UNIVERSITA' DEGLI STUDI DI PADOVA

DIPARTIMENTO DI SCIENZE ECONOMICHE ED AZIENDALI
"M.FANNO"

CORSO DI LAUREA MAGISTRALE IN
BUSINESS ADMINISTRATION

TESI DI LAUREA

"LEAN MANUFACTURING IN THE VENETO REGION: AN EMPIRICAL ANALYSIS"

RELATORE:

CH.MO PROF. Andrea Furlan

LAUREANDA: Camilla Zorzetto

MATRICOLA N. 1130355

ANNO ACCADEMICO 2016 – 2017

Il candidato dichiara che il presente lavoro è originale e non è già stato sottoposto, in tutto o in parte, per il conseguimento di un titolo accademico in altre Università italiane o straniere.
Il candidato dichiara altresì che tutti i materiali utilizzati durante la preparazione dell'elaborato sono stati indicati nel testo e nella sezione "Riferimenti bibliografici" e che le eventuali citazioni testuali sono individuabili attraverso l'esplicito richiamo alla pubblicazione originale.

Firma dello studente

Table of Contents

Introduction

Lean Management is a systemic organisational approach whose ultimate aim is to create the maximum value through the elimination of any source of waste in organisations. By following a path constituted of five principles and implementing properly a wide set of practices and tools, companies that adopt Lean have the possibility to collect several business improvements, not only at the operational level, but also for the benefit of the entire organisation.

Born and originally developed in the automotive sector in the second half of the last century, Lean has then spread in several different industries and has captured the attention of many academic studies, especially for the potential benefits entailed by its implementation.

Several authors have pointed out the fact that Lean implementation is often deemed to be highly context dependent. In fact, tendency toward implementation and its effect may vary according to the specific context within which firms operate. For this reason, in line with the approach adopted by many authors, this thesis will focus on analysing Lean Management within a specific context, here represented by manufacturing companies located in the Veneto region, with the aim of providing a deep overview on Lean application, on the factors possibly related to its implementation and on its potential outcomes.

Specifically, primary data for this analysis has been directly collected from a sample of 75 manufacturing firms through a survey based questionnaire, and then have been integrated with a set of information provided by AIDA database.

First of all, it is important to point out that the context dependency of Lean Management has been proved to exist not only in relation to the geographic area in which firms are located. In fact, several studies have inspected the possible influence exerted by factors like company Size, Age and Industry on Lean implementation. However, authors have not always reached a common conclusion on these issues. For this reason, the analysis will start by investigating whether exist any possible correlation between the above-mentioned contextual factors and Lean Management implementation. In addition, the analysis will be integrated by inspecting the potential influence on Lean exerted by two others contextual variables, namely the classification of the firm as a Family Business and the Export Turnover. These factors, despite not directly studied in the literature in terms of their possible correlation with Lean, can offer a broader perspective on the relationship between context and Lean Management in the population subject to study.

Then, another important aspect widely recognised and covered in literature is represented by Lean Management outcomes. In fact, several authors have investigated the relationship between Lean and the possible benefits entailed by its implementation in terms of Business performances. However, despite the ample attention paid in literature to operating outcomes of Lean Management, less space has been devoted to analyse the direct effect of Lean implementation on financial results. By the way, potential financial outcomes of Lean Management are particularly relevant to be investigated because, if existing, they could reasonably hint that Lean practices adoption represents a key element for the implementation of a successful strategy. Therefore, it will be assessed whether Lean Management implementation can be expected to entail financial improvements measured by company Return On Sales, Return On Asset and Bank Debt over total Turnover.

Finally, the analysis will be concluded by closing the loop between context and Lean Management outcomes. In specific it will be investigated whether the above-mentioned contextual factors - Size, Age, Industry, classification as Family Business and Export Turnover - exert a moderating effect on Lean implications, influencing the way in which Lean Management improves business performances.

Therefore, to sum up, the present thesis has been carried out in order to serve the following research purposes:

- To provide a broad overview on Lean Management implementation in manufacturing firms located in the Veneto region,
- To study the possible effect exerted by contextual factors on Lean implementation,
- To assess whether Lean application and a higher leanness degree may result in significant financial improvements,
- To analyse the moderating effect potentially exerted by the context on Lean outcomes.

CHAPTER 1

PRINCIPLES AND TECHNIQUES OF LEAN MANAGEMENT

Lean management: historical background

The term Lean management (LM – but also Lean production, or even just Lean) refers to a production system originated in automotive industry. It has been first pioneered by Toyota, when the auto company was looking for a solution to the crisis that it was facing in the 1950s.

This operational paradigm, also known as Toyota Production System (TPS), has been explicitly described as lean production (LP) only in 1990 by Womack, Jones and Roos, who were studying in depth this system. In particular, they defined LP as "*an entirely new way of making things*", making reference to the fact that this new approach was totally different from mass production, the most diffused system used to manufacture cars at that time.

This system, based on large scale batch production, was introduced by an American car manufacturer, Henry Ford, in 1920s. First it spread in US, and then in 1950s it was exported and implemented even in Europe.

Mass production has dominated for decades the car-manufacturing scenario, being for years the system adopted by the main players in the auto industry.

However in 1950s, while European market characteristics allowed the application of Ford's principles in that area, the post war-scenario in Japan prevented from the implementation mass production also in their manufacturing system.

Hence, Toyota needed an alternative solution to overcome its financial distress caused in particular by the World War II, so it invented a completely new way to organize their production.

In particular, the post-war scenario in Japan presented the following characteristics (Womack *et al.,* 1990):

- Small but high-requiring domestic market for auto
- High employment protection and lack of temporary workers, that turned salaries into a fixed investment rather than a variable cost for companies
- Severe lack of financial capital and foreign exchange that made impossible to invest in new production technologies or to buy them from Western Countries
- High pressure exerted by foreign competitors, which prevented Japan from expanding abroad and increased competitiveness in the Far East

These peculiarities send Toyota into a vicious circle which make the adoption of mass production an unfeasible solution:

1. the tiny Japanese market did not ask for large volumes, making large-scale production unnecessary
2. producing small quantities prevented Toyota from achieving economies of scale and cutting costs
3. high costs, in turn, affected negatively Toyota's competitiveness, preventing the demand from growing.

Anyway, as reported by Holweg (2007), even if suitable, production in large batches was likely to entail serious drawbacks. Huge inventories, typical of mass production, might have caused unnoticed defects and so higher costs. In addition, the lack of flexibility that characterises this production system would have prevented Toyota from meeting all its customers demand and needs.

Therefore, Taiichi Ohno, industrial engineer employed in Toyota, designed a strategy focused on producing small volumes and reducing costs by eliminating waste (Holweg, 2007), instead of looking for economies of scales at any cost. This strategic approach, which eventually allowed Toyota to overcome the drawbacks shown by mass production, represents the basis of Toyota Production System (TPS).

The Toyota Production System

TPS represents a new method for defining, organising and managing operations and is the main precursor of LM or, to use the words of Liker and Morgan (2006), “the best-known example of lean processes in action”.

This system can be depicted by using the TPS House (see Figure 1), a useful representation that clarifies what are the main elements that compose its structure.

The analogy is not random: like a house needs a solid foundation in order to be stable, similarly TPS can be strong and stable if and only if all the single parts are strong, stable and constructed so as to form a coherent whole.

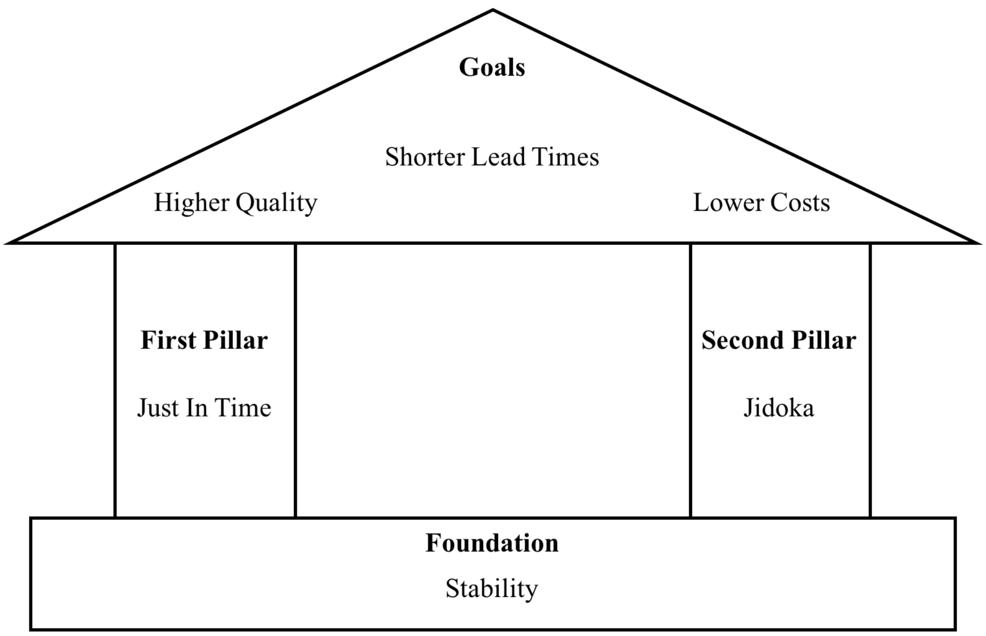


Figure 1:
The TPS House

The final goals: Quality, Cost and Time

The roof of the house represents the final goals of the whole system: to manufacture products with the highest possible quality, to contain costs and to reduce lead time as much as possible.

Generally, these three goals are perceived as mutually exclusive – for example it is often believed that quality has to be sacrificed in order to lower costs – but actually, from the TPS perspective, quality cost and time can be positively correlated.

For instance, quality reduces significantly the need for rework, cutting down both the lead time and the production costs.

TPS, hence, aims to reach all of these goals simultaneously, and in order to do this, the strategy is based on two pillars, Just In Time (JIT) and Jidoka.

Just In Time

TPS has been based on the total subversion of the "Just in case" (JIC) logic – typical of mass production - and its substitution with the JIT system.

Mass producers build up large inventories of materials, components and finished products, in order to anticipate any problem that may entail production shut-downs. In this way, the plant can continue to work, despite partial break-downs, material shortages or quality problems, because buffers prevent from disruptions.

Nevertheless, JIC has several drawbacks, including the following (Sayer, 1986):

- It makes the firms rigid and unable to promptly respond to market changes
- Large inventories require huge capital investments to be founded
- When a defective part emerges, it is simply substituted with one present in inventory, but by doing so, manufacturers have no inventive in digging into the root of the problem, which is then likely to keep emerging periodically

On the contrary, JIT logic is not based on the idea of anticipating problems as much as possible, but on the attempt to be as much responsive as possible to changes, by producing only what is needed, when it is needed, and in the amount needed (Pieńkowski, 2014).

To do so, the company has to be able to switch the production very quickly, leveraging first of all on set-up time reduction and using specific techniques.

As a result, responsiveness increases, buffers tend to be much lower, and many drawbacks of JIC system should be overcame.

Jidoka

The second pillar of TPS is Jidoka. This Japanese word, that can be translated as "Autonomation" or "Automation with human touch", refers to the ability of ensuring that equipment (or even the whole operation) stops whenever abnormality or defects are detected (Sugimori *et al.,* 1977).

The efficacy of this practice is related to the fact that, if machines are able to reveal any unconformity and to stop automatically, and if every operator has the authority to stop the whole production process whenever he or she detects an error, then only products with satisfying quality standards will be passed down the line (Pieńkowski, 2014).

Among others, two important benefits that can be directly derived from the implementation of Jidoka are the following (Sugimori *et al*., 1977):

- It makes the machines able to stop automatically also when the amount required has been produced. Hence, it makes overproduction less likely to occur, facilitating JIT implementation;
- It facilitates control for abnormalities, because when machines stop, corrective actions are directed only toward the specific defective part detected.

The foundation of TPS House

TPS needs a strong foundation – namely, process stability - in order to provide a base on which JIT and Jidoka can be implemented.

Stability means that the process must be:

- *Capable*, or "*right each time"* – operators and machines do not produce defective products and do not make systematic errors
- *Available* - operators must be able and ready to work and use machines when they are asked to do so.

Without a stable base, efforts exerted to implement the two pillars are useless. For instance, JIT cannot be employed if the facility is not always available to work when it is needed.

Similarly, abnormalities detection is difficult – or even impossible – if standards have not been defined to be used in comparison

Process stability can be reached through the proper implementation of a series of specific tools (for example Standard Operating Procedures, 5S and Total Productive Maintenance) that will be widely presented later in the chapter.

Lean Management as a system

The concept of LM refers to an organizational paradigm that aims to eliminate waste and create the maximum possible value in organizations through the employment of a proper operational process and the implementation of a specific set of principles and tools

In order to offer a clearer image of what LM actually is, Arlbjørn *et al.* (2008) have suggested to depict lean as a pyramid (see Figure 2), a system made of three different dimensions.

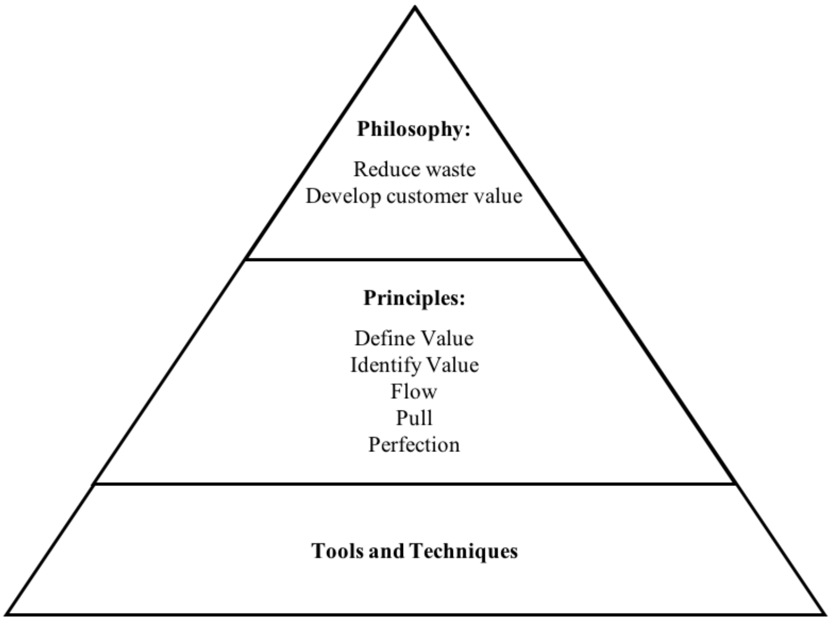


Figure 2: Lean as a pyramid

Source: adapted from Arlbjørn *et al.* (2013, p. 177)

Each of the three dimensions is equally relevant and necessary and, taken all together, they constitute the essence of LM.

When a company decides to implement a process of Lean transformation, it must fully employ the philosophy of waste reduction, follow the five lean principles and practically apply a wide set of tools.

What is important to emphasise is that LM is neither simply a philosophy, nor a simply set of tools. LM is an integrated and holistic system, that characterise a firm from its deep fundaments up to the everyday activities and techniques, with direct effect on the company overall strategy.

Philosophy

Value is the heart of LM: it is the centre and ultimate goal of all the principles, techniques and activities.

Specifically, Womack and Jones (2003) have defined value as "a capability defined by the customer/end user and provided to them at the right time and cost".

To put it more simply, value can be intended as the element customers are willing to pay for.

In fact, as noted by Ballard *et al*., (2001) if and only if a product can be used to fulfil the purpose for which it has been bought, then the product has a value for the buyer.

Cleary, only if this happens the customer is willing to bear the cost of buying the product.

As a consequence, the final aim of any organisation must be to create and deliver value to its final customers (Mossman, 2009).

For this reason, companies must eliminate from their processes any waste, that is any human activity which absorbs resources but creates no value (Womack and Jones, 2003).

In Japanese "waste" is literally translated to Muda. Actually, Muda is every action done by a company which a customer is not willing to pay for (Pieńkowski, 2014), but it is not the only kind of wasteful activity a company can perform. Instead, Muda is the superficial and visible waste; the other two types of waste are Muri and Mura.

Muda, Muri and Mura - also indicated as the three Mu's - are, taken together, all the activities that prevent a company from being perfectly efficient in its production system.

Mura

Mura means "unevenness" and it is related to variations in the production process pattern caused not by the final customer but voluntarily by the firm itself.

These variations in production schedule are extremely important to be avoided, especially because they are likely to generate the other two types of waste - it is no coincidence, actually, that Mura is often intended as the "mother" of all wastes.

For this reason, one of the key elements that characterize LM is the production levelling - in Japanese, Heijunka – whose mechanism will be described further in the chapter.

Muri

Muri can be translated as “overburden” or “unreasonableness”. It takes place any time a company overloads its machineries and operators, asks them to perform unnecessary or dangerous activities or makes them work under their actual capacity.

As said before, Muri is often caused by Mura: if the workforce is (almost) fixed and the facility is characterized by a generally constant level of capacity - which is pretty common in companies that use huge machineries, in case of variability in production pattern operators and equipment will be overloaded when the production volume will exceed the capacity level, while in the opposite situation they will lie idle (see Figure 3).

Both overburden and inactivity have drawbacks: overloading causes stress, that reduces the unitary productivity of machines and operators and makes more likely the occurrence of defects; underutilization, instead, forces people and machines to wait, lying idle without generating value. These negative effects are all examples of Muda.

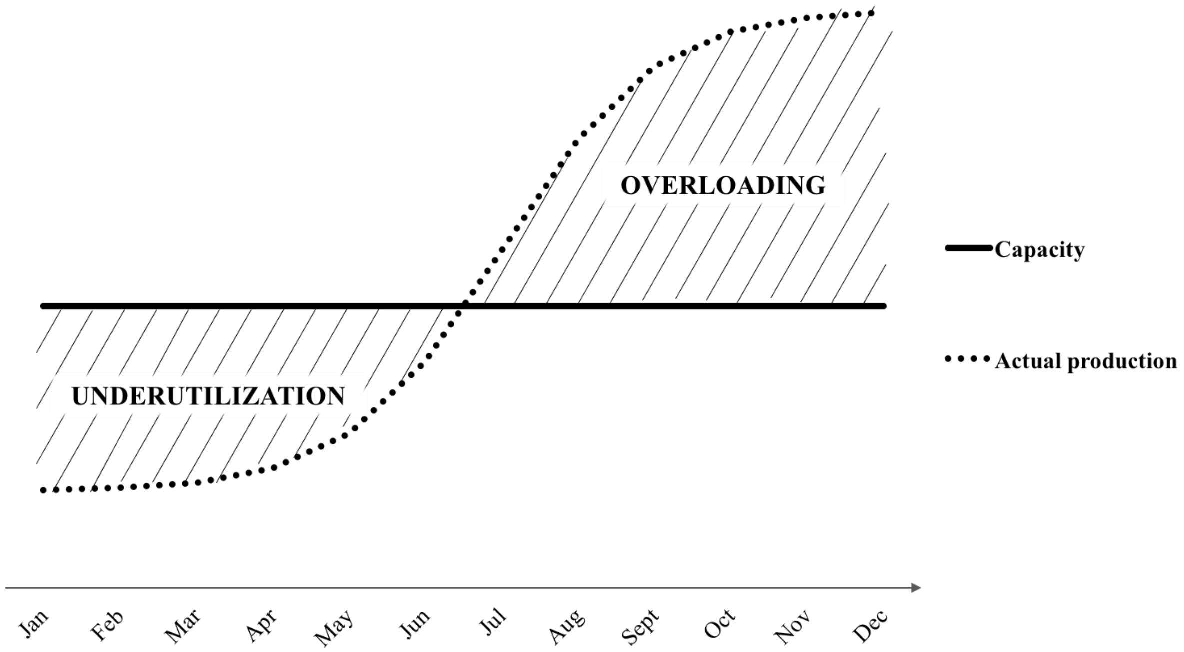


Figure 3: Overloading and Underutilization of facilities caused by variations in actual production

Muda

Muda is a word used to indicate a whole set of unnecessary activities that a company can perform, absorbing resources without producing value for customer.

These activities directly impact on the "roof" of the TPS House, making the three goals - lower costs, higher quality and shorter lead time - impossible to reach.

Traditionally, Taiichi Ohno recognized seven traditional types of Muda:

1. *Overproduction*

   It is the exact opposite of Just In Time production, and means producing something that is not required by a customer, or producing it before the actual order or in excessive quantity.

   Overproduction is an obstacle in reaching the three final aims of TPS: it absorbs time and causes unnecessary expenses (think about the costs for raw materials for producing something that no one has asked for: these expenses will never be recovered).

   Moreover, it easily generates all the other six types of Muda.

2. *Transportation*

   Transportation is related to the action of moving material, parts and products without it being necessary, and so without adding any value.

   This Muda, often due to improper layouts and poor organization of production, can extend the time needed for processing an item and therefore makes production costs higher.

3. *Inventory*

   Unnecessary stocks tie financial resources to products long before they are actually sold, so they require huge capital to be founded.

   Moreover, inventory is likely to hide problems and defects, making them more difficult to be discovered, to the detriment of the overall quality of Operations.

4. *Motion*

This type of waste is related to unnecessary movements made by operators or machineries, like moving from one workstation to another, or looking for parts, documents or tools.

Motion causes a decrease in efficiency and additional costs - for example, workers get paid for making moves that do not generate any value.

5. *Waiting*

This Muda occurs when operators lie idle for example waiting for information to be delivered, materials and parts to arrive, tools or machines to be available. The time spent waiting does not generate value but absorb time, that is a valuable resource, and hence it reduces productivity and increases costs.

6. *Overprocessing*

Overprocessing means performing unnecessary and not value adding activities - for example the use of sophisticated tools when simpler ones would be sufficient, or adding product features that the customer does not require.

These activities are costly and time consuming, but cannot be reflected into the final price of the product, because customers are not expected to appreciate them. Hence, Overprocessing causes losses for the company.

7. *Defects*

This Muda is related to existence of errors, imperfections or non-compliance in products that make customers not willing to pay for it.

Any time a company produces defects, it is wasting financial resources and time, and decreasing the overall quality of its Operations.

Principles

LM principles represent guidelines that lean companies follow and remind constantly while running their business, in order to employ lean philosophy.

Define Value

The first step that every lean firm takes is to specify what value actually is.

First of all, value must be defined by the final customer (Womack and Jones, 2003, p. 16). In fact, only if customers are the final focus of every process - from product development to after sales services - companies can create and deliver a value actually appreciable by clients.

Value definition, hence, requires to question what customers really want, to design a specific and corresponding value proposition and to develop a product portfolio based on it (Melton, 2005).

In addition, value has to be expressed with reference to a specific product taken as a whole, and not as a sum of its parts (Womack and Jones, 2003, p. 16).

This means that any product must be looked at “through the eyes of the customer” (Womack et al., 2003, p. 34), in order to avoid to offer a sum of excellent components, but that on overall has no value at all for the customer.

Identify Value

The second LM principle prescribes to identify all the activities that generate value, to separate them from the ones that actually do not and to eliminate as much as possible the latter.

The relevance of this step can be quickly understood.

One of the LM milestones is waste elimination, but waste is only defined in relation to value (Mossman, 2009) – in fact, waste is *every action that absorb resources without adding any value*.

Hence, without the proper identification of what value actually is, clearly it would be impossible to identify waste too, and so no corrective actions could be taken.

It is therefore necessary to identify *where* value gets created by looking at the value stream, which comprises all the specific actions that any company needs to perform when conducting their business and producing their products.

The entire value stream must be *mapped:* each single product (or family of products) has to be literally followed through its productive path, and notes have to be taken concerning all the steps entailed in the process, in order to recognize any potential source of waste.

By doing so, companies identify three types of actions:

1. *Value creating activities*

   Activities that actually add value to work-in-progress, and so are significantly appreciated by final customers.

2. *Necessary but Non-value creating activities – Type 1 waste*

   Activities that do not add appreciable value, but cannot be totally removed because of several constraints - for example natural limits of the current state of technology or strict requirements in terms of quality controls imposed by law.

3. *Avoidable Non-value creating activities – Type 2 waste*

   Activities that are totally unnecessary and not specifically required neither by the final customer nor by any other agent.

As Bicheno and Holweg (2008) state, the third category refers to source of pure waste, and so these activities must be eliminated primarily.

Type 1 waste, instead, cannot be totally avoided by definition, but must be reduced through simplification. Moreover, being Type 1 waste "the easiest to add to but difficult to remove" (p.20), it must be prevented before everything.

After this cleaning step, Type 2 waste should be absent, while Type 1 waste should have been reduced at the minimum.

Flow

Flow is one of the core concepts that underlie lean implementation.

According to Toyota's Vision, parts have to follow a one-piece flow, moving directly and smoothly from one value-adding station to the next one, up to reaching the final customer (Rother, 2009, p.45), as opposite to the traditional *batch-and-queue* production.

In order to do so, lean plants are characterized by small, and often general-purpose, equipment that are arranged sequentially according to a line layout. This arrangement makes possible to process one single item at a time, without building in intermediate stocks between one productive step and the other, because items once processed are directly moved from a stage to the next one.

Moreover, plants are usually organized in cells, small productive "islands" each of which contains all the equipment and resources needed to process a specific product or family of products. A simplified example of one-piece flow production is reported in Figure 4.

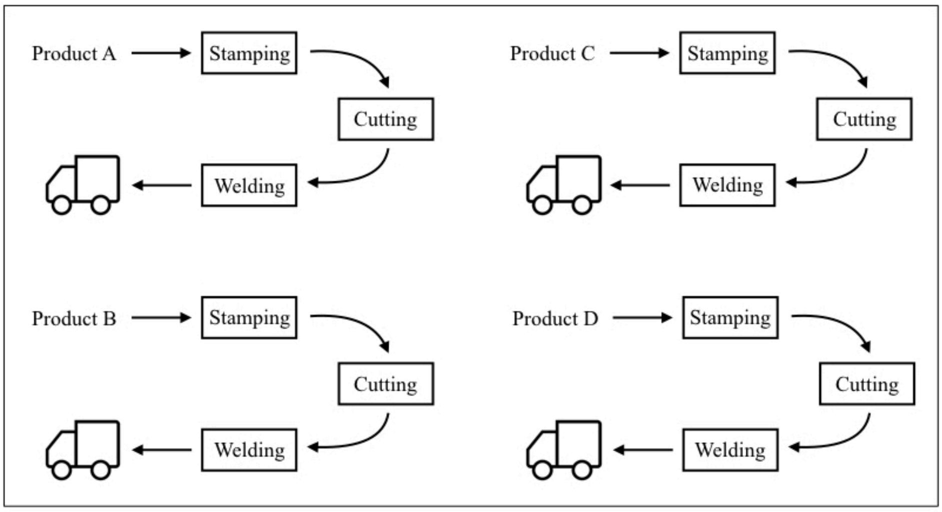


Figure 4: Example of *one-piece flow* production

This arrangement makes several benefits to accrue, as the following:

- Storage space and costs are dramatically reduced, because there is no need for in-between inventories
- Waiting time get minimised, increasing production efficiency rate
- If a mistake occurs, it is likely to be noticed almost immediately when the single defective items is passed down the line; therefore, it can be fixed before being reproduced in hundreds of parts
- The cell arrangement allows the firm to carry on the production for different product

types simultaneously. This way, the operations are much more flexible and there is no need to produce large batches in advance, reducing inventory costs and the risk of overproduction.

Pull

Pull principle states that "no one upstream should produce a good or a service until the customer downstream asks for it" (Womack and Jones, 2003, p.67). This means that at every level, production must be triggered by actual demand made by the following workstation or the final customer.

The opposite logic is represented by Push strategy, according to which firms launch production before receiving actual orders, trying to anticipate the demand.

In companies adopting Push approach, production is triggered by Material Requirement Planning (MRP) system, which plans the activity for every single productive step, dictating from the top the timing for production and the quantities that have to be processed (see Figure 5).

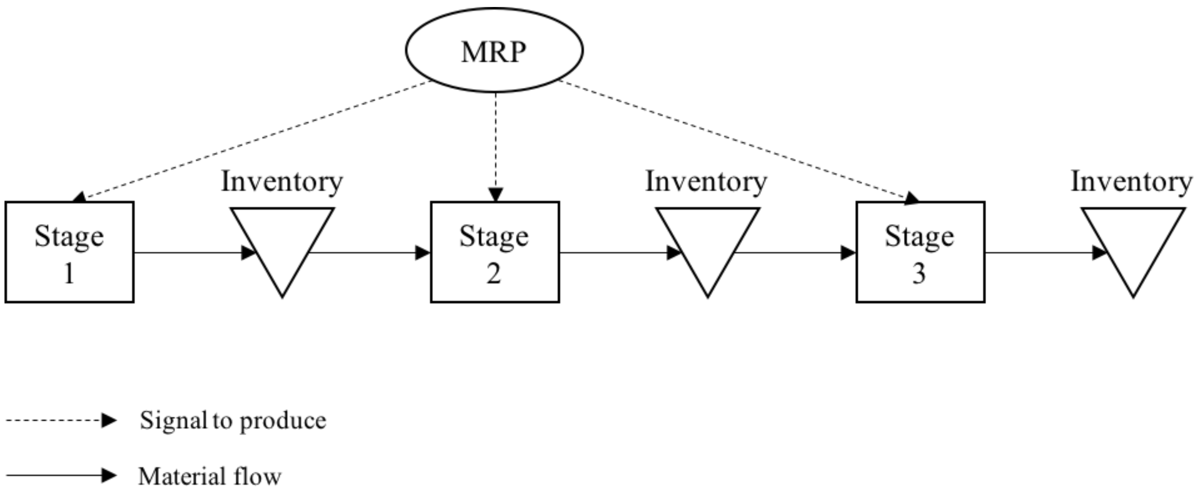


Figure 5: Push control system

As can be seen by the figure, every level of production processes items independently on the actual need of downstream but just to respond to the order of producing coming from the top.

