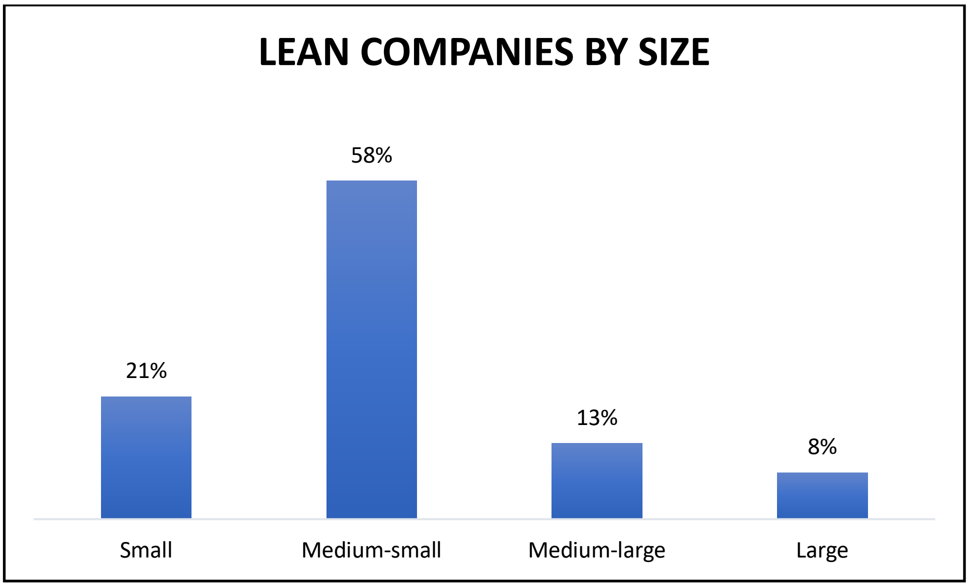

Figure 17: Lean companies divided by size

Lean transformation is not only operational but also cultural, and to implement Lean successfully, all the company personnel should be involved in the change.

Lean companies chose to involve people in the Lean change in different ways, covering different roles in the processes, as shown in the graph below (Fig. 17).

Supervisors are involved in 88% of cases, and operators with a similarly high percentage, because they are fundamental elements of Lean (73%); it is also important to notice that in just half of the cases CEOs are involved (48%).

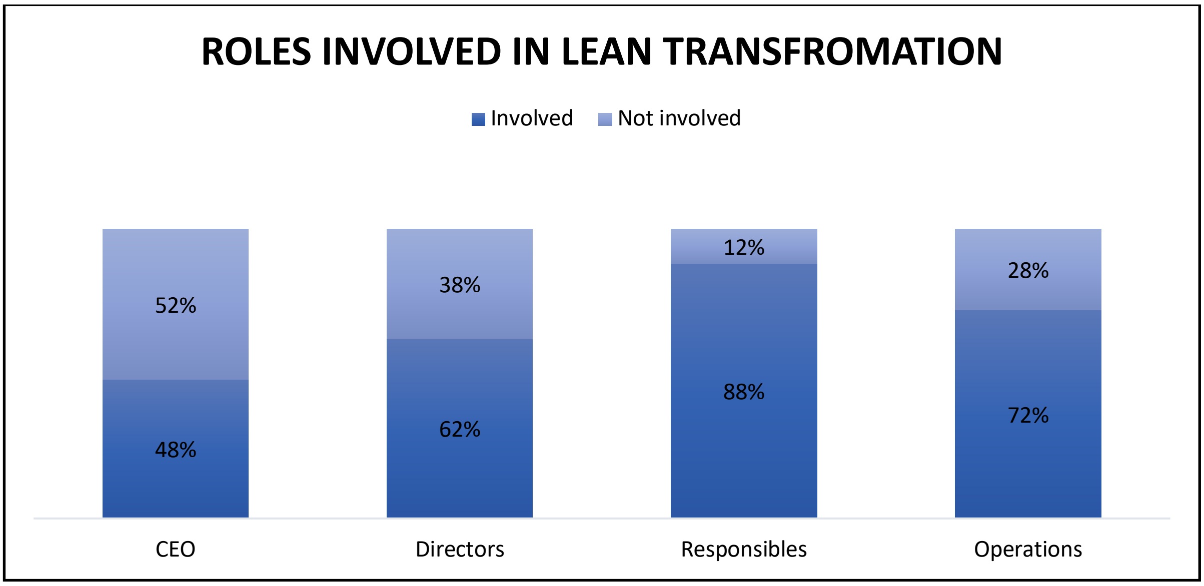

Figure 18: Percentage of roles involved in Lean Transformation

Considering that the Lean change is very important and expensive in terms of time and effort, some companies usually prefer to have some external consultants to check that everything works smoothly. The graph shows that 63% of firms prefer to hire an external Lean expert to guide them in the implementation and change of Lean, not only because they do not have any internal figure suitable for the role, but also because they do not have enough workers to do it.

