IMPACT OF LEAN MANUFACTURING ON PROCESS INDUSTRIES

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Abstract

This thesis seeks to find out the impact of Lean manufacturing (LM) on different sectors of process industries.

The theory of this thesis was established mainly on published high-impact scholarly literature, such as books, journals, conferences and theses, as well as several online websites on the subject matters of LM.

Afterwards, several hypotheses were formulated in order to check the findings of the present research regarding the impact on LM implementation on process industry.

The research method for testing these hypotheses used in the thesis is to investigate several published case studies on LM in different sectors of the process industry. The findings from the results of these case studies have been substantiated by a case study which was conducted via questionnaire based interviews in one alcoholic beverage industry.

The thesis reveals the importance of the inherent production process characteristics of each facility that sets out to implement lean as well as the range of expectations and benefits that can be witnessed upon successful employment of the most suitable LM practices. Additionally, attention is drawn towards the necessity of a continuous organization commitment to the adoption of LM.

Future research prospects that stem from the present thesis consist of an analysis of many different lean practices and tools separately, their implementation as well as the impact they would effectuate on different sectors of the process industry contrary to the combined analysis of the LM tools studied in this thesis. Moreover, while the scope in this thesis was the implementation and the outcome of LM, it would be of interest to investigate the factors that inhibit successful implementation on process industries.
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<thead>
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<th>Word</th>
<th>Definition</th>
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<tbody>
<tr>
<td>5S</td>
<td>Sort, Set, Shine, Standardize, Sustain</td>
</tr>
<tr>
<td>FMCG</td>
<td>Fast-moving consumer goods.</td>
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<tr>
<td>IF</td>
<td>Impact factor</td>
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<tr>
<td>JIT</td>
<td>Just-in-time</td>
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<tr>
<td>KPI</td>
<td>Key performance indicator</td>
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<tr>
<td>LM</td>
<td>Lean manufacturing</td>
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<td>MTS</td>
<td>Make-to-stock</td>
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<tr>
<td>OEE</td>
<td>Overall equipment effectiveness</td>
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<td>RMG</td>
<td>Ready-made garments</td>
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<tr>
<td>SME</td>
<td>Small and medium-sized enterprises</td>
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<td>SMED</td>
<td>Single-minute exchange of dies</td>
</tr>
<tr>
<td>TPM</td>
<td>Total productive maintenance</td>
</tr>
<tr>
<td>TPS</td>
<td>Total production system</td>
</tr>
<tr>
<td>TQM</td>
<td>Total quality maintenance</td>
</tr>
<tr>
<td>VSM</td>
<td>Value stream mapping</td>
</tr>
<tr>
<td>WiP</td>
<td>Work in progress</td>
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Chapter 1: Introduction

1 Introduction

2018 is the 10\textsuperscript{th} anniversary of the global economic crisis breakout. During this decade, the global market was hugely destabilized as both consumer demand and industrial production collapsed. In a uniquely occurring incident, as mentioned by a chemical sector representative, companies were left with large quantities of inventory items that could not be disposed of due to rapidly receding sales (Beacham, 2018).

Both in the EU as well as the USA, industrial production sustained severe reductions, especially during the notification and spreading of the crisis, as depicted in Figure 1 and Figure 2 presented below.

![Figure 1. Industrial production volume rates, period 2005-2016, EU-28 area (Eurostat, 2018)](image1)

![Figure 2. Industrial production volume rates, 2005-2016, USA area (Federal Reserve Bank of St. Louis, 2018)](image2)
Up to this moment, the production rates have not regained the momentum achieved before the crisis breakout nonetheless, during the past two years a stabilized rising trend has been observed (Atradius Conduction team, 2017). The economic crisis incident turned the industries’ focus on ways of cost reduction by any means such as wage cutdowns, facility shutdowns, mergers, even quality sparing. Instead in these times of recession, the industrial world should perceive these tight economic circumstances as an opportunity to re-engineer and improve processes and operational characteristics towards a lean mode of production, ridding of waste and unnecessary expenses while enforcing quality at all stages (Anthony, P., 2018).

From another point of view, the market today is more than ever full of stiff competition. There is a rising demand for different types of products with a vast multitude of production processes, considering in parallel the industrial need for cost reduction while sustaining quality at the same time (Moser, Isaksson and Seifert, 2017). To achieve those benefits, a different approach in manufacturing could be adopted, which would ensure more an efficient production mechanism. Lean manufacturing (LM) can provide the impetus needed to excel in the production of a variety of quality products (Melton, 2005; Womack and Jones, 2003).

The concept of LM can be dated back to the middle of the 20th century, when it was introduced as the Toyota Production System (TPS) to describe the manufacturing process of automotive at the Toyota Motor Company's factory based in Nagoya, Japan (Ohno, 1988). However, the modern framework of Lean Manufacturing, which has been widely adopted by many industries during the past decades, was introduced and explained by Womack, Jones, and Roos on their path-breaking book “The machine that changed the world” (Womack, Jones and Roos, 1990). What began as a process upgrade program targeted to aid the Toyota Motor Company to improve productivity and increase revenues, is today a subject of continuous study and a production system that is adopted by many industries who wish to benefit from the advantages of LM such as improved quality delivered, reduced inventory, elimination of waste and constant process optimization (Art of Lean, n.d.; Ohno, 1988; Womack and Jones, 2003).

1.1 Problem discussion

The process industry in Europe employs 6,8 million workers and yields more than €1.6 billion of total turnover, thus accounting for around 20% of workforce and income in the EU region. Being in the center of most industrial processes and having to deal with the strict
guidelines of Horizon 2020, regarding energy consumption and efficiency, while still under the rigid economic circumstances of the decade crisis, process industries need to approach a more sustainable mode of operation, reducing energy consumption and emissions while preserving high quality delivered (European Commission, 2013).

Moreover, the market trends affected by the prevalent and rapidly changing conditions of globalized competition and varying demand that steadily embeds new clients with unique needs, request an immediate reply from process industries who possess a key role in the supply chain. For these industries, it is becoming evident that the advantage required to skip ahead from the competition is none other than the ability to respond fast to fluctuating demands and immediate deliveries of the products required (Moser, Isaksson and Seifert, 2017).

Interestingly, the efforts conducted to respond to these needs are oriented towards better forecasting and planning of needs and vendor-managed inventories (Moser, Isaksson and Seifert, 2017) whereas a more holistic approach covering the production operation in total, such as lean manufacturing, could yield better and more substantial results.

Although the adoption of lean thinking, in a timely and adequate manner, benefits the process industry significantly (Abdulmalek, Rajgopal, and Needy, 2006), the implementation of lean is still quite low in such cases compared to discrete manufacturing industries (Abdulmalek, Rajgopal, and Needy, 2006; Melton, 2005). This is attributed to the fact that process industries often operate differently compared to discrete manufacturing industries: they require equipment larger and less flexible, they produce in larger batches and the setup changeover times when producing different products, can take up a lot of time. The differences in operation together with the fact that LM was introduced and processed in the automotive industry and later on mostly in manufacturing industries, enforce the idea that process industries are not eligible for implementing LM (Abdulmalek and Rajgopal, 2007).

This is why the principal objective of this thesis is to provide a theoretical guide to understanding the fundamental concepts and methods of Lean Manufacturing and some key tenets that either promote or impede a beneficial outcome after the application of LM principles on process industries. This thesis does not include only the advantages of LM, instead gives the reader an extensive research literature-based analysis with an indication as to what factors help or obstruct the successful implementation of lean manufacturing on process industries.
1.2 Problem formulation and purpose

Although there is a wide range of books and articles covering the implementation and effects of Lean Manufacturing in discrete manufacturing industries, to the authors’ knowledge, there is no research work available that combines the vital information of notable scholarly published articles on LM for the process industry, taking into account the unique characteristics of each sector; the process industry is divided into many sectors and subsectors, each one baring specific production parameters which may vary greatly among different industrial facilities, that pose a key role in the implementation of LM tools.

This thesis is intended to provide guidance and perspectives for researchers who want to delve into the Lean Manufacturing paradigm on process industries to continue their research, or Industrial Supervisors responsible for production, who have decided to adopt LM practices in their facilities and are on the initial steps of implementing the appropriate tools.

This work will be the collection of handful information from high-impact publications which can act as a stepping stone of LM research.

In parallel, a case study regarding a process industry that has implemented LM, with data acquired through a structured questionnaire-based and semi-structured interpersonal interviews, will provide a closer look into the practical implications of moving towards a lean philosophy direction and will allow for an evaluation and verification or opposition of our research hypotheses.

1.3 Delimitations

In this thesis, the research methodology conducted consists firstly of reviewing published peer-reviewed scientific papers in order to gain an insight of the status of LM implementation in process industries and accordingly formulate hypotheses of research. Additionally, an elaboration into these scientific works will be conducted so that all the essential information that a reader/future researcher needs are presented in this text. Criteria for the selection of the research articles are given below:

i. Scientific papers published in international journals and conference proceedings which have a peer-review process will preferably be selected for this thesis.

ii. The present research is conducted on articles that were published from the year 2000 onwards for more up-to-date information.

After this literature review, a case study analysis will be conducted on one process industry facility that will be evaluated as an example of the theoretic framework structured
through the initial parts of the thesis. Only one facility will be examined on the grounds of the thesis due to the following reasons:

i. There is a general lack of will to disclose information of production characteristics, as these can be considered as competitive advantages.

ii. The limited timeframe of the thesis conduction does not allow for extended indexing of process industries that are active in the area of interest.

1.4 Thesis structure

Chapter 1 consists of the brief presentation of the problem in question, together with background information regarding the motive behind the analysis of our thesis.

Chapter 2 is the theoretic core of the thesis. The basic principles and concepts behind the practical implications that will be examined in the chapters to follow are established in this section.

Chapter 3 comprises of the methodology of our analysis, together with comments on the availability of data sources as well as reasons for the selection of the specific pattern of analysis.

Chapter 4 is the results and discussion section of the present thesis. The outcome of the literature review conducted coupled with the case study analysis is demonstrated.

Chapter 5 discusses the observation of our analysis.

Chapter 6 concludes our analysis and provides suggestions for further elaboration on the topic of discussion.
Chapter 2: Theory

2 Theory

This chapter comprises the theoretic framework of the present thesis. The core principles and basic tools of Lean Manufacturing are presented, together with implementation elements in industry, as depicted in various sources of academic literature.

In parallel, the unique characteristics of the Process industry are analyzed with a comparison to the Manufacturing industry traits, while highlighting the motive and necessity of this analysis, before presenting the connection with Lean Manufacturing.

2.1 What is Lean

Lean, also denoted to as Lean Management, Lean Manufacturing (LM), Lean Enterprise, or Lean Production, is a set of principles, tools and techniques that many industrial organizations or companies opt to implement, in order to enhance the efficiency of production and overall customer value while at the same time eliminating waste (Mwacharo, 2013).

Lean is generally used in manufacturing and supply chain management but it is a philosophy that can be applied to an entire industry organization (Mwacharo, 2013).

The primary idea of LM is to supply better quality commodities to more consumers at a lower price. In doing so, it eventually leads society to more prosperity (Melton, 2004). The importance of creating an organized production system based on LM is enormous. The main points of LM are (Melton, 2005; Womack and Jones, 2003):

- Eliminate waste in the production process
- Build quality into the production process
- Reduce costs.
- Create and formulate tools that will add value to the organization’s functional performance.

The introduction of lean thinking in business is composed of five discrete phases that form a continuous process since lean embeds the notion of continuous improvement:

1. Analyzing and documenting the current process and measuring performance.
2. Accurately defining value and the value stream network.
3. Identifying undesirable effects and suggesting changes to eliminate the source of these effects.
4. Applying recommended changes
5. Measure the achieved performance. (Womack and Jones, 2003; Melton, 2005)
   Figure 3 provides a holistic view of the introduction of Lean from thinking to manufacturing.

