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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.
Key Words: *- ILM (Impact Lean Manufacturing), IP (Industries Process), PP (Production Process), LP (Lean Practices), CA, (Combined Analysis), Implementation, investigate, COC (continuous organization commitment)*

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I. INTRODUCTION

1.1 Problem discussion

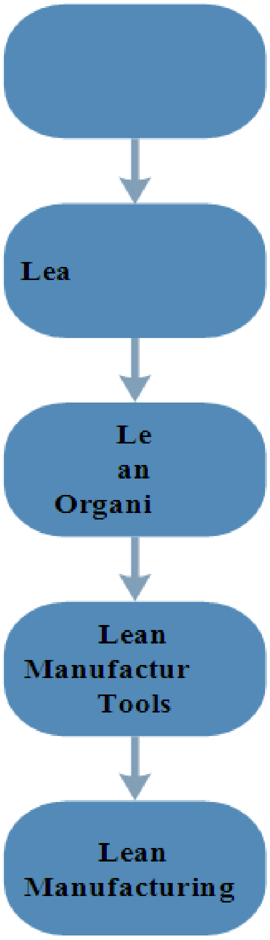
The process industry in India employs 6,8 million workers and yields more than Rs.1.6 billion of total turnover, thus accounting for around 20% of workforce and income in the Indian region. Being in the center of most industrial processes and having to deal with the strict Guidelines of Horizon 2020, 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.

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 that 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, Isakson and Seifert, 2017).

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.



1.3Delimitations

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.

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.

1.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 ManufacturingAccurately defining value and the value stream network.

2.Identifying undesirable effects and suggesting changes to eliminate the source of these effects.

3.Applying recommended changes

4.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.

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

II. 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 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.

2.1.1 Lean principles

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

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

2.1.2 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).

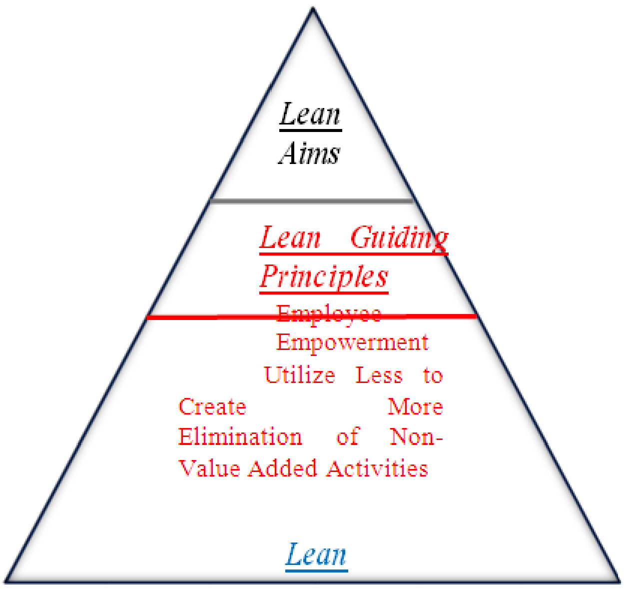


Figure 4. Key elements of Lean

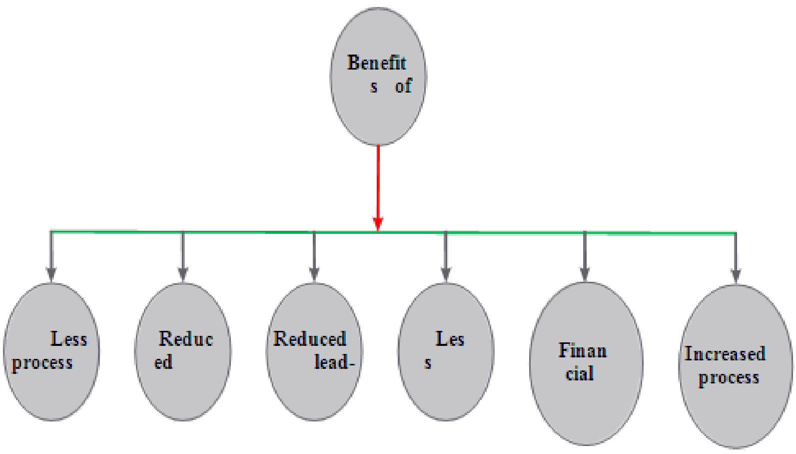
2.2 Why go Lean

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.

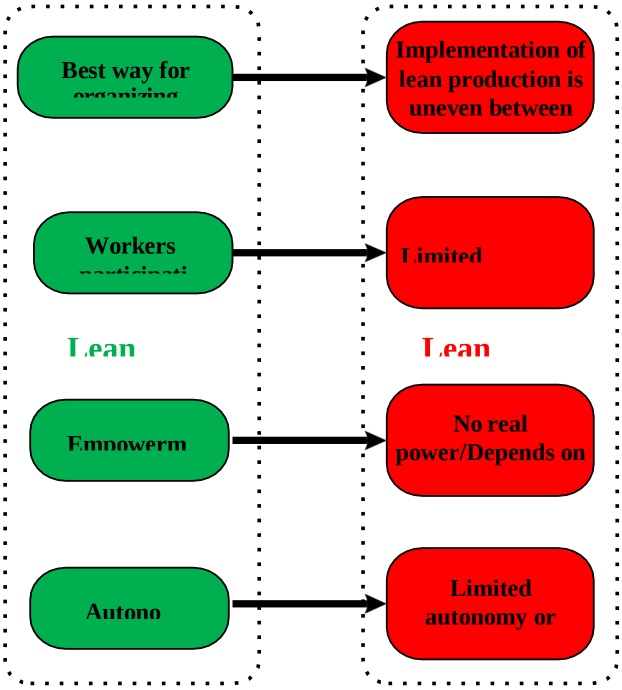
•*Faster delivery times* – By applying the principles of just-in-time and pull, production orders are conducted when needed and therefore delivered faster to the customer. Lead time is reduced.