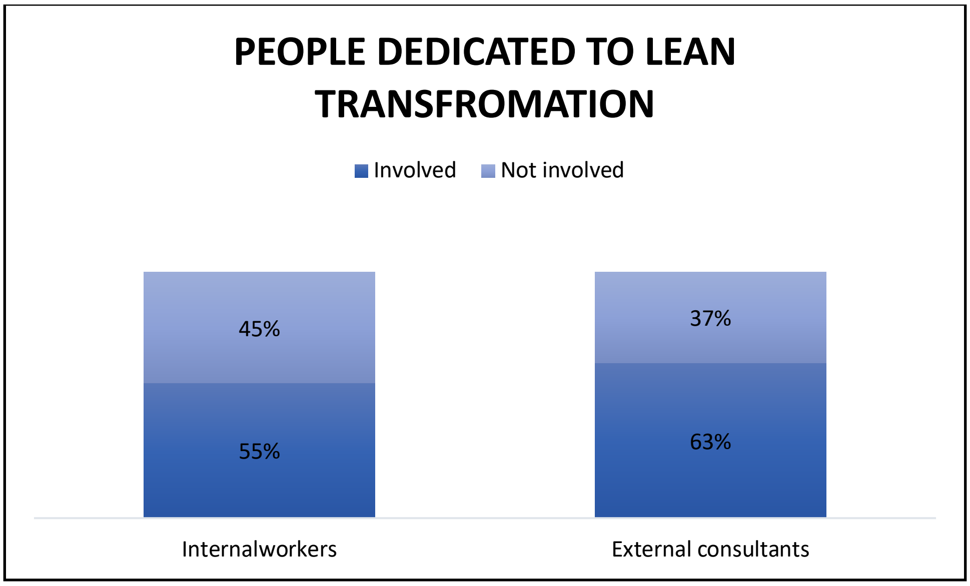

Figure 19: Percentage of people dedicated to Lean Transformation

Only 20 companies, (16% of the firms that implement Lean), opted for internal workers only.

Later in the thesis, Lean companies are divided by year of implementation, because time is an important variable in these changes. Indeed, researchers like Womack, Jones and Ross (1990) sustained that Lean production techniques need time and commitment to be successfully implemented.

Hence, in the graph above, companies are divided by the number of years they have been implementing Lean: less than 5 years is the most represented category with 41%, and the second category is between 6 and ten years (25%). It is important to highlight that seven companies (5%) adopted Lean more than ten years ago, at the beginning of the 21st century.

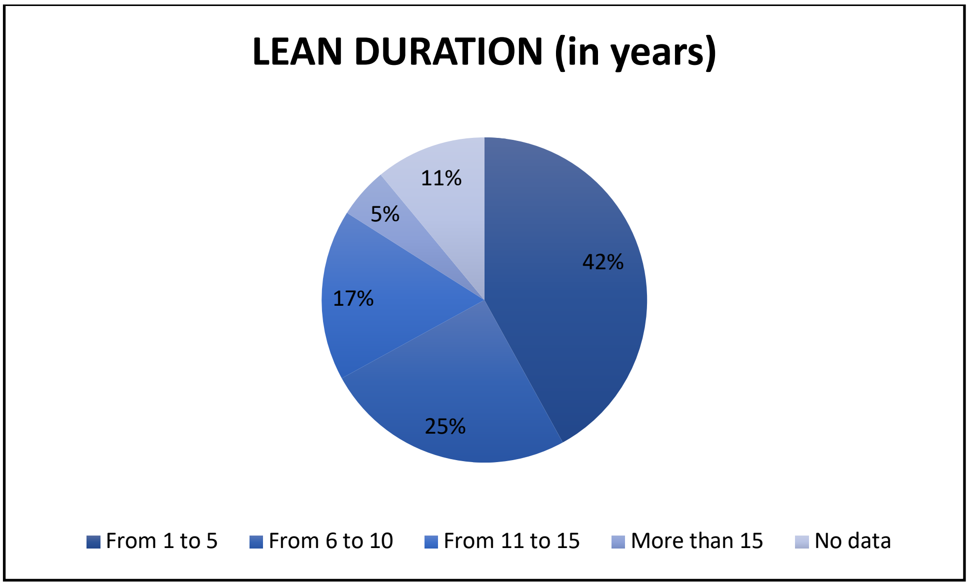

Figure 20: Years of adoption of Lean

Considering the sample of 128 companies applying Lean, only 54% declared they invested part of their revenues in Lean improvement, with an average investment of 3.35 million.

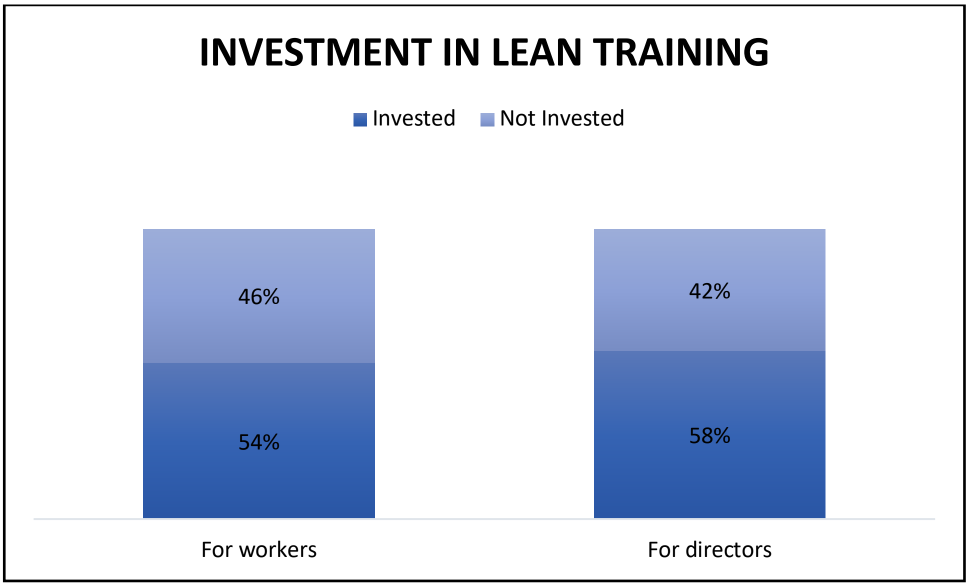

Figure 21: Investment in training (%)

In the first chapter the majority of the techniques of Lean were described in order to clarify how companies adopt Lean and implement this organizational change. In the survey firms filled out which of those tools were applied. The data collected were summarized in the graph below (Fig. 22).