![Diagram](image)

**Figure 3. A holistic view of Lean adoption (Aulakh and Gill, 2008).**

### 2.1 Origin of Lean

Lean manufacturing is the name under which the Toyota Production System (TPS) became widely known and later on adopted by many companies worldwide (Shimokawa et al., 2009). It is the fruit of the persistent and yearly research and efforts of Toyota Motor Company's chief production engineer Taichi Ohno, under the supervision of the engineer and one of Toyota family owners, Eiji Toyoda, to increase productivity and efficiency of the corporation plant in Nagoya, Japan, in times of severe difficulties for the company. The trigger for these makeovers was a visit and subsequently a set of comparisons to Ford’s Rouge automotive manufacturing facility in Detroit, USA. Ohno set off to bring some of the high-efficiency production characteristics he witnessed in Detroit, hoping to aid Toyota increase productivity and improve its economics; instead, he established a system that proved to be a breakthrough.
Lean—the term selected to describe TPS—was first mentioned by John Krafcik (Krafcik, 1988), in an attempt to highlight the core differences between the dominant model of mass production and the new model demonstrated by Ohno. Lean production required such fewer resources to the extent where a new product could be produced in half the time that would be necessary otherwise in terms of mass production (Womack et al., 1990).

Direct adoption of the processes and operational characteristics of mass production that gave the Rouge factory the lead in productivity was not possible, due to significant differences in market conditions as well as workforce consistency among the two countries. In parallel, the weakened Japanese economy deprived the business of cash liquidity that was necessary for major equipment upgrades. On top of that, during his own visits to Ford’s facility, Ohno realized the extent of waste created as a result of the mass production methods applied in Detroit. These were the main motives behind Ohno’s questioning and analysis of the reasons of lower productivity rates in the Nagoya-based Toyota factory versus the much higher efficiency of the Ford Rouge factory (Womack et al., 1990). In Table 1 a comparison between lean and mass production characteristics is depicted.

<table>
<thead>
<tr>
<th>Trait</th>
<th>Mass Production</th>
<th>Lean Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Origin</td>
<td>Henry Ford</td>
<td>Toyota</td>
</tr>
<tr>
<td>People-design</td>
<td>Narrowly skilled professionals</td>
<td>Teams of multi-skilled workers at all levels in the organization</td>
</tr>
<tr>
<td>People-production</td>
<td>Unskilled or semi-skilled workers</td>
<td>Teams of multi-skilled workers at all levels in the organization</td>
</tr>
<tr>
<td>Equipment</td>
<td>Expensive, single-purpose machines</td>
<td>Manual and automated systems which can produce significant volumes of large product variety.</td>
</tr>
<tr>
<td>Production methods</td>
<td>Make high volumes of standardized products</td>
<td>Make products which customer has ordered.</td>
</tr>
<tr>
<td>Organizational Philosophy</td>
<td>Hierarchical—management take responsibility</td>
<td>Value streams using appropriate levels of empowerment—pushing responsibility further down the organization</td>
</tr>
<tr>
<td>Aim for</td>
<td>Good enough</td>
<td>Perfection</td>
</tr>
</tbody>
</table>
2.2 Lean Manufacturing implementation checkpoints

The implementation of Lean manufacturing—its principles as described by Womack in 1990— as depicted in literature and the case studies on various industries do not seem to follow a specific methodology. Instead each time, the principles are applied according to the experience and the suggestions of the engineer or consultant responsible for bringing LM into a facility (Tsigkas, 2013). This suggests that a different combination of lean tools can be utilized, depending on the various aspects of the value-creating process, in order to turn to a lean approach.

On the grounds of a production process, LM is effectuated as follows:

1. A product or product type is elected as the flow unit to be studied and improved. This flow unit is the value that the customer pays for eventually.
2. The value stream is drawn, presenting in detail all steps entailed in the production process. The performance of each process is calculated as the flow rate of units processed in a specific period of time. The process with the smaller flow rate—nominated as the bottleneck of the entire production process—provides the actual production rate that should be followed. In this way, inventory accumulations are eliminated, as each process handles the number of units that can directly proceed on to the next process.
3. The flow of units is meticulously structured and optimized so that none of the types of waste are present. In the same time, work is done towards normalizing flow to avoid variations in the production; by estimating average demand of the product over an extensive period of time, such as one year, the daily production required to cover this demand is estimated and set as the target quantity.
4. Next, in the process, the pull notion is effectuated: production only occurs according to the actual demand from the customer. Thus, in the early processes of the production operation, no material or part is produced unless required downstream.
5. Finally, a measurement of the performance and efficiency achieved by eliminating waste and coordinating production to skip inventory accumulation and variances in the previous steps gives information and signs for further improvement. This further improvement triggers the cycle to begin again. Constant analysis of the incoming production data, continuous education of all staff to better grasp the lean principles and get involved in the optimization of the production process, consist of the notion of perfection described in lean. (Womack and Jones, 2003; Tsigkas, 2013).
2.2.1 Lean principles

The three major lean thinking concepts are (Womack and Jones, 2003):

- Value identification
- Waste elimination
- Flow (of value to the customer) generation

The critical set point of lean thinking is value. Value is created by the business in the form of a product or service that the customer will buy; thus, it is the customer who defines the product’s value, based on their needs and desires. This value from a producer’s aspect is difficult to be calculated and distinguished due to the fact that the production process is composed of many different steps, some of which have no connection to the final product sold; in fact, according to lean thinking, some of these actually don’t add any sort of value to the product, and they only comprise of waste (Womack and Jones, 2003).

Waste, or Muda as in Japanese, can be encountered in seven different forms: defaults, overproduction, waiting, conveyance, processing, inventory, and motion. Each of these types of waste has its own causes and solutions and when eliminated, provides multiple benefits:

- The defaults that require reworking at the end of the production process are the result of quality issues that should have been resolved long ago, and while they add no further value to the final product, they add up to cost, utilizing labor, time and materials that could be allocated to value- bringing operations.
- Overproduction causes inventory pileup requires additional space for storage and handling, deprives of useful workhours and most importantly hinders problem resolution thus further creating waste.
- Waiting is time wasted while processes such as setup changeovers, equipment breakdown or material delivery delays take place. In a production facility, time is a valuable resource and cannot be spared.
- Conveyance is the excess transportation of materials and people, caused by poor planning of operations or facilities’ layout. Resources should be allocated wherever needed in the minimum time required.
• Processing refers to over processing when operations that take place are not required to meet the customer demands. This is the result of poorly defined quality standards or poor control of quality.

• Inventory, although vital for the smooth operation of a producing facility, absorb material, spatial and human resources when in excess. Additionally, extra inventory covers supply chain quality issues that can be detected and resolved as soon as the abundance of materials is depleted and precisely what is needed is ordered.

• Motion is linked to the core of workers’ behavior; unnecessary actions, work layouts that promote futile movement, lifting of heavy machinery, take up time and effort and render workers counterproductive. (Drew, McCallum and Roggenhoffer, 2004; Melton, 2005; Ohno, 1988)

Flow according to Melton (2005), “is the concept which most obviously contradicts with mass production systems; the comparison of one-piece flow versus batch and queue processes. It is a lack of flow in our manufacturing processes which accounts for the huge warehouses which house the mass of inventory which consumes the working capital of the business.” Flow incorporates the stream of value across the processes of the business. In the context of lean manufacturing, flow must be continuous and steady, without blockages or fluctuations, for example, due to inventory accumulation (Womack and Jones, 2003; Melton, 2005).

There are two structure principles behind LM: the first is the just-in-time manufacturing (JIT) and the second is Jidoka, which can be transcribed as build in quality. JIT is the idea of producing and delivering solely, what is needed at the amount and time needed, employing the minimum resources required. This leads to delivery of higher quality products at a lower cost and in less time. Jidoka is the concept of empowering the workers to continually improve quality of the production process by observing and interfering so that, at the sight of a single defect, the production must be halted- referred to as Poka Yoke in Japanese- until the issue is resolved. These two ideas together effectuate the elimination of waste, Muda (Art of Lean, n.d.; Ohno, 1988).

2.2.2 Lean Tools
A set of lean tools can be implemented to achieve the aims of lean philosophy and can be categorized into three categories: quality, production processes, and methods.

Quality lean tools, such as the following contribute to the improvement of the quality offered to the customer:
• Kaizen is the concept of constant improvement; there is always space for further optimization of a process, and this should be the background thought in every operation of an industry.

• Total Productive Maintenance (TPM) is the aspect of equipment and machinery maintenance, where prevention of defaults with correction and proper use is prevalent during handling.

• Poka- Yoke is the idea of empowering every single worker that takes part in the production process to take immediate action whenever needed in order to prevent defaults in the production. Thus, the worker is transformed from a simple actuator into a major contributor to the production process.

Production process tools such as JIT, aim to make the production procedure more efficient. Among these are the following:

• Cellular manufacturing is the separate production of a specific part or product in one line or area, where all necessary tools and materials are gathered and organized in place so that maximum production efficiency can be achieved.

• Production smoothing or, as referred to in Japanese, Heijunka, is the normalization of daily production. A steady pace in the production process improves overall efficiency and contributes to JIT.

Last, method lean tools assist in optimizing the overall operation of the producing facility. Some of these are the following:

• Work standardization refers to accurately defining each operation of the production process and the circumstances under which these are carried out so that better control of the outcome and a higher rate of efficiency and default detection is achieved.

• Setup reduction time is the concept of interchanging equipment easily, in low timeframes and efficiently so that the production process can achieve better flexibility when a variety of products is produced.

• Line balancing defines the unanimous pace of work around a producing facility so that synchronization is achieved among the different operations (Art of Lean, n.d.; Abdulmalek et al., 2006; Ohno, 1988).

These three categories of lean tools are often interrelated and provide multiple benefits and results to the overall improvement of a production facility and process (Abdulmalek, Rajgopal and Needy, 2006; Melton, 2005). In the following figure the structure of lean, from
lean tools utilized up to the further aims of lean techniques implemented in the process, is depicted in Figure 4.

Figure 4. Key elements of Lean (Abdulmalek, Rajgopal and Needy, 2006)

2.3 Why go Lean

As depicted in literature (Ohno, 1988; Womack and Jones, 2003; Tsigkas, 2013; LMJ, 2014), there are several benefits of using Lean in an organization:

- **Improved quality** – the lean process goes through several activities with problem-solving techniques to strengthen the production process and steadily eliminate defaults, eventually improving quality of the product.

- **Faster delivery times** – By applying the principles of just-in-time and pull, production orders are conducted when needed and therefore delivered faster to the customer. Lead time is reduced.

- **Improved visual management** - LM enhances management by setting up visual control of the process, thus allowing for easy identification of the problem when it occurs in the manufacturing process.
• **Enhancements of worker efficiency** - In LM, employees are trained as a workgroup with full control rights, in the same process every day. Eventually, their efficiency increases through repetition and a better understanding of the operations conducted. "Practice makes perfect" can be applied to this reasoning.

• **Improved efficiency of human resources** - Getting more done by fewer workers. By increasing worker’s skill set and contribution as well as making them more involved in the production process, LM allocates human resources in a better way thus maximizing their performance and leads to fewer workforce requirements.

• **Easier to manage work areas** – The work instructions and standardization of work make it easier for workers to know what they have to do and when. This makes managing a work area much more efficient.

• **Total company involvement** – LM can be implemented not only in one area but also in every sector of a company. By doing so, everyone feels like part of the whole team and strives for the common goal.

• **Problem elimination** - LM employs root cause analysis conducted by a cross-functional team thus investigating a problem until it is fully resolved.

• **Increased space utilization** – Better space utilization is achieved by fine-tuning operations improving floor planning and by reducing inventory thus storage space for parts.

• **Safer work environment** - LM renders the work environment more organized by removing unnecessary elements which lead to a safer workplace.

• **Improved employee morale** - In LM, employees feel that they are members of a team and contribute their share to the organization. This reduces uncertainty in the workplace and strengthens employee morale. Initially, this is not profoundly witnessed, but over time, it becomes more visible once the concept of lean gets accepted by the workforce of the company.