The main problem of Push system is that it is based on demand forecast which, by nature, cannot be totally reliable.

On the contrary, Pull logic is characterised by a different relationship with the market (Forza, 1996): production is not based on forecasts, but on actual demand for goods coming from downstream customers (both internal or external).

In particular, in Pull systems the order to launch production comes directly from the downstream customer: information flows bottom up, a signal to launch the production – or to provide items - is sent back to the upstream supplier and then the material flow of product moves forward to the client. The mechanism is summarised in Figure 6.

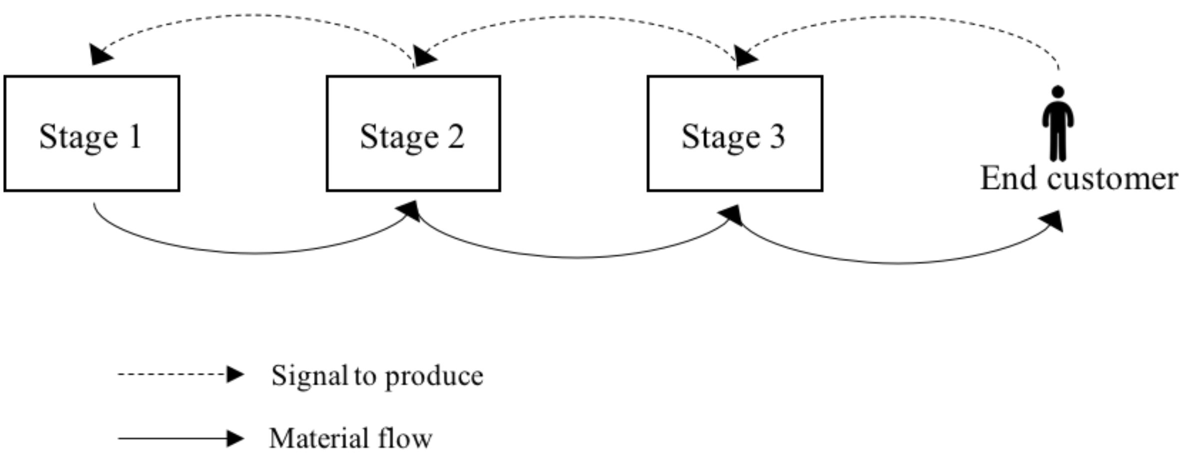


Figure 6: Pull control system

Given the difficulties in perfectly harmonising the whole line and in order to cushion unexpected demand fluctuation, Pull system relies also on the use of controlled inventories – generally defined *Supermarkets*.

These stocks are voluntarily built up to a certain level in each stage of the production process. When a product is required by downstream clients, parts are taken from the storage. Then, the upstream station produces items just until the level of stock is restored. In this way, inventory is kept at the minimum level needed to buffer possible demand fluctuation, without causing the major effects associated to inventories.

Once again, LM gives pride of place to the customer: as Value has to be necessarily defined in terms of the customer, so Flow has to be activated by him, being literally pulled from down up.

Perfection

Companies which decide to embrace LM for the first time have to put in place fundamental changes, both in material and in cultural terms. This radical change – in Japanese *Kaikaku* - represents a necessary step in order to become lean and involves the implementation of the first fourth principles just described above.

Then, as Womack and Jones (2003) highlight, once this first step has been made, a virtuous circle is likely to create (see Figure 7).

Getting the value to flow smoothly allows to lighten further sources of waste, and removing these Muda lets the value stream to be pulled even faster.

At the same time, the higher the attention paid to specify value, the more are the occasions to enhance implementation of flow and pull principles that, in turn, help in founding additional specifications to value.

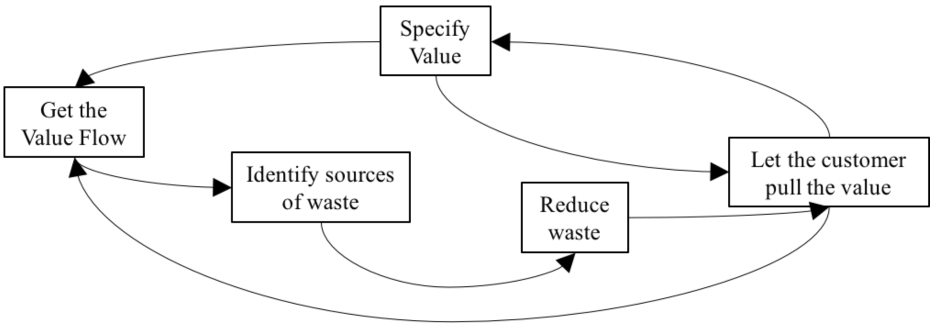


Figure 7: Virtuous Circle in implementing lean principles

This virtuous circle shows that it is always possible to improve performances by increasing quality, reducing lead time and cutting cost.

Therefore, lean companies continuously strive for perfection, exerting all their effort in enhancing their ability in implementing lean principles.

As Karlsson and Åhlström report (1996, pp. 28-29), this continuous strive for perfection, that they define as the second most fundamental principle of lean production after elimination of waste, has a specific Japanese name, Kaizen, that literally means "continuous improvement".

In this respect, it is interesting to notice that according to LM perspective true perfection is a target that actually can never be reached.

In fact, being perfect would mean create the maximum value for customers, offering them the highest quality and variety of products without any defect nor inventory nor delay.

The complete achievement of this aim seems clearly unrealistic, especially if we consider that "customers' views are continuously changing and standards are rising" (Bicheno and Holweg, 2008, p.193).

However, quest for perfection, even if endless, generate "surprisingly twists" (Womack *et al.*, 1990, p.14) because even the simple fact of raising the bar pushes firms to achieve actual progresses, although they might never be perfect.

Tools and Techniques

Lean Tools and Techniques compose the base of Lean Pyramid and as such represent a key and necessary element on the way to full implementation of LM.

In fact, while lean principles prescribe the path to follow in order to create maximum value for customers, lean tools represent the practical implementation of those principles (Mostafa, Dumrak and Soltan, 2013): techniques embody the procedures that allows to operationalize the theoretical base of LM.

In Table 1are listed some of the main and most diffused lean tools, which have been grouped according to the purpose they are expected to serve.

Value Stream Mapping

Value Stream Mapping (VSM) consists in following each single family of products – namely a group of products that pass through similar processing steps and over common equipment (Rother and Shook, 1999) - along its production path, in order to assess where value gets actually created.

VSM is a "paper and pencil tool" performed directly on site while visiting the plant (in Japanese Gemba – the place where value creation occurs).

Objective	Tools
Identify Value along the Value Stream	Value Stream Mapping
Give Stability to the process	5S Total Productive Maintenance Standard Operating Procedures Visual Management
Implement Just In Time	Heijunka Layout Kanban Single Minute Exchange of Dies Simultaneous Engineering
Control defects and enhance quality	Andon Poka Yoke
Continuously Improve	Kaizen and PDCA cycles Lean Six Sigma A3 Suggestion System

Table 1: Diffused lean tools and corresponding objectives

Using a set of predefined symbols and icons, a graphical representation of every step in the process flow is drown down, from raw materials to customer (Rother and Shook, 1999), in order to map two distinct but strictly related types of flow:

- *Material Flow* – the easiest to detect and describe, because related to the motion of items and physical parts within the plant

- *Information Flow* - harder to catch at first sight, but equally important, because it is the flow that gives each process information about what to produce next.

The two steps - and outcomes – of performing VSM are:

- *Current State Map*

  This first outcome returns a snapshot of how the process is currently organized (Singh *et al*., 2010), in order to identify any "value leak".

  It consists in observing the current process starting from customer requirements and going backward.

  Notes have to be taken on several information and measures, both related to the overall production process (like Takt Time, total Production Lead Time and Value-added or Processing Time) and to each single workstation (Cycle Time, Changeover Time, machine Uptime and availability and number of shifts) and inventory (average quantity and waiting time).

  Once depicted, the current state map has to be analysed in order to detect any source of waste that can prevent the value stream from flowing. Necessary modifications and changes to fix some aspects of current operations will be entered on the future state map.

- *Future State Map*

  Future State Map is a picture of how the system should look after the inefficiencies in it have been removed. In particular, it is drawn systematically by answering a set of questions on efficiency and on implementation of lean tools (Abdulmalek *et al*., 2007).

  This approach will end in building an ideal state of operations, according to lean principles and perspective.

VSM is the starting point for the application of all the others lean techniques and procedures: it provides a snapshot of how the operations should look like, and this desired state gets reached through proper implementation of specific LM tools.

<u>5S</u>

5S is a systematic method for organizing and standardizing the workplace (Kilpatrick, 2003), whose objectives are to reduce waste and variability and to improve productivity (Bicheno and Holweg, 2008).

This instrument is easy to implement, offers an immediate return, especially in terms of quality and productivity and can be applied to the entire company as a whole.

5S gets employed by following five prescriptive guidelines:

1. *Seiri* or *Sort*

   Classify items to be kept in the workplace or stored according to a criterion commonly defined. For example, items used more than twice a week must be kept, while the others are stored.

2. *Seiton* or *Straighten*

   Each remaining item has to be properly located in a place "where it is silly to put it anywhere else" (Bicheno and Holweg, 2008, p. 79).

   Correct location has to be clear and self-explanatory: every specific place can be signalled by footprints, shadows, signal boards or trolleys, colours can be used to signal the belonging of specific items to a certain area, locations can embed technologies which record if the items placed there is right or wrong.

3. *Seiso* or *Shine*

   Tide up periodically workplace, tools, machines and equipment, and to visual scan the area on regular basis, in order to detect and fix immediately any non-conformity.

   Cleaning and checking activities occur simultaneously and are integrated: during clean up issues and abnormalities come to the surface and gets fixed. Moreover, it is important not only to fix the problems recorder, but also define a way to prevent them from occurring.

4. *Seiketsu* or *Standardise*

    Once the first three S have been implemented, it is possible to codify them and adopt standard procedures.

    In particular, these might entail activities like measuring, recording, training and work balancing.

5. *Shitsuke* or *Sustain*

    The final S represents the prescription of Sustainability of the progress made so far: 5S must become a habit, it has to be performed regularly and everyone has to be directly involved on a daily basis.

Total Productive Maintenance

Total Productive Maintenance (TPM) is a technique aimed at improving reliability, consistency and capacity of machineries (Bhasin and Burcher, 2006) and sustaining through time their optimal functioning conditions.

Given that LM implementation cannot be successful with a high level of breakdowns (Bicheno and Holweg, 2008) TPM has the objective of reducing at minimum machine failures and emergency maintenance.

In specific, TPM stands for “productive maintenance with total participation”: it gets implemented through team-based activities of productive maintenance that are systematically carried on by employees at every level – from top management to shop-floor workers (Chan *et al*., 2005).

TPM is a systemic and synergic practice, and requires operators and maintenance staff to work together to enhance overall effectiveness and reduce failures.

Operators perform a set of routine maintenance activities – like cleaning, oiling and visual inspections - as part of their everyday work

At the same time, maintenance staff provides technical support, fixes deterioration and design weaknesses and offers enhanced maintenance skills (Chan *et al*., 2005).

Standard work and Standard Operating Procedures

Standard work is "the safest and most effective method to carry out a job in the shortest repeatable time" (Sundar *et al*., 2014).

Basically, it can be intended as the "best way" of performing a specific job, that has been defined, codified and shared through proper work instructions.

As reported by Bicheno and Holweg (2008), it seeks to create "processes and procedures that are repeatable, reliable and capable", and it is operationalised by means of Standard Operating Procedures (SOP), process documents that describe in detail how a given operation should be performed by operators (De Treville *et al*., 2005).

In particular, SOP generally includes several information and contents, like operation purpose and requirements, set-up and maintenance instructions, safety issues, illustrations and checklists (Edelson and Bennett, 1998).

Visual Management

Visual Management (VM) is an approach aimed at making the current and planned state of operations and processes transparent to everyone (Slack *et al*., 2013)

More in details, it has been defined by Tezel *et al.* (2016) as "the strategy of increasing pervasive information availability, […] removing blockages in the information flows".

Operations visibility, or "control by sight" represents a core element of LM and it gets employed with the aim of gaining the maximum possible amount of information without needing to leave the Gemba or having recourse to IT systems and databases (Bicheno and Holweg, 2008).

VM process of information sharing and communication, in fact, is realized directly in the workspace, that has to be made self-explanatory and auto-regulating through the use of proper practices.

In general, all VM tools are usually integrated into process elements, and are intended to provide information to employees, responding to a pre-identified information need and relying minimally on textual or verbal communication (Tazel *et al.,* 2016).

Two of the most popular and significant VM tools are Poka Yoke and Andon Boards, which are more extensively described below.

<u>Poka Yoke</u>

Poka Yoke – literally "fool-proof" – systems represent a form of visual guarantee directly incorporated into a process with the aim avoiding mistakes and ensuring the reliability of the outcome.

These devices are generally inexpensive and prevent defects through automatic inspection – they do not rely on human interaction - stopping or giving warning every time an abnormality gets detected (Bicheno and Holweg, 2008).

According to the operating mode, a Poka Yoke devices are classified as (Bicheno and Holweg, 2008):

- *Contact devices*, which come in direct contact with each single product or are characterized by a specific shape that prevent mistakes from occurring
- *Fixed Value devices,* tools whose design makes clear if an item is missing or has not been used
- *Motion step devices,* that ensure that the correct number of steps has been made.

Figure 8: Example of Fixed Value Poka Yoke device

The kit contains all and only the parts that have to be used to perform a specific process.

If some spaces are empty before the process begins, it means that a specific part is missing.

If there are one or more parts left in the kit after the item has been processed, it means that the process has not been performed properly.

Andon

Andon is a form of visual quality control. It is a system applied with the aim of immediately warning operators, maintenance staff or management of a problem occurring in manufacturing processes.

Andon system requires the direct and active involvement of operators and it is implemented through the use of two basic elements: the Andon board and the Andon line (also known as Andon cord or rope).

The former can be an actual cord hanging from the ceiling or a lever or a button located near the operator; every time the operator identifies a problem, he pulls the cord or push the button. In some cases, they might be more than one cord, which have to be pulled differently according to the problem magnitude – for instance, a green cord for simpler issues, and a red cord for more severe problems.

Once the rope is pulled, a visual indication – for example a yellow light - in the Andon board notifies the existence of the problem at that specific workstation and signals the needs for help. At that point, a supervisor should come to the workstation to help out.

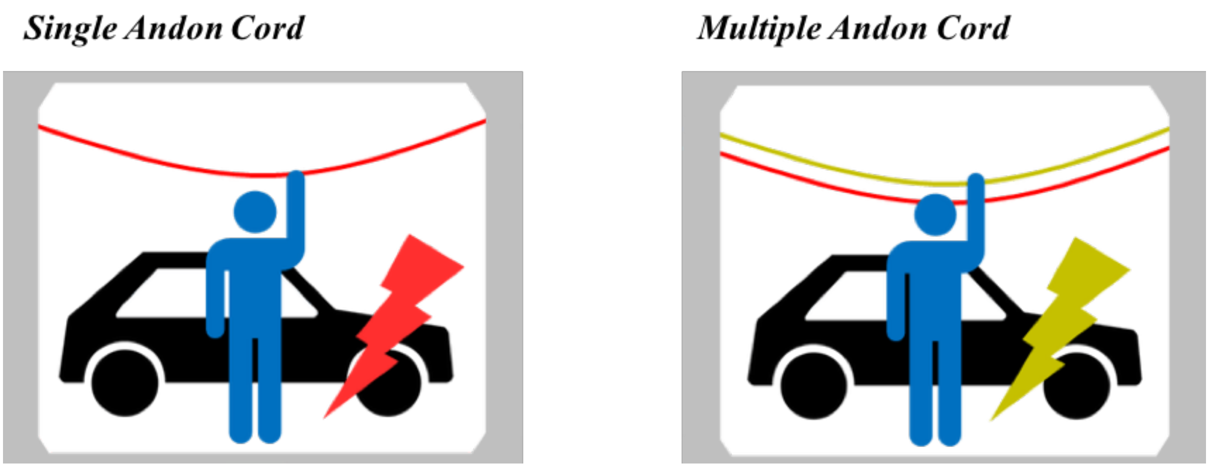


Figure 9: Example of Andon cords

If the problem cannot be immediately solved, further help is demanded by pulling one more time the Andon cord – or pulling the red rope. Usually a red light in the Andon board attracts attention of managers and engineers.

If still the problem cannot be solved, the line is stopped until the issue gets finally fixed.

Once the problem is finally fixed, the alert signal is called off the Andon board and the production restarts.

Heijunka

Previously have been highlighted the risks entailed by unevenness and high variability in production, especially in terms of Mura occurrence.

The tool called to reduce that risks by minimizing variability is Heijunka, which represents intentional levelling of assembly processes (Rother, 2009).

This approach prescribes to apply levelling on two aspects of production (Rother, 2009; Slack *et al.,* 2013):

- *Product Mix*
  Product are manufactured according to a specific sequence like, for example, A → B → C; the system should try to complete one sequence every day ("Every Part Every Day") by reducing lot size.

- *Production Volume*
  Every day the system should process the same amount of a certain item – for example, every day 10 A, 40 B and 30 C.

A simplified comparison of conventional and levelled scheduling is presented in Figure 10.

In case of conventional scheduling, each item is produced in large batches and production is switched only when each batch is completed.

This approach leads to inventory accumulation – every time a batch is so large that it takes several days to complete it, like in the case of both B and C items – and discontinuity and differences in daily production pattern – every day is different from the others (Slack *et al.,* 2013). Moreover, it reduces significantly production flexibility, because it might require days before switching production and dispatching an item.

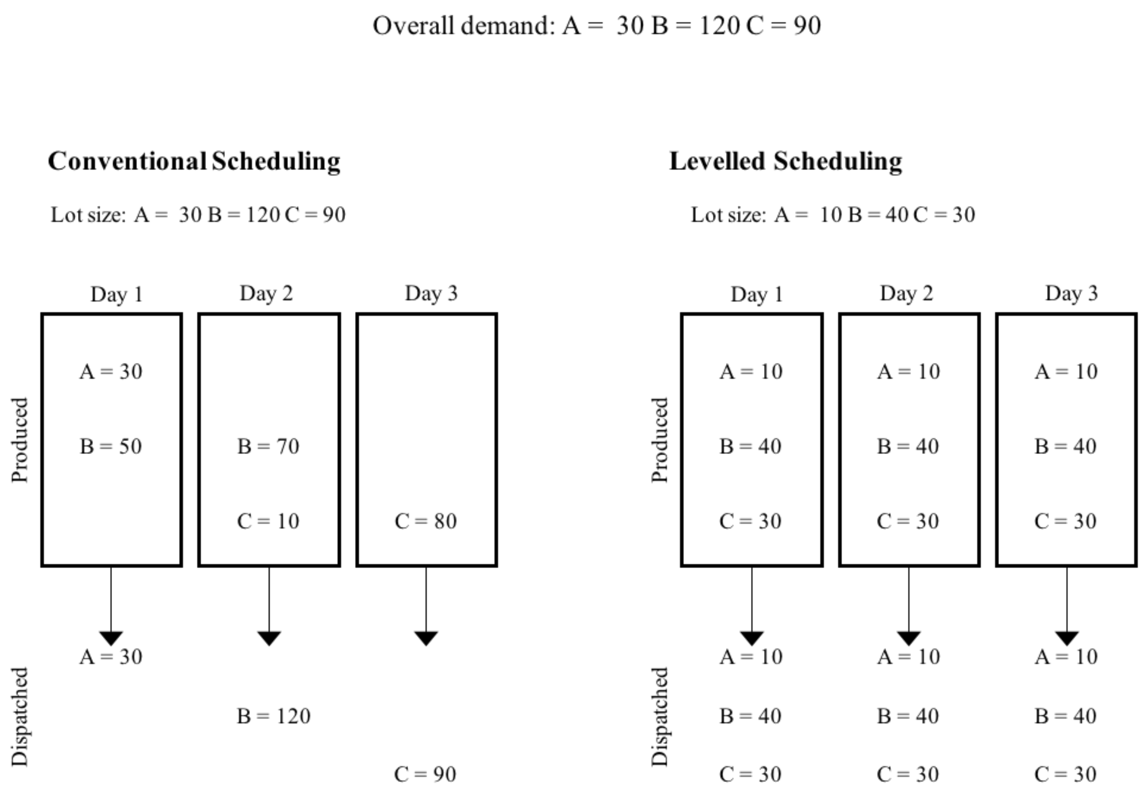


Figure 10: Heijunka compared to conventional scheduling

On the contrary, with levelled scheduling, production is based on smaller batches – in the example, 1/3 of batches in conventional scheduling – completed every day, so without building inventory. The same production pattern is always repeated every day, improving process regularity, and flexibility is enhanced.

Small batch production, hence, represent a necessary condition to proper Heijunka implementation.

In this regard, it results absolutely essential the capacity to perform quick changeovers in order to switch easily and quickly the production from one model to a different one.

This concept was already clear to Ohno, who originally modified Toyota equipment and machines and adjusted changeovers procedure, making them simpler and quicker, in order to reduce set-up delays (Holweg 2007; Womack *et al*. 1990).

Changeover reduction has been further advanced in late Fifties by Shingo, who developed the Single-Minute Exchange of Dies (SMED) system (Holweg, 2007).

According to Shingo and Dillon (1989), changeover activities can be either:

- *Internal* – activities that can be performed only if the process has stopped, such as dies removing
- *External* – activities that can be performed while the production process is still running, such as transporting tools from the storage to the machine

The more the Internal activities, the longer the machine stops, and hence the longer the changeovers.

The key point about SMED, then, is to distinguish between these two types of setup activities and to perform the conversion of Internal operations into External ones, which represent “the most powerful principle in the SMED system” (Shingo and Dillon, 1989).

Layout

As previously anticipated, layout represent a core element in LM and “sets the framework for every lean transformation” (Bicheno and Holweg, 2008): machines and equipment must be properly located in order to avoid several types of waste and to allow processes to flow smoothly.

Traditionally, batch-and-queue production is combined with Functional layout, according to which resources are grouped for reasons of practical proximity. Every batch is processed in one function or department and then, once the whole lot has been worked, it is moved to another function.

This layout entails several drawbacks and waste like, above all, significant transportations, long lead times, recurring bottlenecks and difficulties in detecting defects on time (Bicheno and Holweg, 2008).

On the contrary, LM implies one piece flow production, which needs a product oriented layout, rather than a resources arrangement focused on machines’ efficiency.

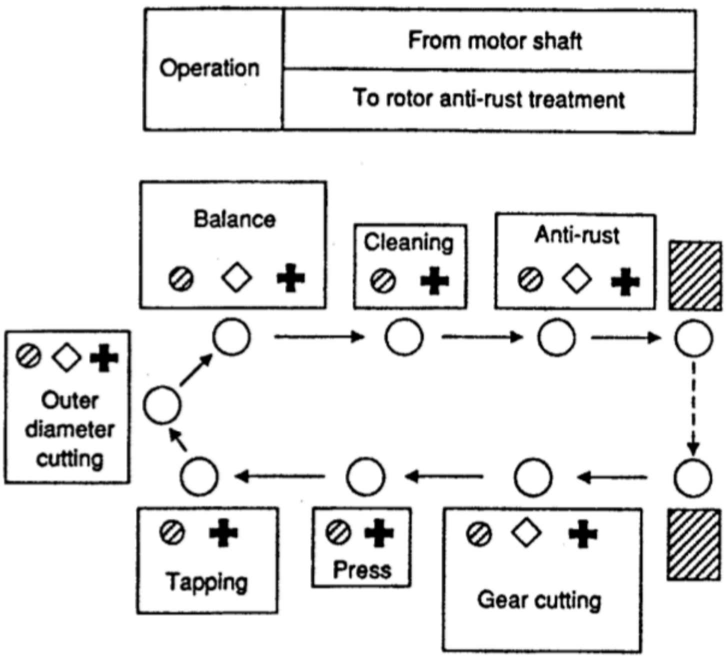
The result is a special type of cellular layout, defined U-shaped production line, that is typical of JIT systems (Miltenburg, 2001).

According to this layout, machines needed to manufacture a certain product or family of products are grouped and located sequentially around a U-shaped line, along which one or more operators move performing their tasks (see Figure 11).

As described by Miltenburg (2001), in simple U-shaped lines, that can be used alone or constitute the basic module for more complex cellular structures, production flows along the line, and each time an item reach the end of the line, one new item gets inserted in the cell in order to be manufactured.

While the production is running, one or more operators perform some manual tasks (machine loading and unloading, quality checking, machine starting and supervising) and the machines work automatically, performing tasks like drilling, welding, assembling, etc. (Miltenburg, 2001).

According to how tasks are assigned to operators, the arrangement can be different: some plants assign one cell to one single operators, ore place several operators to run the same cell, each one of them taking an item through all the operations along the line, while others group operations into workstations and assign each workstation to one single operator (Miltenburg, 2001).



Quality check	Safety caution points	Standard stock-in-hand	No. of standard stock-in-hand operations	CT	No.	Net time
◇	✚	⊘	7	37"	A-01-T	35"

Figure 11: Example of U-shaped production line

Source: Miltenburg (2001, p. 204)

U-shaped production lines bring several benefits:

- Reduce Throughput Time and improve overall quality
- Provide flexibility, because they make easier to adapt production volumes to actual demand
- Increase product variety and easiness in introducing new products
- Minimize inventory, waiting, motion and transportation.

Kanban

In order to operationalise pull principle, LM prescribes the use of Kanban system, which is a controlling and signalling system used to authorize the release of materials (Slack *et al.,* 2013).

Kanban – which stands for "card" or "signal" – is strictly linked to the abovementioned concept of Controlled Inventory: Supermarkets cushion possible lack of perfect synchronization between processes, and Kanban are used to link upstream and downstream processes in order to compel the former to produce only on the basis of actual demand expressed by the latter.

This system is generally based on the use of order cards – the Kanban, precisely – that moves from one station to another to trigger a specific action.

Kanban are generally classified as (Rother and Shook, 2003; Sugimori *et al*., 1977):

- *Production Kanban*, which orders the upstream station to produce the items withdrawn by the downstream customer
- *Conveyance* or *Withdrawal Kanban*, a "shopping list" sent by the downstream process that instructs the material handler to get and transfer parts taken from supplier station.

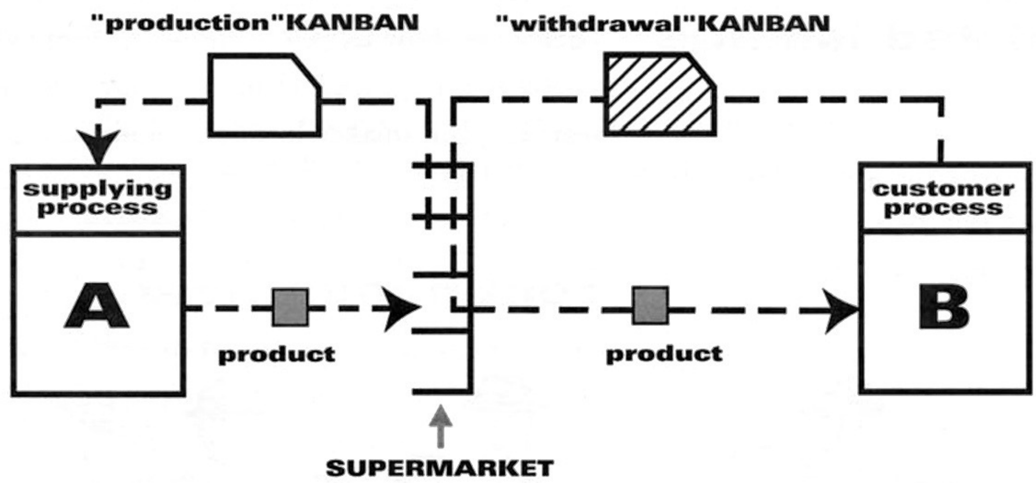


Figure 12: Example of Kanban system

Source: Rother and Shook (2003)

As Sugimori *et al.* (1977) describe, Kanban cards are generally attached to part containers.