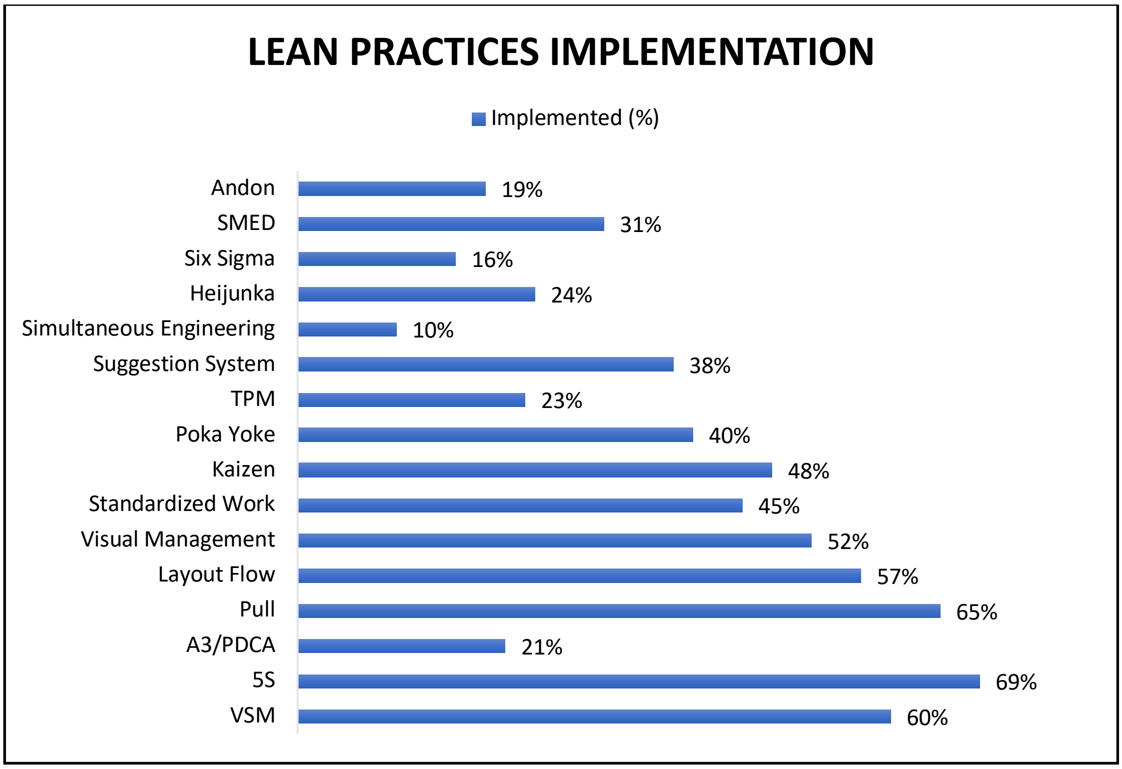

Figure 22: practices implemented in companies (%)

The graph highlights that the most applied technique is 5s (69%), and also PDCA cover an important percentage (65%). While the technique applied the less is the Simultaneous Engineering with an application percentage of 10%.

FINANCIAL INDEXES

A series of financial indexes were selected to describe the sample collected and to analyze company performances: Ebitda[7]/Sales and ROA.

Ebitda/Sales is a ratio used to assess company profitability by comparing revenues with earnings.

ROA is a financial index identified as the net income over the average total asset, and it is a

[7] EBITDA means Earnings before Interests, Taxes, Depreciation and Amortization.

measure of profitability of company assets in generating revenues, what a company can do with what it has.

Bearing in mind that the aim of this thesis is to analyse performances of companies to assess the true effect of Lean, data must be divided between companies that implement Lean and those that do not.