    In Figure 5 a graphical representation of the significant benefits of lean industries is provided.
2.4 Factors that inhibit Lean

Despite the benefits LM can have on an organization, there are issues which hinder successful lean implementation (Melton, 2005). The two primary problems are the perception that there are no tangible benefits from lean adoption and the inherent humane resistance to change. Managers, as well as workers, often defy the effect of the changes introduced in the context of LM and stall or cancel further process modifications.

Figure 6 presents some of the issues that arise from the difference between the lean theory and lean practice, as consequences of the human factor.
Moreover, LM implementation is not a one-off process but rather, it is continuous (Mwacharo, 2013) and should constantly be supported (Drew, McCullum and Roggenhofer, 2004). The firms or organizations need to revise their strategy on a regular basis to sustain the efficiency achieved due to lean adoption; a company must be well prepared before implementing LM and must commit to doing all the hard work needed for a smooth transition into lean thinking. Otherwise LM might prove to be beneficial initially, but in the long run, it will fail miserably (Bicheno and Holweg, 2009). Although one might think that reducing inventory, as instructed by LM, at once is the solution, this is not the right way to implement lean. It should be a gradual process, identifying waste and removing it step-by-step. Therefore, determining the real Muda in all the departments is also a big challenge. Therefore, keeping motivation for a regular assessment of already implemented LM tools is one of the major obstacles to lean adoption.

Implementation of lean not only on manufacturing facilities but also on all the departments of a company such as accounting, human resources, marketing, distribution and
so on (Womack, and Jones, 2003) is also a major challenge. To reap the total benefit of lean philosophy all departments need to modify their operations accordingly otherwise the results could be detrimental, with significant losses (Bicheno and Holweg, 2009).

Figure 7. The factors opposing and driving a change to lean (Melton, 2005)

2.5 Process industry characteristics and prospects of LM implementation

The manufacturing of products can be divided into two main categories (King et al., 2008):

- Products assembled from smaller ready-made parts into individual units, such as computers, automobiles, cell phones, electronics, etc.

- Products that during production undergo specific refining processes such as chemical reactions, blending, baking, etc. and in their final state cannot be separated into their original parts. Examples of such products are foods, chemicals, pharmaceuticals, and materials.

The former is referred to as discrete industry and the second as process industry (Abdulmalek, Rajgopal and Needy, 2006; King et al., 2008). Often, the principal and rather a simplistic comparison between the two types of industries is whether the form of processing is discrete or continuous. A better-refined distinction lies upon the final outcome of the production operation: in discrete manufacturing a large number of different parts is reduced.
towards the end of the manufacturing industry assembly line while on the contrary, the limited raw materials initially provide a wide variety of different products at the end of the process industry production process (King et al., 2008).

A more detailed comparison of the manufacturing-discreet and process industry’s main characteristics is depicted in the following table:

Table 2. Discrete versus Process industry characteristics (Abdulmalek, Rajgopal and Needy, 2006; King et al., 2008)

<table>
<thead>
<tr>
<th>Discrete Industry</th>
<th>Process Industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Items</td>
<td>Materials</td>
</tr>
<tr>
<td>Variable volume</td>
<td>High volume</td>
</tr>
<tr>
<td>Extended variety</td>
<td>Low variety</td>
</tr>
<tr>
<td>Flexible equipment</td>
<td>Dedicated equipment</td>
</tr>
<tr>
<td>Reduced setup times</td>
<td>Lengthy setup times</td>
</tr>
<tr>
<td>Cellular/ product layouts</td>
<td>Fixed layouts</td>
</tr>
<tr>
<td>Parallel machines</td>
<td>Fixed routing</td>
</tr>
</tbody>
</table>

Additionally, a segmentation of the process industry based on the type of product they produce can be conducted into the following categories:

1. Glass, ceramics, stone, and clay: Typical products of this category are lighting products, flat glass, fiber optics glass, glass containers, concrete, gypsum, cement, paving and plaster, abrasives and asbestos.

2. Steel and metal: In this category belong coils, sheets, slabs, bars, stainless steel and structural steel, sheet metal, primary smelt refining as well as nonferrous metals.

3. Chemicals: This sector comprises of many important product categories such as pharmaceuticals, detergents, paints, inorganic and organic chemicals, cosmetics, plastic products and agricultural chemicals.

4. Food and beverages: Regarding a large variety of products such as meat and dairy products, canned food, baked goods, sugar products, oils, alcoholic beverages, and refreshments.

5. Textile: The category includes clothes and clothing, carpeting, towels, cord and twine, automotive upholstery, reinforcing materials, bulletproof vests, decorative braids, and ribbons.

6. Lumber and wood: Products including general logging, wood containers, mobile homes, miscellaneous wood products and panels.
7. Paper and pulp: Including cardboard, newsprint, printer’s paper, packaging material tics, etc. (Abdulmalek, Rajgopal, and Needy, 2006)

Stemming from the above segmentation within the process industry but also from the different definitions that have been attributed as a result of the comparison to the manufacturing- discrete industry, it is evident that a brief base of characterization is not adequate. Instead, classifying and deciding on the type of operations conducted in a process industry is not easy, should not do under a broad scope but instead should take into account specific production operations and characteristics.

An efficient characterization framework that is fruitful for further conclusions should include

a) product characteristics,

b) process characteristics and also,

c) information of the stage at which the product reaches its final discrete state.

These three traits are crucial for evaluating a facility and deciding upon improvements or enhancements in the production process (Abdulmalek, Rajgopal, and Needy, 2006).

The product characteristics of a process industry stem from the raw materials used and the volume of the produce; there can be many, or few raw materials used and likewise, these can be similar or come from a wide variety. For instance, in the meat food industry, meat is the main ingredient which leads to a variety of products while in the baked goods industry, a group of raw materials is necessary for the final outcome. Concerning the volumes produced, there can be small batch produces dedicated to a specific market segment, such as pharmaceuticals or high-volume goods such as beverages. From these examples, it is immediately obvious that vast differences can be found even in industries of the same sector (Abdulmalek, Rajgopal, and Needy, 2006).

The process characteristics concern the flow of raw materials through the production operation processes and are defined by the type, setup and use of the equipment that is employed. While process industries are assumed to have a continuous flow process with automated routines and specific dedicated equipment, in reality, there can be many setup variations where machines may either be of general use and quite flexible or specific and dedicated. For instance, in the pharmaceuticals sector, a general use mixture tank can be dedicated to the production of a specific drug only. On the other hand, in the food sector, a general container can be employed for the production of many different flavors. On the other hand, in the chemicals sector, a reactor tank can be dedicated to a single material process with
specific circumstances applied due to the unique nature of the process (Abdulmalek, Rajgopal, and Needy, 2006).

Finally, the stage at which the materials are reaching a discrete, single unit product form is a key determinant for the characterization of the process industry. The general assumption is that in process industry materials are blended or processed and reach their complete discrete form at the end of the continuous operation process. However, that is not always the case, and the differences among different sectors can be huge; for example, in the textile industry the discrete units are produced at the very first stages of the producing process while in the chemicals industry the products become discrete at the final stage (Abdulmalek, Rajgopal, and Needy, 2006).

2.6 Formulating research Hypotheses

The above analysis and re-classification of process industry and its various sectors allow a reconsideration of LM implementation. The prevalent idea that LM is suitable only for industries of discrete manufacturing, mostly attributed to the fact that lean thinking originally came from one such industry, Toyota Automotive, can be re-evaluated.

In each case, evaluation and assessment of the lean tools that are available needs to be conducted. For instance, in a liquid manufacturing industry, the production line cannot stop as often as in a discrete assembly industry, upon the detection of default or problem in the production process. Another similar aspect is the inventory parts that in manufacturing industries accumulate as a result of the multi-segmented production/assembly operation and are signs of a process default; in the chemical industries, such inventory cannot accumulate because production operations consist of few steps, however, the spare parts that are present to cover for equipment failure, can be a corresponding indicator of a default in the production process (King et al., 2008; Floyd, 2010; Panwar et al., 2015).

Stemming from the process industry classification scheme presented above, the type of product that is produced directly limits or allows the implementation of specific tools of LM. Industries that utilize small quantities of raw materials and produce high volumes of the final products, such as beverage industries, are inherently more efficient and do not require or allow tools such as JIT and standardization to be implemented. However, due to the high dependency on equipment reliability and availability, the lean tools of Kaizen and Total Productive maintenance would be very beneficial (Abdulmalek, Rajgopal and Needy 2006).
**Hypothesis 1 (H1):** Quality lean tools such as Kaizen and Total Productive Maintenance are better-suited for Process industries that require only a few raw materials and produce large volumes of a limited variety of products.

In a similar aspect, while in manufacturing industry the bottlenecks of the production can be dealt with adding more workers around the specific process, in a high-volume process industry a corresponding solution would deal with machinery and equipment efficiency rather than the number of workers (King et al., 2008).

Regarding the process characteristics, the inherent flexibility of the production process allows the application of some lean tools and excludes the use of others. For instance, in the production process of pharmaceuticals that is quite inflexible due to the setup of the equipment, tools such as Total Productive Maintenance that tend for the efficiency of the machinery are handy, but production smoothing or small batches would not be easily applied nor effective. On the contrary, a high variety and flexible industry such as the beverage or the food industry would be benefited from implementing lean tools such as SMED and work standardization (Abdulmalek, Rajgopal and Needy 2006; King et al., 2008).

**Hypothesis 2 (H2):** Process industries utilizing inflexible and dedicated machinery cannot implement **Production process lean tools** such as batching and Production leveling-Heijunka.

**Hypothesis 3 (H3):** Process industries utilizing flexible and non-dedicated machinery can implement **Method lean tools** such as Work Standardization and SMED- single minute exchange die.

Concerning the stage at which the product becomes discrete, it is deducted that process industries are not always continuous and bare some common characteristics with discrete manufacturing industries. For instance, in the textile industry where the fabrics become discrete units quite early in the process, lean tools such as small batches and just-in-time can be very useful (Abdulmalek, Rajgopal and Needy 2006; King et al., 2008).

**Hypothesis 4 (H4):** **Production process lean tools** such as batching and Just-In-Time are better-suited for Process industries where the product becomes discrete at the early stages of the production process.
Lean production techniques can have an enormous impact not only on discrete manufacturing but also on process industries (Dunstan, Lavin and Sanford, 2006.). Panwar et al. (2015) provide a succinct description of the impact LM effectuates on the process industry and how these production operations improve with the adoption of lean principles. In one of the earliest works on Lean implementation in the process industry (Billesbach, 1994), it is vividly shown that there are various benefits lean thinking can offer, apart from waste reduction also increased profits. According to this research “The plant simultaneously achieved 10% improvement in product quality and 300% increase in employees’ suggestions.” (Billesbach, 1994); the case study analyzed in this context was a textile plant, as a typical example of the process industry. In yet another relevant study, the impact of LM is vividly depicted in steel industries (Abdulmalek and Rajgopal, 2007). The authors, in this case, provided an in-depth analysis regarding lean implementation using a simulation approach to show the benefits observed in the steel industry. After applying LM, lead time was reduced at a significant percent- around ~70%- of total production time. In a survey about the influence of LM on food, chemical and textile industries conducted by Koumanakos (2008), it was demonstrated that organizations without lean implementation had lower profits due to maintaining higher inventories. On the contrary, the improvement of financial performance was evidenced when the process industries of that type utilized and implemented LM. Lean manufacturing not only assists in enhancing manufacturing performance through removing different types of wastes in the process industry but it also works as an impetus to compete efficiently in the present days, where quintessential priorities such as product quality, feedback capability and customer satisfaction are prevalent (McLeod 2008; Gabauer, Kickuth, and Friedli 2009).

**Hypothesis 5 (H5):** Process industries can benefit from the implementation of LM tools, either by reducing required resources and/or waste, or by increasing overall performance rates.