Once a part of a container starts to be used by the upstream process, withdrawal Kanban gets removed from that container and sent back to the supermarket. Here, an analogous part is picked up, and the withdrawal Kanban is attached on the container of that part, while production Kanban is removed and sent back to the upstream station as a signal to replenish the withdrawn.

Simultaneous Engineering

Simultaneous Engineering - also named Concurrent Engineering or Simultaneous development - is a systematic and integrated approach applied in the context of lean product design and development, with the aim of reducing both related costs and time-to-market.

Traditionally, product design and development entail the performance of a series of activities, which tend to be performed one at a time, starting only when the previous one is completed.

In particular, each set of actions is attributed to a specific function which perform it independently and, once finished, pass it down to the following function, with little or no interaction between the different areas.

To some extent, this traditional sequential approach resembles the logic underlying batch and queue production system - it is focused on the maximum exploitation of specialised skills - and as such entails parallel issues: it is time-consuming, costly and it is likely to require several throwbacks to previous stages when an issue occurs (Slack *et al*., 2013).

On the contrary, Simultaneous Engineering prescribes the overlap of these stages and the parallel performance of the design and engineering activities.

This approach is firstly based on the constitution of multitasking teams that includes people from all the departments involved from product design to commercialisation, in order to foster the interaction of complementary skills.

Team members are almost equally involved and exert the same influence on the overall project advancement, approaching the single project from different standpoint and offering different skills to the overall team.

As a result of this simultaneous and multidisciplinary collaboration, conflicts between departments decline, unnecessary activities are minimised, overall design and developments costs are significantly reduced and time-to-market gets shortened.

Kaizen Events

Continuous Improvement - or *Kaizen* – represents one of the core principles of LM. This principle gets operationalized through a wide range of tools and techniques used by lean companies.

One common mechanism for implementing this concept, hence, is represented by Kaizen Events (KE), that are focused and structured team-based projects used to improve a work area and achieve specific goals (Glover *et al.,* 2013).

According to Bicheno and Holweg (2008) KE "fill the gap between individual […] improvement initiatives and bigger initiatives" like value stream improvement, which entail the involvement of the whole value stream, and have a dual role: to make improvement and to foster communication among people.

Generally, KE take from 3 to 5 days of full work, and may involve both internal members of the organization and outsiders called to help in solve some complex issues - like, for instance, a change in layout; however, some KE (called Mini Kaizen) might take less time – from half a day up to 2 days - and entails the intervention of only internal members (Bicheno and Holweg 2008).

Independently on the type of KE, Bicheno and Holweg (2008) suggest to work through the following activities:

- Before the event, select the area that is going to be object of improvement, the team that is going to participate and the time for the event

- During the event, provide an overview of aims and background, observe directly the process, generate ideas, try to implement possible solutions and finally perform a final check and adjustments

- After the event, close down all the outstanding topics and perform review sessions on a routine basis.

PDCA cycles

Within the context of Kaizen, PDCA ("Plan-Do-Check-Act") cycles represent a key instrument to address problem solving processes in a Continuous Improvement perspective.

This improvement cycle, in particular, represent a systematic approach to problem solving that consist of a path of standard response to a critical factor.

As Pieńkowski (2013) states, the response process starts with the identification of the factor that needs to be solved or improved, which triggers the start of PDCA cycle.

Plan phase entails a careful analysis of all the elements that might have caused the occurrence of the issue, up to identifying its root cause; then, it is necessary to formulate an action plan to solve the problem.

The Do phase consists in the actual and rapid implementation of the action plan previously designed.

'Check' means that actual effectiveness of the proposed countermeasure has to be assessed.

Then, if the countermeasure does not work, the process restarts from the 'Plan' phase; otherwise, if the corrective action is effective, it has to be consolidated and standardized within working procedures – 'Act' phase.

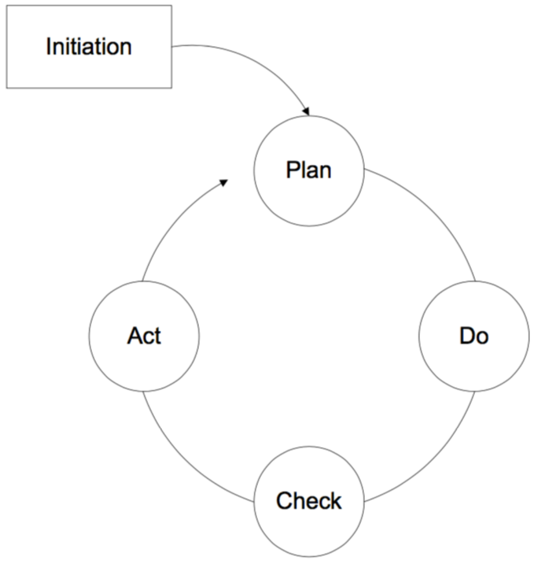


Figure 12: The response process standards
Source: Pieńkowski (2014)

<u>*A3*</u>

A3 is a standard documentation method used to implement a systematic problem solving and continuous improvement approach based on the PDCA cycle principles above-mentioned.

This tool takes its name from the paper size used to apply the technique itself. A3 implementation, in fact, consists in filling properly some visual sections in order to assess the current state of operations, the future desired state and supervise the implementation of the solution provided.

The traditional A3 report, in particular, prescribes to approach problem solving by identifying the following aspects and filling the corresponding area in the sheet:

1. *Background:* identification of the context details, highlighting the relevance of the problem
2. *Current conditions:* synthetic description of the issue
3. *Goals:* Description of expected outcomes and results
4. *Analysis:* identification of the root-cause of the problem

5. *Purposed countermeasures:* formulate and report possible solutions for all the causes previously identified and define a plan for implementing them

6. *Effect confirmation:* assess the effectiveness of the countermeasures

7. *Follow-up:* Schedule the periodic review of the problem, in case of occurrence of wider issues, and communicational improvements and results to the rest of the organisation.

On overall, the benefit of the A3 technique relies on the fact that this simple visual instrument is a powerful tool to address properly, rapidly, simply and effectively different issues that involves several people.

Moreover, as highlighted by Shook (2009), the ultimate goal of A3 is to ensure transparency of problem solving processes and enhance people involvement by teaching a synthetic and structured standard for addressing this kind of processes.

Six Sigma

Six Sigma is a measurement system used to improve process quality by controlling the defect rate within a process.

This systematic approach is focused on achieving and sustaining superior performance improvements by strictly reducing process output variation.

In particular, the term Six Sigma derive from the maximum spread of variation allowed in any process (Bicheno and Holweg, 2008).

Sigma is the symbol of variance, and imposing a Six Sigma level means that the defect rate of any process must not exceed 3.4 defects every million parts produced, corresponding to 99,99% of quality rate.

One of the main benefits associated to Six Sigma is that its implementation is based on a systematic and disciplined approach to problem solving (Snee, 2010). This system, in fact, prescribes to follow five specific steps for improving processes (Dahlgaard and Dahlgaard-Park, 2006):

1. *Define*

   Identify the problem that needs to be fixed or the process to improve

2. *Measure*

   State which components of the product/process are more significant in terms of customer satisfaction

3. *Analyse*

   Assess the current state of operations, detecting all the potential sources of variation – which are likely to be detrimental to customer satisfaction

4. *Improve*

   Implement process improvement on the components that have been defined as more significant

5. *Control*

   Document and monitor process condition by using statistical process control methods, and if needed, repeat one or more of the first four steps.

Snee (2010), on overall, has defined Lean Six Sigma – the integration of key LM principles together with Six Sigma approach - as “a business strategy and methodology that increases process performances resulting in enhanced customer satisfaction and improved bottom line results”: the implementation of this technique, hence, goes far beyond the simply process improvement that may surely be achieved with it, up to gaining a broader strategical connotation.

Suggestion System

Employees involvement represents a core element in Continuous Improvement process. In this regard, Kaizen can be narrower translated as “ongoing improvement involving everyone” (Imai, 1986).

In particular, the extreme relevance of employees’ ideas and contribution in Toyota is directly expressed by the slogan “Good products, good ideas”, which means that the company strongly capitalises on its personnel’s contribution and direct involvement in order to be successful (Monden, 2011).

Hence, involvement in LM companies is often accomplished through the definition of Suggestion Systems, which are structured schemes and procedures to be followed in order to highlight and solve issues.

Suggestion process may be held either by a single worker or a team of employees led by a supervisor.

Once a problem emerges, the procedure for generating solutions is carried on through the following steps (Monden, 2011):

1. *Define the problem,* determining the nature of the issue and its effects
2. *Examine the problem,* shedding light on its causes
3. *Generate ideas,* starting from the suggestion of all the team members
4. *Summarize ideas,* selecting the best solution among the ideas proposed
5. *Submit the proposal*

This structured path that has to be followed for generating and submitting suggestions is then consistently accompanied by a structured scheme for suggestion implementation, employees rewarding, and feeding back giving on suggestion implementation status (Karlsson and Åhlström, 1996).

In Toyota, for example, new suggestions are examined every month by a specific committee, which immediately notifies the results of the examination. Outstanding Employees and teams are then rewarded either with monetary and non-monetary compensations, like official commendations, commemorative gifts and trophies (Monden, 2011).

CHAPTER 2

CONTEXTUAL FACTORS AND PERFORMANCE IMPLICATIONS OF LEAN: A LITERATURE REVIEW

Literature review outline

Since its first diffusion outside of the Japanese and automotive boarders, Lean Manufacturing has deeply captured the interest of both firms and academics.

Since 1990s, this organisational paradigm has spread far beyond the motor-vehicles industry (Womack, 2006) and to this day, lean principles and techniques have been widely adopted and implemented in several different kinds of businesses, ranging from manufacturing enterprises, to service companies, from administrative processes, to healthcare and public administrations (Arlbjørn and Freytag, 2013).

In parallel with this operating diffusion, academics have exerted huge effort in research on LM implementation and effects on business performances, resulting in great diffusion and steady growth of publications on this topic (Jasti and Kodali, 2015; Negrão *et al*., 2017).

On overall, LM has been studied and investigated from different point of view and perspectives.

In this respect, for sake of order and coherence, it can be useful to draw on the approach purposed by Negrão *et al*. (2017), who conducted a literature review on lean practices, and to adapt it - with some differences - to the purpose of this analysis.

In particular, these authors have performed an analysis clustering publications in articles focused on studying the degree of adoption of lean practices and works that have studied the correlation between lean adoption and business performances.

In this chapter instead, a distinction can be drawn between studies that have investigated the possible factors influencing LM adoption and its degree of implementation and works that have observed the correlation between LM and performances.

Moreover, it results firstly necessary to properly inquire into the possible methods generally used to assess and quantify leanness degree at company level. In fact, on the one hand the extent of adoption represents the possible outcome resulting from the effect exerted by contextual factors. On the other hand, the same degree of LM implementation has to be studied as possible factor mainly affecting a firm's performances.

For this reason, the following review will start by resuming some different methodologies provided by different authors for assessing the extent of LM adoption at firm level - from now on generally referred as leanness.

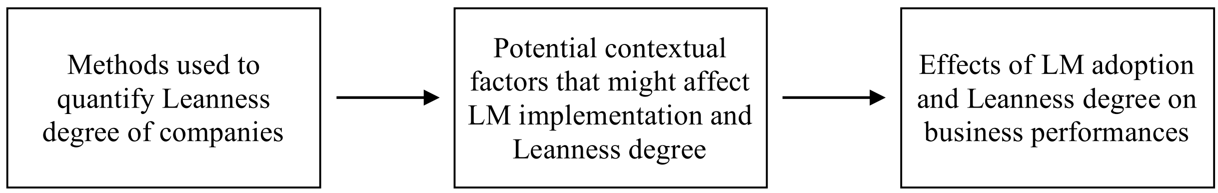


Figure 13: Structure of the literature review

This structure offers the possibility to present coherently and in an orderly fashion distinct perspectives widely and differently studied and, at the same time, it provides a path to be followed in performing the empirical analysis of this study.

As a result, the empirical analysis reported in Chapters 3 and 4 will be conducted as follows: after having properly defined how to define the degree of leanness of a company and designed an appropriate index to measure it empirically, the research will be focused on assessing the degree of adoption of LM in the sample, on inquiring into the possible elements most likely to be correlated to it, and on investigating the possible effects exerted by LM implementation on business performances.

Leanness degree measurements

As already anticipated, assessing the actual extent to which a company implements and executes LM principles and practices serves as necessary starting point for performing several types of analysis and studying different sides of LM adoption.

In addition, a proper and effective measure of leanness not only serves academic and research purposes, but might also constitute a useful and insightful internal instrument, that firms can use to personally assess their improvements in LM implementation and follow as a blueprint for lean transformation.

Nevertheless, there seems to be still a lack in the literature concerning the provision of a method for assessing the actual degree of implementation of LM (Lucato *et al.*, 2014).

Moreover, even if several attempts have been made to measure improvements in LM adoption and the related impact on performances, the topic of assessing the extent of lean application seems not to have already been fully discussed, especially considering that not all the authors that have dealt with Lean implications have always measured and studied the degree of leanness in overall terms (Wan and Chen, 2008).

For instance, Fullerton *et al.* (2003) have investigated the positive impact of a high degree of JIT on firms' profitability.
The authors have highlighted the importance of analysing the potential benefits of JIT in terms of performance by measuring manufacturing practices that reflect the application of JIT, rather than examining its overall implementation "as an either/or proposition" (p. 388).
Nevertheless, they have focused only on the effect exerted by the single degree of implementation of a series of practices, without considering the degree of implementation of the system as a whole.
In particular, the authors have identified 10 practices - focused factory, group technology, reduced setup times, total productive maintenance, multi-function employees, uniform workload, Kanban, JIT purchasing, total quality control, and quality circles - considered to be representative of JIT; the extent of implementation for each single practice has been evaluated on the basis of a Likert scale that spans from 1 (no intention to implement the corresponding practice) to 6 (the practice is fully implemented).

Instead of extracting from that evaluation an overall measurement for the degree of JIT adoption, practices have been grouped converging into three main components of JIT implementation - JIT manufacturing, JIT quality and JIT unique elements.
Then, the effect of the intensity of implementation of each component on financial indicators has been assessed, but without providing a connection between overall intensity of JIT implementation and business performances.

Similarly, Shah and Ward (2007) have suggested to measure the degree of LM adoption on the basis of the 10 factors - Supplier feedback, JIT delivery, Supplier development, customer involvement, pull, continuous flow, set up time reduction, TPM, Statistical process control and employee involvement.
To these 10 factors correspond 48 practices and tools, each of which has to be evaluated on the basis of a Likert scale that spans from 1 (no implementation) to 6 (complete implementation) in order to quantify the extent of their implementation.

Doolen and Hacker (2005) have performed an assessment on multiple dimensions integrated within lean enterprise system.
In particular, they have identified six impact areas - manufacturing equipment and processes, shop floor management, new product development, supplier management, customer relations, and workforce management - and to each one of them they have attributed a specific set of supporting activities, for a total of 29 practices.
Each single practice has been required to be evaluated on a scale from 1 to 5 according to the frequency of use. Then, the average implementation level of each area has been computed as the mean value of corresponding practices' score.

These three methods here reported are all examples of Lean measurements made by quantifying the extent of implementation of single lean initiatives or set of tools.

Despite these approaches might be useful and serve several analytical purposes - for instance, their measurement has allowed Shah and Ward (2007) to assess the existence of linkages and interconnections among different lean factors - they fail to provide an aggregate leanness measure at the whole firm level.

In any case, literature on leanness measurement offers also several efforts exerted by many authors that have addressed the topic of LM assessment by adopting an aggregate perspective on this subject.

In particular, the benefit provided by overall leanness assessment is that it is likely to be the simplest and most complete element to be accounted for when performing comprehensive analysis on factors affecting lean implementation and on LM performances.

For instance, Soriano-Meier and Forrester (2002) have investigated the global extent of LM implementation at firm level, defining it “Degree of Adoption” (DOA).
In particular, they have based their measurement of companies’ leanness on the identification of nine lean principles suggested by Karlsson and Åhlström (1996) - Waste elimination, Continuous Improvement, Zero Defects, JIT deliveries, Pull of materials, Multifunctional teams, Decentralisation, Integration of functions and Vertical Information Systems - and on their evaluation.
Each principle has been evaluated separately according to intensity of its adoption, getting a score from 1 (no adoption) to 7 (total adoption). Then, overall DOA has been computed as the mean value of the nine scores collected by the principles.
DOA calculation, even if has the drawback of being expressed in a numerical term that might be not self-evident (e.g. a DOA score of 4,36 has a limited meaning if not compared to the maximum value of 7, and still might be quite unclear at first sight), has the merit of being pretty easy to compute and suited for being applied in several different analytical contexts that require an overall company-level assessment on LM implementation.
What they have defined “Degree of Leanness” (DOL), instead, captures a temporal dimension, being intended as the change through time of the variables used to assess the DOA. In this case, the computation becomes more difficult and the temporal dimension makes the instrument less suited to be applied in different analytical contexts, because takes years to collect the data for the assessment.

Moreover, apart from academic implications, an aggregate leanness measure might be a more insightful instrument suited to be used also by managers for self-assessing the stage of their company with regard to LM and its effects.

For instance, remaining on the self-assessment perspective, Wan and Chen (2008) have suggested the adoption of a dynamic Self-Benchmarking approach based on Data Envelopment Analysis (DEA).
According to their method, leanness level of manufacturing systems can be measured by comparing the efficiency of different production units in terms of costs incurred, time absorbed and value generated.

Each production unit gets a score from 0 to 1 considering their leanness level, which in this case is represented by their input/output ratio, where input are time and cost and output is the value created.
A score of 1 is associated to a virtual optimal unit in terms of efficiency, which is identified by removing non-value-adding time and costs from the most efficient process. This ideal unit represents the benchmark for comparing the other production units, whose score in fact is expressed as a percentage of that overall maximum efficiency.
The overall leanness of the manufacturing system is the computed as the average of the scores totalised by all the productive units.

Clearly, the measuring method suggested by Wan and Chen (2008) offers several benefits, like the high understandability of the index expressed on a scale from 0 to 1, the comprehensive perspective and its adaptability of frontier to changes.

Nevertheless, in this case leanness gets measured only with reference to the idea of efficiency as "producing more with less" and so to the concept of value enhancement and waste reduction, without considering the application of any LM tools, which instead are the operating instruments through which waste reduction and value enhancement get actually achieved.

From this perspective, a Non-lean company could be ideally considered as characterised by a high degree of leanness regardless of the actual implementation of LM practices and principles, but solely on the basis on its ability to reduce at maximum non-value added activities. This approach, then, could lead to biases in analysis focused on assessing elements, causes and effect of LM actual adoption.

For this reason, a more sensible assessment instrument should be strictly based on the application of LM practices and techniques.

In fact, even if the application of lean practices does not automatically ensure the implementation of underlying lean principles (Spear and Bowen, 1999), techniques are much easier to observe and measure, (Saurin *et al.,* 2011), because of their visible and tangible dimension, which differentiates them from cultural elements and philosophical attributes that are much harder to detect and measure (Shah and Ward, 2007).

Moreover, leanness assessment based on tools usage makes more sense to companies that have recently started their LM transformation (Saurin *et al.,* 2011): companies tend to start their "Lean journey" by implementing sets of practices, while the lean culture and all the other intrinsic invisible LM elements are aspects that tend to be built over time.

For these reasons, leanness assessment based on practices implementation should prevail in analysis like the present one, that aim to study empirically causes and consequences of LM application including in the sample companies that are likely to have different years of experience in lean transformation.

Actually, several authors have based their aggregate leanness assessment on measurement of implementation of LM practices and techniques.

Taj (2008) has performed a lean overall assessment based on a study previously developed by Lee (2004) which returns as output an overall leanness measurement.
In particular, this assessment is focused on the evaluation of nine key areas of manufacturing - inventory, team approach, processes, maintenance, layout/handling, suppliers, setups, quality and scheduling/control - matched with 3 to 6 questions each, for a total of 40.
Questions get a score from 0 to 4 according to
The global score for each section, that ranges from 0 to 100%, is computed from the point collected by the matching questions.
Then, an overall Lean Index gets computed on the basis of both the nine sections scores and on the specific weight of each section in terms of impact on manufacturing performance.

Also Lucato *et al.*, (2014) designed an overall leanness evaluation method, implementing and enhancing the "SAE J4000 standard", an instrument purposed by the Society for Automotive Engineers (SAE) for identifying and measuring best practice used in LM contexts.
J4000 standard is based on the identification of six main elements typical of LM operations - management/trust, people, information, supplier/organisation/customer chain, product and element and process flow - and their evaluation on the basis of the score collected by 52 corresponding components. In particular, each component has to be graded with a score between 0 and 3 according to its level of implementation.
In order to offer a single measurement index for each element, Lucato *et al.* (2014) have suggested to compute the degree of leanness (DOL) of each element as the ratio between the total number of points obtained from the evaluation of the corresponding components and the maximum score obtainable.
Analogously, the authors have then computed the overall DOL for the company as a whole as the mean of the points scored by the six elements.

Taj (2008) and Lucato *et al.* (2014) seem to suggest two measures pretty in line with the purpose of this analysis.

First, they offer instruments for assessing the overall level of leanness of a company, that represents a necessary variable for conducting the analysis expected to be performed in this study.

Second, the assessment in both cases focuses on a single-time dimension (differently from Soriano-Meier and Forrester, 2002) and is based on the evaluation of the actual implementation of a set of LM practices. These two features allow to potentially perform a complete analysis of all and only the companies that have somehow started their Lean transformation, regardless of the actual experience they have.

Practice-based logic, in particular, is extremely relevant, in measurement contexts, especially considering that, as already anticipated, techniques application is much easier to be assessed rather than principles implementation.

Nevertheless, all the approaches presented fail to cover another relevant aspect that has to be taken into consideration when assessing firms' degree of leanness.

These approaches are focused on the assessment of leanness of producing processes, with only a small - or even null - interest in inquiring into the effective and actual implementation all over the whole firm, considering all the departments that compose it.

This tendency has been highlife also by Marodin and Saurin (2013), who have noted that in the literature "lean assessment methods have a stronger focus on the shop floor, in detriment of the use of lean in other areas of a company".

Moreover, little or no attention is paid to the possible synergic effects or, at the contrary, inefficiencies that might arise from the involvement or exclusion of different areas of the company.

In fact, as Marodin *et al.* (2015) have highlighted, the implementation of some specific practices cannot disregard its actual diffusion in several departments and supporting areas.

For example, Production Levelling would have a marginal impact if not complemented by proper levelling actions and practices also al purchasing, logistics and sales level.

Besides, in general, it should be recalled that LM is not simply a set of tools, but a complex and integrated system of harmonised parts. For this reason, the actual spread of lean practices in different areas of the firm is an element that has to be accounted for.

Moreover, department coverage could possibly constitute a valid alternative to the Likert scale often used for assessing the tools grade of implementation (e.g. Soriano-Meier and Forrester 2002; Fullerton *et al.,* 2003; Doolen and Hacker, 2005; Shah and Ward, 2007; Lucato *et al.*, 2014).

In particular, the main disadvantage of using Likert scales is linked to the possible subjectivity of the answers: "full" or "partial" implementation - which are items generally measured in the scales - might have different meanings according to different respondents.

On the contrary, the fact of assessing whether a practice covers or not every department might offer a more objective measure of the extent of implementation of that tool.

Authors	**Overall Leanness Assessment**	**Single time dimension**	**Practices-based**	**Dept. coverage**
Fullerton *et al.* (2003)	Missing	X	X	Missing
Shah and Ward (2007)	Missing	X	X	Missing
Doolen and Hacker (2005)	Missing	X	X	Missing
Soriano-Meier and Forrester (2002)	X	Missing	X	Missing
Wan and Chen (2008)	X	X	Missing	Missing
Taj (2008)	X	X	X	Missing
Lucato *et al.*, (2014)	X	X	X	Missing

Table 2: Summary of leanness measurement reviewed in the chapter

As a result, in order to perform a significant leanness assessment, LM implementation should be measured bi-dimensionally: not only considering the extent of practices adoption, but also assessing the actual diffusion of LM practices in different departments.

To sum up, from the literature review and considering the analytical purposes underlying this research, it has emerged the necessity to design a proper instrument for measuring the overall leanness of companies that must comply with the following criteria:

- It must be simply to be computed and expressed in self-evident terms (e.g. a number ranging from 0 to 1 or a percentage)
- It has to be focused on a single-time dimension
- It has to be computed on the basis of the actual implementation of LM practices
- It must measure the diffusion of practices within the organization, considering the actual departments involvement.

The design and computation of the instrument matching these criteria - hereinafter referred as "Leanness Index" - are widely presented and explained in Chapter 3.

Contextual factors on LM adoption and degree of implementation

Many academic works on LM implementation and effects tend to be focused in a particular geographic area.

For example, Ghosh (2012) and Deshmukh *et al.* (2017) have tested the effectiveness of LM on operating performances in Indian manufacturing plants; Taj (2008) and Taj and Morosan (2011) have focused their studies on lean application in Chinese manufacturing industries; Kuo *et al.* (2008) have conducted a research on LM plants in Taiwan; Moori *et al.* (2013), Godinho Filho *et al.* (2016) and Marodin *et al.* (2016) have analysed LM performance in Brazilian firms, while Fullerton *et al.* (2003) and Fullerton and Wempe (2009) targeted only US companies.

In this regard, Negrão *et al*. (2017) have stated that this decision of "narrowing down the scope" of the studies in order to analyse "companies that share the same geographical location" results to be highly logical and appropriate, considering that LM has been suggested to be highly influenced by the context within it is implemented.

For the same reason, it seems equally reasonable the decision to focus the present study on analysing the LM implementation by restricting the subject to manufacturing firms located in the Veneto region.

Firms that share the same geographic area, in fact, are expected to be influenced by the same political, legal, social and technological factors. For this reason, external environment - the same for all the companies in the sample - can be deemed to be controlled for in the analysis, preventing it from influencing LM implementation.

Nevertheless, apart from external environment, several other factors and peculiarities might exert an influence or at least be correlated to companies' decisions toward LM implementation.

In this regard, several authors have analysed the possible effect on LM adoption of contextual elements like firm's size, age and industry, and in some cases they still have not reached a common conclusion with regard to the effect of each specific factor.

Moreover, as reported by Marodin *et al.* (2016), the majority of the studies on context and LM implementation were theoretical or based on small-scale case studies; on the contrary, empirical tests on contextual variables have been performed to a lesser extent.

For this reason, it results important to summarise the empirical contribution provided by some authors on the effect that is likely to be exerted by several specific factors on LM.

Then the study here reviewed will be extended by means of the analysis that will be performed in Chapter 4 on this regard.

Size

One of the first factors that might have proved to be somehow related to LM implementation is represented by firm Size.

In particular, many authors have handled this subject, but they have often reached different conclusions on the actual effect exerted by company size on LM adoption and extent of implementation, to the extent that it may be considered to be still an open discussion (Negrão *et al.*, 2017).

Several authors, in fact, have proven that company size might exert a positive and significant effect on LM implementation.

According to White *et al.* (1999) Large firms tend to be more prone to adopt LM, if compared to Small firms.
Moreover, also the extent of practices implementation is likely to change according to company size: on average, Small manufacturers implement a lower number of techniques, and the majority of the companies that have adopted lean in an extensive manner were classified ad Large.

In line with Withe *et al.* (1999), also Shah and Ward (2003) have found significant differences in terms of lean practices implementation between small and large firms. In particular, the majority of the practices subject to their study have been proven to be more extensively adopted in larger firms.

Analogously, also Doolen and Hacker (2005) found a positive and significant correlation between firm size and LM implementation when assessing the extent of the adoption of several practices.

Finally, also Marodin *et al.* (2016) confirmed that Larger firms tend to implement LM practices to a greater extent than Small-Medium ones.

In general, the theoretical argument for this positive correlation between company size and LM implementation is that Large firms are more likely to possess more resources - in terms of both financial and human capital - that, on the one hand, can be reflected into larger investments and, on the other hand, correspond to a broader range of skills and expertise, that might facilitate lean adoption (Shah and Ward, 2003; Doolen and Hacker 2005).

Nevertheless, the same conclusion has not been reached by all the authors.

At the opposite, in fact, Bayo-Moriones *et al.* (2008) have rejected the hypothesis of a positive effect of company's dimension on lean implementation, finding also significant evidences on the negative impact exerted by firm size on LM tools adoption.

In particular, they linked this negative result to the fact that some lean practices - especially lot size reduction - in order to be implemented require companies to be more flexible and responsive in their operations, and these characteristics are much more likely to be found in small firms.

Then, setting themselves in an intermediate position, Lucato *et al.* (2014) have not found any significant difference between large and small firms in LM implementation, neither when measuring the extent of single practices adoption nor when assessing the overall leanness degree at company level.