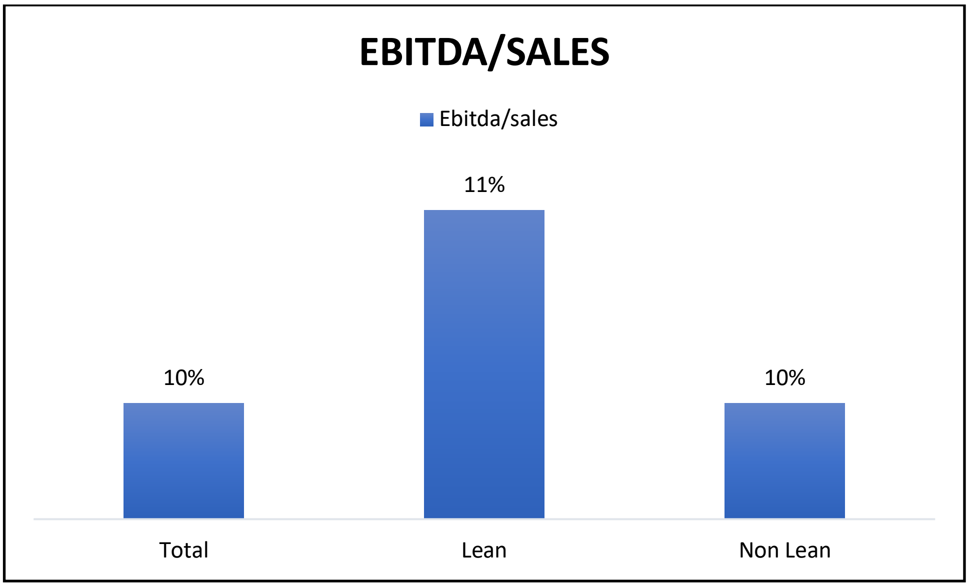

Figure 23: Ebitda/Sales comparison

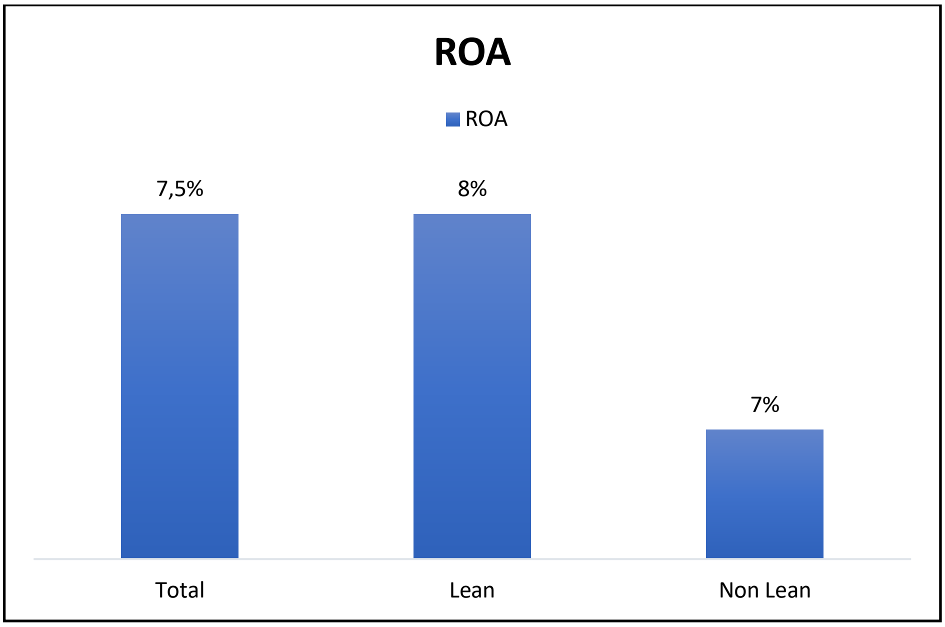

Figure 24: ROA comparison

Figures 23 and 24 compare the three indexes registered by Lean companies, the rest of the companies and the average of the entire population; it is immediately clear that companies implementing Lean have better performances that the average of the total companies in the four regions investigated.

As regards the graph presented before, it is important to notice some evidence of the facts whose root causes will later be extensively analysed. The graph related to Ebitda/Sales shows that Lean companies perform slightly better (11%), than the average of the total population (10%), and also better than Non-Lean companies alone (10%).

Looking at the ROA, differences are minimal between each category, but in general the same is found in the two variables: Lean companies perform better than the others and reach a level of performance even better than the average, although the measures observed are very similar.

In the next chapter, Lean is thoroughly analysed first to show its effects over a period of 7 years, a regression to understand if there are correlations between economic results and Lean practices and an analysis over comparable companies.

CHAPTER 4: ASSESSMENT ON LEAN COMPANIES

4.1 METHODOLOGY

In this chapter different analysis were conducted in order to assess the performances of Lean companies of the sample previously descripted: a first analysis considering only Lean companies that have implemented Lean in the period between 2008 and 2016, a significant test for the variables analyzed, a regression and in the end the study on a smaller sample of comparable companies. For the first analysis the variables selected to assess performances are: Ebitda/Sales and ROA.

The Ebitda/sales is a financial ratio used to assess the profitability of the company in percentage, dividing its revenues with its earnings. In particular, Ebitda is derived from revenues and represent the value of earning remaining after the account of all operating expenses. It can be defined also as Ebitda Margin, higher is the value recorded for this measure more is able the company to keep its earnings at a good level via efficient processes and operations.

Ebitda can be viewed also an index of company liquidity. Indeed, a comparison between the total revenue gained and the residual net income before expenses is made with this measurement reporting also the real amount a company can expect to receive after operating costs have been paid. It is not the proper index for liquidity, but it gives the possibility the same to understand the ability of a company to cover its debts.

The Ebitda to sales ratio can be considered more reliable when comparing companies with similar size and belonging to the same industry. This because different companies have different cost structures across industries, furthermore in our analysis indexes were divided by the average value of the industry calculated on the ATECO 2007 code (4 digit). So, it is possible to define the analysis as standardize for the average, in order to wash data from external effect or environmental factors or crises. In this way what should be clear is the influence of Lean on companies' performances.

ROA (Return On Assets) is an indicator of the profitability of a company in relation to its assets. It gives to companies' managers, stakeholders or analysts on how the company is efficient at using its assets and resources to generate gains. It is displayed as a percentage and it is calculated as Net income over Total assets.

Total assets of a company are the sum of its total liabilities and shareholders' equity. Both of these types are at the base of the investments in the company. Sometimes to the formula is added interest expenses in order to contrast the negative effect of debt in case companies use more debt than equity to finance its operations.

Higher is the number of ROA, higher are the earnings of company with less investment. Also, for this variable it should be better to compare the ROA among companies of the same industries. Even the numbers related to the ROA analysis are all standardized as explained before.

It is also described a regression in order to understand the correlation between economic performance represented by the Ebitda/Sales variable and the practices implemented in Lean companies.

Later in the chapter a regression on Lean practices will be presented and also will be formed from the sample 9 couple of firms in order to verify in a smaller study the influence of Lean.

The latter analysis will use as variable of measurement not only Ebitda/Sales but also the Gearing ratio. The Gearing ratio, calculated as Total Debt over Total Equity, is a measure of the extent of companies leverage. It is used by companies to gauge the extent to which a company is taking on debt as a means of leveraging its assets. A high Debt/Equity ratio is often associated with high risk; it means that a company has been aggressive in financing its growth with debt.

These variables will be used to better understand the differences in performance among Lean companies and Non-Lean companies in different time period and situations.