It should be highlighted that although the literature mentioned above substantiates the necessity of examining and implementing lean principles in the process industry and while, as research has shown, LM techniques can be more beneficial for process industries than for discrete manufacturing industries (White and Prybutok, 2001), in a relative survey that was
conducted regarding implementation of LM in the industrial world, results showed that only 32% of the process industries examined had adopted LM as opposed to an 80% of discrete manufacturing industries that had already implemented LM (Fullerton, R. R., 2003).

2.7 Summary

This chapter has provided a theoretical framework for this thesis work. In this chapter, an in-depth, comprehensive overview of Lean paradigm is provided to the reader. Origin of lean is discussed along with the process of lean thinking which allowed for elaboration into process industry as far as LM is concerned. Moreover, the importance of LM implementation on process industries and the challenges that arise from this effort have been analyzed. In the end, the research hypotheses that will be evaluated in the following chapters are formulated.
Chapter 3: Methodology

3 Methodology

The present chapter describes the methods and tools used to structure and support the arguments of this thesis problem and test the hypotheses formulated in the theoretic analysis chapter.

At first, a literature review of academic journals is conducted in order to examine the validity of the Hypotheses formulated previously.

Afterward, through interpersonal and a semi-structured questionnaire interviews, data is acquired for a specific company facility as part of a case study, in order to validate the hypotheses and to further support the arguments extracted from the prior journal review. Figure 8 presents the research methodology of this thesis.

3.1 Literature review

The initial part of the present thesis consists of the literature review. The aim of conducting this critical literature review is to provide a clear insight of the issue under examination and present important aspects of the research that has been conducted so far as well as the various trends of contemporary or future research that are of interest to the authors and possibly to the readers. Therefore, at the beginning of this research, an effort was made to gather information from a wide range of academic journal articles but also from well-known books.
3.1.1 Limitations of the period of study

No limitation was set concerning the publishing time period of journals and books selected, regarding the aspects of general and historic information and principles of Lean Manufacturing; the literature sources available date back to the 90’s and contain an elaborate analysis of the routes and results expected from LM, which was considered rather important in order to provide an accurate description of this system. However, considering the proportionally late adoption of LM practices in the fields of process industries but also due to the fast occurring changes in the production processes of the relevant sectors, the query for relevant data was limited to scientific papers published in international journals and conference proceedings after the year 2000, to get the most recent and up-to-date information. As sources of data query and retrieval, the BTH library database (BTH, 2018) was employed, as it gives full access to the journals of interest. Additionally, queries were conducted through the Google Scholar (2018) search engine database for all up-to-date information and cross-references, which were afterward crosschecked with the BTH library database (BTH, 2018) in order to get hold of the complete articles that were only partially retrieved.

3.1.2 Nature of literature review

According to Saunders, Lewis, and Thornhill (2012), the literature review can be either deductive or inductive. In the deductive approach, research is conducted on a theoretical basis and afterward evaluated through data analysis. On the contrary, an inductive approach—reasoning from detailed facts to general principles/rules— is conducted when a set of data is gathered, and the aim is to explain it via a newly proposed theory that will be interrelated to existing literature. For the present thesis, the literature review was conducted as per the deductive approach; the aim is to evaluate the impact of Lean Manufacturing on process industry, first by exploring existing literature and then by testing the validity of the deducted assumptions in an actual case study.

3.1.3 Extent and expectations of literature review analysis

After a thorough query on the latest peer-reviewed academic journal articles referring to and analyzing implementation aspects of LM on process industries, two journals per each of the following process industry sectors were selected for further analysis, following the segmentation and classification provided by Abdulmalek, Rajgopal, and Needy (2006):

1. Glass, ceramics, stone, and clay
2. Steel and metal
3. Chemicals
4. Food and beverages
5. Textile
6. Lumber and wood
7. Paper and pulp

This type of approach for the selection of literature to be analyzed is critical for the comparative examination of the different and unique characteristics that each industrial sector bears as described in section 2.5- Prospects of LM implementation on Process industry”; these characteristics allow for the implementation of different elements and tools of LM, which are considered vital in the context of the present thesis. Additionally, the size of the sample case studies selected to analyze is believed to be statistically representative of each process sector and adequate as a tool to test the formulated hypotheses for the following reasons:
- It provides a wide base of analysis among the different sectors of the process industry.
- It allows the completion of the analysis in the predefined timeframe.
- It consists of a large percent of the total available literature published online with an elaborate analysis of the case studies presented.
- A high impact factor (IF) (Carbone, 2014) for each journal article studied was of importance, to give validity to the findings of the present analysis.

The points of interest in the reviewed articles were:
- The specific operational characteristics of the industries presented in each case study
- The LM tools utilized
- The efforts that were conducted to implement the relevant LM tools
- The expectations of LM implementation in each case
- The effects, both short-term and long-term, that the implementation of LM had in the sectors and operations of interest in each industry, wherever possible with corresponding rates.

3.2 Interview: Interpersonal and questionnaire-based

An interview can be either fully structured, semi-structured or unstructured. In a fully structured interview, the questions to be asked to the person interviewed are standardized and predefined, already from the organization of the examination process. In a semi-structured interview, only a set of topics for discussion have been predetermined; the actual setup of the
questions, the way and order they are presented lies in the attitude of the conductor. Last, an unstructured interview is similar to open dialogue with no limits, apart from the general thematic of the conversation (Robson and McCartan, 2016).

For the execution of the case study analysis, a set of interviews was conducted. According to the types of interviews described above, a preliminary unstructured interview was performed with the Production Engineer of Facility A, on the 16th of February 2018, in order to acquire general data concerning Facility A and details of its mode of operation regarding LM impact.

In the latter stages of the current thesis analysis, a questionnaire which is considered as a structured interview (Robson and McCartan, 2016) was sent out to specific staff members of Facility A of Company B. This questionnaire has helped us to acquire detailed data of the production process and get a broader spectrum of opinions on the practices and effects of LM implementation. We sent this questionnaire to the employees who are the members of the LM implementation team. The questionnaire recipients include the Facility Head Manager, the Production Manager, the Quality Control Manager, the Production & Maintenance Manager, the Logistics & Purchasing Supervisor and one of the Bottling operators.

The questionnaire that was sent out was divided into two sectors, company characteristics/general overview and LM implementation- impact. The questions were selected meticulously so that they would give a broad view of the issues under the research scope: identify the facility under analysis, understand the unique characteristics that define the production process, show which LM tools are of importance and finally point out the outcome of the LM implementation.

Additionally, it should be noted that this questionnaire is addressed to facilities that already implement or have implemented LM practices; the target of this data query is to understand which LM practices better suit a facility according to its needs and goals and which is the outcome of this implementation. Thus, questions regarding the steps of implementation or the possible problems that arose during this process are not included in the questionnaire.

Regarding the format of the information retrieved, the questions require answers on a scale from one to five, defining in this way the magnitude of the size/ effect under question. This kind of data can be efficiently collected, analyzed and presented for statistical analysis. However, a free commenting section has also been included so that the interviewees have been able to give personal insight based on their experience of LM. These free commenting
answers are not intended to be compared or statistically analyzed but allow for a better understanding of each worker’s idea of LM as witnessed on a daily basis, through different work positions and perspectives.

Some of the questions presented to the interviewees were:
- What is the type of products produced?
- What is the volume of the raw materials required?
- What is the volume of the final products produced?
- What is the flexibility of the equipment utilized in the process?
- When did the implementation of LM tools begun in the organization?
- Which LM tools are on the scope of the implementation?
- What has been the impact of the implementation of LM tools in the production process?

This questionnaire can be utilized as a guide to analyze any case study of a process industry’s production process characteristics and LM practices implementation and thus allow the testing of the research hypotheses formulated in the context of the present thesis.

3.3 Case study Analysis

The case study analysis was planned and carried out in order to support the findings from the theoretic review with real-world data. As Yin describes (2013), a case study is a tool used to answer a question: what, why, how? In the context of this thesis, a case study is utilized to answer the question what: “What is the impact Lean Manufacturing has on process industries?”.

The industrial facility selected for the conduction of the case study analysis will be named Facility A of Company B for reasons of confidentiality. The reason for the non-disclosure of the facility’s and company’s full data is the nature of the data enquired: the production techniques can often be regarded as a competitive advantage against the competition. Moreover, the exact identity of the facility will not add more knowledge to the issue under discussion. Thus in order to avoid a confidentiality agreement between Company B and BTH as well as for the rapid conduction of this research and free discussion on the case study outcome, the identity data will be kept generic.

Facility A is an alcoholic beverage bottling unit located in the industrial area of Volos, Greece. It is a medium-sized facility, employing 20-50 workers in total. There are two types of alcoholic beverages that are bottled in seven sizes of glass bottles, 0.05lt, 0.2lt, 0.35lt, 0.75lt, 1lt, 2lt, and 5lt. The production process consists of six different production stages:
- The alcoholic fermentation/ preparation of the alcoholic beverages takes place in a set of specialized tanks suitable for the chemical procedure.
- The prepared alcoholic beverages are transferred into common but dedicated storage tanks, due to the highly aromatic character of one of the two beverages, so common usage of the storage tanks would lead to extended and costly cleaning requirements.
- The beverages are transported through a network of pipelines to the bottling line, filling the bottles via automatic filler. The empty bottles are manually supplied to the bottling utility.
- The bottles are labeled passing by an automatic labeling machine. The labels are manually supplied to the labeling utility.
- The bottles are placed into boxes of various capacities according to the client specifications. The boxes are manually supplied to the boxing utility.
- The boxes are set upon a pallet via an automatic palletizing unit. The pallets are manually supplied to the palletizing utility (Production Engineer of Facility A, personal communication, 16th February 2018).

Facility A poses certain characteristics of interest that reflect the literature review findings of the previous chapters, as mentioned in paragraph “2.5 Process industry characteristics and prospects of LM implementation”:

- As regards the product characteristics, there are only two beverages that are produced in very large volumes, based on relatively high volumes of a limited variety of raw materials.
- As regards the process characteristics, this is a simple but inflexible process; there are only seven discrete production stages that involve the utilization of some unique equipment—the alcoholic distillation/ fermentation tanks—, some common but dedicated machinery—the ready mixture storage tanks— and general industrial machinery—the labeling and palletizing utilities. There cannot be any reconfiguration among these discrete production stages; the order of flow is specific.
- As regards the stage at which the product reaches its final discrete state, this takes place in stage 3, in the middle of the production operation, when the alcoholic mixture is filled into bottles.

The specific facility was selected because, according to the authors’ knowledge, it has implemented principles of LM in the past years and at the time that the present thesis analysis is conducted the implementation has yielded results and is continuously supported by
company B, both for facility A as well as for other facilities located in other countries (Production Engineer of Facility A, personal communication, 16th February 2018). By analyzing the facility’s characteristics as mentioned above and information regarding LM implementation as deducted from the interviews—both interpersonal and questionnaire-based—there will be fruitful conclusions bridging the case study analysis with the implications of the literature review conducted in the first part of the thesis.

3.4 Summary

This chapter provides a comprehensive description of the research methodology is used in this thesis. A pictorial framework is shown to help the reader to understand the methodology. Two components of the methodology are discussed in this chapter. Those are a literature review, case study analysis which includes different types of interview (interpersonal and questionnaire-based).
Chapter 4: Results

4 Results

Two databases have been employed as a source of information for the present thesis. These are the BTH library (BTH, 2018) and Google Scholar (Google Scholar, 2018). Google Scholar is a freely accessible web search engine of scholarly literature for various disciplines. Among the various online search engine databases available for scholarly literature (i.e., Web of Science and Scopus), Google scholar was chosen due to its efficacy and ever-increasing improvement through its advanced algorithm to find the most relevant papers in the subject under the research scope (Aalst, 2010; Jamali and Nabavi, 2015). Furthermore, the BTH library database allowed full access to some of the papers which are not open-accessed in Google scholar.