In general, the lack of significance in the effect exerted by firm size on LM implementation might be somehow intended as a Zero-Sum effect: on the one hand the flexibility of small firms, which might facilitate LM adoption, can be counterbalanced by a lack of financial and human capital necessary to the purpose; on the other hand, structural rigidity and inertia of larger firm might be outweighed by larger resources. On overall, the result is the absence of differences in LM application between small and larger firms.

Therefore, given the opposite results and theoretical explanations provided by the literature, it results necessary to test for the possible effect of company size both on lean implementation and on its degree of adoption.

Industry

It has already been highlighted that LM, after its birth in the automotive sector, has successfully spread among a wide variety of industries.

As a result, several authors have inspected the potential difference in LM implementation among different industry sectors.

Shah and Ward (2003), analysed the potential effect exerted by industry on the implementation of a set of lean practices bundles making a comparison between "process industries" and "discrete part industries".
First, the authors found that, in general, lean practices are all implemented and characterised by a high level of application in both industries. Then, more specifically, observed that the degree of implementation of some bundles differs across industries, while the application of others does not change.

Pretty in line with the previous findings, Doolen and Hacker (2005) found only small but significant evidence regarding differences in lean adoption across three set of industries (Printed Circuit and Assembly, Equipment Manufacturers and Wafer and Semiconductor Manufacturers). LM practices related to manufacturing equipment and processes are implemented to differing degrees, while the extent of adoption of all the other techniques does not differ passing from one sector to another.

However, neither Shah and Ward (2003) nor Doolen and Hacker (2005) did inquire into potential differences on the overall leanness degree of companies, because they focused on the application of single set of techniques.

This aggregate measure, instead, has been investigated by Bayo-Moriones *et al.* (2008) who has proved that it seems to exist small differences in overall LM adoption in different sectors: in general, all companies tend to implement LM at the same extent regardless of the industry where they belong, with to only exception for non-metallic mineral products industry, which showed a lower leanness degree.

Also Lucato *et al.* (2014) inquired into the overall degree of leanness of each company comparing three different sectors (Automotive, Metal-mechanical and Other). Also in this case, slightly but statistically significant differences concerning overall LM implementation across different industries have been found. Here, in particular, evidences showed that metal-mechanical companies were characterised by a lower degree of leanness in comparison to the other sectors.

In general, we can conclude saying that several empirical evidences have shown that LM implementation is likely to differ across sectors. However, it should sound reasonable to further investigate the topic by analysing potential differences among industries regarding not only the overall degree of leanness but also the likelihood of LM adoption.

In particular, it would be useful to assess specifically whether there are industries more prone than others to adopt LM, and then if, once LM has been implemented, differences still exist among sectors according to the average leanness of companies. In fact, in papers here reviewed no explicit distinction has been made between Lean and Non-lean companies when assessing LM implementation and leanness degree. Hence, a useful insight could result from a separation of companies into these two groups.

Age of the Firm

Another critical factor which might exert an influence on LM is represented by company age.

From a theoretical perspective, older companies might be characterised by higher "resistance to change" (Shah and Ward, 2003), in the sense that they might be more prone to stick to their current operating procedures and routines and so less apt to adopt new system, as might be represented by LM. For this reason, it would be sensible to expect a negative effect exerted on company age on LM adoption.

However, literature has offered more univocal evidences, pointing out to the uncertain significance of this element.

In particular, for example, Shah and Ward (2003) have studied the effect of plant age on the adoption of several lean practices. They found dissenting results: some tools were significantly and positively related to plant age, other were negatively affected by age, and finally some other relationships not resulted of any significance.

Nevertheless, apart from concluding the uncertainty of the effect exerted on LM implementation by age, the study did not provide a result on the relationship between age and the company overall leanness degree.

Bayo-Moriones *et al.* (2008), confirmed the indeterminacy of the effect of age on several practices: age has resulted to be significantly - and negatively - related to just one practice over the 4 analysed. On overall, then, the research highlighted the absence of significant relation between firm age and aggregate adoption of LM techniques at company level.

At this point, it might result reasonable to study the effect of company age not only on overall degree of LM implementation, but also on general lean adoption, comparing Lean and Non-lean companies on the basis of their age. This analysis could confirm or reject the absence of age influence on both cases.

Effects of LM on business performances

The influence determined by LM implementation on business performances has been widely observed by academics.

In particular, several evidences have shown the positive impact exerted by lean practices on operating performances.

For instance, Ghosh (2012) inspected the linkage between seven lean practices and three performance indicators, namely Productivity, Manufacturing Lead Time and First-pass correct output. From this research emerged that all the techniques were significantly and positively related to at least one performance indicator, with the exception of TPM, which showed to influence negatively the productivity.

Similarly, Belekoukias *et al.* (2014) have assessed the impact of five LM practices on five key performance indicators - Quality, Costs, Speed, Flexibility and Dependability - and on an overall measure of operating performance. Evidences showed that, on overall, some practices (JIT and Automation) have a positive and significant impact on operating performances, while others (Kaizen, TPM and VSM), affect them to a lesser extent or even negatively.

In both papers, Ghosh (2012) and Belekoukias *et al.* (2014) have provided evidences on the fact that LM practices might affect performances, but also that the effect might be significantly different depending on the specific technique analysed. What they did not provide, hence, was an assessment of the effect exerted by the overall LM implementation on performances.

This aggregate point of view, instead, has been adopted by Taj and Morosan (2011), who displayed a positive and significant relationship between a construct named "Production system design", which measures the extent of application of several lean practices, and three operating performances indicators - Flow, Flexibility and Quality.

Similarly, also Fullerton *et al.* (2014) have provided empirical evidences in support of the positive and significant exerted by LM implementation - measured as the extent of the adoption of several lean practices like Manufacturing Cells, Kanban, One-piece-flow, 5S and Kaizen - and operating performances.

Considering these empirical evidences, we can conclude that, on overall, LM implementation seems to positively affect operating businesses, especially when considered on aggregate basis.

What is important to underline in this regard is that, as long as LM has to be intended as a broad and all-encompassing system whose benefits should concern not simply firm's operations, but its overall strategy, LM effectiveness should be tested also with respect to financial impact. A positive effect of LM in financial terms, in fact, would reasonably suggest that lean practices adoption may represent a key element for the implementation of a successful strategy.

In this topic, Fullerton *et al.* (2014) provided evidences on the existence of significant and positive relationships both between LM and operating performances and between operating performances and financial results, concluding that, on overall, LM implementation has a positive impact on operating results, which in turns determine an improvement in financial performances. Nevertheless, the authors here did not test directly for the effect exerted by LM on financial performance.

Direct impact of LM practices on financial results has been investigated by other studies. For instance, Green (2014) provided empirical evidence on the positive effect of JIT on financial results, finding a positive and statistically significant relationship between JIT practices and an aggregate measure of organisational performances, which takes care of company's ROS, ROA and profitability.

Even more extensively, Fullerton *et al.* (2003) explored the linkage between JIT practices and three specific performance indicators - ROS, ROA and Cash Flow Margin.
First, the authors have provided evidences on the fact that companies that adopt JIT practices are characterised by significantly superior performances in terms of all the three indicators.
Then, evidences have shown that the extent to which all the three JIT elements here analysed is significantly and positively related to ROS, ROA and Cash Flow Margin.

In general, several studies seem to confirm the positive impact of LM on financial performance.

However, before proceeding with generalisations on this topic, this financial effectiveness should be tested in the sample subject to this study. In fact, differences in the context should somehow imply different conclusion concerning this aspect. As a result, the last part of the analysis performed in this work will concern the assessment of the financial impact of LM.

The extensiveness of the research performed by Fullerton *et al.* (2003) should be reasonably taken as a guiding pattern to perform this analysis.

For this reason, financial performances will be assessed on the basis of both profitability and liquidity dimension.

Moreover, the first analysis will be performed comparing Lean adopters and Non-Lean companies, in order to assess whether LM implementation actually determines significant differences in terms of performances in the sample.

Then, it will be observed if the overall degree of leanness of the companies in the sample has an impact on financial results. In this context, differently from the approach used by Fullerton et al. (2003), who analysed the impact of three JIT general components, here the analysis will focus on the impact of an aggregate measure of leanness - the Leanness Index.

CHAPTER 3

RESEARCH AND METHOD

Research overview

What has emerged from the analysis of the literature is that, despite the large number of extensive and significant contribution provided by academics, there still seems to be scope for addressing the issue of LM implementation in a more orderly fashion.

For this reason, the analysis presented in this work will concern three different aspects of LM implementation and, for each of them, it will be performed on two levels.

In particular, the two aspects analysed in this research are:

- The effect exerted by several contextual variables - firm size, age, sector, familiarity of the business, percentage of export turnover - on LM adoption;
- The effect of LM on business performances;
- The moderating effect potentially exerted by context on LM performances.

As anticipated, both the analysis will be performed on two levels:

- First comparing firms that not adopt LM to LM adopters
- Second, focusing only on Lean adopters, comparing firms on the basis of their degree of leanness.

As a result, the next two chapters will cover the following aspects of the research:

- Chapter 3 contains the research method used in this study - wide information about data collection, survey design and sample description, and primary evidences on LM application in the sample
- Chapter 4 includes the three-level analysis above-mentioned.

Research method and description

Data collection

In order to fulfil the research objectives, I have resort to two sources of information:

- A specific survey questionnaire submitted to a representative sample of manufacturing firms located in Veneto.

  Data collected through the survey were related to company's characteristics and lean implementation.

- AIDA, electronic database containing official information on capital companies located in Italy.

  AIDA has been used both for selecting the sample of companies subject to research and for deriving financial, commercial and classification data necessary to carry out the analysis

Information collected with the survey has been combined with data provided from AIDA database, in order to identify for each company a broad set of personal data (such as the dimension, age of the firm, sector etc.), wide information on lean and its degree of implementation and an overview on their business performances.

Sample description and characteristics

The reference population has been selected among all the companies included in AIDA which satisfied simultaneously the following search criteria:

- Field of operation located in Veneto

- ATECO code between 10 and 33; (this range covers all and only the commercial activities classified as "manufacturing")

On overall, 23.635 firms match these criteria, corresponding to the total reference population. Companies have been sorted by Turnover, from highest to lowest.

The survey has been sent by e-mail to 906 companies from that list, starting from the highest Turnover and proceeding downward. On total, 103 questionnaires have been sent back, of which 75 completed (and hence considered valid for the analysis).

The sample used for the analysis is composed by the 75 respondents that submitted a valid questionnaire.

Industries

Concerning the industries represented in the sample, companies have been clustered according to their sector of activity.

Industry	**Number of firms**	**Percentage on total sample**	**Actual percentage in the reference population**
Food and Beverage	7	9%	7%
Textiles and Apparel	2	3%	10%
Paper and Printing	3	4%	5%
Chemical	7	9%	2%
Plastics and Rubber	4	5%	5%
Non-metallic Mineral	4	5%	6%
Metal	11	15%	26%
Computer and Electronic	1	1%	3%
Appliances	7	9%	6%
NEC machineries	16	21%	14%
Transportation equipment	1	1%	1%
Furniture	7	9%	8%
Other	5	7%	6%
TOTAL	**75**		

Table 3: Industries represented in the sample

On overall, 13 different sectors are represented by the sample, covering industries also widely different from one another.

In particular, in Table 3 are reported the 13 industries represented in the sample (first column), and, for each of them, are provided the number of companies included in the sample (second column), the percentage covered out of the total sample (third column) and the percentage represented in the reference population (fourth column).

From the comparison of the third and fourth columns, it appears that the sample is a good representation of the reference population: with the only exception of the Textiles and Apparels industry, in general the percentage represented in the sample is pretty in line with the actual distribution in the population.

The wide range of industries represented prevents from invalidating the results of the analysis due to excessive homogeneity of the sample. Moreover, the representation of several distinct sectors allows to analyse potential effects of LM exerted by industry.

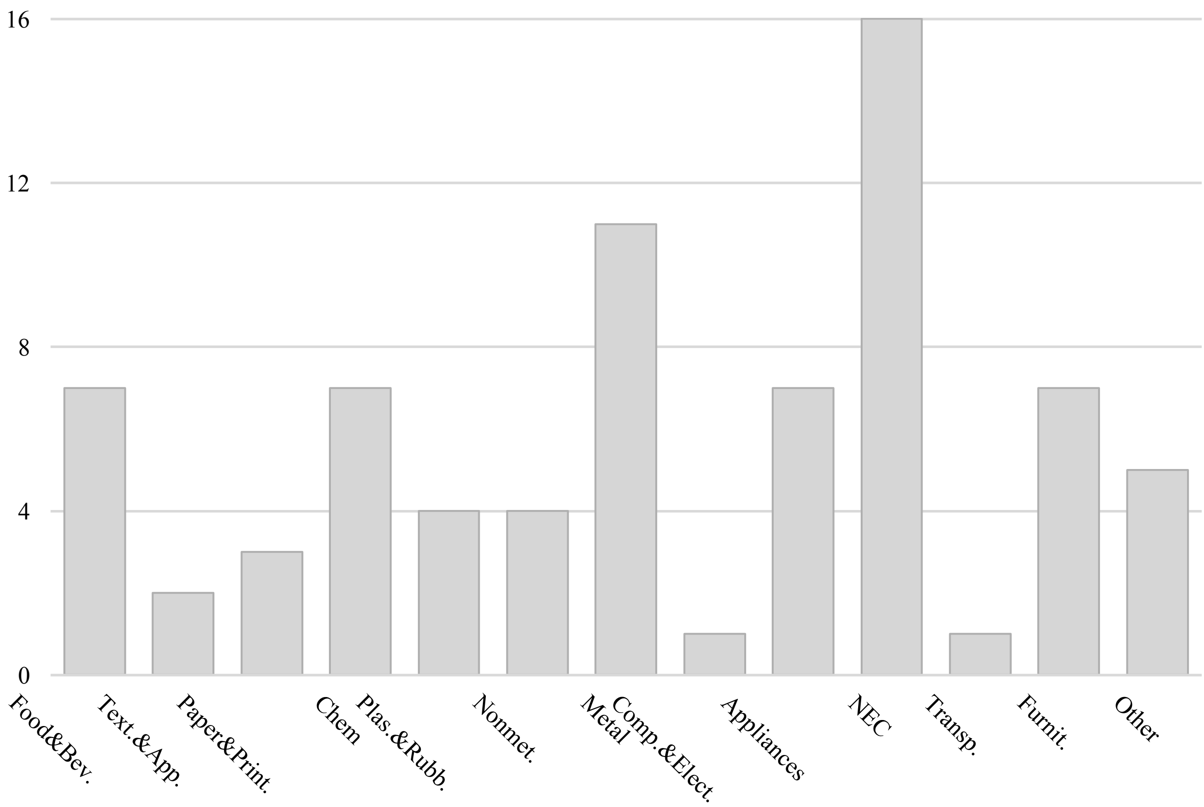


Figure 14: Companies distribution by industry

Number of Employees

Regarding companies size, the best proxy used to measure this dimension is represented by Number of Employees. The range covered by the sample spans from 10 employees (lower value recorded) up to 1.500 employees (higher value recorded), with a mean value of 199 employees and median value represented by 104 employees.

Companies have also been clustered according to the European Commission classifications, which defines companies with less than 50 employees as “Small”, companies with less that 250 employees as “Medium” and companies with 250 employees or more as “Large”.

The majority of the companies in the sample are classified as Medium (44 firms), while Small and Large enterprises are similarly represented by 14 and 17 firms respectively.

Moreover, as Figure 15 shows, among Medium firms, frequency tends to decrease constantly at the increase of size. This distribution pattern is in line with the fact that the median of the distribution is significantly lower than the mean value (104 compared to 199).

Almost the majority of the sample companies have less than 100 employees, but there is still a significant representation of larger sizes.

This data can be considered consistent with the current pattern of the Italian economic system, which is characterised by a larger diffusion of SMEs in comparison to Large firms.

# of employees	
Average	199
Median	104
Minimum	10
Maximum	1.500

Class	**Number of firms**	**Percentage on total**
Small (employees < 50)	14	19%
Medium (employees < 250)	44	59%
Large (employees 250+)	17	23%
TOTAL	**75**	**100%**

Tables 4a and 4b: Data on number of employees and classification

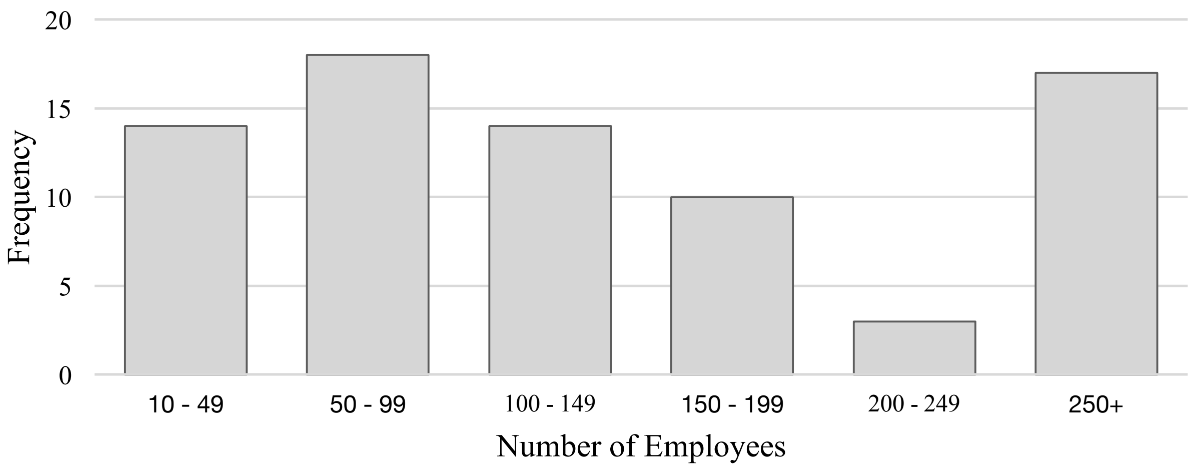


Figure 15: Frequency distribution of Number of Employees in the sample

Turnover

In terms of Turnover, the sample covers a range from a minimum value of 5 million euros to a maximum of 939 million euros recorded in 2016. On average, companies have recorded 67 million euros in 2016, while the median value is represented by 33 million euros. Again, the distribution of companies according to Turnover shows that the majority of the sample is concentrated in the lower tail of the distribution, while a large number of firms covers a wide range of higher values (see Figure 16). This pattern is consistent with the distribution of sample according to number of employees.

Turnover 2016 *In million euros*	
Average	67
Mode	33
Minimum	5
Maximum	939

Table 5: Data on companies Turnover

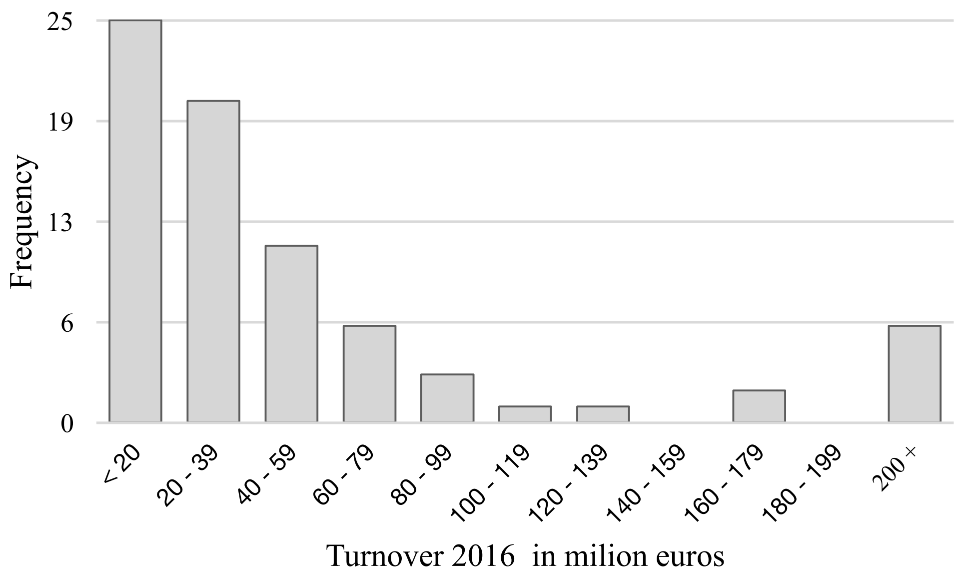


Figure 16: Frequency distribution of sample companies Turnover

Age

In terms of age, the sample covers a range that spans from 2 years since foundation up to 256 years, with a mean age of 48 years.

Companies, in particular, have also been clustered according to their age. Companies established less than 25 years ago are defined “Young”, companies with age between 25 and 50 years are “Adult” and companies that have been active for more that 50 years are considered “Old”.

Companies Age	
Average	48
Mode	33
Minimum	2
Maximum	256

Class	**Number of firms**	**Percentage on total**
Young (< 25)	13	18%
Adult (25 - 50)	35	47%
Old (50+)	26	35%
Missing	1	1%
TOTAL	**74**	**100%**

Table 6a and 6b: Data on Age of Companies

Family Businesses

Finally, companies have also been asked whether they are Family Business or not. In particular, in the context of this research, have been considered as Family Business those companies in which the owners are directly and effectively involved in running the business. On overall, 54 over 75 firms are classified as Family Businesses, corresponding to the 72% of the sample. Again, this data can somehow reflect the current Italian economic system composition, in which Family Business account for the 85% on total, as reported by AIDAF – Associazione Italiana delle Aziende Familiari.

Class	**Number of firms**	**% on total**
Family Businesses	54	72%
Non-family Businesses	21	28%
TOTAL	**75**	**100%**

Table 7: Classification of companies in Family and Non-Family Businesses

Survey description

The survey questionnaire submitted to sample firms has been designed to collect specific types of information, that could not be extracted from AIDA database. It has been written in Italian given that all the companies to whom it has been sent are all located in Italy.

The questionnaire has been created by means of the online survey software provided by SurveyMonkey, and then it has been send via e-mail to the selected sample of firms.

In specific, the first part of the questionnaire was aimed at collecting general information about each firm's attributes.

The data there collected have been used to serve two major purposes: first, to correctly identify the respondent and match the information recorded in the questionnaire with the data provided by AIDA, and second to collect specific information to create a snapshot of the actual organisational context that characterises each single company in the sample. This information has been used to deepen the analysis on LM implementation and results.

Considering its identification and classification purposes, therefore, this section has been addressed to be answered by all the respondents, regardless of actual LM implementation.

The information asked to be provided by the company are summarised in Table 8.

Information	**Purpose**
• Company name • Turnover year 2016 • City where the main field office is located • Brief description of the main activity	To identify the respondent and associate it with the corresponding data extracted from AIDA
• Number of employee • Year of establishment • Family Business (Yes/No)	To identify Firm's characteristics – size, age, nature, product variety - that might have effect on performances and lean implementation

Table 8: Information collected in the first part of the questionnaire

The second part of the questionnaire, instead, has been designed to collect specific information related to degree of and arrangements for LM adoption.

For this reason, first it has been asked the respondent whether the company adopts LM techniques or not, was addressed to be answered by all the respondents.

Then, only in case of positive response, the respondent has been asked to answer further questions designed to assess the actual degree of lean implementation and to obtain a more detailed snapshot on LM application.

First of all, it has been asked to specify in which year lean transformation has been started.

Then, the assessment of the degree of lean implementation has been performed by mean of the matrix reported in Figure 17.

	Production	Inventory	Logistics	Quality	Purchasing	Sales	R&D	Administration	IT
VSM	☐	☐	☐	☐	☐	☐	☐	☐	☐
5S	☐	☐	☐	☐	☐	☐	☐	☐	☐
A3	☐	☐	☐	☐	☐	☐	☐	☐	☐
Kanban	☐	☐	☐	☐	☐	☐	☐	☐	☐
Flow layout	☐	☐	☐	☐	☐	☐	☐	☐	☐
VM	☐	☐	☐	☐	☐	☐	☐	☐	☐
Standardized work	☐	☐	☐	☐	☐	☐	☐	☐	☐
Kaizen Events	☐	☐	☐	☐	☐	☐	☐	☐	☐
Poka Yoke	☐	☐	☐	☐	☐	☐	☐	☐	☐
TPM	☐	☐	☐	☐	☐	☐	☐	☐	☐
Suggestion System	☐	☐	☐	☐	☐	☐	☐	☐	☐
Simultaneous Engineering	☐	☐	☐	☐	☐	☐	☐	☐	☐
Heijunka	☐	☐	☐	☐	☐	☐	☐	☐	☐
Six Sigma	☐	☐	☐	☐	☐	☐	☐	☐	☐
SMED	☐	☐	☐	☐	☐	☐	☐	☐	☐
Andon	☐	☐	☐	☐	☐	☐	☐	☐	☐

Figure 17: Matrix used for assessing LM practices implementation

On the vertical axis of the matrix have been placed 16 LM techniques and tools (VSM, 5S, A3 Kanban, Flow layout, VM, Standardized Work, Kaizen events, Poka Yoke, TPM, Suggestion System, Simultaneous Engineering, Heijunka, Six Sigma, SMED and Andon), which correspond to the techniques described in Chapter 1.

On the horizontal axes are located 9 different departments (Production, Inventory, Internal Logistics, Quality, Purchasing, Sales, R&D, Administration&Control and IT).

Each firm was asked to indicate for each of the 16 techniques whether they are applied and in which departments.

The matrix allows to assess the width of LM implementation, by measuring the actual use of each single tool, and to investigate its depth by considering the number of department actively touched by lean transformation.

This matrix has represented the starting point for computing for each firm its own “Leanness Index”. This indicator, which represents the instrument used to measure the actual degree of implementation of LM, will be widely covered and descriptor later in the chapter.

Primary evidences on LM implementation

From the primary analysis of the survey, the first outcome that can be extracted is the number of firms which implement LM in their plants.

In this regard, it is important to highlight that companies have been classified as “Lean adopters” not on the basis of the answer they gave to the question “Are any Lean Techniques implemented in your plant?”, but on the actual number of lean practices adopted reported in the matrix.

In fact, in one case, a company confirmed to implement LM practices, but then no tool has been ticked in the matrix. In this situation, this company has been included among Non-Lean adopters, because LM adoption, for the purpose of this research, must be matched by the implementation of at least one technique.

On the contrary, another company denied LM implementation, but has defined a specific year in which Lean Transformation has started and then it has ticked some practices in the matrix. In this case, the company has been considered a Lean adopter, because these last data provided automatically pointed to lean adoption.

In all other cases, all companies that have confirmed LM implementation have ticked at least one technique, while those who have denied LM adoption have left the matrix blank.

Lean Adoption and Investments

On overall, 42 firms, corresponding to 56% of the sample, implement LM, while only 33, corresponding to 44% of the sample, do not. This data results to be extremely positive and optimistic respect to the current spread of LM in Veneto.

In terms of Investments on LM, data have been collected on expenditure incurred in 2016.

On average, in 2016 companies have invested 415.000 euros in Lean Transformation, corresponding to 0,9% of total Turnover, but half of the sample has invested no more than 0,1% of turnover (50.000 euros).

The maximum value recorded (1 million euros, corresponding to 22% of total turnover) represents a virtuous exception linked to investments on machineries and equipment.

On overall, the frequency distribution of Lean Investments (% of total turnover) is reported in Figure 18.