4.2 RESULTS AND DISCUSSION

All the analysis made on data are represented below in order to explain the influence of Lean on companies' performance. Initially there is a presentation of the average level of Ebitda/Sales and ROA over a 7 years period. The choice of seven year is based on the fundamental hypothesis: Lean is considered to improve performances in that period of time and then to stabilize it.

Hence, the graph in the figures represent a comparison over a period of 7-9 years, in particular the period between 2008 and 2016. It is possible to notice how in the Ebitda over sales comparison Lean companies achieve always a better result, moreover the graph shows that in the first four years there are opposite trend, then for both categories there is an improvement.

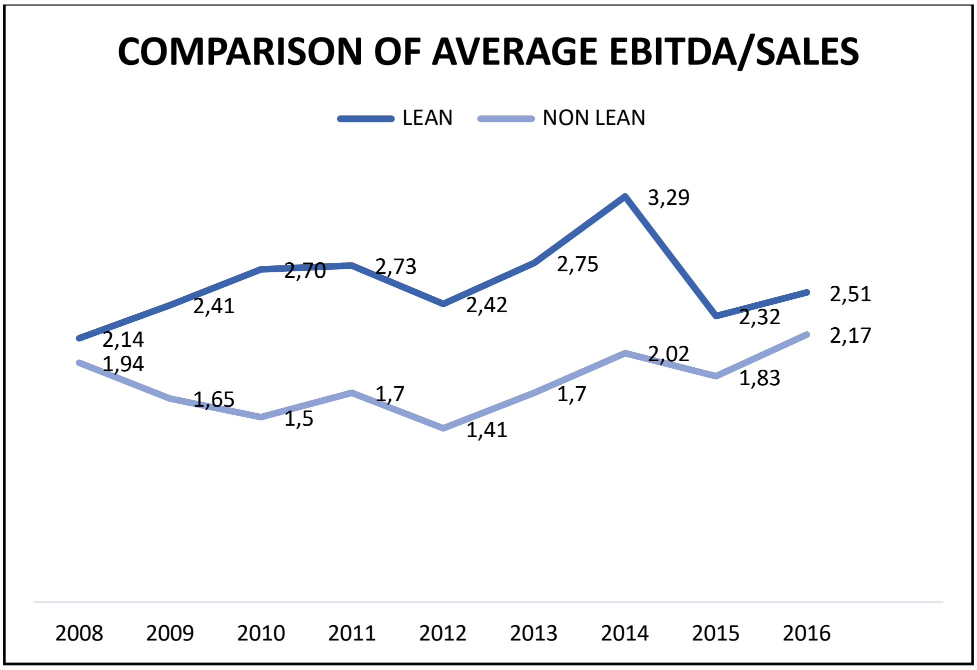

Figure 25: Effect of Lean on Ebitda/Sales of the companies

Instead in the second graph, where the variable compared is ROA, the result is slightly different. In the first years after implementation the average level of ROA for Lean companies goes under the average value for Non-Lean companies. This can be explained as results of implementation cost for Lean companies, moreover the majority of companies considered started Lean in the period 2010-2013, the only period where the ROA is under the level of Non-Lean firms.

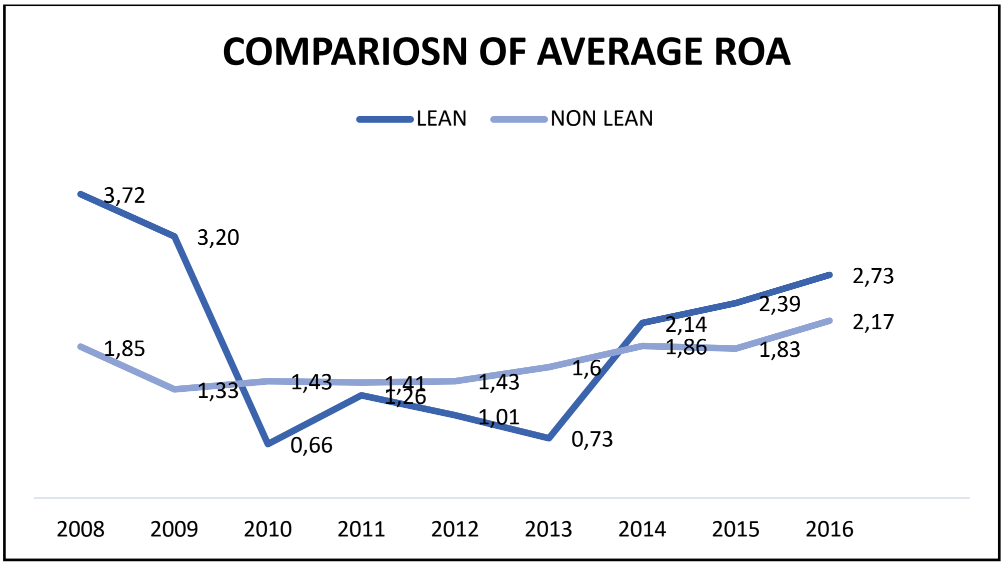

Figure 26: ROA comparison for companies in the sample

After a general introduction of comparison of data, to prove the general consistency the period analyzed is changed, shorter and referred to the last three years of data available (2015-2017). Data considered here are always an average, but they are not normalized for the average level of industries.

The comparison reveals positive results achieved both for Lean and Non-Lean companies and that Lean companies are always better in both results. So even if the phenomenon of Lean is considerably young, it is already a positive element for the success of one company.

Furthermore, in order to confirm what highlighted in these analyses it is performed a significance test. The significance test should confirm the based hypothesis that Lean help companies to perform better than the other.