Figure 9 presents the year-wise distribution of scientific paper works of process industries regarding lean implementation which was studied for the conduction of this thesis. It has been already mentioned that information was obtained from the research works dating from 2000 onwards. As demonstrated by Panwar et al. (2015, Fig. 3), only a limited number of research papers has been published in the pre-2000 period, as part of scientific works in different types of publications (Journal, conferences, etc). Additionally, the interest and enthusiasm of researchers and practitioners for the possibilities of LM implementation in the process industry have been gradually increasing since 2000.

![Figure 9. Distribution of year-wise from 2000 onwards](image-url)
Figure 10 shows the number of case studies for different types of process industries investigated in this thesis.

![Chart showing the distribution of literature regarding the type of process industry]

**Figure 10. Distribution of literature regarding the type of process industry**

### 4.1 Literature case study analysis

#### 4.1.1 Glass and Ceramics

In the work conducted by Bonavia and Marin (2006), regarding the ceramics industry in Spain, a number of 76 facilities was studied for the type of LM tools and the extent that these were utilized. The facilities examined, as described in this work, require a small number of raw materials and produce a range of 100-200 different patterns of products, which require the same manufacturing facilities. The products are homogenous and are produced in a similar way, becoming discrete from the early stages of the production process, after the molding phase. The machinery is placed in line one after the other and setup changeover times take up a lot of time. Thus there is little flexibility. The workers only perform specific tasks on which they are highly specialized. The general notion of production is stock oriented. Some special constraints that are outlined are the necessity to keep the fire ovens at maximum capacity around the clock and the high degree of automation in the production line.

The results of the analysis conducted show that standardization of operations and Total Productive Maintenance were the tools utilized by all the facilities of the research. Interestingly, Single Minute Exchange Die (SMED) was not implemented by all the examined facilities which would be expected due to the expensive and heavy machinery
utilized for the production process. Results were not unanimous regarding the performance increase relating to LM.

The next case study we investigated was conducted by (Patel and Thakkar, 2014) for Indian ceramic process industry which produces bricks. The lean manufacturing tool 5S (Gapp, Fisher and Kobayashi, 2008)—Seiri (Sort), Seiton (Straighten, Set), Seiso (Shine, Sweep), Seiketsu (Standardize), Shitsuke (Sustain)—was applied in this work to figure out the problems of a ceramic industry in India and checked how 5S helps to eliminate unnecessary waste and thereby increase the efficiency of the company. This case study dealt with “reducing the process wastes, the process flows smoothness, preserving proper quality control, enhancing storage facilities, safety, security, and savings of process cost.” Visual management techniques in the form of ‘before lean’ and ‘after were also used to understand the impact of lean tools. The company applied the lean technique to mainly two departments; those are storage department and insulator department. After applying the 5S lean tool, the storage department showed improvement in the space utilization was 12.91% (Patel and Thakkar, 2014) along with the reduction of other process wastes such as the movement of the employee. The workplace of the insulator department became more effective than ‘before lean’ states. Moreover, this case study also provided a notion that 5S techniques should be checked periodically for the long-term benefits to the company.

4.1.2 Steel and metal
In their research of lean manufacturing implementation in process industries, Abdulmalek, Rajgopal and Needy (2006) described a case study of a steel mill industry. The production process utilized only 3 ingredients in medium quantities, producing coils of steel sheet also in medium quantities compared to other process industries. The production is split into two sectors, the hot and cold ends; in the hot end, the machinery is dedicated, specialized and inflexible whereas in the cold end there is the use of general purpose, non-dedicated equipment. The product becomes discrete after the hot end, so in the middle stages of the production process. According to this profile, as stated, the facility could employ Total Productive Maintenance, production smoothing and SMED.

There is another case study done by Abdulmalek and Rajgoapal (2007). In this case study, they have investigated value stream mapping (VSM) lean tool which is different than their previous case study (Abdulmalek, Rajgopal, and Needy, 2006). VSM is used to check the applicability and finding new opportunities to implement different lean methods. In this work VSM mainly used for to measure different types of benefits for the administration such
as reduced production lead-time and lower work-in-process inventory. This case study has concluded with the outcome of diverse lean tools applicability which is given in the following in Table 3.

Table 3. Applicability of lean tools in the steel industry (Abdulmalek and Razgopal, 2007)

<table>
<thead>
<tr>
<th>Name of tools</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cellular manufacturing</td>
<td>Negative</td>
</tr>
<tr>
<td>Setup reduction</td>
<td>Inconclusive</td>
</tr>
<tr>
<td>5S (Sort, Set, Shine, Standardize, sustain)</td>
<td>Positive</td>
</tr>
<tr>
<td>VSM (Value stream mapping)</td>
<td>Positive</td>
</tr>
<tr>
<td>JIT (just-in-time)</td>
<td>Inconclusive</td>
</tr>
<tr>
<td>Production leveling</td>
<td>Inconclusive</td>
</tr>
<tr>
<td>TPM</td>
<td>Inconclusive</td>
</tr>
<tr>
<td>Visual systems</td>
<td>Positive</td>
</tr>
</tbody>
</table>

4.1.1 Chemicals

Chowdary and George, in their work (2012) present a lean manufacturing implementation study in a pharmaceuticals company. The facility under focus produces a wide range, both of pharmaceuticals and non-pharmaceutical products and utilizes an equally large variety of raw materials. With a workforce of only 12 people and spreading in an area of 10,000 square feet, this seems to be a relatively small facility. As part of the case study, the various problems of the facility outlined to provide a better understanding of the lean solutions suggested: the space utilized is a vast fixed operating cost that the company undergoes, and the second problem is the inability to deliver the orders on time.

The LM tools introduced to improve the operating conditions of one of the facility’s production lines were 5S, work cell and the introduction of Prior Inspection, after some specific tasks such as the labeling. Among the benefits from the LM tools implementation were a reduction in work in progress material as well as the space that formerly was utilized for such matters, a decrease in the needed workforce and also in the Non-value-added time.

In (Nenni, Giustiniano and Pirolo, 2018), the authors have presented a case study of a medium MNC pharmaceutical company that implemented lean tools in their manufacturing process changing from effectiveness to efficiency, i.e., focused on efficiency improvement. The reason for shifting their attention from effectiveness to efficiency is an attempt for improving production manufacturing management by re-engineering production flows. in other words, unlike other pharmaceutical company which focuses on effectiveness by using
TPM and TQM, this company targeting the objective of a low inventory before trying to build a stable process. The products of this company are pills, tablets, capsules, etc. around 4000 employees have worked there. The annual production is roughly about up to 200 million packages of medicines which has gone to both European and Global market. By applying the aforementioned lean tool, this case study has revealed the steady improvement of efficiency metrics (key performance indicator (KPI)), Works in Process (WiP), Cycle Time, etc.

4.1.2 Food and beverages

In a research conducted by Dora et al. (2014), a total of 35 European food companies was studied for the extent of LM implementation. The type of products differed among the examination sample enterprises, consisting of meat, chocolate, confectionary and other food productions so that the raw materials would vary from a few to an average variety. The products also were of diverse variety in each company, consisting of a range between 45 to 370. All of the companies examined were SMEs, so the volume of the products delivered was small and distributed to the European Union. Additionally, since all of the mentioned types of products require excessive processing, a product’s discrete form is achieved at the latest stages of the production process.

The statistical analysis of the results showed that the degree of implementation of LM was non-unanimous among the sample companies. The most commonly employed tools were relating to customers, suppliers and Total Productive Maintenance.

The measured benefits from the implementation of lean practices involved scrap rate reduction, cycle and delivery time reduction as well as profitability increase, improved delivered quality, employees complain reduction and improved sales.

Tanco et al., (2013) have provided a case study of a seasonal food process industry of an SME. The company they studied for their investigation has produced nougat bar. The company tried to implement a few lean tools to find the change of the production system whether it is worth or not to continue. They mainly used VSM and overall equipment effectiveness (OEE) as a lean tool for their production. According to (Tanco, et al., 2013), this case study is used to have the findings "Whether the path to improvement is marked by increased spending on systems and machinery, human capital, or both, engineers and managers in the frontlines of food production recognize that improvement is a quest and not a destination." The authors in (Tanco, et al., 2013) have figured out that conventional lean
tools were applicable in the process food industry although the outcome of the improvement remained inconclusive.

4.1.3 Textile
In the work published by Hodge, et al. (2011), a case study-based research was conducted on the implementation of lean practices by the textile industry. In total, 11 USA-based textile producing facilities, varying from small to large in regards to production capacity, were studied precisely for the LM practices employed and the outcome that these effectuated; almost all of these facilities perform the same tasks of cutting, sewing, and weaving and produce a variety of finished products for a wide list of clients. The production process involves specific machinery that is not flexible, and the products reach a discrete state at the latter stages of the production process. The analysis’ results show that all facilities employed visual control, 5S as one of the first tools of interest and Value Stream Mapping. The benefits that the interviewed responsible witnesses as a result of lean were a reduction of raw materials utilized, a decreased inventory reaching as much as 50% in one of the facilities, reduced changeover times, increased production rates, increased quality outcomes and reduction in the production time.

Saleeshya and Raghuram (2012) have presented an insightful case study of the lean implementation of Indian textile industry. This case study is carried out in a South Indian textile industry. The authors emphasized that the findings of this case study probably apply to most of the Indian textile industry which produce ready-made garments (RMG). It is not easy to implement lean techniques in discrete process industries; textile industries are no exception. These industries are full of automatic machinery, with high inflexibility highly inflexible and have high volume/low variety products. This case study has provided 'before' and 'after' comparison of lean implementation with numerical data and while demonstrating benefits of lean tool applicability with a few radar plots. 5S, VSM, Kanban, Kaizen, poka-yoke, and visual controls are the lean tools which used in the mentioned south Indian textile industry. A results summary of the implemented lean techniques of this study is provided in Table 4.
Table 4. The gist of lean implementation results (Saleeshya and Raghuram, 2012)

<table>
<thead>
<tr>
<th>Division</th>
<th>Implemented lean tools</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winding</td>
<td>Machine knotting</td>
<td>Regular and proper knotting diameter thus reducing warp and weft breaks.</td>
</tr>
<tr>
<td>Warping</td>
<td>Creel reordering</td>
<td>Reduced confusion while drawing thus saving 30 min in drawing process time.</td>
</tr>
<tr>
<td>Warping</td>
<td>Smooth handling of cones</td>
<td>Reduced the damages to cones and thus reducing the warp breaks.</td>
</tr>
<tr>
<td>Warping and sizing</td>
<td>5S layout</td>
<td>Organised work environment. And tools are available.</td>
</tr>
<tr>
<td>Sizing</td>
<td>Pressurized rollers</td>
<td>Proper sized diameter thus reducing warp breaks.</td>
</tr>
<tr>
<td>Weaving</td>
<td>Humidity control</td>
<td>Reduced warp and weft breaks.</td>
</tr>
<tr>
<td>Weaving</td>
<td>Worker compliments</td>
<td>Motivated worker thus reduced attending times</td>
</tr>
<tr>
<td>Overall</td>
<td>Reduced warp and weft breaks through various process</td>
<td>Increased the efficiency of weaving machines.</td>
</tr>
</tbody>
</table>

4.1.4 Lumber and wood

Pinto (2015) conducted his research in a small Portuguese company, producing only two products, beams and pallets, and facing problems of demand reduction and energy cost increase. There are only a few raw materials, the major being wood and required in large volumes, and the production process consists of numerous stages that utilize machinery rather inflexibly. The products become discrete at the final stages of the production process.

To improve the production conditions and overcome the specific problems that were targeted, work organization and 5S were employed after an extended Value-stream-mapping analysis. The outcome of the lean tools utilized was a decrease in lead time, in the intermediary stock, in the transportation of materials around the workstation and in the overall waiting time. Additionally, there was an increase in the efficiency index.