Lean Investments ***Year 2016***		
	Amount ***in thousand euros***	**% on Turnover**
Average	415	0,9%
Median	50	0,1%
Minimum	5	0%
Maximum	1.0000	22%

Table 9: Data on Lean Investments (2016)

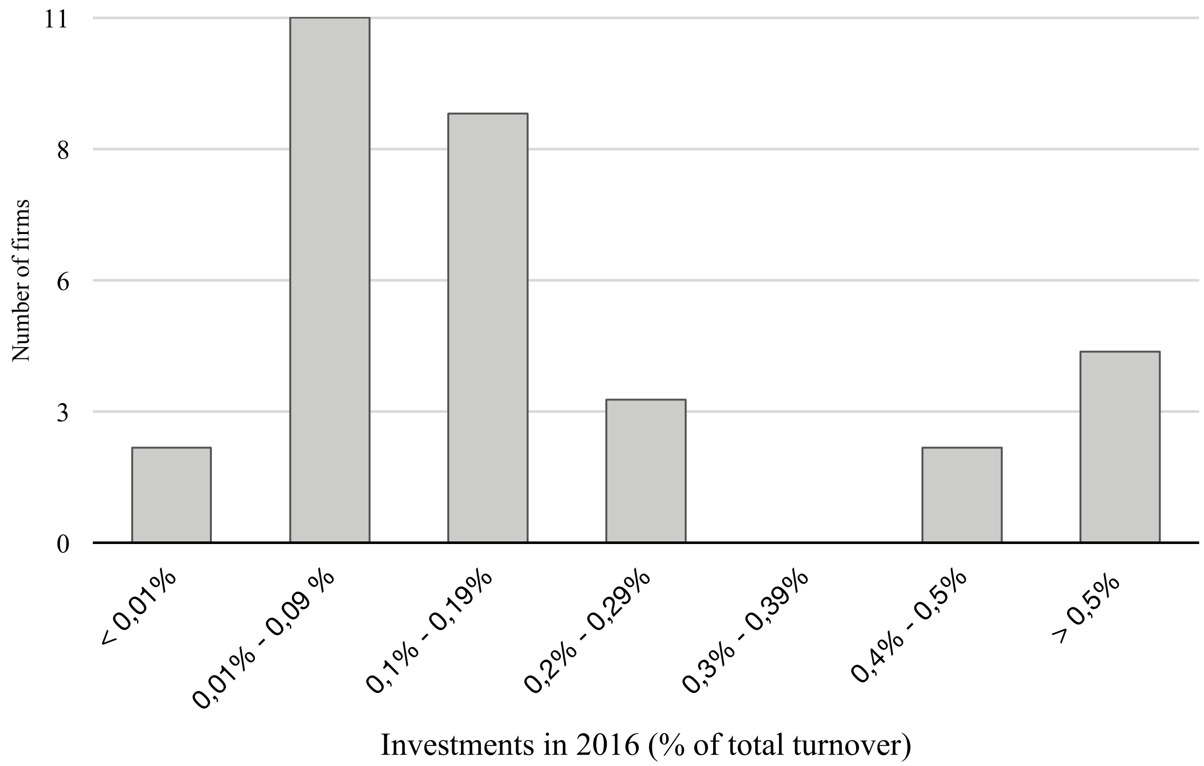


Figure 18: Frequency distribution of Lean Expenditure made in 2016

Experience in Lean Transformation

In terms of range of experience with LM covered in the sample, the company that first implemented lean has started to adopt it 18 years ago, while some companies are in their first year of lean transformation. On average, adopters have started LM implementation 6 years ago.

For the purposes of the analysis, Lean adopters have been arbitrarily divided into "Young adopters", with 5 or less years of experience, and "Old adopters", with more than 5 years in LM implementation.

Years of Experience with LM	
Average	6
Median	5
Minimum	1
Maximum	18

Experience with LM *(in years)*	**Number of firms**	**Percentage on total**
1 - 5	21	50%
6 - 10	10	24%
11 - 15	6	14%
15+	1	2%
Missing	4	10%
TOTAL	**42**	

Tables 10a and 10b: Data on adopters' experience with LM

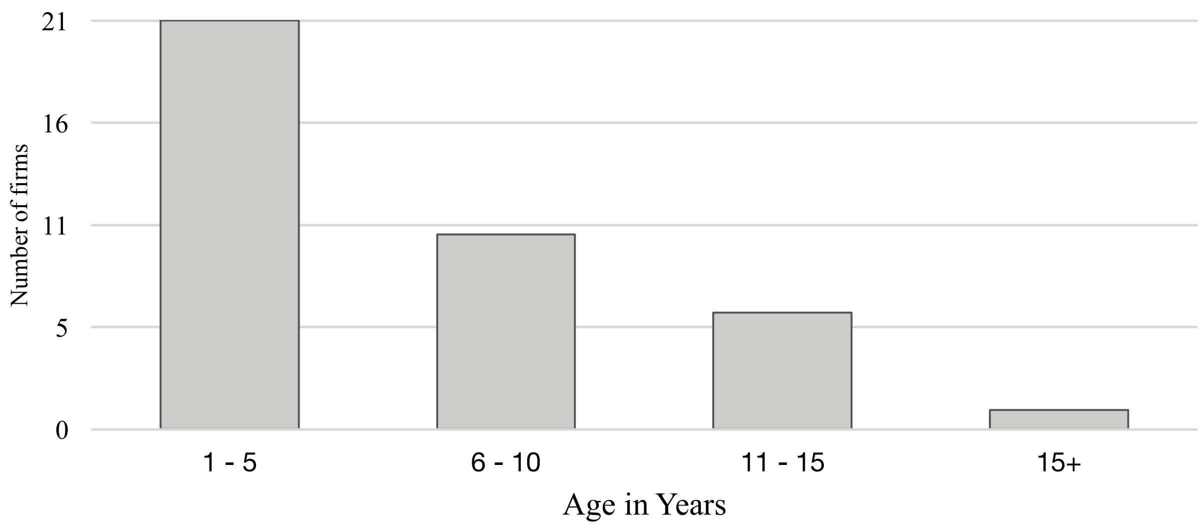


Figure 19: Frequency distribution of years of experience in LM in the sample

Lean practices adoption and department coverage

From a primary analysis of the matrix, it is possible to observe both the diffusion of each LM practice and the departments coverage.

In terms of tools usage, on average lean adopters implement 7 practices over 16 available.

For the purposes of this analysis, companies have been clustered in three groups, almost equals in terms of size, according to the numbers of tools adopted: Low tools adopters implement 5 or less LM techniques, Medium Tools adopters implement between 6 and 10 tools and High Tools adopters apply 11 or more tools.

Tools used	
Average	7
Mode	7
Minimum	1
Maximum	16

	Number of firms	% on total
Low tools adopters *(1 - 5 tools)*	17	40%
Medium Tools adopters *(6 - 10 tools)*	15	36%
High Tools adopters *(11 - 16 Tools)*	10	24%
TOTAL	**42**	

Table 11: Data on LM practices adoption

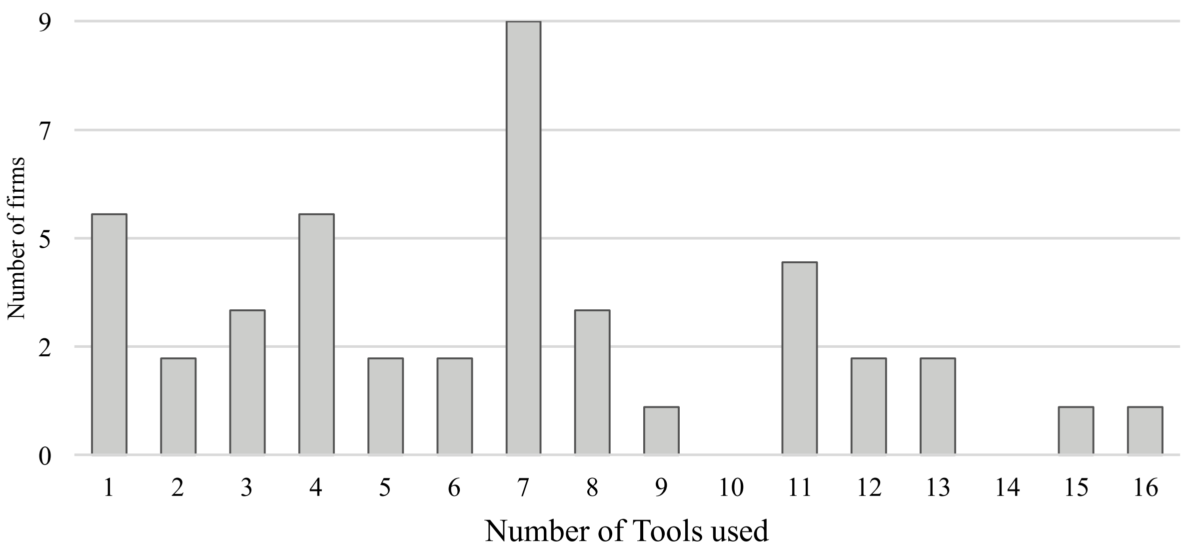


Figure 20: Frequency distribution of number of tools used

What emerges from the analysis of Figure 20 is that on overall the majority of the companies adopt less than half of the tools available (8 over 16), as confirms the median value of 7 tools per firm.

Negative peaks are represented by 4 and 1 values, which are both the number of tools adopted by 5 firms each.

In terms of department coverage, on average lean adopters apply LM practices in 5 departments over 9 available.

Companies have also been clustered in three groups according to the numbers of departments involved: Low involvers apply LM techniques in 3 or less departments, Medium involvers in 4, 5 or 6 departments and High involvers in 7 or more departments.

Departments involved	
Average	5
Median	5
Minimum	1
Maximum	9

	Number of firms	**% on total**
Low involvers *(1 - 3 departments)*	14	33%
Medium involvers *(4 - 6 departments)*	15	36%
High involvers *(6 - 9 departments)*	13	31%
TOTAL	**42**	

Table 12: Data on departments involvement in LM transformation

By looking at Figure 21, it results interesting to notice that Lean Adopters are quite irregularly distributed according to the number of departments covered with LM practices.

In particular, considering the range from 1 to 7 departments involved, the frequency distribution seems to be quasi-normally distributed, ascending regularly from 1 to 3 and then degreasing steadily from 4 to 7.

However, at value 8 the frequency increases and reaches a positive peak of 8 firms; 12 companies over 42 (corresponding to 29%) involves 8 or more departments.

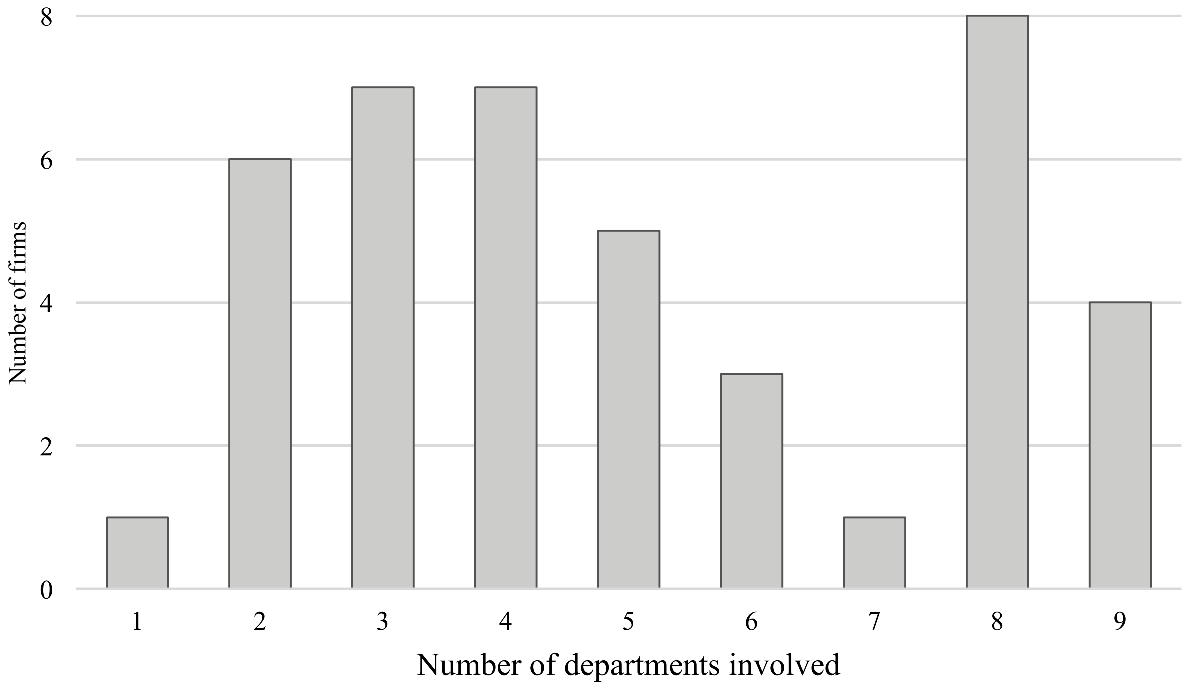


Figure 21: Frequency distribution of number of departments in which LM practices are applied

Concerning the specific departments in which LM practices are implemented, main results are summarised in Table 13.

In the first column are listed the 9 departments that might be object of LM implementation; the number of firms that actually apply at least one practice in the department and the corresponding percentage with respect to total adopters are contained in the second and third column, respectively; the average number of tools applied on each department and the corresponding percentage with respect to total number of practices are contained in the fourth and fifth column, respectively.

Not surprisingly, the department most involved in lean transformation is Production: 41 firms – corresponding to the 98% of adopters - use at least one LM tools in this area. Inventory and Internal Logistics stand in second and third place, being involved by 34 and 33 adopters respectively.

Then, LM are less diffused in the other departments, spanning from Purchasing - covered by 25 adopters - to Accounting – involved only by 12 firms.

Department	# of involvers	% on total involvers	# of practices used on avg.	% on total practices
Production	41	98%	7	41%
Inventory	34	81%	4	24%
Logistics	33	79%	3	20%
Purchasing	25	60%	2	15%
Quality	22	52%	3	20%
R&D	17	40%	3	20%
IT	15	36%	2	12%
Sales	13	31%	2	12%
Accounting	12	29%	1	9%

Table 13: Data on departments coverage and tools application

Generally, the ranking in terms of involvement is almost the same – with some slight differences – in terms of number of tools applied.

In fact, Production is the department where the higher number (7) of practices are implemented on average, followed by Inventory (4) and Logistics (3). Also, Quality and R&D departments, even if involved by lesser adopters (22 and 17 firms) are affected by the use of 3 practices on average. Instead, only 2 techniques are used on average in Purchasing – although it is involved by the 60% of adopters – IT and Sales departments. Accounting still stands in last place, with just one tool applied on average.

A further analysis concerning the possible differences among departments in terms of practices applied has been conducted by identifying for each area the three most used and less adopted techniques.

Production					
Most diffused Tools	*% on total adopters*	*Number of adopters*	*Less diffused Tools*	*% on total adopters*	*Number of adopters*
5S	79%	33	Heijunka	19%	8
Kanban	62%	26	Andon	14%	6
VSM	60%	25	Simultaneous Engineering	10%	4

Inventory					
Most diffused Tools	*% on total adopters*	*Number of adopters*	*Less diffused Tools*	*% on total adopters*	*Number of adopters*
5S	57%	24	Andon	2%	1
Kanban	43%	18	Simultaneous Engineering	0%	-
VSM	36%	15	SMED	0%	-

Internal Logistics					
Most diffused Tools	*% on total adopters*	*Number of adopters*	*Less diffused Tools*	*% on total adopters*	*Number of adopters*
5S	48%	20	Simultaneous Engineering	0%	-
VSM	33%	14	Six Sigma	0%	-
VM	24%	10	SMED	0%	-

Quality					
Most diffused Tools	*% on total adopters*	*Number of adopters*	*Less diffused Tools*	*% on total adopters*	*Number of adopters*
5S	29%	12	Andon	2%	1
VM	19%	8	Heijunka	0%	-
Suggestion System	19%	8	SMED	0%	-

Purchasing					
Most diffused Tools	*% on total adopters*	*Number of adopters*	*Less diffused Tools*	*% on total adopters*	*Number of adopters*
Kanban	29%	12	TPM	0%	-
VSM	24%	10	SMED	0%	-
Kaizen Events	17%	7	Andon	0%	-

Sales					
Most diffused Tools	*% on total adopters*	*Number of adopters*	*Less diffused Tools*	*% on total adopters*	*Number of adopters*
Suggestion System	12%	5	Six Sigma	0%	-
VM	10%	4	SMED	0%	-
Kaizen Events	10%	4	Andon	0%	-

R&D					
Most diffused Tools	*% on total adopters*	*Number of adopters*	*Less diffused Tools*	*% on total adopters*	*Number of adopters*
VM	21%	9	Six Sigma	2%	1
Suggestion System	21%	9	SMED	0%	-
VSM	14%	6	Andon	0%	-

Accounting					
Most diffused Tools	*% on total adopters*	*Number of adopters*	*Less diffused Tools*	*% on total adopters*	*Number of adopters*
Sugg. System	10%	4	Six Sigma	0%	-
5S	7%	3	SMED	0%	-
VSM	5%	2	Andon	0%	-

IT					
Most diffused Tools	*% on total adopters*	*Number of adopters*	*Less diffused Tools*	*% on total adopters*	*Number of adopters*
Suggestion System	17%	7	Six Sigma	0%	-
5S	12%	5	SMED	0%	-
VSM	7%	3	Andon	0%	-

Table 14: Most and less diffused tools for each department

What results interesting to notice is that is seems to exist a sort of "homogeneity" in tools diffusion through departments, in the sense that generally the same practices tend to be always highly (or low) diffused in the majority of areas, with few exceptions.

In fact, for instance, VSM is in the top-three of 7 over 9 departments, 5S ranks among the three more diffused practices in 6 over 9 departments and Suggestion System in 5 over 9.

Similarly, Six Sigma figures as one of the less diffused tools in 5 departments over 9, Andon is in the bottom-three of 9 departments (being used only in Production, Internal Logistics and Quality) and SMED is not even adopted by one single firm in all the departments different from Production.

In this respect, it is interesting to notice the difference between Production department, where all the 16 techniques are used by not less than 4 companies, and all the other areas, where no company uses all the practices.

This data is in line with what emerged in Table 13 concerning the average number of tools used for each department, and confirms the primacy of Production department, which results to be not just the only area in which almost all the lean companies have implemented LM techniques, but also the department most extensively covered with lean practices.

Then, an additional analysis can be performed with regards to overall practices diffusion, computing for each technique the number of firms which adopt it in at least one department and the average number of departments where it is applied.

Tool	# of adopters	% on total adopters	# depts. involved on avg.	% of depts. involved
5S	33	79%	3	37%
VSM	28	67%	3	34%
Kanban	28	67%	2	27%
VM	26	62%	3	31%
Kaizen Events	22	52%	3	35%
Flow Layout	22	52%	2	22%
Poka Yoke	21	50%	3	29%
Standardized Work	19	45%	3	31%
Suggestions System	16	38%	5	53%
SMED	15	36%	1	11%
A3	11	26%	3	37%
TPM	11	26%	2	23%
Six Sigma	10	24%	2	19%
Heijunka	8	19%	2	21%
Andon	7	17%	1	14%
Simult. Eng.	4	10%	2	25%

Table 15: Data on practices diffusion and departments coverage

This analysis of overall tools diffusion and departments coverage hints that practices spread among firms might not necessarily imply a high internal diffusion among departments, and vice-versa. Figure 22 is likely to provide a useful insight on this aspect.

In Figure 22, LM tools are located in a Positioning Map that measures simultaneously the Adoption rate - actual number of firms by which they are implemented, on the horizontal axis - and the Department coverage - the average number of departments in which they are implemented, on the vertical axis.

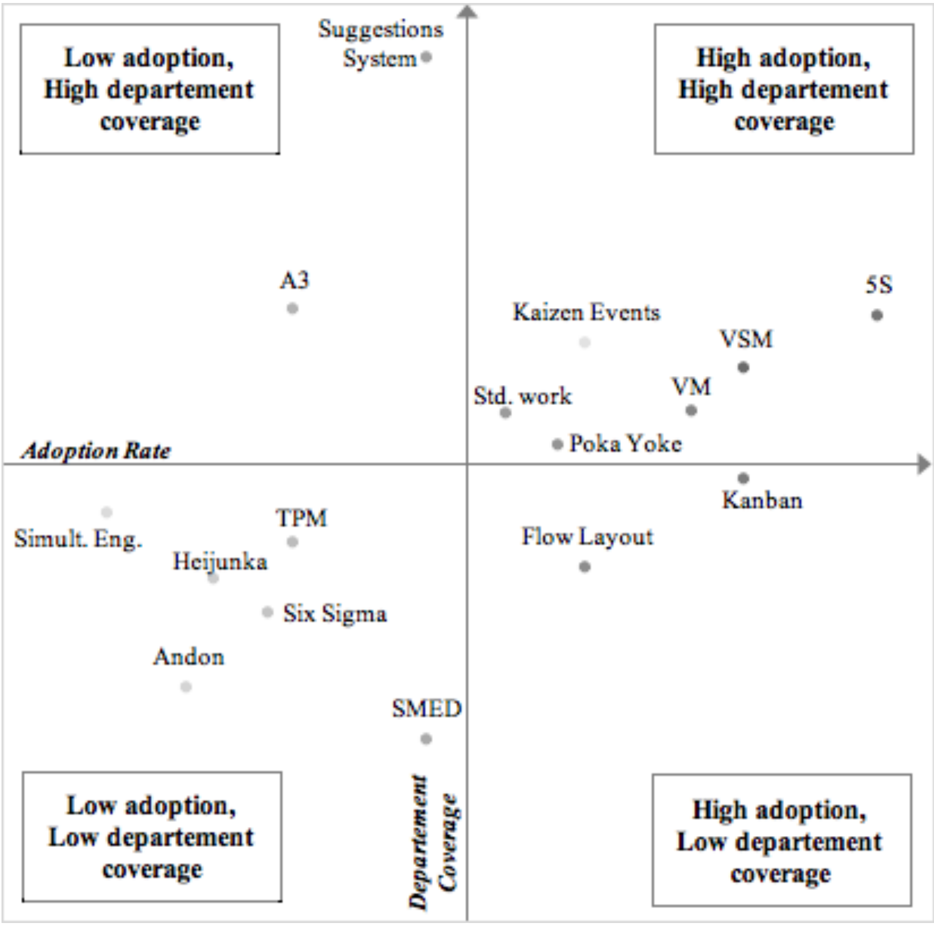


Figure 22:

Positioning map of LM according to Adoption Rate and Department Coverage

As the graph shows, several practices are placed along the diagonal which intersects the first and the third quadrant: for these tools (e.g. 5S, Standardised Work, TPM, Heijunka) Adoption rate and department coverage seems to be positively correlated.

At the same time, however, other practices are placed outside this area, being located in the second or fourth quadrant. These techniques, in particular, are either pretty diffused but generally applied in few departments (e.g. Flow Layout) or not widespread, but generally used in many departments (e.g. Suggestion System).

By looking only at the Adoption rate, an important dimension would be missed: practices would be considered just on the basis of their diffusion, without properly weighting this data for the actual intensity of this diffusion, measured by the internal coverage.

These data reveal that the simple adoption of a tool does not necessarily mean that this tool is also widely diffused within the organisation.

The same reasoning, then, could be possibly performed also at single firms level, suggesting that the same tool, even if applied by several firm, could be differently diffused within the organisation, covering a different number of departments. An insight on this aspect is provided by Table 16, in which for each tool are indicated the maximum and the minimum number of department in which is implemented when adopted.

As can be noticed, the Table confirms that practices implementation is likely to differ from one firm to another in terms of departments coverage, and this aspect shall not be omitted when measuring the leanness of a company.

In fact, for instance, with regards to 5S, there is at least one company that apply it in all departments and at least one that uses it in just one single area.

Clearly, the extent of the application of the same tool is different, and especially if we account for the possible synergies and systemic effect of the simultaneous application of the same technique in different areas - as mentioned in Chapter 2 - this different coverage has to be taken into consideration.

Therefore, this would validate what already anticipated in Chapter 2: in order to properly measure the actual degree of leanness of a firm, a correct Leanness Index must be designed and computed not purely on the basis of the techniques applied, but also considering the actual department coverage. This aspect will be the first issue covered in the following paragraph.

Tool	Minimum # of dept.	Maximum # of dept.	Tool	Minimum # of dept.	Maximum # of dept.
VSM	1	9	*Poka Yoke*	1	8
5S	1	9	*TPM*	1	4
A3	1	8	*Suggestion System*	1	9
Kanban	1	5	*Simultaneous Engineering*	1	4
Flow Layout	1	4	*Heijunka*	1	4
VM	1	6	*Six Sigma*	1	3
Standardised Work	1	9	*SMED*	1	1
Kaizen Events	1	9	*Andon*	1	3

Table 16: Minimum and maximum number of departments covered by each practice

Leanness index: design and calculation

Evidences reported in the last paragraph suggest that at firm level tools application and department coverage might not be aligned.

Moreover, same tools might be applied differently in different companies, according to the number of areas in which the practices are actually diffused.

This means that the simple adoption of LM practices might not be fully representative of the actual degree of leanness of a company, if not considered also in relation to the actual number of departments covered by that techniques.

For example, a company may implement several techniques, but be focused solely on few departments. On the other hand, another firm might use fewer technique, but diffusing them all over the whole organisation.

If the degree of leanness were measured only considering the number of tools adopted, the first company would be surely considered leaner than the second one.

As already reported in Chapter 2, LM is not simply a set of tools and practices should be considered not just as a mere operating instrument that has to be used where and when necessary (e.g. taking 5S merely as a tidying tool to be used when a place results to be too disorganised), but as a necessary element of a complete and perfectly harmonised system of parts.

Hence, the vertical dimension - the internal diffusion - must be taken into consideration when assessing the leanness of degree of a company, especially considering that the actual efficacy of some tools might be seriously undermined if these practices are not widespread all over the organisation.

In fact, considering the holistic and systemic nature of LM and given that all the 16 tools used in this research are potentially suited to be applied in all the 9 departments listed in the matrix, this possible discrepancy between tools diffusion and department coverage has to be taken into consideration when assessing the overall degree of leanness.

For this reason, the Leanness Index for each firm in the sample has been computed starting from the data provided by the matrix previously described and documented in Figure 19.

For each single company, a score has been assigned to practices according to the number of departments in which they are applied. The score spans from 0, when a tool is implemented nowhere, to 1, when it gets used in all the 9 departments.

For instance, the specific score of i-th practice is computed as follows:

$$\text{Score tool}_{i} = \frac{Number\ of\ departments\ in\ which\ it\ is\ implemented}{9}$$

Then, the average score of all the 16 tools represents the overall Leanness Index of the firm.

$$\text{Overall Leanness Index} = \frac{\sum_{i=1}^{16} Score\ Tool_i}{16}$$

This Leanness Index, which is equal to 0 for companies that do not apply LM practices and 1 for those who implement all the 16 tools in all the 9 departments, represents the percentage of actual technique/department combinations implemented by the company over all those available.

For instance, assume to compute the overall Leanness Index of a company that implements 3 tools: 5S, applied in Production, Internal Logistics and Accounting department, Kanban, used in Production and Inventory, and SMED, applied only in Production department.

5S, being implemented in 3 departments over 9, scores 0,33; Kanban, used in 4 departments over 9, scores 0,22; SMED, applied in just 1 department, scores 0,11. All the other tools score 0 - and for sake of simplicity can be directly omitted in the numerator of the fraction used to calculate the Leanness Index.

The overall Leanness Index of the company is computed as follows:

$$\text{Overall Leanness Index} = \frac{0{,}33+0{,}22+0{,}11}{16} = 0{,}0413$$

A value of 0,0413 means that this company is currently implementing the 4,13% of the Lean combinations available.

From the computation of the Leanness Index for all the firms, it has been possible to extract interesting information about the overall Leanness Index of the sample.

Leanness Index	
Average	0,125
Median	0,080
Minimum	0,014
Maximum	0,417

Table 17: Data on Overall Leanness Index

In particular, it has emerged that the overall leanness Index of the sample spans from 0,014 to 0,417 and, on average, companies implements the 12,53% of the total combination available, while the majority of the sample actually covers less than the 8% of that.

Once again, the difference between mean and median value reported in Table 17 can be explained in the light of the frequency distribution that is depicted in Figure 23.

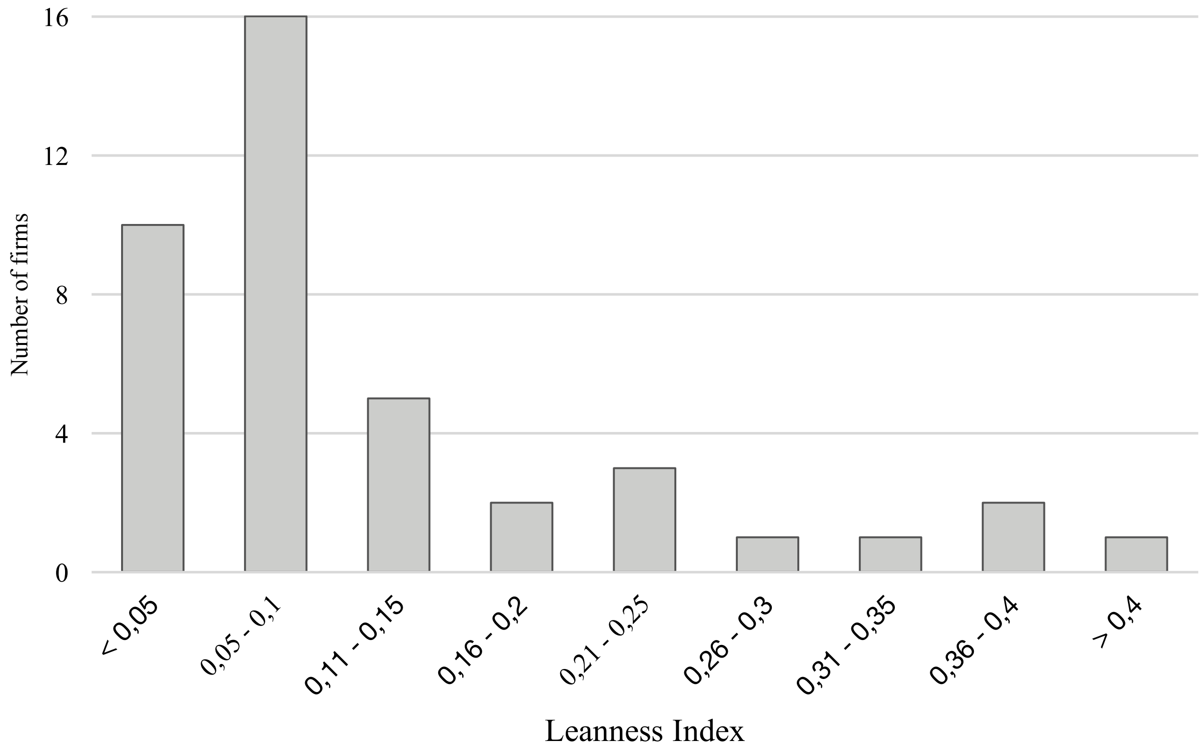


Figure 23: Frequency distribution of the variable "Leanness Index"

As the picture displays, in terms of degree of Leanness the majority of the firms in the sample - exactly the 62% - are concentrated in the area that covers Leanness indexes that span from 0,01 to 0,1.