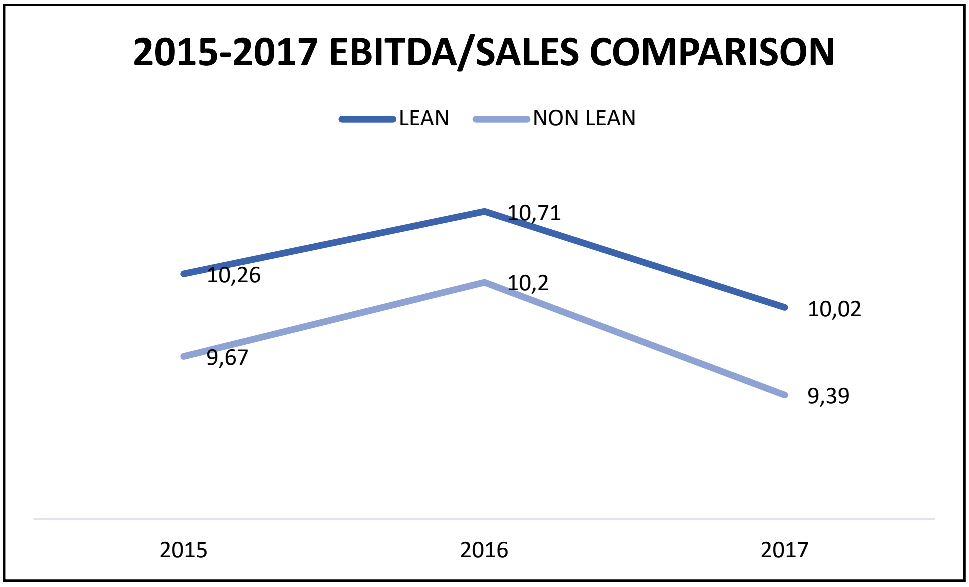

Figure 27: 2015-2017 Ebitda/Sales comparison

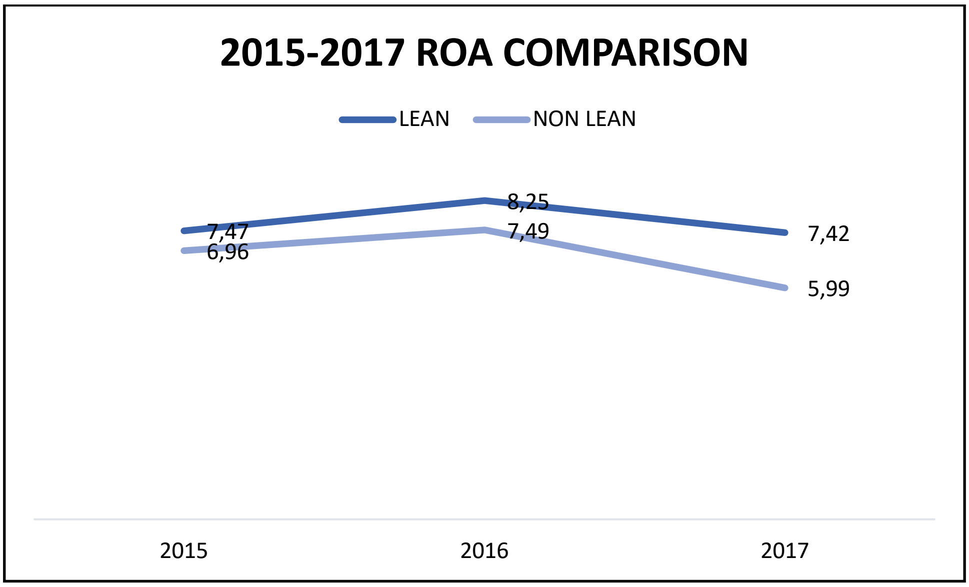

Figure 28: 2015-2017 ROA comparison

In order to understand if the values of the sample are significant or not, a hypothesis test can be developed for each variable and see if in the total population the means tend to be equal or different; in this case are considered two series of values: series 1 containing the values for Lean companies and series 2 containing the values of non-Lean companies. The hypothesis is the following, with a level of confidence equal to 95%:

$$\begin{cases} H0: \mu 1 = \mu 2 \\ H1: \mu 1 \neq \mu 2 \end{cases}$$

The null hypothesis (H0) indicates that, in the total population, the means of the variable tend to be similar and so that the sample is a good representation, the alternative hypothesis (H1) states the contrary. μ1 and μ2 are the means of the population while $\bar{X}1$ and $\bar{X}2$ are the means of the sample, and $S^2 1$ and $S^2 2$ that are the variances of the sample, while the size of the two series are n1=128 and n2=122.

The formula for the test statistic used is $T = \frac{\bar{X}1 - \bar{X}2 - \mu1 - \mu2}{\sqrt{\frac{S^2 1}{n1-1} + \frac{S^2 2}{n2-1}}} \sim N\ (0,1)$, used for large sample (n > 30) to test the difference between means.

Using the normal distribution tables, it is possible to determine the level of acceptation and rejections for our hypothesis: the range is $\pm$ 1.96, H0 is accepted, otherwise H0 is rejected and H1 accepted.

For the Ebitda/Sales variable $\bar{X}1$= 10.71 and $\bar{X}2$= 10.2; $S^2 1$= 51.2 and $S^2 2$= 49.5

$T_{EBITDA/Sales} = \frac{10.71 - 10.2 - 0}{\sqrt{\frac{51.2}{128-1} + \frac{49.5}{122-1}}}$ = 0.57; H0 is accepted.

For what concern the ROA variable $\bar{X}1$= 8,25 and $\bar{X}2$= 7,49; and $S^2 1$= 50.94 and $S^2 2$= 53.89.

$T_{ROA} = \frac{8.25 - 7.49 - 0}{\sqrt{\frac{50.94}{128-1} + \frac{53.89}{122-1}}}$ = 0.83; H0 is accepted.