A case study based on secondary wood industry (furniture) is discussed in (Velarde, et al., 2011). This case study provided an in-depth online-based survey analysis which demonstrated positive outcome for the lean implementation. They showed a relation between the benefits and the barriers of lean implementation. Their results showed that more than 40% of the company benefitted by implementing lean while only less than 10% company found
very challenging and negative using lean in this secondary wood industry. According to (Velarde, et al., 2011), “The opportunity shown by the South Atlantic Region indicates a possible increase in their competitiveness levels that could reverse the tendency to move operations offshore or in the short term reduce the current trend. Lean manufacturing seems to be a good alternative for all the companies facing tough market conditions.”

4.1.5 Paper and pulp

In the work published by Moura (2015) an LM implementation study was carried out for a tissue paper factory which needed the advantage to get ahead of the competition. The objectives of the study were the reduction of waste and the improvement of productivity. The study was focused on the tissue paper manufacturing process of one of the paper mills in the second plant of the company. For this specific product the raw materials are few in variety but large in quantity, as is the final product; the company under examination is one of the leading producers of paper products in Portugal but also has a wide exporting activity, with a presence in more than 60 countries. The production process consists of various steps that require specific machinery for the preparation of the paper pulp and later the processing of the tissue paper produced; this is an inflexible process. Additionally, the product reaches a discrete form in the latter stages of the production process. The extensive analysis conducted in this paper suggested that the SMED practice was of vital importance for this production line, yielding very positive results, such as an increase in the productive time of 1.5 hours which is translated in annual revenues of almost 150,000€.

The case study in (Lehtonen and Holmström, 1998) is the outcome of a national research project of the Nordic paper industry, namely, fine paper, newsprint and calendared paper. The authors produce a case study of four paper mills and simulate the performance change after implementing one of the lean tools (JIT). The work has attempted to find the answer to the following question. “Is just-in-time (JIT) applicable in the paper industry logistics?” The scenario simulation methodology means that the existing logistics operations of a case paper mill are first modeled as a benchmark point, and then all the changes by implementing JIT termed as lean scenario model. The change can then be assessed as the difference between the base case and lean-implemented scenario model results. In this study, JIT is used in logistics and production phase. This study shows that decreasing the paper machine cycle length which eventually increases delivery frequency by utilizing JIT have made a significant impact on supply chain performance. The performance improvement graph in this work answer the questions of applicability of JIT in the paper industry.
4.2 Observations from the case study analyses

The above analysis provides fruitful data for the testing of the Hypotheses formulated in paragraph 2.6. In Table 5, a summary of the observations from the case studies analyzed is presented in tabular form, allowing for a comparative synthesis which will be employed afterward to test these research hypotheses. The characteristics of each production process as well as the outcome of implementing Lean practices (positive/negative/inconclusive) are presented.
Table 5. Summary table of Process Industry profiles analyzed and LM tools implemented

<table>
<thead>
<tr>
<th>Industry Sector</th>
<th>Industry Subsector</th>
<th>Production characteristics</th>
<th>Type of process</th>
<th>Stage of discrete product</th>
<th>Types of Lean tools/techniques used</th>
<th>Outcome (Positive / Negative / Inconclusive)</th>
<th>Case study Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel and metal</td>
<td>Steel sheet</td>
<td>Small</td>
<td>Inflexible</td>
<td>Middle</td>
<td>TPM, SMED</td>
<td>Positive</td>
<td>(Abdulmalek, Rajgopal, and Needy, 2006)</td>
</tr>
<tr>
<td>Steel &amp; metal</td>
<td>Steel sheet</td>
<td>Medium</td>
<td>Inflexible</td>
<td>Middle</td>
<td>VSM, 5S, Visual Control</td>
<td>Positive</td>
<td>(Abdulmalek and Rajgopal, 2007)</td>
</tr>
<tr>
<td>Food &amp; Beverages</td>
<td>Various foods</td>
<td>Medium-Large, Large</td>
<td>Inflexible</td>
<td>Later</td>
<td>TPM</td>
<td>Inconclusive</td>
<td>(Andersson, et al., 2009)</td>
</tr>
<tr>
<td>Ceramics</td>
<td>Tiles</td>
<td>Small</td>
<td>Inflexible</td>
<td>Early</td>
<td>Standardization, TPM</td>
<td>Inconclusive</td>
<td>(Bonavia and Marin, 2006)</td>
</tr>
<tr>
<td>Chemicals</td>
<td>Pharmaceuticals</td>
<td>Large</td>
<td>Inflexible</td>
<td>Middle</td>
<td>5S, Work Cells, Prior Inspection</td>
<td>Positive</td>
<td>(Chowdhury and George, 2012)</td>
</tr>
<tr>
<td>Textiles</td>
<td>Various</td>
<td>Small</td>
<td>Inflexible</td>
<td>Later</td>
<td>Visual Control, VSM, 5S</td>
<td>Positive</td>
<td>(Hodge, et al., 2011)</td>
</tr>
<tr>
<td>Industry</td>
<td>Products</td>
<td>Size</td>
<td>Flexibility</td>
<td>Time</td>
<td>Methods</td>
<td>Impact</td>
<td>Reference</td>
</tr>
<tr>
<td>----------------</td>
<td>----------------</td>
<td>--------</td>
<td>-------------</td>
<td>-------</td>
<td>-------------------------------------------------------------------------</td>
<td>-----------------</td>
<td>---------------------------------------</td>
</tr>
<tr>
<td>Ceramics</td>
<td>Tiles</td>
<td>Small</td>
<td>Inflexible</td>
<td>Early</td>
<td>JIT, TQM, TPM</td>
<td>Positive</td>
<td>(Marin-Garcia and Bonavia, 2015)</td>
</tr>
<tr>
<td>Paper and Pulp</td>
<td>Tissue paper</td>
<td>Small</td>
<td>Inflexible</td>
<td>Later</td>
<td>SMED</td>
<td>Positive</td>
<td>(Moura, 2015)</td>
</tr>
<tr>
<td>Chemicals</td>
<td>Pharmaceuticals</td>
<td>Large</td>
<td>Inflexible</td>
<td>Later</td>
<td>The reengineered production process, Pull system/Kanban</td>
<td>Positive</td>
<td>(Nenni, Giustiniano, and Pirolo, 2018)</td>
</tr>
<tr>
<td>Ceramics</td>
<td>Bricks</td>
<td>Medium</td>
<td>Flexible</td>
<td>Later</td>
<td>5S</td>
<td>Positive</td>
<td>(Patel and Thakkar, 2014)</td>
</tr>
<tr>
<td>Lumber &amp; Wood</td>
<td>Beams</td>
<td>Small</td>
<td>Inflexible</td>
<td>Later</td>
<td>5S Standardization</td>
<td>Positive</td>
<td>(Pinto, 2015)</td>
</tr>
<tr>
<td>Lumber &amp; Wood</td>
<td>Pallettes</td>
<td>Large</td>
<td>Inflexible</td>
<td>Later</td>
<td>5S, VSM, Kanban, Kaizen, poka-yoke, and visual controls</td>
<td>Positive</td>
<td>(Saleeshya and Raghuram, 2012)</td>
</tr>
<tr>
<td>Textiles</td>
<td>Clothing</td>
<td>Large</td>
<td>Inflexible</td>
<td>Later</td>
<td>5S, VSM, Kanban, Kaizen, poka-yoke, and visual controls</td>
<td>Positive</td>
<td>(Saleeshya and Raghuram, 2012)</td>
</tr>
<tr>
<td>Food</td>
<td>Pastry</td>
<td>Large</td>
<td>Flexible</td>
<td>Later</td>
<td>OEE, VSM</td>
<td>Inconclusive</td>
<td>(Tanco, et al., 2013)</td>
</tr>
<tr>
<td>Lumber &amp; Wood</td>
<td>Furniture</td>
<td>Small</td>
<td>Inflexible</td>
<td>Later</td>
<td>5S, JIT, SMED, Kanban</td>
<td>Positive</td>
<td>(Velarde, et al., 2011)</td>
</tr>
</tbody>
</table>
4.3 Case study analysis based on a questionnaire

Regarding the case study of Facility A of Company B, questionnaires that were sent out were completed by the Production Manager, the Quality Control Manager, the Production and Maintenance Manager, the Logistics & Purchasing Supervisor and one of the Bottling operators. In total, five out of six questionnaires that were sent out were completed. All of the before mentioned were actively involved in the implementation of LM in the production and maintenance process, but in different parts of Facility A, so their opinions would yield a more spherical approach on the issue under examination.

The Facility’s profile as depicted in the answers shows that this is a Food and Beverages industry, employing less than 50 workers, the major product type is spirits and the major product unit is the 700ml bottle. The raw materials utilized are 6-20, relatively few compared to other industries, the volume of raw materials is superior to 1000 tonnes per year, which is a large quantity, the number of products, referring to the different sizes of the bottles are among 20-50 which is a medium variety and the volume of products produced is superior to 1000 tonnes per year which again is a very large quantity. The parts of machinery utilized, as shown in the questionnaires are both common and dedicated, noted as easily transferable and of medium cost. Last, the product becomes discrete at the later stages of the production process.

The implementation of LM practices began in 2009, with expectations of improving processes, in detail, identification & exclusion of non-added value steps, the rationalization and simplification of the existing processes, the reduction of wastes, the increase of production rates and the standardization of processes. All staff members agreed that these expectations have been met to a great extent, explaining that there is a continuous improvement methodology going on, regarding several different aspects such as production cost decrease, improvement of processes, optimization of energy consumption, area & space lean utilization. In addition, it is the overall impression that the organization supports the implementation of LM actively, through continuous training via seminars and projects addressed to all staff members.

Regarding the LM tools concerning process and equipment employed, the answers included zero defects, scrap reduction, Single minute die exchange, Andons, quick changeover techniques and Total Productive Maintenance as practices utilized and implemented to a great extent. Concerning the manufacturing planning and control LM tools, the answers states Kaizen- continuous improvement, total quality management, workplace
organization, supply chain management, all in great extent and to a lesser extent, Value stream mapping, production stop policy and Takt time.

Commenting on the outcome of the before mentioned practices, the replies suggest an increase in productivity, a decrease in manufacturing cost, an increase in profits, a reduction of total cost of production and an increase in return on investments. Concerning the effect on equipment and processes, the replies stated a decrease in delivery time, an increase in flexibility in the production, a better utilization of resources, a decrease in the inventory, decrease in changeover times and the defect rate as well as in waste from scrap and rework and last, a decrease in equipment failure rate and equipment idle time due to malfunction. In the effects on the behavior of the labor force of the facility, the answers stated an increase in the employee involvement in the production process and an increase in customer satisfaction and customer return rates.

It is worth noting that in the free commenting section, the Bottling operator said that “work seems to be easier even though the paperwork has been increased”, the Production Planning Manager stated that “The implementation specifically in the bottling department has been boosting the efficiency of the line and the morale – mood of the operators. The Continuous improvement notion from the operators is the feedback for our side that the implementation has been successful”, the Logistics & Purchasing Supervisor said that “The implementation of lean manufacturing has organized our work in the warehouse, helped us to have a better flow of the raw materials and inventory. Overall the feedback is very positive” and last, the Production & Maintenance Manager stated that “One of the most important things in the successful implementation of Lean Manufacturing methodology is stakeholders’ involvement and continuous attention. Sometimes this requires extra support and training (and constant repetition of goals already achieved) of personnel in order to extrapolate the correct mentality. So, good leadership skills, ability to listen and honest feedback are key tools for target achievement”.

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Chapter 5: Discussion

5 Discussion

In this chapter, the findings from the literature-based case studies analyzed as well as the questionnaire-based case study conducted, are discussed and connected to the theoretical framework set out in the first chapters. The information assembled from the published journals give a good overview of the various characteristics observed between different sectors or even different segments belonging to the same sector of Process Industries.

Next, structured on these characteristics, a path towards LM implementation is observed in each case, allowing for the testing of the formulated hypotheses. Last, the findings from a case study of Facility A, structure and enhance this theory-stemming hypotheses.