All the other firms (38% on total), instead, are spread out a larger range of values that go from 0,11 up to 0,4 and more.

In general, this suggest that, although there are some virtuous exceptions represented by the companies that implement LM to a large extent, the majority of the firms in the sample tend to adopt Lean less extensively.

Moreover, the range of Lean Index values covered by the 62% of the sample is quite narrow (less than 10% of difference from the highest to the lowest value) and companies in this range tend to differentiate one from another by only 0,4% in terms of Leanness.

As a result, considering firms' high concentration in the lower tail of the distribution and reasonably assuming that the small variations in terms of Leanness Index are not likely to determine a noticeable difference among companies, is it possible to expect quite homogeneous effect exerted by LM in the sample.

In addition, what is interesting to notice at this stage is that the higher concentration of firms in the lower tail of this frequency distribution might really remind another distribution presented in the chapter.

In particular, a similar distribution pattern has been pointed out when observing the years of experience of Lean Adopters. In fact, the majority of Lean Adopters has no more than 5 years of experience, and the frequency of this variable tends to follow a decreasing pattern (see Figure 19).

This similarity might suggest a possible correlation of Leanness Index with experience with LM.

In effect, evidences on the positive correlation between LM duration and extensiveness have been provided by several authors.

For example, Tortorella *et al.* (2017), have proved that companies with higher experience in LM tend to be more prone to implement Lean Supply Chain practices to a larger extent.

Even more specifically, Marodin *et al.* (2016) have provided empirical findings on the positive effect of the LM duration on the degree of implementation of a set of Lean practices. Nonetheless, the authors did not inspect into the influence over the overall degree of practice implementation at company level.

On overall, these evidences and the analogies in distribution patterns may suggest a positive and significant relationship between LM duration and extent of LM practices implementation.

In order to test for this possible relationship, a two-sample T-test for the difference between means has been performed.

In this case, the null-hypothesis (H_o) is that the Leanness Index is equal, in mean, between Young and Old LM adopters.

In particular, Young LM adopters are the companies that have started their Lean transformation no more than 5 years ago, while Old LM adopters have more than 5 years of experience in LM.

Leanness index		**Mean value**	**Mean difference**	**p.value**
Lean Experience	*Young adopters (< 5 years)*	0,100	-0,060	0,100*
	Old adopters (5+ years)	0,161		

Table 18: T-test for the difference between Leanness Index means of Younger and Older Lean adopters

As reasonably expected, at 10% significance level, null-hypothesis is rejected: Lean companies with higher experience in LM tend to adopt it more extensively.

The result is confirmed by regressing “Leanness Index” on “Age Lean”, that is the variable that measures in years the Experience in LM.

Leanness Index	**Beta**	**Std error**	**p.value**
Const.	0,056	0,03	0,071**
Age Lean (years)	0,011	0,004	0,007***

Table 19: Simple linear regression results for the relationship between Leanness Index and Age Lean

The low significance level observed for the coefficient of the variable "Age Lean" (p = 0,007) confirms, as expected, that Experience in LM and Leanness Index are bounded by a positive and extremely significant correlation: as companies proceed in their Lean transformation, they are likely to increase significantly the extent at which LM gets implemented.

On overall, what can be extracted from this analysis in that evidences point out to the fact that LM seems to require time for being extensively implemented.

Therefore, considering that LM adoption in the Veneto region can be deemed to have had a relatively recent expansion - firms in the sample have on average 6 years of experience in Lean - it results more reasonable the fact that it still has not been adopted to a high extent by the majority of the companies analysed in this study.

CHAPTER 4

ANALYSIS AND DISCUSSION

Context and LM implementation

As previously anticipated, the empirical analysis has been performed starting by inspecting the possible effect exerted by several contextual variables on LM implementation.

Contextual variables here considered are the elements presented in Chapter 2: Size, Industry, and Age of the company.

Furthermore, will be tested for the effect of two additional features: the classification of company as Family Business and its External Turnover. These aspects have not had great resonance in the literature concerning the effect of context on LM implementation; nonetheless, it might result interesting to test for their potential influence, in order to provide a broader and more complete overview of issue.

For each variable, its influence will be tested first with respect to LM implementation as a "either/or" proposition, comparing LM adopters to Non-lean companies, and then with respect to the overall leanness degree of LM firms.

The only exception to the application of this methodology is represented by the variable "Experience in LM" which, by definition, can be quantified only for Lean adopters; for this reason, the effect of this variable will be tested only with respect to Leanness Index.

All the analyses have been performed using the SPSS 24.0.0.2 software for Mac. All the data used for this part of the analysis have been collected through the survey questionnaire.

Size

Size of companies has been measured by the Number of Employees.

This proxy can be considered validated by its wide utilisation in academic research (e.g. White *et al.*, 1999; Shah and Ward, 2003; Doolen and Hacker, 2005; Lucato *et al.*, 2014; Marodin *et al.*, 2016).

As already anticipated, companies with less than 50 employees have been classified as "Small", companies with a number of employees between 50 and 250 as "Medium" and companies with 250 employees or more as "Large".

Effect on LM adoption

In order to assess the possible relationship between Size and Lean adoption, a Pearson's chi-squared test for statistical independence has been performed.

The null-hypothesis (H_o) is that the variables "Lean Adoption" and "Size class" are independently distributed.

"Lean adoption" is a binary variable which assumes value "No" when the company does not adopt any Lean practice and "Yes" when at least one tool is applied.

"Size class" is a categorical variable whose possible values are "Small", "Medium" or "Large".

The contingency table that displays the frequency distribution of the variables and the chi-squared test values are depicted in Table 20.

		Size Class			**TOTAL**
		Small	*Medium*	*Large*	
Lean Adoption	*No*	9	20	4	33
		64%	45%	24%	
	Yes	5	24	13	42
		36%	55%	76%	
TOTAL		14	44	17	75

	Test Value	**df**	**p-value**
Chi-square	5,267	2	0,072*

Table 20: Chi-squared test for statistical independence of company Size and LM adoption

The p-value of the Chi-squared test (t = 5,267, p = 0,072) leads to the rejection of the null-hypothesis: Lean Adoption and Size class are not independently distributed.

By observing the contingency table, it emerges that the majority of Small companies do not implement LM (64% non-adopters vs. 36% adopters); on the contrary, in Medium and Large companies LM adoption prevails. In particular, the prominence of LM adopters seems to increase together with the size (45% non-adopters vs. 55% adopters in Medium firms; 24% non-adopters vs. 76% adopters in Large firms).

As a result, data seem to lead to the conclusion that Size exert a significant and positive influence on Lean implementation: the larger is the company, the more likely it seems to be prone to adopt LM.

Effect on Leanness Index

A Pearson's chi-squared test for statistical independence has been performed also to assess the possible relationship between Size and Leanness degree of Lean adopters.

The null-hypothesis (H_o) is that the variables "Lean Adoption" and "Size class" are independently distributed.

In this case, "Lean adoption" is a binary variable which assumes value "Low" when the company Leanness Index is lower than 0,08, and "High" when it is higher.

"Size class" still represents the previous classification.

The contingency table that displays the frequency distribution of the variables and the chi-squared test values are depicted in Table 21.

The p-value of the Chi-squared test (t = 2,044, p = 0,360) leads to the acceptance of the null-hypothesis: Size and lean degree of adoption are not significantly related.

		Size Group			**TOTAL**
		Small	*Medium*	*Large*	
Lean adoption	*Low*	4	11	6	21
		80%	46%	46%	
	High	1	13	7	21
		20%	54%	54%	
TOTAL		5	24	13	42

	Test Value	**df**	**p-value**
Chi-square	2,044	2	0,360

Table 21: Chi-squared test for statistical independence of company Size and Leanness Index

The same result is confirmed by the two-sample T-test for the difference between means.

In this case, the null-hypothesis (H_o) is that the Number of Employees is equal, in mean, between Low and High lean adopters.

Nr of Employees		**Mean value**	**Mean difference**	**p-value**
Lean Adoption	*Low*	229,43	22,19	0,804
	High	251,62		

Table 22: T-test for the difference between size means of Low and High Lean adopters

Although companies with a higher Leanness Index tend to be slightly larger, on average (252 employees vs 229 in low Lean Adopters), this difference does not result to be statistically significant ($p = 0{,}804 > 0{,}1$).

The same result is also obtained by regressing the Leanness Index on the Number of Employees.

By looking at the p-value of the t-test for the significance of the coefficient of the variable "Number of Employees" (p =0,137), we can accept the null-hypothesis (H_o: beta = 0) and conclude that Number of Employees and Leanness Index are not linked by a linear relationship.

	Beta	**Std error**	**p.value**
Const.	0,104	0,022	0,000***
Number of employees	0,00	0,000	0,137

Table 23: Simple linear regression results for the relationship between Leanness Index and Number of Employees

However, by computing the average Leanness Index for each Size class, it can be observed that Small and Medium firms have, on average, the same degree of leanness, while Large companies are leaner than the smaller ones.

		Number of firms	Average Leanness Index
Size class	*Small*	5	0,107
	Medium	24	0,107
	Large	13	0,167
TOTAL		42	0,125

Table 24: Average Leanness Index for Size Classes

For further investigate the topic, hence, Small and Medium firms have been merged into a single class - also considering the small number of firms included in the "Small" class, and the two-sample T-test for the difference between means have been newly conducted.

In this case, the difference results significant at 90% confidence level (p = 0,096 < 0,100).

		Mean value	Mean difference	p-value
Size Class	*Small/Medium*	0,107	0,06	0,096*
	Large	0,167		

Table 25: T-test for the difference between size means of Low and High Lean adopters (Small/medium vs Large firms)

This evidence might suggest that Size can still be somehow linked to Leanness Index, even if not linearly and, in particular, that Larger companies are more prone to implement LM to a larger extent than the Small-Medium ones.

Industry

As already reported, the sample includes companies belonging to 13 different industries.

In particular, firms have been clustered according to first two digits of their ATECO 2007 code: each industry includes companies characterised by the same ATECO code.

Generally, each industry corresponds to one specific two-digits ATECO code, but in some cases some categories have been merged into one. The decision of merging two categories has been made in order to avoid possible biases due to the small number of representative firms of those specific categories, and always keeping into consideration their “industrial proximity”: two categories, in order to be merged, should have represented two similar economical environments and be subject to analogous market forces.

As a result, ATECO codes 10 and 11 have been merged in the “Food and Beverage” industry, 13 and 14 in “Textiles and Apparel”, 17 and 18 in “Paper and Printing”, 24 and 25 in “Metallic Minerals”.

In other cases, some categories, although represented only by a small number of firms, have not been merged with others, because they lacked the above-mentioned “industrial proximity”. In these cases, the limited size of the industry has been taken into consideration when discussing the results of the analysis.

Effect on LM adoption

In order to assess the possible relationship between Size and Lean adoption, a Pearson’s chi-squared test for statistical independence has been performed.

The null-hypothesis (H_o) is that the variables “Lean Adoption” and “Industry” are independently distributed.

As for the analysis of the effect of Size, the binary variable “Lean adoption” assumes value “No” when the company does not adopt any Lean practice and “Yes” when at least one tool is applied.

“Industry” is a categorical variable whose possible values are the thirteen industries represented in the sample.

The contingency table that displays the frequency distribution of the variables and the chi-squared test values are depicted in Table 26.

By observing the p-value of the Chi-squared test (t = 18,676; p = 0,097) it results that, at 90% confidence level, null-hypothesis has to be rejected: there exist significant differences among industries concerning LM adoption.

		Lean Implementation		TOTAL
		No	*Yes*	
Industry Sector	*Food and Beverage*	5 71%	2 29%	7
	Textiles and Apparel	2 100%	0 0%	2
	Paper and Printing	2 67%	1 33%	3
	Chemical	3 43%	4 57%	7
	Plastics and Rubber	0 0%	4 100%	4
	Non-metallic Minerals	2 50%	2 50%	4
	Metallic Minerals	7 64%	4 36%	11
	Computer and Electronic	0 0%	1 100%	1
	Appliances	1 14%	6 86%	7
	NEC machineries	5 31%	11 69%	16
	Transportation equipment	0 0%	1 100%	1
	Furniture	2 29%	5 71%	7
	Other	4 80%	1 20%	5
TOTAL		33	42	75

	Test Value	df	p-value
Chi-square	18,676	12	0,097*

Table 26: Chi-squared test for statistical independence of Industry and LM adoption

Actually, in several industries the percentage of Lean Adopters is consistently different than the average value computed for the sample as a whole (corresponding to 56% of LM adopters).

In some cases, the discrepancy is accompanied by a small number of firms representing that specific industry (Textiles and Apparel, Paper and Printing, Computer and Electronic, Transportation Equipment). In these cases, generalisations should not be made regarding the actual proportion of Lean adopters in the sector.

In some other cases, the discrepancy could be considered to be validated by a larger number of firms in the category. For example, LM seems to prevail in Chemical, Plastic and Rubber, Appliances manufacturing, Furniture and NEC machineries manufacturing industries. On the contrary, Lean seems to be less diffused in Food and Beverage, Metallic Minerals manufacturing and Other manufacturing industries. Finally, Lean and Non-lean adopters seem to be equally distributed among Non-metallic Minerals manufacturers.

In order to avoid the possible distortion caused by the low numerously of several industries, the same Pearson's chi-squared test for statistical independence has been performed, classifying companies as “Discrete Parts manufacturers” or “Process manufacturers”.

		Industry		**TOTAL**
		Discrete parts manufacturers	*Process manufacturers*	
Lean adoption	*No*	13	20	33
		33%	56%	
	Yes	26	16	42
		67%	44%	
TOTAL		39	36	75

	Test Value	**df**	**p-value**
Chi-square	3,725	1	0,053*

Table 27: Chi-squared test for statistical independence of Industry and LM adoption

As Table 27 shows, LM seems to be more diffused among Discrete part manufacturers rather than among Process manufacturers (67% vs 44% adopters) and this difference results to be statistically significant ($p = 0{,}053 < 0{,}100$).

This result is in line with the outcome of the first Chi-squared test, especially considering that the industries where LM is less diffused are actually Process manufacturers.

Effect on Leanness Index

The differences across industries in terms of leanness degree have been tested by means of a One-Way ANOVA test. The analysis of variance has been performed by comparing mean values of Leanness Index by industry category.

By observing the p-value of the F statistic (see Table 28), that is higher than any reasonable significance level, it is possible to conclude that there are no evidences on significant differences in terms of leanness degree among different industries.

Leanness Index	**Sum of squares**	**d.f.**	**Mean square**	**F statistic**	**p-value**
Between groups	0,152	11	0,014	1,277	0,284
Within groups	0,324	30	0,011		
Total	0,475	41			

Table 28: Analysis of Variance (ANOVA) performed on the variables “Leanness Index” and “Industry”

A further insight on this issue can be obtained by observing for each industry the average Leanness Index and comparing it to the average value computed for the sample (see Table 29).

In general, the industries whose Leanness Index deviates more than ± 5% from the overall mean value (0,125) are the ones represented by a reduced number of firms (Textiles and Apparel, Computer and Electronic, Transportation equipment, Other), and so these differences can be considered as potentially biased.

In all the remaining industries, instead, Leanness Index is pretty in line.

Therefore, data seems to point out the fact that Leanness Index can be deemed not to vary consistently across industries.

		# of Lean Adopters	Average Leanness Index	D from average value
Industry Sector	*Food and Beverage*	2	0,097	-3%
	Textiles and Apparel	0	0,000	-13%
	Paper and Printing	1	0,159	3%
	Chemical	4	0,152	3%
	Plastics and Rubber	4	0,078	-5%
	Non-metallic Mineral	2	0,093	-3%
	Metal	4	0,071	-5%
	Computer and Electronic	1	0,416	29%
	Appliances	6	0,094	-3%
	NEC machineries	11	0,148	2%
	Transportation equipment	1	0,013	-11%
	Furniture	5	0,166	4%
	Other	1	0,048	-8%
	Average	42	0,125	

Table 29: Computation of average Leanness Index for each industry and comparison to the average value of the sample

This result is validated also by the Pearson's chi-squared test for statistical independence performed classifying one more time companies as Discrete parts manufacturers and Process manufacturers (see Table 30).

In particular, evidences have been provided on the fact that no significant difference exist between the two groups of industries concerning the degree of LM implementation.

Therefore, it is possible to conclude that Leanness Index does not seem to vary significantly across industries.

		Industry		TOTAL
		Discrete parts manufacturers	*Process manufacturers*	
Lean adoption	*Low*	12 46%	9 56%	21
	High	14 54%	7 44%	21
TOTAL		26	16	42

	Test Value	df	p-value
Chi-square	0,404	1	0,525

Table 30: Chi-squared test for statistical independence of Industry and Leanness Index

Age of the company

Age has been measured by the number of years passed since company's foundation.

As already anticipated, companies founded less then 25 years ago have been classified as "Young", companies aged between 25 and 50 as "Adult" and companies older than 50 as "Old".

<u>Effect on LM adoption</u>

Analogously to the approach used to test for the influence of Size, a Pearson's chi-squared test for statistical independence has been performed also to assess the possible relationship between Age and LM adoption.

The null-hypothesis (H_o) is that the variables "Lean Adoption" and "Age group" are independently distributed.

"Age group" is a categorical variable whose possible values are "Young", "Adult" or "Old".

The p-value of the Chi-squared test ($t = 0{,}788$, $p = 0{,}674$) implies the acceptance of the null-hypothesis: Age and LM adoption are not significantly related. In fact, even if Young companies seems to be more prone to implement LM and the tendency toward Lean application tend do decrease with age, these differences are not statistically significant.

		Age Group			TOTAL
		Young	*Adult*	*Old*	
Lean adoption	*No*	5	15	13	33
		36%	43%	50%	
	Yes	9	20	13	42
		64%	57%	50%	
TOTAL		14	35	26	75

	Test Value	df	p-value
Chi-square	0,788	2	0,674

Table 31: Chi-squared test for statistical independence of Age and LM adoption

Effect on Leanness Index

Pearson's chi-squared test for statistical independence has been performed also to assess the possible relationship between Age and Leanness degree of Lean adopters.

In this case the null-hypothesis (H_o) is that the variables "Lean Adoption" and "Age group" are independently distributed.

"Lean adoption" assumes value "Low" when the company Leanness Index is lower than 0,08, and "High" when it is higher.

"Age group" still represents the previous classification.

		Age Group			TOTAL
		Young	*Adult*	*Old*	
Lean adoption	*Low*	5	10	6	21
		56%	50%	46%	
	High	4	10	7	21
		44%	50%	54%	
TOTAL		9	20	13	42

	Test Value	df	p-value
Chi-square	0,188	2	0,910

Table 32: Chi-squared test for statistical independence of company Age and Leanness Index

The p-value of the Chi-squared test (t = 0,188, p = 0,910) leads to the acceptance of the null-hypothesis: Age and lean degree of adoption are not significantly related.

However, similarly to what has been noted for LM adoption, also the tendency toward a more extensive lean implementation tend to slightly decrease with Age.

The same result is confirmed by the One-Way ANOVA test performed by comparing mean values of Leanness Index by Age group.

Leanness Index	**Sum of squares**	**d.f.**	**Mean square**	**F statistic**	**p-value**
Between groups	0,028	2	0,014	1,217	0,307
Within groups	0,447	39	0,011		
Total	0,475	41			

Table 33: Analysis of Variance (ANOVA) performed on the variables "Leanness Index" and "Age Group"

As expected, the p-value of the F statistic (p = 0,307 > 0,100) confirms that there are no evidences on significant differences in terms of leanness degree among different Age groups.

In fact, as can be seen in Table 32, although Leanness Index tend to increase with age, the two-sample T-test for the difference between means confirms that any difference is statistically significant, leading to confirm the assumption that Leanness degree seems not vary significantly according to company Age.

Leanness Index	**Average**	**Difference**	**T-test**	**p-value**
Young	0,102			
Adult	0,111			
Old	0,163			
Young - Adult		-0,009	-0,263	0,795
Young - Old		-0,061	-1,150	0,264
Adult - Old		-0,052	-1,199	0,246

Table 34: T-test for the difference between Leanness Index means of Young, Adult and Old companies

The same result can be seen by regressing Leanness Index on Age.

As before, the p-value of the t-test for the significance of the coefficient of the variable “Age” (p =0,229), leads to the acceptance of the null-hypothesis (H_o: beta = 0): Age is not linearly bounded to Leanness Index.

Leanness Index	**Beta**	**Std error**	**p.value**
Const.	0,088	0,035	0,015**
Age	0,001	0,001	0,229

Table 35: Simple linear regression results for the relationship between Leanness Index and Age

Family Business

In order to proceed with the analysis of the effect of the nature or the business on LM implementation, respondents have been asked to specify whether they are or not Family firms.

In particular, this characteristic has been intended as the overlap of company’s proprietorship and management; hence, Family Businesses has been defined as firms whose shareholders are also managers of the company.

Effect on LM adoption

A Pearson's chi-squared test for statistical independence has been performed to assess whether the classification of a company as a Family Business might influence LM adoption.

The null-hypothesis (H_o) is that the variables “Lean Adoption” and “Family Business” are independently distributed.

Both “Lean Adoption” and “Family Business” are binary variables which can assume values “Yes” or “Not”.

		Family Business		TOTAL
		No	*Yes*	
Lean adoption	*No*	8 38%	25 46%	33
	Yes	13 62%	29 54%	42
TOTAL		21	54	75
	Test Value		**df**	**p-value**
Chi-square	0,413		1	0,521

Table 36: Chi-squared test for statistical independence of Family Business and LM adoption

As Table 36 shows, although Family Businesses seem to be less prone to adopt LM than Non-family firms (54% of adopters in Family firms vs. 62% of adopters in Non-family ones), the chi-square statistic is associated to a p-value higher than any reasonable significance level ($p = 0{,}521 > 0{,}100$), leading to the acceptance of the null-hypothesis.

Therefore, it could be affirmed that, on overall, no significant difference exists between Family and Non-family firms in terms of LM adoption.

Effect on Leanness Index

A Pearson's chi-squared test for statistical independence has been performed also to assess whether the classification of a company as Family Business influence the degree of leanness.

Here the null-hypothesis (H_o) is that the variables "Lean Adoption" and "Family Business" are independently distributed, where "Lean Adoption" assumes value "Low" when the Leanness Index is lower than 0,08 and "High" otherwise.

As Table 37 displays, among both Family businesses and Non-family ones, Lean adopters are almost equally distributed between "High" and "Low" adopters.

The p-value of the Chi-square statistic ($p = 0{,}739$) confirms that Lean degree of adoption and the nature of the business are independently distributed.

		Family Business		TOTAL
		No	*Yes*	
Lean adoption	*Low*	6 46%	15 52%	21
	High	7 54%	14 48%	21
TOTAL		13	29	42

	Test Value	df	p-value
Chi-square	0,111	1	0,739

Table 37: Chi-squared test for statistical independence of Family Business and degree of leanness

The same result is confirmed by the two-sample T-test for the difference between means.

In this case, the null-hypothesis (H_o) is that the Leanness Index is equal, in mean, between Family and Non-family firms.

Leanness Index		Mean value	Mean difference	p.value
Family Business	*No*	0,139	-0,020	0,591
	Yes	0,119		

Table 38: T-test for the difference between Leanness Index means of Family and Non-family firms

As emerges from Table 38, even if Family Businesses apply LM, on average, less extensively than Non-family firms, this difference does not result to be statistically significant (p = 0,591). Therefore, it can be concluded that the extent of LM implementation (Leanness Index) does not vary significantly between Family and Non-family firms.

Export Turnover

An additional factor taken into consideration for its possible correlation to LM implementation has been the openness degree and the competitiveness in foreign markets that characterise each firm.

In this case, the proxy used to measure this condition is the percentage of 2016 Turnover recorded in foreign markets (Export Turnover).

Effect on LM adoption

In order to assess the possible relationship between LM adoption and Export Turnover, a Pearson's chi-squared test for statistical independence has been performed.

The null-hypothesis (H_o) is that the variables "Lean Adoption" and "Export Group" are independently distributed.

"Export Group" is a binary variable which assumes value "Minor" when the company has recorded in foreign markets less then 50% of total 2016 Turnover, "Major" otherwise.

As can be noticed in Table 39, companies whose turnover has been recorded mainly in Italy tend to be less prone to adopt LM (16 Adopters vs 21 Non-adopters); on the contrary, firms that generate at least half of their Turnover abroad are more incline to implement Lean (26 Adopters vs. 12 Non-Adopters).

This difference is validated by the p-value of the Chi-square statistic (p = 0,028): at 95% confidence level, null-hypothesis is rejected, leading to the conclusion that exist a significant relationship between Export Turnover and LM adoption.

		Export Group		**TOTAL**
		Minor (< 50%)	*Major (<= 50%)*	
Lean adoption	*No*	21	12	33
		57%	32%	
	Yes	16	26	42
		43%	68%	
TOTAL		37	38	75

	Test Value	**df**	**p-value**
Chi-square	4,823	1	0,028**

Table 39: Chi-squared test for statistical independence of Export Turnover and LM adoption

The same result is confirmed by the two-sample T-test for the difference between means.

In this case, the null-hypothesis (H_o) is that the percentage of Export Turnover is equal, in mean, between Lean and Non-lean companies.

Export Turnover (% over Total Turnover 2016)		**Mean value**	**Mean difference**	**p.value**
Lean Adoption	*No*	37%	19%	0,013**
	Yes	56%		

Table 40: T-test for the difference between Export Turnover means of Lean and Non-Lean companies

As Table 40 shows, companies that implement LM tend to be more open in terms of market, recording more than half of their turnover abroad (56%) and almost 20% more than Non-Lean companies (37%). This difference, as before, is validated by the p-value of the T statistic ($p = 0{,}013 < 0{,}05$).

Therefore, it can be stated that External Turnover is significantly and positively related to LM adoption.

Effect on Leanness Index

The possible relationship of Export Turnover also with Leanness Index has been assessed, as before, by mean of Pearson's chi-squared test for statistical independence of degree of leanness and Export group.

The null-hypothesis (H_o) is that the variables "Lean Adoption" and "Export Group" are independently distributed.

"Lean Adoption", as before, depends on the Leanness Index of the company ("Low" if Leanness Index < 0,08, "High" otherwise)

"Export Group" in this case takes value "Minor" if the company has recorded in foreign markets less then 63,5% of total 2016 Turnover, "Major" otherwise. This threshold corresponds to the median value of the Export Turnover among Lean Adopters.

		Export Group		
		Minor (< 63,5%)	*Major (<= 63,5%)*	**TOTAL**
Lean adoption	*No*	11 52%	10 48%	21
	Yes	10 48%	11 52%	21
TOTAL		21	21	42

	Test Value	df	p-value
Chi-square	0,095	1	0,758

Table 41: Chi-squared test for statistical independence of Export Turnover and LM degree of adoption

The contingency table shows that in each of the two groups ("Minor" and "Major" Export groups), firms are almost equally distributed between Lean and Non-Lean adopters, and the p-value of the Chi-square statistic (p = 0,758) allow to conclude that Lean Adoption and Export Turnover are independently distributed.

The analysis has been deepened by performing a two-sample T-test for the difference between means, included in Table 42.

Leanness Index		**Mean value**	**Mean difference**	**p.value**
Export Group	*Minor (< 63,5%)*	0,108	0,034	0,316
	Major (<= 63,5%)	0,142		

Table 42: T-test for the difference between Leanness Index means of Minor and Major exporters

As can be seen by observing the p-value of the T statistic (p = 0,316 > 0,100), although companies characterised by a larger percentage of turnover recorded in foreign markets are also characterised by a slightly higher Leanness Index in mean (0,142 vs 0,108 of Minor exporters), this difference is not statistically significant.

Finally, the same result is provided by the result of simple linear regression for the relationship between Leanness Index and Export Turnover reported in Table 43.

Leanness Index	**Beta**	**Std error**	**p.value**
Const.	0,106	0,034	0,004***
Export Turnover *(% over Total Turnover 2016)*	0,000	0,001	0,591

Table 43: Simple linear regression results for the relationship between Leanness Index and Export Turnover

By looking at the p-value of the t-test for the significance of the coefficient of the variable "Export Turnover" (p =0,591), the null-hypothesis (H_o: beta = 0) have to be accepted: Export Turnover and Leanness Index are not linked by a linear relationship.