Hence for all the parameters considered it is possible to observe that H0 is accepted, of consequence it is possible to assure that in the total population the means tend to be equal. This conclusion assure that the sample is significant and representative of the reality.

This analysis leads to investigate if among top and worst companies implement Lean and in which percentage. A company is classified as top 10% considering the average value of its Ebitda/Sales over last three years (2015-2017), the same method was used to identify the worst ones. Among top companies Lean is implemented in the majority of the companies (56%), but it not possible to assert that Lean grant the success of a company and excellent performance, as a matter of fact among worst companies Lean is implemented in the 36% of the cases.

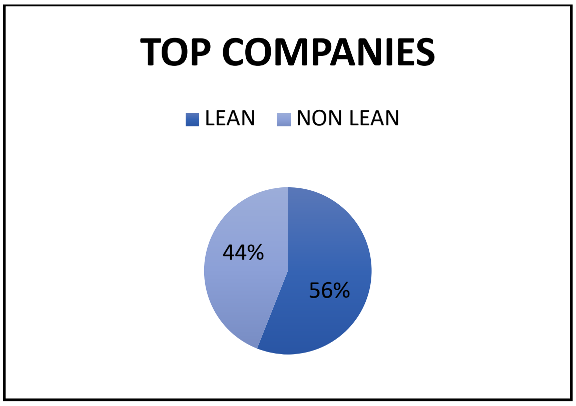

Figure 29: TOP companies Lean (%)

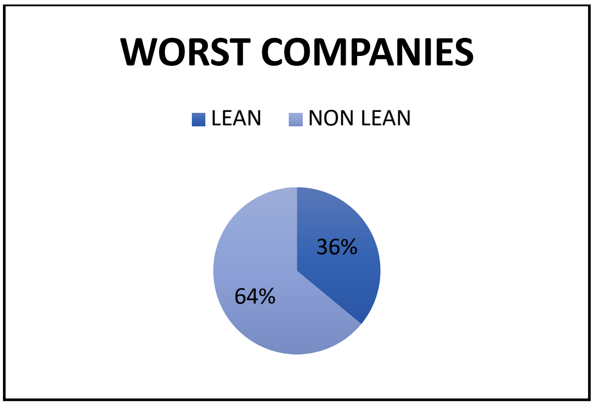

Figure 30: WORST companies Lean (%)

A wide used analysis to understand correlation between variables is the regression analysis, it relates on the relationships among a dependent variable and a one or more independent variables. In this particular the case the correlation searched is between Lean, Lean practices and Ebitda/Sales in Lean companies that have implemented Lean in the period from 2013 to 2017, the sample has been restricted to 188 companies.

The variables considered in addition to Ebitda/Sales are: the size of the companies determined as the number of employees they have; the type of manufacturing adopted; if they have plant abroad; if they are or not family business and what bundle of practices they applied: JIT (Pull, Flow and SMED), TQM (Andon, Poka Yoke, Six Sigma and Simultaneous Engineering) and TPM (Total Productive Maintenance). In this case the value of the variable can change depending on the number of practices correlated to the technique.

Number of observations: 188

R-squared: 0.054

Ebitda/Sales 13-17	Coefficient	Std. Error	z	P > |x|
Size	0.127	0.441	0.29	0.774
Type of manuf.	0.617	0.930	0.66	0.508
Abroad plant	1.216	-1.145	1.06	0.290
Family Business	0.710	-1.068	0.66	0.507
JIT	0.875**	0.337	2.59	0.010
TQM	-0.568	-1.128	-0.50	0.615
TPM	0.478*	0.269	1.78	0.077
Constant	4.172	-8.193	0.51	0.611

Table 11: Multiple Regression – Lean manufacturing adoption, Ebitda/Sales performance

The model suggested a strong positive correlation among performance and Lean practices related to Just In Time, that means: Pull, Flow and SMED. Indeed, the model says that the economic results of the firm improve of 0.875 per practices implemented, with a level of significance of 5%. Furthermore, the model reveals also a good relationship for performance with Total Productive Maintenance and TQM applied together (0.478) with a significant test of the 10%.

In this case the line that should connect all the dots, representing the value, does not describe with a quite good level the relationships existing, the R-squared is low (0.054), but the aim was not to explain the entire phenomenon, but instead to show the existence of important correlations.

The last analysis was made extrapolating from the sample companies comparable on the base of the ATECO 2007 code (4 digit) and the turnover of 2016 that was one of the first questions of the questionnaire. The couples resulted were 9 each belonging to a different industry. This couples were divided from Lean and Non-Lean and then results of Debt/Equity ratio and Ebitda/Sales from the year of implementation were compared in average with the results of the other group, composed by only Non-Lean companies.