From the results obtained from the scholarly published literature case study analysis, it is deduced that one of the main reasons for LM implementation on Process industries is to improve not only productivity but also enhance the overall production process. The comparison between the data retrieved from the literature case study analyses and observations from Facility A show the existence of a correlation; correlation in this context is the reliability of the information provided by the respondents of the questionnaire. Additionally, it can be deduced that the answers received from the questionnaires are reliable due to the anonymity of the respondents and the non-disclosure of the company’s profile; after all, knowing that the company name will not be disclosed is believed to have prompted and inspired the respondents to provide more reliable and honest responses.

The literature-based case study analyses are in line with the theoretic findings that suggest that (Panwar et al., 2015) “the inflexibility of equipment, compulsion to utilize full capacity for cost effectiveness, quality dependency on time, temperature, high variations in demand, strict environmental considerations and other such typical process characteristics could cause for successful implementation of lean in process industries”.

5.1 Sector and subsector endogenous differences

As discussed in chapter 2.6, the characteristics that describe the production process of a facility can differ greatly among different process industries; however, these characteristics define key points and provide the actual margin needed in the various options of LM implementation. Towards the investigation of this scheme, the first four columns of Table 5.
depict the said variance, even in facilities that produce similar products. As expected, the variety and volume of raw materials differ from small to large, as do the corresponding final product attributes. For instance, the Steel and Metal industry case studies examined (Abdulmalek, Rajgopal, and Needy, 2006; Abdulmalek and Rajgopal, 2007) show a small variety of raw materials and products- both require less than 5 raw materials and produce sheets of steel for further uses- required and produced in medium quantities respectively. On the contrary, the two Chemicals case studies analyzed (Chowdhury and George, 2012; Nenni, Giustiniano and Pirolo, 2018), as expected, required a large variety in medium amounts of raw materials for the production of an extended variety of products in medium quantity. Moreover, as expected in certain cases, such as among the two Food process industries examined (Andersson, et al., 2009; Tanco, et al., 2013), the variety and volume of raw materials required was smaller in the latter case, due to the specificity of the product type- pastries- while the volume of the final product was larger compared to the former case study, due to the size of the producing facility and its penetration to the market.

Regarding the production process characterization, in terms of flexibility and uniqueness or dedication of the equipment and machinery utilized, again there was a range of flexible and inflexible processes. The majority of the case studies showed inflexible processes, due to the fact that most production sequences consisted of an initial formulating stage such as baking, mixing, bathing and other forms of specific processing followed in most cases by subsequent, further stages of purifying or formulating.

Last, the third parameter of the model explained in paragraph 2.6 of the theoretic framework, the stage at which the final product becomes discrete, as expected was varied from early to later stages of the production process, among the different case studies. For example, in the Ceramics case studies (Bonavia and Marin, 2006; Patel and Thakkar, 2014) a discrete form was identified from the earlier stages whereas in the Food process industries examined (Andersson, et al., 2009; Tanco, et al., 2013) the product reached a discrete stage in the later stages of the production.

From all these endogenous differences observed in each sector, the necessity to take into account the characteristics in each case specifically before moving on to further discussion and suggestion of the suitable practices for LM implementation is obvious and prevalent.
5.2 LM practices adopted

Moving on to the actual LM practices in each case study analyzed in Paragraph 4.1, it should first be noted that in the majority of these cases the initial target was the reduction of waste and increase in productivity. Interestingly and according to the theoretical framework laid in paragraphs 2.5 and 2.6, not the same tools were utilized in each case as a consequence of the differences observed in each production process, as explained above.

The most often utilized LM practices were TPM and 5S, regardless of the type of process industry subsector or product produced. The implementation of TPM seems logical as most process industries are capital intensive, utilizing heavy and expensive machinery that requires meticulous and methodical maintenance; naturally, in the context of LM, the input of TPM to make sure proper handling and default prevention is a target for all workers that are involved in the relevant stages of the production process is a must. Moreover, the employment of 5S as a means to enhance performance and boost quality in all stages of the production, again, due to the multistage nature of the process industry seems to be a basic tool.

Other tools that were utilized by some of the facilities described in the analyzed case studies were SMED, Visual Control, Standardization, JIT, Kanban and VSM. On the contrary, Lean practices such as stopping the line, Cellular manufacturing and Focused factory either required extensive customization in order to be implemented in the production process or were unsuitable for the described process industries; this observation is in accordance with the relevant theory findings (Panwar, et al., 2015).

5.3 LM implementation outcome

The seventh column in Table 5 and probably the most important aspect on the grounds of this thesis, depicts the effect that the implementation of the above mentioned LM practices had on the Process Industries described in the case studies analyzed. In the majority of the cases, a positive outcome was observed, most often witnessed as a reduction in waste- Muda, an increase in productivity or an overall boost in performance. It is to be noted that in some cases the results were inconclusive, such as in the Food Process Industry described in the work by Andersson et al. (2009) or in the Ceramics case study conducted by Bonavia and Marin (2015).

This is a rather interesting observation, as a comparative case study outcome, as it depicts the importance of continuous and targeted efforts by all sides for the positive implementation.
of LM. Different lean mechanisms, techniques, and tools are not solely sufficient to implement lean without the company's management/administration commitment to continuously invest in its employees and encourage a culture of continuous improvement. It is a safe statement that “The tools and techniques are an outcome of Lean, not the other way around (Mendis, 2012).”

5.4 Hypotheses testing and validation

Via the hypotheses formulated in paragraph 2.6, the target was predominantly to examine the connection between the inherent characteristics of a process industry and the type of LM practices implemented and later on, the effect that these specific adopted practices effectuated.

According to the first Hypothesis (H1), Quality lean tools (i.e., Kaizen, TPM, 5S, etc.) are better suited for the process industries that require only a few raw materials and produce large volumes of a limited variety of products. As observed, H1 is valid as most case studies that bare a limited variety of raw materials and indeed produce only a few products in large quantities, have implemented TPM, with the exception of the Food process industry described by Andersson, et al. (2009), who utilized a large variety of products but also implements TPM.

H1 is also enforced by the case study analysis of Facility A: this is a facility that utilizes a few raw materials- less than five- and produces a large quantity of only a few products- more than 10,000 tonnes per year of fewer than 10 products which differ mostly in the final packaging. This facility has implemented TPM and Kaizen to a broad extent.

The second Hypothesis (H2) states that production process lean tools (i.e., Batching, Production Levelling- Heijunka, etc.) cannot be implemented by Process industries that utilize dedicated and inflexible machinery and equipment. According to the prior analysis, H2 is valid as all but two case studies examined, bare an inflexible production process due to the nature of the equipment utilized, which is dedicated or process-unique, and thus do not implement any sort of production process lean tools.

Additionally, H2 is also confirmed according to the case study analysis of Facility A: the production process consists of dedicated and specific distillation equipment making the production process rather inflexible. As noted in the employee's responses to the questionnaire, no production process lean tools have been implemented.
According to the third Hypothesis \((H3)\), method lean tools (i.e., Standardization, SMED, etc.) are better suited for Process industries that utilize flexible and non-dedicated machinery and equipment. According to the prior analysis, \(H3\) is \textit{not valid} as five of the examined case studies that utilize have implemented SMED or Work Standardization, bare an inflexible production process and utilize equipment which is dedicated or process-unique.

\(H3\) is also proved invalid by the observations of the case study of Facility A: even though this is described as an inflexible process utilizing dedicated machinery, nonetheless it has implemented Standardization and SMED, to a great extent.

The fourth Hypothesis \((H4)\) states that Production process lean tools (i.e., Batching, JIT, etc.) are better suited for process industries where the product reaches a discrete state at the earlier stages of the production process. As observed, \(H4\) is \textit{not valid} as such lean practices were only witnessed in three case studies that all formed discrete products at the later stages of the production process.

Moreover, \(H4\) is rejected via the observations of the case study of Facility A: the product, in this case, becomes discrete relatively early, however, none of the respondents mentioned the adoption of any Production process lean tools such as JIT to any extent.

Last, the fifth Hypothesis \((H5)\) suggests that process industries can benefit from the implementation of LM tools either by reducing required resources and/ or waste or by increasing overall performance rates. According to the analysis results, \(H5\) is \textit{valid} as all but three case studies showed that there was a positive outcome from the implementation of lean.

The \(H5\) hypothesis is also validated by the information obtained from the case study analysis of Facility A. The various respondents mentioned that since the LM implementation begun, they witnessed an increase in productivity and profit rates while at the same time the manufacturing cost and cost of total production decreased. Additionally, they observed improvements in overall performance, suggested by a decrease in delivery time, an increase in flexibility in the production process, a better utilization of resources, decreases in the inventory and in changeover times and the defect rate as well as in waste from scrap and rework.

It is worth mentioning that the three exceptions observed in the literature base case study analyses, even though they did not present positive results, they neither showed negative effects from the implementation; the issue in these cases was that there was no longevity of the positive effects initially observed, which led to questioning of the lean practices and provided inconclusive results. As already mentioned, without continuous and persistent
efforts both by the workers but most importantly from the organization’s supervisors, the benefits LM might effectuate on a facility cannot be long-term.

Additionally, as evidenced by the reply from one of the respondents of the questionnaires “One of the most important things in the successful implementation of lean manufacturing is the stakeholders’ involvement and continuous attention.”
Chapter 6: Conclusions

6 Conclusion

This thesis sets out to investigate and identify the impact of lean manufacturing on process industries. Published scholarly articles have been employed throughout the present research, to find out the impact. Moreover, a questionnaire-based case study analysis was conducted to support the literature based arguments further.

In the course of the thesis, an in-depth, comprehensive overview of the Lean paradigm was provided, in particular towards a model of implementation on the process industry. The goal was to outline the importance and difficulties of LM implementation on process industries as well as the challenges and expectations that arise from this effort. In doing so, several research hypotheses were formulated in order to test the aspects of implementation and the overall impact of LM on process industries. The hypotheses testing procedure was conducted in two parts: a literature-based case study review as well as a case study analysis conducted through structured, questionnaire-based interviews. In the end, results of the case studies and thoughtful discussion from the case study observations are provided to justify the formulated hypotheses.

The thesis reveals the importance of the inherent production process characteristics of each facility that sets out to implement lean as well as the range of expectations and benefits that can be witnessed upon successful employment of the most suitable LM practices. Additionally, attention is drawn towards the necessity of a continuous organization commitment in the adoption of LM.

6.1 Answers to the research hypotheses

The findings suggest that a careful design plan is taking into account all production data referring to the following three variables, must be conducted prior to setting out for the implementation of any LM practices:

- Variety and Volume of raw materials and products
- Type of machinery utilized in the production process
- The stage at which the product becomes discrete

After these details have been outlined, the appropriate LM tools that can be utilized should be selected according to the following directions:
- Process industries that require only a few raw materials and produce large volumes of a limited variety of products should orient their efforts towards the implementation of Quality lean tools such as Kaizen, TPM and 5S.
- Production process lean tools such as Batching and Production Levelling- Heijunka should be out of the scope of implementation process industries that utilize dedicated and inflexible machinery and equipment.
- SMED, Work Standardization and relevant Method lean tools could be included in the implementation scope of companies baring both flexible and inflexible production processes, regarding the type of machinery utilized.
- The stage at which the product becomes discrete is not an important parameter when opting to implement Production process lean tools such as JIT.
- If the target upon the decision of LM implementation involves reducing required resources and/ or waste or increasing overall performance rates, then with careful and meticulous efforts the implementation will have positive effects in the long term. Attention should be draw to the fact that from the beginning of the implementation and onwards “One of the most important things in the successful implementation of lean manufacturing is the stakeholders’ involvement and continuous attention.”

6.2 Limitations

The limitations that narrowed the range of data available for the construction and evaluation of the arguments in this thesis were at first a consequence of the literature selected to be studied. The desire to analyze academic journals with a high IF regarding the field of LM together with the publication time period restriction, from the year 2000 onwards, provided quality material but from a narrower base.