Results discussion

On overall, several different information can be extracted from the analysis here presented.

First of all, concerning the correlation between LM adoption and firm Size, evidences have been provided on the fact that larger companies tend to be more prone to adopt Lean and to implement it more extensively. These results are in line with White *et al.* (1999), Shah and Ward (2003) and Doolen and Hacker (2005).

In this regard, it seems possible that the higher financial capital and the wider range of human skills and competencies which tend to characterise Large companies with respect to Small ones, are likely to be perceived as fertile ground for LM, fostering both its implementation and its extensive adoption in larger firms.

The flexibility and reduced bureaucracy that characterise smaller firms and that might positively influence LM implementation, instead, are likely to be overcompensated by the possible lack of resources, leading to a lower implementation of Lean in smaller firms.

Concerning contextual effect of Age, data has pointed out that although younger firms seem to be more prone to adopt LM rather than older ones, this difference is not significant: actually, in fact, company Age does not differ significantly between Lean and Non-lean firms.

Analogously, despite leanness seems to increase with age, this positive correlation is not significant.

It is interesting to notice that, even if not significantly, the correlation of Age is negative with LM adoption and positive with Leanness Index. These dissenting results together with their non-significance are in line with findings provided by Shah and Ward (2003) and Bayo-Moriones *et al.* (2008).

As a result, it is possible to conclude that Age is not significantly related neither to LM adoption nor to Leanness Index. In this sense, companies might be either more open or resistant to change their operation and to introduce new procedures independently on their actual age.

Concerning Industry, instead, evidences have been provided that LM is likely to be adopted in some sectors rather than others.

In particular, if we consider only the industries with more than 3 firms in the sample, it can be reported that LM seems to be more diffused in sectors like Chemical, Plastic and Rubber, Appliances manufacturing, Furniture and NEC machineries manufacturing industries, while it tends to be adopted only by few firms in Food and Beverage, Metallic Minerals manufacturing and Other manufacturing industries.

In any case, LM is adopted by at least one firm in each sector (as before, “Textile and Apparel” has been taken out of the computation because of the small number of companies in the category) and, in general, Leanness Index does not vary significantly across industries.

Clearly, this evidence seems to be point out to the fact that some industries might be more attractive in terms of Lean implementation, but in general LM seems to be suited for being applied in any manufacturing context, without difference in terms of degree of adoption.

However, it is important to take into account that the reduced number of sample firms in several industries subject to analysis would allow only limited and cautious generalisation of the conclusion here reported on this topic.

For this reason, the analysis has been performed also classifying companies as “Discrete part manufacturers” and “Process manufacturers”. The results provided by this analysis are in line with what has been previously found: LM adoption tend to vary across industries - in particular, LM seems to be less diffused among Process manufacturers - but, once adopted, it tends to be implemented almost at the same extent in both sectors.

Another contextual factor that is deemed to bond Lean adopters is the percentage of External Turnover on total. In particular, from the analysis of the sample has emerged that Lean companies are likely to record the majority of their turnover in foreign market, while Non-lean firms focus their sales mainly in Italy.

This data can be subject to two different interpretation. On the one hand, Export turnover might exert a positive influence on LM adoption, either by making companies more open and by requiring them to be more responsive to changes. As a result, higher exportations might entail higher incentive to adopt Lean. On the other hand, the same factor can be not as a cause, but as an effect of LM implementation: companies that adopt Lean increase their competitiveness, being more able to enter foreign markets.

In any case, the effects potentially caused either by Export turnover or LM do not persist when comparing companies according to their leanness index: there are no significant relationship between leanness degree and Export.

Finally, the contextual effect exerted by the classification of companies as Family Business has been investigated.

In this regard, evidences have been provided on the fact that, even if Family Businesses appear to be less prone to adopt LM and, once adopted, to implement it to a lesser extent in comparison to Non-family firms, on overall no one of these differences appears to be statistically significant. As a result, it could be reasonably concluded that the fact or being or not a Family Business does not exert any significant contextual effect on LM adoption and degree of implementation.

By the way, apart from the correlation of some contextual variables (Size, Industry, Export Turnover) with LM adoption, evidences have pointed out that, on overall, context seems not to influence significantly Lean adopters’ behaviour in terms of leanness degree.

In fact, actual Leanness Index appears not to be related to any contextual factor, with the exception of Size.

This lack of correlations, however, has to be considered carefully: as previously noted in Chapter 3, the majority of the companies in the sample are characterised by pretty low Leanness Indexes which tend to vary from one another by less than 1%.

As a result, it is possible that the absence of correlation between degree of LM implementation and contextual factors might be due to the small variability of Leanness Index, which makes all companies in the sample almost similar. This fact might prevent from the possibility to intercept appreciable effects exerted by context, because these should entail differences in terms of leanness larger than the ones provided by the sample.

LM implementation and Business Performances

The analysis on the potential effect of LM on Business performance has been performed focusing on three main financial index, Return On Sales (ROS), Return On Asset (ROA) and Bank Debt over total Turnover, which have been taken from AIDA database.

Potentially, all these three indicators might be reasonably expected to be positively influenced by Lean.

First, in fact, if we consider that according to some authors Lean is about "doing more with less" (Towill and Christopher, 2002), LM adoption should directly impact on profitability, measured by ROS and ROA: the implementation of practices aimed at creating value for the customer and eliminating any source of waste should be expected to - among other several benefits - entail higher operating margins and to enhance the exploitation of investments.

In addition, LM implementation might entail important benefits also in terms of liquidity: minimisation of inventory, for example, allows to tie less financial capital to stocks; this additional - or somehow "recovered" - liquidity, hence, could be re-invested, reducing the needs for resorting to Bank Debt.

In this paragraph, first will be analysed LM effect on performances comparing Lean and Non-Lean firms; then, it will be assessed whether financial results change according to the extent of LM implementation.

Comparison between Lean and Non-Lean companies

In order to assess the possible effect on LM on performance, a two-sample T-test for the difference between means has been performed, comparing Lean and Non-Lean companies according to their average ROS, ROA and Bank Debt over total Turnover.

As Table 44 shows, Lean adopters appear to record better performances in all the three fields in comparison to Non-lean firms.

In particular, ROS and ROA are, respectively, 2,54% and 2,77% higher in Lean firms. However, only the difference in terms of ROS is statistically significant.

The significant difference in terms of Bank Debt over Turnover is even larger: the debt is 7,05% lower when LM is implemented.

Index	Lean Adoption	Mean Value	Mean difference	p.value
ROS	*No*	5,73%	2,54%	0,069*
	Yes	8,27%		
ROA	*No*	7,46%	2,77%	0,103
	Yes	10,23%		
Bank Debt / Turnover	*No*	19,13%	-7,05%	0,100*
	Yes	12,08%		

Table 44: T-test for the difference on Financial performances between Lean and Non-lean firms

The analysis has been deepened by performing three multiple linear regressions - one for each index - for further investigate the relationship between LM and financial results.

In this case the variable "Lean adoption" has been transformed in a dummy variable which assumes value 0 when the company does not adopt LM and 1 otherwise.

These regressions have been performed by controlling for factors that might somehow be linked both to financial results and LM adoption, in order to reduce the confounding effect that might be exerted by those variables and have a clearer understanding on the relationship between LM and outcomes.

In particular, in order to control for the possible effect exerted by industry, ROS, ROA and Bank Debt over total Turnover have not been considered in absolute terms, as in Table 44, but normalised to the average value for each specific industry.

By doing so, ROS and ROA assume values lower than 1 when the company's performances are lower than the average of its industry, while are higher than 1 otherwise.

Symmetrically, Bank Debt over total Turnover assumes value lower than 1 when the company is less indebted than the average of the industry, higher than 1 otherwise.

This normalisation has allowed to control for the industry without including in the model 12 dummies.

By the way, two dummy variables have been included, instead, in order to control for the Size and the fact of being or not a Family Business.

In particular, the dummy "Size" assumes value 0 when the company is Small or Medium, and 1 when it is Large.

The dummy "Family Business" assumes value 1 when the company is a Family firm and 0 otherwise.

First of all, the values of Variance Inflation Factor (VIF) included in the last column of Tables 45, 46 and 47, are all almost equal to 1, excluding potential issues of multicollinearity.

Concerning the significance of the coefficient, the results are pretty in line with what has been found performing the T-test presented in Table 44.

In particular, Lean adoption still results to be positively and significantly correlated to ROS, even when controlling for Industry, Size and Family Business (see Table 45). In fact, the parameter associated do Lean adoption is positive (beta = 0,688) and significant (p = 0,060) < 0,100. Hence, it is possible to conclude that Lean adoption seems to exert a positive and significant influence over ROS of companies.

Similarly, Table 47 shows that Lean adoption is also significantly (p = 0,077 < 0,100) and negatively (beta = - 0,538) correlated to Bank debt: Lean adoption is likely to be associated to a reduction in bank indebtedness.

Finally, even when controlling for Industry, Size and Family Business, evidences still persist on the absence of significant relationships between ROA and LM adoption. In fact, even if the parameter associated to Lean Adoption is positive (beta = 5,991), actually its value is not significantly different from 0 (p = 0,353 > 0,1000).

Hence, as before, the multiple linear regressions point out that Lean adoption seems to improve performances in terms of ROS and to reduce Bank Debt, but not to affect significantly ROA.

Normalised ROS	Beta	Std error	p.value	Tolerance	VIF
Const.	1,746	0,619	0,006***		
Lean adoption	0,688	0,360	0,060*	0,945	1,058
Size	-0,568	0,426	0,187	0,950	1,052
Family Business	0,500	0,388	0,202	0,994	1,006

Table 45: Multiple linear regression results for the relationship between Lean adoption and Normalised ROS - controlled for Size and Family Business

Normalised ROA	Beta	Std error	p.value	Tolerance	VIF
Const.	-2,357	11,008	0,831		
Lean adoption	5,991	6,404	0,353	0,945	1,058
Size	-0,397	7,573	0,958	0,950	1,052
Family Business	12,806	6,902	0,068	0,994	1,006

Table 46: Multiple linear regression results for the relationship between Lean adoption and Normalised ROA - controlled for Size and Family Business

Normalised Bank Debt / Turnover	Beta	Std error	p.value	Tolerance	VIF
Const.	0,520	0,222	0,022**		
Lean adoption	-0,358	0,199	0,077*	0,942	1,062
Size	0,284	0,234	0,230	0,941	1,062
Family Business	0,484	0,219	0,031**	0,997	1,003

Table 47: Multiple linear regression results for the relationship between Lean adoption and Normalised Bank Debt over total Turnover - controlled for Size and Family Business

Leanness Index effect

After having assessed the effect of Lean adoption of company's ROS, ROA and Bank Debt over total Turnover by means of two-sample T-test for the difference between means and multiple regression, the same analysis has been performed for investigating the potential effect of changes in Leanness Index over performances.

As it has been done in the context analysis, Lean adopters have been classified into two groups: High lean adopters, characterised by a Leanness Index higher than 0,08, and Low Lean adopters, with a Leanness Index equal or lower than 0,08.

First of all, Table 48 shows that, surprisingly, companies that adopt LM to a superior extent seem to perform worse in terms of profitability: both ROS and ROA are slightly higher for Low-Lean adopters. However, this difference does not result to be statistically significant.

On the contrary, High-Lean adopters seem to perform better in terms of indebtedness, because their Bank Debt over total Turnover is, on average, 2,92% lower than the one of Low-Lean firms. Nevertheless, even this difference does not result to be statistically significant.

Index	Lean Adoption	Mean Value	Mean difference	p.value
ROS	*Low*	8,4%	-0,26%	0,896
	High	8,14%		
ROA	*Low*	10,44%	-0,43%	0,864
	High	10,01%		
Bank Debt / Turnover	*Low*	13,61%	-2,92%	0,559
	High	10,69%		

Table 48: T-test for the difference on Financial performances between High and Low Lean adopters

The same results are provided by the three multiple linear regressions performed to investigate the relationship between Leanness Index and financial results.

In this case the independent variable corresponds to each company's Leanness Index.

As before, the dependent variables are the normalised ROS, ROA and Bank Debt over total Turnover, and dummy variables have been introduced in order to control for Size and the classification of company as Family Business.

Normalised ROS	**Beta**	**Std error**	**p.value**	**Tolerance**	**VIF**
Const.	2,376	0,836	0,007***		
Leanness Index	2,236	2,402	0,358	0,925	1,081
Size	-0,981	0,550	0,083*	0,932	1,073
Family Business	0,960	0,533	0,080*	0,992	1,008

Table 49: Multiple linear regression results for the relationship between Leanness Index and Normalised ROS - controlled for Size and Family Business

Normalised ROA	**Beta**	**Std error**	**p.value**	**Tolerance**	**VIF**
Const.	-2,558	16,945	0,881		
Leanness Index	48,299	48,678	0,327	0,925	1,081
Size	-2,987	11,158	0,790	0,932	1,073
Family Business	17,919	10,813	0,106	0,992	1,008

Table 50: Multiple linear regression results for the relationship between Leanness Index and Normalised ROA - controlled for Size and Family Business

Normalised Bank Debt over total Turnover	**Beta**	**Std error**	**p.value**	**Tolerance**	**VIF**
Const.	0,091	0,419	0,830		
Leanness Index	-0,218	1,135	0,849	0,923	1,083
Size	0,254	0,259	0,333	0,940	1,063
Family Business	0,284	0,266	0,292	0,979	1,021

Table 51: Multiple linear regression results for the relationship between Leanness Index and Normalised Bank Debt over total Turnover - controlled for Size and Family Business

First of all, even in these cases the values of Variance Inflation Factor (VIF) are all almost equal to 1, excluding potential issues of multicollinearity.

Then, in line with the results provided by the T-test for the difference between means, the three regressions show that, despite the degree of leanness appear to be positively related to profitability and to reduce Debt, actually no one of the parameters associated to Leanness Index is significantly different from 0 (p = 0,358 in the first regression, p = 0,327 in the second regression, p = 0,849 in the third regression).

As a result, it is possible to conclude that neither ROS, nor ROA, Bank Debt over total turnover seems to be linearly related to Leanness Index.

Results discussion

By looking at the empirical evidences provided by the analysis included in the last paragraphs, it is possible to conclude that, on overall, LM is likely to provide financial benefits to company which adopt it in comparison to firms which do not.

In specific, Lean adopters displays significantly better performances in terms of both ROS and Bank Debt over Turnover; however, despite the apparent positive correlation also with ROA, this last relationship does not result to be statistically significant.

First of all, these data point out the fact that companies that start to implement lean practices within their organisation are able to extract more value from their selling activities: either by reducing their costs associated to production, or by improving their value proposition and hence boosting sales or adjusting price, Lean companies might expect to improve their profitability increasing their earning margins and, furthermore, outcompete rivals.

Symmetrically, LM adoption seems to be accompanied by a lower resort to Bank Debt in percentage terms on company turnover. This result is particularly interesting and important, because it highlights that the benefits potentially entailed by LM adoption are likely to exceed the operating area: Lean implementation does not simply serve operating purposes, allowing to collect important benefit at the operations level - process improvements and speed-up, cost reduction, quality enhancement, higher flexibility and reliability - but is aimed at affecting the whole organisation. In particular, concerning the liquidity aspect, empirical evidences here reported suggest that the implementation of LM principles and practices could untie financial resources that in traditional firms might be placed under a heavier production system, and reinvest them internally, reducing the need to recourse to external financing.

However, performances seem not to improve with a superior extent of LM implementation. This founding, together with the lack of impact on ROA, conflicts with evidences provided by Fullerton *et al.* (2003).

On overall, data appear to suggest that a relevant disparity exists between Lean and Non-lean firms - at least concerning ROS and Bank Debt, but that no substantial differences can be observed among LM adopters, like there was a sort of “stair-step effect”: once companies start to implement Lean they are likely to collect significant performance improvements, but these improvements are expected to stay put regardless of the extent of adoption of principles and practices.

By the way, in this respect it is important to recall an important characteristic of the Leanness Index distribution in the sample that has already been taken into consideration when discussing the results of the contextual factors analysis. In particular, it has been highlighted that the majority of companies in the sample are concentrated in a narrow range of medium-low values of Leanness Index and that, on average, their degree of leanness does not vary significantly from one another. This aspect should lead to the conclusion - already mentioned - that, on average, the sample is representative of a set of companies quite homogeneous in terms of leanness and mainly characterised by a medium-low Leanness Index.

As a result, the fact that the empirical analysis did not point out a significant difference in terms of performance between higher and lower Lean adopters might be reasonably linked back to the fact that the implementing structure actually does not vary significantly across LM firms. In fact, substantial improvements in financial results due to a higher extensiveness of LM implementation are less likely to be noted, because it would require a larger difference among Leanness Index in order to generate - and hence to spot - appreciable gains.

Similarly, the evidence that companies subject to the present study are majorly marked by a Medium-Low Leanness Index might denote that they are still in a “young” phase of adoption, and that LM seems to be still far from being widely and intensively adopted in the area.

In this context, it could be assumed that the improvements measured by ROA, intended as a higher ability to perform a superior exploitation of company’s assets and to enhance the capitalisation on investments, should probably require a more extensive effort in LM implementation in order to be noticed.

As a result, it is reasonable to expect that significant differences between Lean and Non-Lean firms may have been appreciated only if at least a consistent part of LM adopters in the sample would have implemented Lean to a higher extent. Similarly, a higher differentiation of Lean adopters in terms of leanness, could potentially have pointed out to ROA improvements positively related to higher levels of Leanness Index.

Context and Moderating effect on LM performances

After having highlighted how contextual factors may or may not be somehow related to LM adoption and what financial benefits might be entailed by Lean, the final part of the analysis will be focused on inspecting whether contextual elements exert or not a moderating effect on LM performances.

In fact, it is possible that some features that characterise the context within which companies operate might not simply exert an influence on LM adoption, but also influence - either positively or negatively - how Lean affects business performances.

In this paragraph, in particular, it will be analysed the potential moderating effect exerted by the contextual factors already identified - Size, Industry, Age, classification as Family Business and Export Turnover - independently on their actual influence over LM adoption.

For each contextual factor, the analysis will be performed by comparing first Lean and Non-lean companies and then High and Low lean adopters, on the basis of the three performance indicators previously used to analyse LM outcomes - ROS, ROA and Bank Debt over total Turnover.

Multiple T-test for the difference between means have been performed, in order to assess whether the effect of LM on performances might vary according to changes in the context.

Size

In order to assess whether differences between Lean and Non-lean firms in terms of performance results might somehow change according to company size, companies have been clustered as before in Small, Medium and Large firms.

Comparisons on the basis of ROS, ROA and Bank Debt over total Turnover between Lean and Non-lean companies have been performed for each Size class.

What has emerged from this analysis (see Tables 52, 53 and 54) is that Lean companies of any Size appear to be characterised by superior performances in comparison to Non-Lean adopters, with the only exception of Small Lean adopters that display a higher indebtedness with respect to Non-lean firms. However, few of these differences have been found to be statistically significant.

ROS (%)		Mean Value		Mean difference	p-value
		Non-lean firms	*Lean firms*		
Size	*Small*	4,888	10,076	5,188	0,032**
	Medium	6,275	9,282	3,007	0,112
	Large	4,878	5,710	0,832	0,831

Table 52: T-test for the difference in LM effect on ROS according to company size

ROA (%)		Mean Value		Mean difference	p-value
		Non-lean firms	*Lean firms*		
Size	*Small*	8,753	11,622	2,869	0,401
	Medium	7,539	11,759	4,22	0,072*
	Large	4,165	6,864	2,699	0,499

Table 53: T-test for the difference in LM effect on ROA according to company size

Bank Debt/Turnover (%)		Mean Value		Mean difference	p-value
		Non-lean firms	*Lean firms*		
Size	*Small*	17,859	27,657	9,798	0,571
	Medium	17,849	8,710	-9,139	0,061*
	Large	28,390	14,709	-13,681	0,199

Table 54: T-test for the difference in LM effect on Bank Debt over total Turnover according to company size

First of all, the difference in terms of ROS is significant only between Small Lean and Non-lean firms, but not among Medium and Large ones.

Similarly, performance improvements measured by ROA and Bank Debt over total Turnover appear to differ significantly only among Medium firms.

These results, therefore, may lead to the conclusion that Size might somehow influence the effect of LM adoption on performances. However, due to the small size of the sample, the potential moderating effect of company Size is uncertain and difficult to assess and quantify.

The effect of Size has also been tested for concerning the moderating effect on Leanness Index performances (Tables 55, 56, 57).

In this case Lean adopters have been divided into "Small-Medium" and "Large" firms, because of the low number of Small Lean companies.

ROS (%)		**Mean Value**		**Mean difference**	**p-value**
		Low Lean Firms	*High Lean Firms*		
Size	*Small-Medium*	9,894	8,911	-0,983	0,668
	Large	4,675	6,597	1,922	0,635

Table 55: T-test for the difference in leanness effect on ROS according to company size

ROA (%)		**Mean Value**		**Mean difference**	**p-value**
		Low Lean Firms	*High Lean Firms*		
Size	*Small - Medium*	12,416	11,006	-1,41	0,638
	Large	5,503	8,030	2,527	0,556

Table 56: T-test for the difference in leanness effect on ROA according to company size

Bank Debt/Turnover (%)		**Mean Value**		**Mean difference**	**p-value**
		Low Lean Firms	*High Lean Firms*		
Size	*Small - Medium*	13,786	8,056	-5,73	0,326
	Large	13,243	15,967	2,724	0,789

Table 57: T-test for the difference in leanness effect on Bank Debt over total Turnover according to company size

Concerning the potential moderating effect of size on performance improvements related to leanness degree, it results interesting to notice that among Small and Medium firms, a low level of LM adoption seems to entail higher performances in terms of profitability but lower in terms of indebtedness, while among Large companies a high Leanness Index seems to determine ROS and ROA improvement but also an increase in debt level.

However, as it might be expected, in general any of these differences is statistically significant.

This result confirms that Leanness Index appear not to exert any significant effect on performance improvements, and adds that this result holds independently on company size.

Industry

The moderating effect of Industry on LM performances has been analysed by comparing the financial results of Lean and Non-lean companies clustered into two groups: Discrete Parts manufacturers and Process manufacturers.

As before, this classification has been chosen in place of using all the 13 industries represented in the sample in order to reduce possible biases due to low numerousness of some categories.

Tables 58, 59 and 60 show that, in general, Lean adopters perform better than Non-Lean firms: ROS and ROA are higher, while Bank Debt is lower when both Discrete part manufacturers and Process manufacturers.

However, no difference is statistically significant.

Considering that the signs of the differences, even if not significant, do not vary passing from one industry to the other, it could be concluded that Industry is likely not to exert any appreciable moderating effect on performances entailed by LM adoption

ROS (%)		**Mean Value**		**Mean difference**	**p-value**
		Non-lean firms	*Lean firms*		
Industry	*Discrete part manufacturers*	6,499	8,514	2,015	0,359
	Process manufacturers	5,227	7,876	2,649	0,162

Table 58: T-test for the difference in LM effect on ROS according to Industry

ROA (%)		**Mean Value**		**Mean difference**	**p-value**
		Non-lean firms	*Lean firms*		
Industry	*Discrete part manufacturers*	8,686	10,589	1,903	0,481
	Process manufacturers	6,665	9,640	2,975	0,183

Table 59: T-test for the difference in LM effect on ROA according to Industry

Bank Debt/Turnover (%)		**Mean Value**		**Mean difference**	**p-value**
		Non-lean firms	*Lean firms*		
Industry	*Discrete part manufacturers*	15,242	11,008	-4,234	0,559
	Process manufacturers	21,657	13,689	-7,968	0,179

Table 60: T-test for the difference in LM effect on Bank Debt over total Turnover according to Industry.

Furthermore, it has been assessed the possible moderating effect exerted by Industry on performance entailed by a higher degree of leanness.

As Tables 61, 62 and 63 show, Leanness Index appears to exert a different and opposite effect on performances according to the Industry in which Lean adopters operate.

In particular, Leanness Index seems to be positively correlated to performances in Process industry, but negatively correlated among Discrete parts manufacturers. By the way, no one of these differences actually results to be statistically significant.

It has also to be considered the argument already presented, namely that the homogeneity of the sample in terms of Leanness Index makes more difficult to appreciate substantial improvements due to a higher degree of leanness.

Hence, it could be concluded that Industry appears not to exert any substantial moderating effect on the lack of relationship between Leanness Index and Business performances.

ROS (%)		**Mean Value**		**Mean difference**	**p-value**
		Low Lean	*High Lean*		
Industry	*Discrete part manufacturers*	8,979	8,116	-0,863	0,730
	Process manufacturers	7,634	8,187	0,553	0,882

Table 61: T-test for the difference in leanness effect on ROS according to Industry

ROA (%)		**Mean Value**		**Mean difference**	**p-value**
		Low Lean	*High Lean*		
Industry	*Discrete part manufacturers*	11,739	9,604	-2,135	0,519
	Process manufacturers	8,710	10,836	2,126	0,601

Table 62: T-test for the difference in leanness effect on ROA according to Industry

Bank Debt/Turnover (%)		**Mean Value**		**Mean difference**	**p-value**
		Low Lean	*High Lean*		
Industry	*Discrete part manufacturers*	8,418	12,859	4,441	0,468
	Process manufacturers	19,389	6,360	-13,029	0,115

Table 63: T-test for the difference in leanness effect on Bank Debt over total Turnover according to Industry

Age

The moderating effect of Age on LM performances has been analysed by comparing the financial results of Lean and Non-lean companies classified as Young, Adult and Old firms.

ROS (%)		**Mean Value**		**Mean difference**	**p-value**
		Non-lean firms	*Lean firms*		
Age	*Young*	4,352	8,588	4,236	0,360
	Adult	4,422	8,880	4,458	0,026**
	Old	7,763	7,117	-0,646	0,753

Table 64: T-test for the difference in LM effect on ROS according to company Age

ROA (%)		**Mean Value**		**Mean difference**	**p-value**
		Non-lean firms	*Lean firms*		
Age	*Young*	5,659	10,521	4,862	0,360
	Adult	7,240	11,860	4,620	0,092*
	Old	8,411	7,515	-0,896	0,697

Table 65: T-test for the difference on LM effect on ROA according to company Age

Bank Debt/Turnover (%)		Mean Value		Mean difference	p-value
		Non-lean firms	*Lean firms*		
Age	*Young*	18,220	11,459	-6,761	0,522
	Adult	16,561	6,523	-10,038	0,071*
	Old	22,442	20,585	-1,857	0,819

Table 66: T-test for the difference in LM effect on Bank Debt over total Turnover according to company Age

What emerges by looking at Tables 64, 65 and 66 is that among Young and Adult firms LM adoption always seems to improve performances, while Old Lean firms appear to outperform traditional companies only in terms of debt.

However, the only significant difference is the one related to LM performances of Adult firms. In particular, within this Age Group Lean firms outperform Non-lean ones not only on the basis of ROS and Debt, as it could have been expected, but also in terms of ROA.

As a result, consistently to what has been stated concerning Size effect, it is possible to conclude that Age could somehow exert a moderating effect on LM performance; however, it results difficult to study this effect only by means of the analysis performed on this sample, because of the reduced number of firms included.

Moderating effect of Age has been analysed also concerning the relationship between Leanness Index and performances.

What has emerged from the analysis, reported in Tables 67, 68 and 69, is that among Young and Old Lean Adopters Leanness Index and performances appear to be positively but not significantly related. On the contrary, this relation results to be negative among Adult adopters, but significant only when measured with ROS.

In any case, it results difficult to make generalisations starting from these evidences, keeping always into consideration the small numerousness of the sample and its homogeneity in terms of leanness degree.

Therefore, the conclusion that can be drawn from these data is that, in general, seems reasonable to confirm that performances do not vary substantially according to the extent of LM adoption, and that the moderating effect of Age could be difficult to ascertain.

ROS (%)		**Mean Value**		**Mean difference**	**p-value**
		Low Lean Firms	*High Lean Firms*		
Age	*Young*	5,172	12,857	7,685	0,247
	Adult	11,480	6,278	-5,202	0,053*
	Old	5,969	8,103	2,134	0,435

Table 67: T-test for the difference in leanness effect on ROS according to company Age

ROA (%)		**Mean Value**		**Mean difference**	**p-value**
		Low Lean Firms	*High Lean Firms*		
Age	*Young*	8,150	13,485	5,335	0,432
	Adult	13,825	9,893	-3,932	0,320
	Old	6,710	8,204	1,494	0,623

Table 68: T-test for the difference in leanness effect on ROA according to company Age

Bank Debt/Turnover (%)		**Mean Value**		**Mean difference**	**p-value**
		Low Lean Firms	*High Lean Firms*		
Age	*Young*	16,888	6,030	-10,858	0,296
	Adult	3,375	9,356	5,981	0,185
	Old	26,792	15,266	-11,526	0,320

Table 69: T-test for the difference in leanness effect on Bank Debt over total Turnover according to company Age

Family Businesses

Proceeding with the analysis, it has been studied whether the classification of companies as Family or Non-family business might somehow vary how LM affects performances.