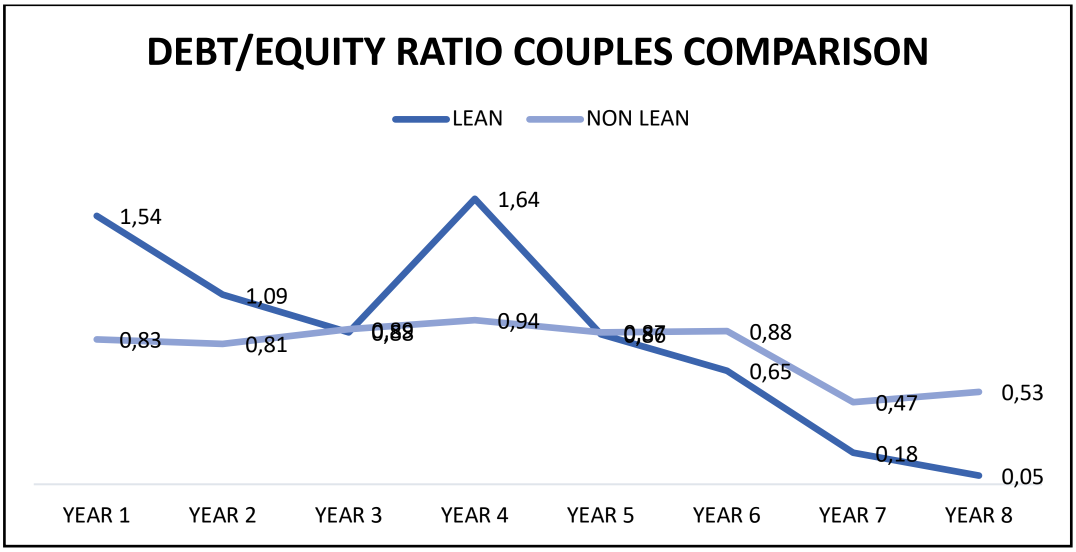

Figure 31: Variation of Debt/Equity ratio in comparable couples

The graph shows that during the initial years of implementation the average value of the Debt ratio is higher in Lean companies, but while for the Non-Lean firms there is a stable trend over years, Lean firms show every year improving results.

It is important to highlight that passing through years the percentage of companies reduce, indeed the 100% of couples have at least two years of implementation, the 89% of the group have 4 years of implementation, the 78% six years and in the end only the 56% has seven years of adoption.

Similarly, to the Debt ratio, the analysis of Ebitda/Sales on the 9 couples show in average a better result for Lean companies; interesting is the trend of both series that are very similar along the 7 years. In this case is evident the influence that adoring Lean has on average on the company's economic results.

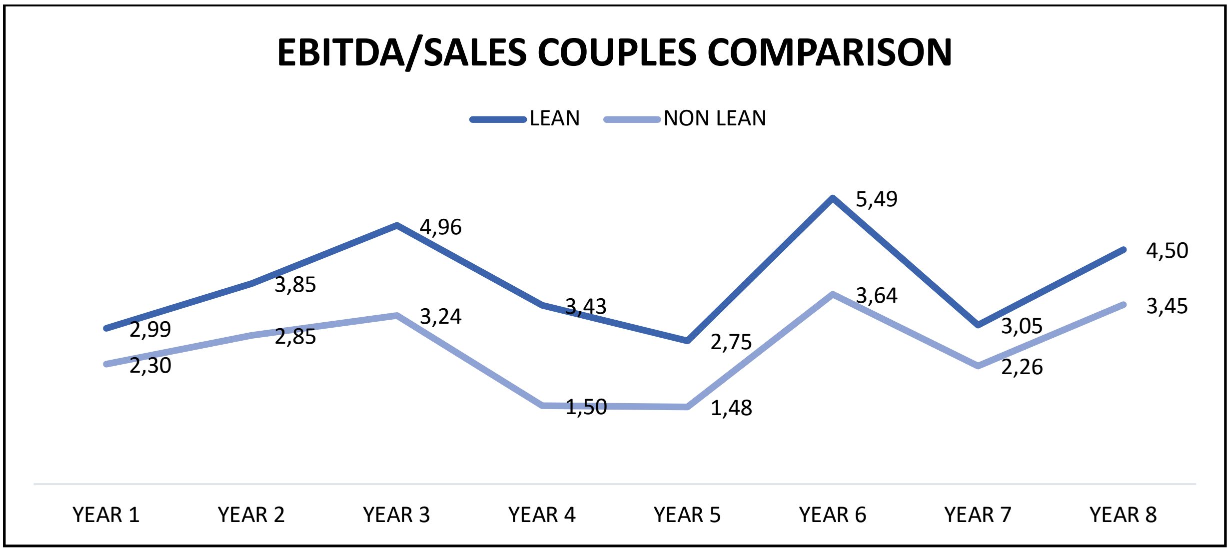

Figure 32: Variation of Ebitda/Sales ratio in comparable couples

CONCLUSIONS

Lean Manufacturing is a phenomenon that has taken place in Japan after the World War II, it started in the automotive industry, in particular from Toyota and its fathers Shigeo Shingo and Taiichi Ono. Nowadays it has been spread all over the world and in almost every industry.

It provides for the application of several techniques and tools, based on 5 principles that represent the Lean philosophy. The final aim is to improve and increase value for the customer eliminating wastes.

In the sample collected for this thesis the companies declaring the adoption of Lean in their plants are 128, they are slightly more than the half, this because in Italy Lean can be defined as a young movement that are going to increase in the next years.

However, it is not totally clear if there is a direct effect of Lean on economic and financial performance, in fact there is not a developed literature on the argument and researchers are still looking for understand how to measure it and its influence inside an organization. It is not in doubt the benefits it takes for the firms, in particular in the operational level also supported from literature that suggests various element for the implementation of practices and it stressed the point of involving employees.

Hence, there is not a direct correlation between Lean and good economic performance, but in the sample collected most of the companies in the top 10% apply Lean are 56%; while among the 10% of worst Lean is applied less than the half of the cases (44%). In chapter three the sample is described in its totality using different variables, not only financial indexes but also size analysis, composition and even the ownership.

Even if the literature does not identify a direct correlation between Lean and economic improvement, there are several elements that support this hypothesis as for example Lean duration. Every analysis show that the impact it is in average immediate on earnings and sales and after some years from the implementation it also improves the financial health of the company.

The goal of the thesis is to understand if the presumed correlation between Lean and good economic results it is verified in the sample chosen; in particular through the use of comparisons of standardize values for economic variables among Lean and Non-Lean companies, furthermore it has been also applied a significant test and a regression.

Result founded in the regression highlighted that no one practice alone can produce good results, but there is a positive correlation in companies that have implemented at least one of the practices related to JIT. Moreover, it has been founded also a positive correlation with the Total Productive Maintenance related to the stability of processes.

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