•*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.



2.1 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



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.

2.3Formulating 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

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.*

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.*
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.*
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.*

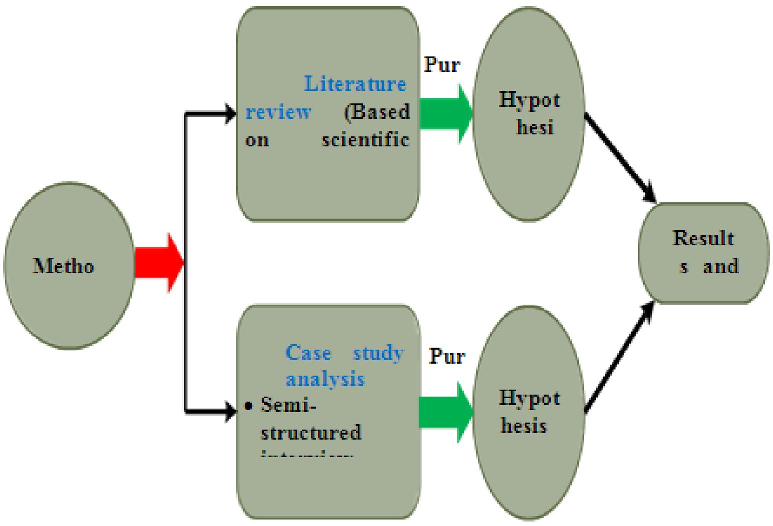
III. METHODOLOGY

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.

3.1.1Extent 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
Steel and metal



2.Chemicals
3.Food and beverages
4.Textile
5.Lumber and wood
6.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.

1.4Interview: Interpersonal and questionnaire-based

An interview can be either fully structured, semi-structured on 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.

For the execution of the case study analysis, a set of interviews was conducted. 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?

1.5Case 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.

IV. RESULTS

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

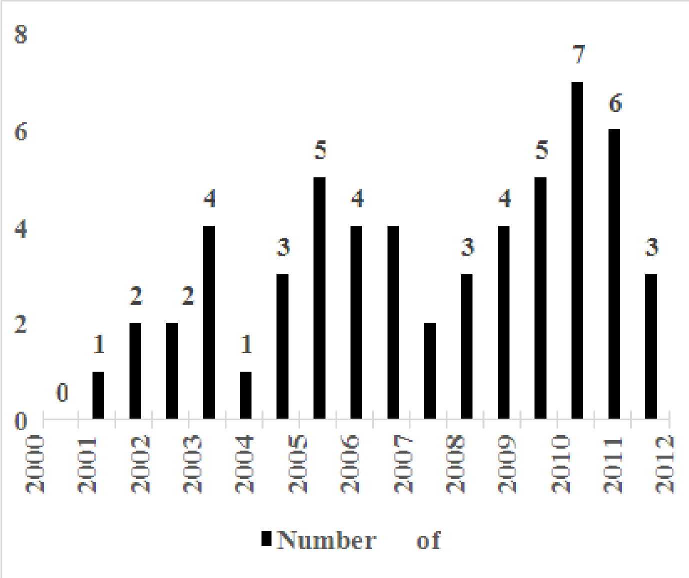


Figure 10 shows the number of case studies for different types of process industries investigated in this thesis.

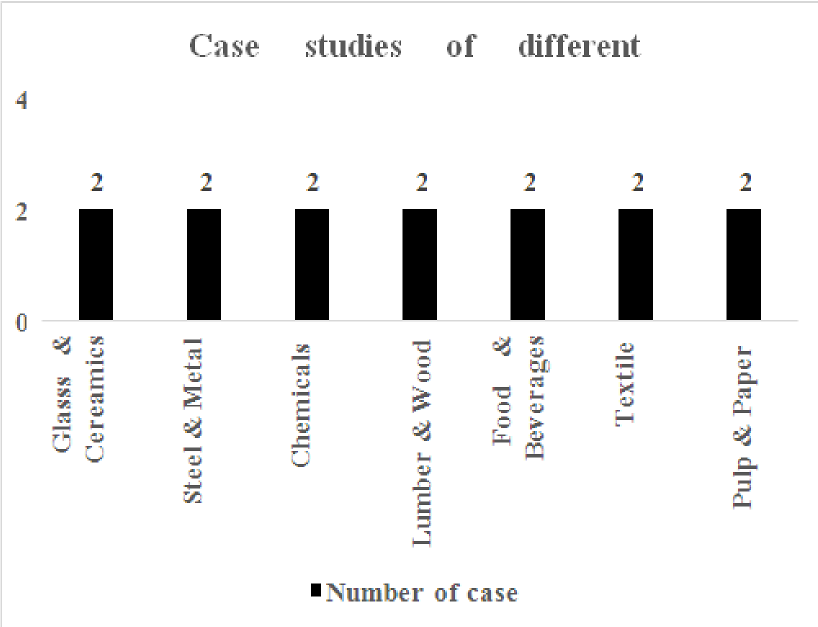


Figure 10. Distribution of literature regarding the type of process industry

V. 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 deducted 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.

1.6LM 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.

1.1LM 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).

1.7Hypotheses 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 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 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 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.

VI. 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.

1.8Answers 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."

1.9Limitations

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.

1.10Implications 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.

1.11Future 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

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