First of all, it has been performed a comparison aimed at highlighting potential differences between Lean and Non-lean firms depending on whether they are Family Businesses or not.

ROS (%)	**Mean Value**		**Mean difference**	**p-value**
	Non-lean firms	*Lean firms*		
Non-family Firms	6,638	7,446	0,808	0,787
Family Firms	5,436	8,641	3,205	0,046**

Table 70: T-test for the difference in LM effect on ROS comparing Family and Non-family Business

ROA (%)	**Mean Value**		**Mean difference**	**p-value**
	Non-lean firms	*Lean firms*		
Non-family Firms	7,357	9,823	2,466	0,458
Family Firms	7,494	10,409	2,915	0,150

Table 71: T-test for the difference in LM effect on ROA comparing Family and Non-family Business

Bank Debt/Turnover (%)	**Mean Value**		**Mean difference**	**p-value**
	Non-lean firms	*Lean firms*		
Non-family Firms	7,963	8,240	0,277	0,458
Family Firms	22,703	13,537	-9,166	0,077*

Table 72: T-test for the difference in LM effect on Bank Debt over total Turnover comparing Family and Non-family Business

As can be seen by looking at Tables 70, 71 and 72, appreciable differences in terms of performances correlated to LM adoption exists only among Family firms.

In particular, Family businesses which adopt Lean are characterised by significantly superior performances in terms of ROS and Bank Debt over total Turnover (but not ROA). This pattern is perfectly in line with what has been previously pointed out when analysing overall LM effect on performance.

On the contrary, in Non-Family businesses, no appreciable differences exist among Lean and Non-Lean companies.

As a result, it can be concluded that the classification of a company as a Family Business is likely to foster the positive effect that Lean adoption may exert on company ROS and Bank Debt over total Turnover.

Then, the same analysis has been performed also to investigate the possible moderating effect on the relationship between Leanness Index and financial performances.

As can be seen in Tables 73, 74 and 75, first of all there are slight and dissonant differences between Low and High Lean adopters in terms of profitability: Leanness Index seems to be positively related to ROS only in Family firms and to ROA in Non-family ones; symmetrically, it relationship appear negative with ROS in Non-family firms and with ROA in Family businesses.

In terms of indebtedness, Non-family firms seem to improve their results by adopting LM, while the difference among High and Low lean adopters among Family businesses is almost equal to zero.

In addition, it can be noted that differences are larger among Non-family firms, especially in terms of Bank Debt.

However, no one of these differences results to be statistically significant. Therefore, it could be concluded that the classification of companies as Family or Non-family firms does not exert any effect on the relationship between Leanness Index and financial performances, that seems to be permanently non-significant.

ROS (%)	**Mean Value**		**Mean difference**	**p-value**
	Low Lean Firm	*High Lean Firm*		
Non-family Firms	7,868	7,084	-0,784	0,860
Family Firms	8,617	8,667	0,050	0,982

Table 73: T-test for the difference in leanness effect on ROS comparing Family and Non-family Business

ROA (%)	**Mean Value**		**Mean difference**	**p-value**
	Low Lean Firm	*High Lean Firm*		
Non-family Firms	8,905	10,541	1,636	0,755
Family Firms	11,023	9,751	-1,272	0,671

Table 74: T-test for the difference in leanness effect on ROA comparing Family and Non-family Business

Bank Debt/Turnover (%)	**Mean Value**		**Mean difference**	**p-value**
	Low Lean Firm	*High Lean Firm*		
Non-family Firms	13,858	5,030	-8,828	0,438
Family Firms	13,550	13,524	-0,026	0,997

Table 75: T-test for the difference in leanness effect on Bank Debt over total Turnover comparing Family and Non-family Business

Export Turnover

The final contextual factor that has been taken into consideration for its possible moderating effect exerted on the relationship between LM and financial performances is Export Turnover.

Coherently to what have been done in the first part of the analysis, companies have been subdivided according to their percentage of Export turnover on total. In this case, the threshold for the subdivision has been represented by the 50% of total Turnover.

ROS (%)		**Mean Value**		**Mean difference**	**p-value**
		Non-lean firms	*Lean firms*		
Export Turnover	*<50%*	6,200	8,962	2,762	0,135
	>= 50%	4,900	7,846	2,946	0,199

Table 76: T-test for the difference in LM effect on ROS according to percentage of Export Turnover

ROA (%)		**Mean Value**		**Mean difference**	**p-value**
		Non-lean firms	*Lean firms*		
Export Turnover	*<50%*	8,389	11,133	2,744	0,239
	>= 50%	5,837	9,760	3,923	0,154

Table 77: T-test for the difference in LM effect on ROA according to percentage of Export Turnover

Bank Debt/Turnover (%)		**Mean Value**		**Mean difference**	**p-value**
		Non-lean firms	*Lean firms*		
Export Turnover	*<50%*	21,670	18,271	-3,399	0,638
	>= 50%	14,681	8,366	-6,315	0,155

Table 78: T-test for the difference in LM effect on Bank Debt over total Turnover according to percentage of Export Turnover

Tables 76, 77 and 78 shows that, even if mean differences are not statistically significant, Lean firms tend in general to perform better than Non-lean companies either in terms of ROS, ROA and Bank Debt over total Turnover, regardless of the level of Export Turnover.

As a result, this data could be considered to be in line with what has been previously stated concerning general effects of LM implementation over performances, and it results possible to conclude that Export Turnover does not seem to exert any appreciable moderating effect on the relationship between LM adoption and financial results.

Finally, the analysis has been extended in order to cover the possible moderating effect of Export Turnover on the relationship between financial outcomes and degree of leanness.

In this case, the threshold used to classify companies has been 63,5%, which correspond to the median value of Export Turnover among Lean adopters.

ROS (%)		**Mean Value**		**Mean difference**	**p-value**
		Low Lean adopters	*High Lean adopters*		
Export Turnover	*<63,5%*	9,464	7,567	-1,897	0,482
	>= 63,5%	7,236	8,658	1,422	0,654

Table 79: T-test for the difference in leanness effect on ROS according to percentage of Export Turnover

ROA (%)		**Mean Value**		**Mean difference**	**p-value**
		Low Lean adopters	*High Lean adopters*		
Export Turnover	*<63,5%*	11,431	9,788	-1,643	0,660
	>= 63,5%	9,352	10,220	0,868	0,806

Table 80: T-test for the difference in leanness effect on ROA according to percentage of Export Turnover

Bank Debt/Turnover (%)		**Mean Value**		**Mean difference**	**p-value**
		Low Lean adopters	*High Lean adopters*		
Export Turnover	*<63,5%*	14,120	16,223	2,103	0,627
	>= 63,5%	13,053	3,846	-9,207	0,112

Table 81: T-test for the difference in leanness effect on Bank Debt over total Turnover according to percentage of Export Turnover

What emerges by looking at Tables 79, 80 and 81 is that the sign of the correlation between Leanness Index and financial results seem to change according to the level of Export Turnover.

In specific, when Adopters export more than 63,5% of their Turnover, extensive LM adoption should entail a slight but positive effect on ROS and ROA and a large reduction on Bank Debt. On the contrary, among adopters that export less than 63,5% of their Turnover, slightly higher performances are likely to be linked to a lower Leanness degree.

However, all these differences are not significantly different from 0. As a result, taking into consideration that in general Leanness Index is expected to have no significant correlation with financial performances, it results possible to conclude that Export Turnover does not exert any moderating effect also concerning the relationship between degree of leanness of a company and financial performances.

Results discussion

This last part of the analysis has pointed out the fact that the context in which firms operate not only may affect LM implementation *per se*, but might also exert a moderating effect on the financial results entailed by Lean.

In general, only small or even non-significant findings have been provided concerning the moderating influence of Size, Industry, Age and Export Turnover on the relationship between LM adoption and performance improvements.

In specific, it has emerged that Lean adopters could seem to perform better than Non-lean firms, regardless of the Industry they belong or their level of Export Turnover. Even if performance differences might not have been statistically significant, it could be suggested that neither Industry nor Export Level seem to influence the financial improvements possibly related to LM adoption.

Concerning moderating effect of Age and Size of companies, instead, empirical evidences have pointed out that significant financial improvements entailed by Lean application can be found only in connection with few specific cases, and not regardless of the dimension or the years of operation of every firm. This data seems to hint that effectiveness can be somehow moderated by the effect exerted by specific Size and/or Age of the company; however, this potential influence is difficult to identify and study, because the reduced number of firms included in the sample could easily highlight an effect not actually occurring within the overall population.

By the way, despite the small or non-significant findings related to the moderating effects of the majority of contextual factors here analysed, empirical evidence has pointed out that LM adoption could be expected to produce larger benefits in Family firms than in Non-family ones.

In fact, while LM adoption seems not to entail significant performance enhancements when applied by Non-Family firms, improvements in terms of ROS and Bank Debt over total Turnover are instead larger and significant when the company is directly managed by members of the same family.

This evidence on the moderating effect of Family Businesses, which appear to be able to exploit more effectively the potentialities provided by LM adoption should be traced back to the direct involvement of management and proprietorship in the Lean transformation of the company.

What characterises Family firms, in fact, is the overlap of ownership and management, in the sense that members of the owning family are also involved in directly running the business. This key element could easily result in a deep and conscious involvement of the owning family in the Lean adoption, and hence foster the transformation process, reinforcing its effectiveness. In fact, the direct and positive participation of top management and ownership is likely to serve as a catalyst for LM implementation, enhancing its benefits.

Finally, empirical evidences have been found on the fact that generally contextual factors do not seem to exert any significant moderating effect on the relationship between Leanness Index and financial outcomes, that results to be permanently non-significant, regardless of the context in which firms operate.

As already explained, the possible justification for the absence of a significant relationship between Leanness Index and performances could be found in the composition of the sample itself, that includes majorly a complex of Lean adopters pretty homogeneous in terms of Leanness Index.

Analogously, in order to test not only for the effect of leanness on performances but also for a moderating effect exerted by the context, the analysis should be performed on a sample more heterogeneous, because the differences among lean adopters in the present sample are too narrow to allow to appreciate significant effects exerted by contextual factors.

Conclusion

The empirical analysis carried out within the framework of this thesis has provided several facts and evidences concerning Lean application in manufacturing firms located in the Veneto region.

First of all, data concerning LM diffusion have pointed out that this organisational paradigm results to hold fair attraction among manufacturing firms of the area. In fact, Lean adopters represents the 56% of the total sample. This data can be deemed to be positive and to offer an optimistic perspective concerning LM spread in Veneto, especially if we consider it together with the fact that the majority of these firms have started their Lean transformation no more than five years ago. This could hint that it would be quite reasonable to expect to record the existence of some new Lean adoptions in the coming years too.

In general, firms that have decided to adopt LM in their organisation often share some contextual elements.

In particular, LM adoption seems first of all to be positively related to the Size of the company: larger companies, in fact, appear to be more likely to adopt Lean rather than smaller firms.

Similarly, also the industry to which every firm belongs can be reasonably deemed to exert often a positive or negative effect toward LM implementation. In fact, LM seems to prevail in some specific industries (Chemical, Plastic and Rubber, Appliances manufacturing, Furniture and NEC machineries manufacturing), while it results to be less or even only marginally diffused in others (Food and Beverage, Metallic Minerals manufacturing and Other manufacturing industries).

Then, the third element that is likely to characterise the majority of Lean adopters and to differentiate them from traditional firms is represented by the level of Export Turnover. Actually, in fact, Lean companies are likely to record more than half of their turnover in foreign market.

Differences between Lean and Non-lean companies do not simply concern the context in which firms operate, but also their financial results. In fact, empirical evidences have been provided on the fact that companies that adopt LM are likely to outperform traditional firms both in terms of Return On Sales and Bank Debt over Total Turnover. This result is extremely relevant, because it points out the fact that Lean implementation does not simply serve operational purposes, reducing costs and enhancing operating profitability, but can also influence positively and significantly the overall performances of the whole organisation, impacting on financial and liquidity aspects too.

On this aspect, it has also emerged that performance implications of LM adoption are likely to be moderated by a specific contextual factor, represented by the classification of companies as Family or Non-family businesses. In fact, it has been proved that performance improvements positively related to Lean implementation are more likely to be recorded by Family firms rather than by Non-family ones. On this regard, this difference could be reasonably traced back to the fact that in Family firms ownership and management, both constituted – in whole or in part – by several members of the same owning family, might be much more directly and consciously involved in Lean transformation, and this participation is likely to make the firm more able to better exploit LM potentialities.

By focusing solely on Lean adopters, and comparing them on the basis of their Leanness Index, no differences have been found, neither in terms of contextual factors which might have influenced companies to implement LM to a greater or lesser extent, nor regarding the possible outcomes entailed by different degree of leanness and the moderating effect exerted by the context.

This lack of any significant difference has to be considered together with the actual degree of leanness that characterises the whole sample. In specific, empirical analysis has highlighted that, on overall, the majority of Lean companies are almost quite homogeneous in terms of tools adoption, departments coverage and overall leanness.

First of all, practices like 5S, Kanban, Value Stream Mapping and Visual Management are implemented by the vast majority of Lean firms, while others like Heijunka, Simultaneous Engineering and Andon are put in place only in few cases.

In addition, the majority of companies tend to focus their efforts only in few departments (in specific, Production, Inventory and Internal Logistics), while other areas tend to be only marginally involved in Lean transformation.

Then, on overall, the majority of companies in the sample are concentrated in a narrow range of medium-low values of Leanness Index and, on average, their degree of leanness does not vary significantly from one another – generally less than 1%.

All these elements make the majority of Lean adopters in the sample, as said before, quite homogeneous in terms of their degree of leanness and, as a result, reduce the opportunities to spot significant differences, both in contextual and in financial terms, among Lean firms.

However, this evidence should not lead to the conclusion that a higher extensiveness of LM implementation is not expected to be possibly correlated to the context and to potentially entail additional benefits. Simply, it could be assumed that the identification and measurement of appreciable variations could require a difference among firms' Leanness Index larger than the one that characterises companies subject to this analysis.

References

ABDULMALEK, F. A., RAJGOPAL, J., 2007. *Analyzing the benefits of lean manufacturing and value stream mapping via simulation: A process sector case study.* International Journal of production economics, 107(1), pp. 223-236.

ARLBJØRN, J. S., FREYTAG, P. V., 2013. *Evidence of lean: a review of international peer-reviewed journal articles*. European Business Review, 25(2), pp.174-205.

ARLBJØRN, J.S., NØRBY, M., NORLYK, B., WIBORG, C., HOLM, N., 2008. *Lean uden grænser? – Lean i offentlige og private virksomheder*. In: ARLBJØRN, J. S., FREYTAG, P. V., 2013. *Evidence of lean: a review of international peer-reviewed journal articles*. European Business Review, 25(2), pp.174-205.

BALLARD, G., KOSKELA, L., HOWELL, G., ZABELLE, T., 2001. *Production System Design: Work Structuring Revisited.* In: MOSSMAN, A., 2009. *Creating value: a sufficient way to eliminate waste in lean design and lean production.* Lean Construction Journal (2009), pp. 13 – 23

BAYO-MORIONES, A., BELLO-PINTADO, A., MERINO-DIAZ-DE-CERIO, J., 2008. *The role of organizational context and infrastructure practices in JIT implementation.* International Journal of Operations & Production Management, 28(11), pp. 1042-1066.

BELEKOUKIAS, I., GARZA-REYES, J. A., KUMAR, V., 2014. *The impact of lean methods and tools on the operational performance of manufacturing organisations.* International Journal of Production Research, 52(18), pp. 5346-5366

BHASIN, S., BURCHER, P., 2006. *Lean viewed as a philosophy.* Journal of manufacturing technology management*, 17*(1), pp. 56-72

BICHENO, J., & HOLWEG, M. (2008). *The Lean Toolbox: The Essential Guide to Lean Transformation.* PICSIE Books.

CHAN, F. T. S., LAU, H. C. W., IP, R. W. L., CHAN, H. K., KONG, S., 2005. *Implementation of total productive maintenance: A case study*. International Journal of Production Economics, *95*(1), pp. 71-94.

DAHLGAARD, J. J., MI DAHLGAARD-PARK, S., 2006. *Lean production, six sigma quality, TQM and company culture.* The TQM magazine, 18(3), pp. 263-281

DE TREVILLE, S., ANTONAKIS, J., EDELSON, N. M., 2005. *Can standard operating procedures be motivating? Reconciling process variability issues and behavioural outcomes.* Total Quality Management and Business Excellence, 16(2), pp. 231-241.

DESHMUKH, G., PATIL, C. R., DESHMUKH, M. G., 2017. *Manufacturing industry performance based on lean production principles.* International Conference on Nascent Technologies in Engineering (ICNTE), pp. 1-6

DOOLEN, T. L., HACKER, M. E., 2005. *A review of lean assessment in organizations: an exploratory study of lean practices by electronics manufacturers.* Journal of Manufacturing systems, 24(1), pp. 55-67.

EDELSON, N. M., BENNETT, C. L., 1998. *Process Discipline: How to Maximize Profitability and Quality Through Manufacturing Consistency.* In: DE TREVILLE, S., ANTONAKIS, J., EDELSON, N. M., 2005. *Can standard operating procedures be motivating? Reconciling process variability issues and behavioural outcomes.*

FORZA, C., 1996. *Work organization in lean production and traditional plants: what are the differences?* International Journal of Operations & Production Management, 16(2), pp. 42-62.

FULLERTON, R. R., MCWATTERS, C. S., FAWSON, C., 2003. *An examination of the relationships between JIT and financial performance*. Journal of Operations Management, 21(4), pp. 383-404.

FULLERTON, R. R., KENNEDY, F. A., WIDENER, S. K., 2014. *Lean manufacturing and firm performance: The incremental contribution of lean management accounting practices.* Journal of Operations Management, 32(7), pp. 414-428

FULLERTON, R. R., WEMPE, W. F., 2009. *Lean manufacturing, non-financial performance measures, and financial performance*. International Journal of Operations & Production Management, 29(3), pp. 214-240.

GLOVER, W. J., LIU, W. H., FARRIS, J. A., VAN AKEN, E. M., 2013. *Characteristics of established kaizen event programs: an empirical study*. International Journal of Operations & Production Management, 33(9), pp. 1166-1201.

GODINHO FILHO, M., GANGA, G. M. D., GUNASEKARAN, A., 2016. *Lean manufacturing in Brazilian small and medium enterprises: implementation and effect on performance.* International Journal of Production Research, 54(24), pp. 7523-7545.

GOSH, M., 2012. *Lean manufacturing performance in Indian manufacturing plants*. Journal of Manufacturing Technology Management, 24(1), pp. 113-122.

GREEN, K. W., INMAN, R. A., BIROU, L. M., WHITTEN, D., 2014. *Total JIT (T-JIT) and its impact on supply chain competency and organizational performance.* International Journal of Production Economics, 147, pp. 125-135.

HOLWEG, M., 2007. *The genealogy of lean production.* Journal of Operations Management, 25(2), pp. 420-437

IMAI, M., 1986. *Kaizen: The Key to Japan's Competitive Success.* In: KARLSSON, C., ÅHLSTRÖM, P., 1996. Assessing changes towards lean production. International Journal of Operations & Production Management, 16(2), pp. 24-41.

JASTI, N. V. K., KODALI, R., 2015. *Lean production: literature review and trends.* International Journal of Production Research, 53(3), pp. 867-885.

KARLSSON, C., ÅHLSTRÖM, P., 1996. *Assessing changes towards lean production.* International Journal of Operations & Production Management, 16(2), pp. 24-41.

KILPATRICK, J., 2003. *Lean principles.* Utah Manufacturing Extension Partnership, 68, pp. 1-5.

KUO, T., SHEN, J. P., CHEN, Y. M., 2008. *A study on relationship between lean production practices and manufacturing performance.* International Symposium of Quality Management, pp. 1-8.

LEE, Q., 2004. *Lean manufacturing strategy*. Strategos. available at: <www.strategosinc.com>

LIKER, J.K, MORGAN, J. M., 2006. *The Toyota Way in Services: The Case of Lean Product Development.* Academy of Management Executive 20(2), pp. 5-20

LUCATO, W. C., CALARGE, F. A., JUNIOR, M. L., CALADO, R.D., 2014. *Performance evaluation of lean manufacturing implementation in Brazil*. International Journal of Productivity and Performance Management. 63(5), pp. 529-549

MARODIN, G. A., FRANK, A. G., TORTORELLA, G. L., SAURIN, T. A., 2016. *Contextual factors and Lean Production implementation in the Brazilian automotive supply chain*. Supply Chain Management: An International Journal, 21(4), pp. 417-432

MARODIN, G. A., SAURIN, T. A., 2013. *Implementing lean production systems: research areas and opportunities for future studies.* International Journal of Production Research, 51(22), pp. 6663–6680

MARODIN, G., SAURIN, T., TORTORELLA, G., DENICOL, J. 2015. *How context factors influence lean production practices in manufacturing cells.* International Journal of Advanced Manufacturing Technology, 79, pp. 1389-1399.

MELTON, T., 2005. *The benefits of lean manufacturing: what lean thinking has to offer the process industries.* Chemical engineering research and design, 83(6), pp. 662-673

MILTENBURG, J., 2001. *U-shaped production lines: A review of theory and practice*. International Journal of Production Economics, 70(3), pp. 201-214.

MONDEN, Y., 2011. *Toyota production system: an integrated approach to just-in-time*. CRC Press.

MOORI, R. G., PESCARMONA, A., KIMURA, H., 2013. *Lean Manufacturing and Business Performance in Brazilian Firms.* Journal of Operations and Supply Chain Management, 6(1), pp. 91-105

MOSSMAN, A., 2009. *Creating value: a sufficient way to eliminate waste in lean design and lean production.* Lean Construction Journal (2009), pp. 13 – 23

MOSTAFA, S., DUMRAK, J., SOLTAN, H., 2013. *A framework for lean manufacturing implementation*. Production & Manufacturing Research, 1(1), pp. 44-64

NEGRÃO, L. L., GODINHO FILHO, M., MARODIN, G., 2017. *Lean practices and their effect on performance: a literature review,* Production Planning & Control, 28(1), pp. 33-56

PIEŃKOWSKI, M., 2014. *Waste measurement techniques for lean companies*. International Journal of Lean Thinking, *5*(1).

ROTHER, M., 2009. *Toyota Kata*. McGraw-Hill Professional Publishing.

ROTHER, M., SHOOK, J., 2003. *Learning to see: value stream mapping to add value and eliminate muda*. Lean Enterprise Institute.

SAYER, A., 1986. *New developments in manufacturing: the just-in-time system*. Capital & Class, 10(3), pp. 43-72.

SAURIN, T. A, MARODIN, G. A., RIBEIRO, J. L. D., 2011. *A framework for assessing the use of lean production practices in manufacturing cells.* International Journal of Production Research, 49(11), pp. 3211–3230

SHAH, R., WARD, P. T., 2003. *Lean manufacturing: context, practice bundles, and performance.* Journal of operations management, 21(2), pp. 129-149

SHAH, R., WARD, P. T., 2007. *Defining and developing measures of lean production.* Journal of Operations Management, 25(2007), pp. 785–805

SHINGO, S., DILLON, A. P., 1989. *A study of the Toyota production system: From an Industrial Engineering Viewpoint*. CRC Press.

SHOOK, J. 2009. *Toyota's Secret: The A3 Report.* MIT Sloan management review, 50(4), pp. 30-33

SINGH, B., GARG, S. K., SHARMA, S. K., GREWAL, C., 2010. *Lean implementation and its benefits to production industry.* International Journal of Lean Six Sigma, 1(2), pp. 157-168

SLACK, N., BRANDON-JONES, A., JOHNSTON, R., 2013. *Operations management.* Pearson.

SNEE, R. D., 2010. *Lean Six Sigma – getting better all the time*. International Journal of Lean Six Sigma, 1(1), 9-29.

SORIANO-MEIER, H., FORRESTER, P. L., 2002. *A model for evaluating the degree of leanness of manufacturing firms.* Integrated Manufacturing Systems, 13(2), pp. 104 - 109

SPEAR, S. BOWEN, H. K., 1999. *Decoding the DNA of the Toyota Production System*. In: SAURIN, T. A, MARODIN, G. A., RIBEIRO, J. L. D., 2011. *A framework for assessing the use of lean production practices in manufacturing cells.* International Journal of Production Research, 49(11), pp. 3211–3230

SUGIMORI, Y., KUSUNOKI, K., CHO, F., UCHIKAWA, S., 1977. *Toyota production system and Kanban system. Materialization of just-in-time and respect- for-human system.* International Journal of Production Research, 15(6), pp. 553-564

SUNDAR, R., BALAJI, A. N., KUMAR, R. S., 2014. *A review on lean manufacturing implementation techniques*. Procedia Engineering, 97, pp. 1875-1885

TAJ, S., 2008. *Lean manufacturing performance in China: assessment of 65 manufacturing plants.* Journal of Manufacturing Technology Management, 19(2), pp. 217-234.

TAJ, S., MOROSAN, C., 2011. *The impact of lean operations on the Chinese manufacturing performance.* Journal of manufacturing technology management, 22(2), pp. 223-240.

TEZEL, A., KOSKELA, L., TZORTZOPOULOS, P., 2016. *Visual management in production management: a literature synthesis.* Journal of Manufacturing Technology Management, 27 (6), pp. 766-799

TORTORELLA, G. L., MIORANDO, R., TLAPA, D. 2017. I*mplementation of lean supply chain: an empirical research on the effect of context*, The TQM Journal, 29(4), pp. 610-623

TOWILL, D., CHRISTOPHER, M., 2002. *The supply chain strategy conundrum: to be lean or agile or to be lean and agile?* In: ARLBJØRN, J. S., FREYTAG, P. V., 2013. *Evidence of lean: a review of international peer-reviewed journal articles*. European Business Review, 25(2), pp.174-205.

WAN, H. D., CHEN, F. F., 2008. *A leanness measure of manufacturing systems for quantifying impacts of lean initiatives.* International Journal of Production Research, 46(23), pp. 6567-6584.

WHITE, R. E., PEARSON, J. N., WILSON, J. R., 1999. *JIT manufacturing: a survey of implementations in small and large US manufacturers.* Management science, 45(1), pp. 1-15.

WOMACK, J.P., JONES, D.T., 2003. *Lean Thinking. Banish Waste and Create Wealth in Your Corporation.* Simon and Schuster.

WOMACK, J.P., JONES, D.T., ROOS, D., 1990. *The Machine that Changed the World.* Simon and Schuster.

Appendix

List of Companies that have taken part to the study:

- Alu-Pro Srl
- Antonio Carraro Spa
- Arcoprofil Srl
- Arredo3 Srl
- Athena Spa
- Battistella Company Srl
- Baumann Srl
- Baxi Spa
- Bedeschi Spa
- Biemmereti Spa
- Biko Meccanica Srl
- Biotec Srl
- Blue Box Group Srl
- Caminetti Montegrappa Spa
- Cantine Vitevis Spa
- Cartiere Saci Spa
- Casa Vinicola Botter Spa
- CFI Srl
- Cieffe Thermal Systems Srl
- Cold line Srl
- Colomberotto Spa
- Colorificio San Marco Spa
- Cramaro Tarpaulin Systems Srl
- De'Longhi Appliances Srl
- Diab Spa
- Diesel Spa
- EagleBurgmann Italia Srl
- Europoligrafico Spa
- Europoliuretani Srl
- Fiamm Componenti Accessori Spa
- Flavio Fraccari Srl
- Fonderie di Montorso Spa
- Forno d'Asolo Spa
- Galdi Srl
- Gasparini Spa
- Geberit Produzione Spa
- Giacomini & Gambarova Srl
- Hidros Spa
- Hubergroup Italia Spa
- Idea Srl
- Ilsa Spa
- Industria Casearia Silvio Belladelli Srl
- Ital-Lenti Srl
- Italcab Spa
- Kastel Srl
- Labomar Srl
- Lamet Spa
- Marmi Rossi Spa
- Media Profili Srl
- Meneghetti Spa
- Molino Rossetto Livio Srl
- Mosconi Spa
- NLMK Verona Spa
- Nuova Farmec Srl
- Officine Meccaniche BBM Spa
- Omis Spa
- Pali Campion Srl
- Palladio Group Spa
- Peter Pan Plast Srl
- Poliver Spa
- Pometon Spa
- RDS Moulding Technology Spa
- Salvagnini Italia Spa
- Sirman Spa
- Sisma Spa
- Sitland Spa
- Soga Spa
- Specchiasol Srl
- Tomasetto Achille Spa
- Union Glass Srl
- Valente Srl
- Varem Spa
- Vemer Spa
- Verniciatura Industriale Veneta Spa
- Zhermack Spa.