Moreover, the conduction of only one questionnaire based case study was a limitation caused by the difficulty of organizing and conducting an elaborate query on process industry facilities that implement LM in such a short time. There is no index or organization of such facilities that could be used as a starting point to send out questionnaire forms for data collection; additionally, even though the format utilized provided privacy, the willingness of the participated companies was a factor that could not be forecasted. Besides, not to disclose the company’s profile and the respondents’ names is also a challenge.
6.3 Implications and contributions

This analysis consists of a detailed collection of information on LM implemented in many different sectors of process industries. Even though the depth of the analysis does not extend greatly, these initial steps are expected to be precious for lean practitioners that are occupied in a process industry environment, exactly because they point to the relevant information that one should look into, leaving outside other aspects of lean that are not of importance.

The findings from the comparative analysis suggest that there are many reasons for which to try and implement LM in a process industry facility. As deducted, whichever the production characteristics might be, a process industry can to some degree implement some lean practices and witness a positive result; the initial doubts usually witnessed in such environments regarding LM, with this work can be avoided more easily.

Moreover, the definition of crucial characteristics in a production process allows for a critical judgment as regards the overall expectations on LM. Since any decision to effectuate changes in a production process is accompanied by an investment plan, the guidelines provided in this work can be utilized as some of the criteria for the conduction of such a plan, in order to reach a verdict whether this investment would be suitable and probable to bring positive results. Thus, for an organization with many different facilities, this thesis could be very helpful in estimating investment the risk and expected profits and deciding on the correct time and way of implementing LM.

6.4 Future research

In this work, an assembly of literature-based case study analyses were conducted and compared to one questionnaire based case study. A wider collection of questionnaire-based case studies would broaden the range of data and personal opinions from LM implementation responsible supervisors and workers.

In another aspect, while this study focused on groups of lean tools that could be better suited and implemented in process industries, depending on the type of the production process and the relevant production characteristics, a future work could consist of an analysis of many different lean practices and tools separately, their implementation as well as the impact they would effectuate on different sectors of the process industry.

Additionally, in this work lean was observed solely from the production process aspect in process industries. However, these industries usually penetrate the FMCG
Moreover, while the scope in this thesis was the implementation and the outcome of LM, it would be of interest to investigate the factors that inhibit successful implementation on process industries.

Further research could be conducted on the economic effects of a broader lean implementation in the process industry, as this sector is predominant in the global economies and any small alteration in the production process can have a major effect in the real economy and the growth rates.
References


Melton, T., 2004, To lean or not to lean? (that is the question), The Chemical Engineer, September 2004 (759): 34–37.


Técnico, Lisboa. Available at: <https://fenix.tecnico.ulisboa.pt/downloadFile/1126295043834516/Artigo%20Joao%20Moura%20Final.pdf> [Accessed 17 April 2018]


Appendix

Here attached is the questionnaire employed to collect data for the case study conducted.
Dear Sir/ Madam,

As part of our MBA studies at the Blekinge Institute of Technology, located in Karlskrona, Sweden, we are working on our thesis titled “Impact of Lean Manufacturing on Process Industries.” For the purpose of gathering data for our thesis, we would kindly ask you to complete the following questionnaire that will aid us in understanding the key characteristics of your organization and the impact that lean manufacturing has effectuated.

All data submitted will be kept confidential. This will take approximately 15 minutes.

Thank you for your kind cooperation.

SECTION 1 - Industry profile

1. Company Name:

2. Name of respondent:

3. The position of the respondent in the organization:


5. Number of employees: 1-50 / 51- 200/ 201- 350/ 351-500/ >500

6. Major product type (if more than one state most important):

7. Major product unit (if more than one state most important):
8. Please rate the size and variety of the required raw materials and produced products of your facility:

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Description</th>
<th>Extent of size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of raw materials:</td>
<td>1-5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6-20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>21-50</td>
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<tr>
<td></td>
<td></td>
<td>51-100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;100</td>
</tr>
<tr>
<td></td>
<td>Volume of raw materials (tones/ annum)</td>
<td>&lt;1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1-10</td>
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<tr>
<td></td>
<td></td>
<td>10-100</td>
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<tr>
<td></td>
<td></td>
<td>100-1000</td>
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<tr>
<td></td>
<td></td>
<td>&gt;1000</td>
</tr>
<tr>
<td></td>
<td>Number of products:</td>
<td>1-5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5-20</td>
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<td></td>
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<td>20-50</td>
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<td></td>
<td>50-100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;100</td>
</tr>
<tr>
<td></td>
<td>Volume of products: (tones/ annum)</td>
<td>&lt;1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1-10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10-100</td>
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<tr>
<td></td>
<td></td>
<td>100-1000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;1000</td>
</tr>
</tbody>
</table>

9. Please rate the flexibility of the equipment utilized in your facility on a five-point scale (1- Very Low, 2-Low, 3-Fair, 4-High, 5- Very High)

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Description</th>
<th>Extent of size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Common equipment (ie. simple tanks, pipe networks)</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Dedicated equipment (ie. Only for one product/ process)</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>Easily transferable equipment</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>Cost of equipment</td>
<td>4</td>
</tr>
</tbody>
</table>

10. Please estimate the stage at which your major product becomes a discrete unit in your facility on a five-point scale (1- Beginning of production process, 5- End of the production process)

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Description</th>
<th>Extent of size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Stage of discrete product</td>
<td>1</td>
</tr>
</tbody>
</table>
SECTION 2- Lean manufacturing implementation and impact

1. What were your expectations from implementing lean manufacturing practices (i.e.)?
   1- Increase of production rates
   2- Reduction of waste
   3- Improvement of processes
   4 - Other
   Explain:........................................................................................................................................
   ...................................................................................................................................................
   ...................................................................................................................................................

2. How long have you been implementing lean manufacturing practices?
   ...................................................................................................................................................
   ...................................................................................................................................................

3. To what extent have your expectations from implementing lean manufacturing practices have been fulfilled?
   1- Not at all
   2- A little
   3- Somewhat
   4- A lot
   5- Highly
   Explain:........................................................................................................................................
   ...................................................................................................................................................
   ...................................................................................................................................................

4. Does the organization support the implementation of lean manufacturing practices?
   1- Not at all
   2- A little
   3- Somewhat
   4- A lot
   5- Highly
   Explain:........................................................................................................................................
   ...................................................................................................................................................
A. Please select and rate the implementation of the following lean tools regarding process and equipment in your organization on a five-point scale (1- Very poor, 2- Poor, 3- Fair, 4- Good, 5- Very Good). **Leave empty if the specific tool is not in your scope.**

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Lean tool</th>
<th>Extent of implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Preventive maintenance</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>JIT/continuous flow production</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Cycle time reduction</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Cellular manufacturing</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Single piece flow production/ one-piece flow</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Zero defects</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Poka-yoke/error proofing</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Scrap reduction</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Kaizen</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Agile manufacturing</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>2 bin auto-replenishment system</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Heijunka/ production smoothening/ line balancing</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Single minute die exchange (SMED)</td>
<td></td>
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<tr>
<td>14</td>
<td>5S</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Automation/ Jidoka</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Andon</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Setup time reduction/quick changeover techniques</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Total productive maintenance</td>
<td></td>
</tr>
</tbody>
</table>

B. Please select and rate the implementation of the following lean tools regarding manufacturing planning and control in your organization on a five-
point scale (1- Very poor, 2-Poor, 3-Fair, 4-Good, 5- Very Good). **Leave empty if the specific tool is not in your scope.**

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Lean tool</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Total quality management</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Pull system/kanban/pull production</td>
<td></td>
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<td></td>
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<tr>
<td>3</td>
<td>Lot size reduction/small lot size/batch size reduction</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Continuous improvement program</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>5</td>
<td>Value stream mapping (VSM)</td>
<td></td>
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</tr>
<tr>
<td>6</td>
<td>Inventory management</td>
<td></td>
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<tr>
<td>7</td>
<td>Workplace organization</td>
<td></td>
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<td>8</td>
<td>Standardized work</td>
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<tr>
<td>9</td>
<td>Simulation</td>
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<tr>
<td>10</td>
<td>Supply chain management</td>
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<tr>
<td>11</td>
<td>Visual management/visual</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Production stop policy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Group technology</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Takt time</td>
<td></td>
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</tbody>
</table>
C. Please rate the impact from the implementation of lean practices, regarding business/finance in your organization, on a five-point scale (1 - Very poor, 2 - Poor, 3 - Fair, 4 - Good, 5 - Very Good) *Leave empty if the specific improvement is not in your scope.*

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Extent of impact</th>
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<tbody>
<tr>
<td></td>
<td><strong>Extent of impact</strong></td>
</tr>
<tr>
<td></td>
<td>1  2  3  4  5</td>
</tr>
<tr>
<td>1</td>
<td>Increase in productivity</td>
</tr>
<tr>
<td>2</td>
<td>The decrease in manufacturing cost/unit cost of manufacturing</td>
</tr>
<tr>
<td>3</td>
<td>Increase in market share</td>
</tr>
<tr>
<td>4</td>
<td>Increase in turnover</td>
</tr>
<tr>
<td>5</td>
<td>Increase in annual sales revenue</td>
</tr>
<tr>
<td>6</td>
<td>Increase in growth rate in sales (€)</td>
</tr>
<tr>
<td>7</td>
<td>Increase in growth rate in sales (units)</td>
</tr>
<tr>
<td>8</td>
<td>Increase in profit</td>
</tr>
<tr>
<td>9</td>
<td>The decrease in total cost of production</td>
</tr>
<tr>
<td>10</td>
<td>Increase in return on investments</td>
</tr>
<tr>
<td>11</td>
<td>Increase in return on sales</td>
</tr>
<tr>
<td>12</td>
<td>Increase in return on assets</td>
</tr>
</tbody>
</table>
D. Please rate the impact from the implementation of lean practices, regarding equipment and process in your organization on a five-point scale (1- Very poor, 2-Poor, 3-Fair, 4-Good, 5- Very Good)

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Extent of impact</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>The decrease in delivery speed / delivery lead time</td>
</tr>
<tr>
<td>2</td>
<td>Increase in flexibility in production</td>
</tr>
<tr>
<td>3</td>
<td>Increase in capacity utilization / shop utilization / better utilization of resources</td>
</tr>
<tr>
<td>4</td>
<td>Decrease in inventory</td>
</tr>
<tr>
<td>5</td>
<td>The decrease in manufacturing cycle time</td>
</tr>
<tr>
<td>6</td>
<td>The decrease in changeover time / setup time</td>
</tr>
<tr>
<td>7</td>
<td>Decrease in defect rate / rejection rate / % rejection</td>
</tr>
<tr>
<td>8</td>
<td>The decrease in work in progress</td>
</tr>
<tr>
<td>9</td>
<td>Decrease in waste / scrap and rework</td>
</tr>
<tr>
<td>10</td>
<td>The decrease in % of time machines are standing due to malfunction</td>
</tr>
<tr>
<td>11</td>
<td>The decrease in equipment failure rate</td>
</tr>
</tbody>
</table>

E. Please rate the impact from the implementation of lean practices, regarding human behavior in your organization on a five-point scale (1- Very poor, 2-Poor, 3-Fair, 4-Good, 5- Very Good)

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Extent of impact</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>Increase in labor productivity</td>
</tr>
<tr>
<td>2</td>
<td>Increase in employee satisfaction</td>
</tr>
<tr>
<td>3</td>
<td>Increase in employee involvement in the production process.</td>
</tr>
<tr>
<td>4</td>
<td>Increase in customer satisfaction</td>
</tr>
<tr>
<td>5</td>
<td>Increase in customer return rates / customer retention speed / delivery lead time</td>
</tr>
</tbody>
</table>
Please share your comments, if any, regarding the Lean Manufacturing implementation/impact, in your organization.

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We highly appreciate the time you have given for the completion of this questionnaire. Thank you very much.

Please forward your answers to the following emails: saidul87@gmail.com or mitrogogos@yahoo.com

Kind regards,
Kazi Mohammed Saidul Huq
Konstantinos Mitrogogos

Kind regards,
Kazi Mohammed Saidul Huq
Konstantinos Mitrogogos