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Analysis about Lean helping the increasing demand in luxury yachts.

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Abstract en español

Durante los últimos años, el sector de los astilleros de lujo ha experimentado un crecimiento de la demanda, y los astilleros han tenido que hacer frente a este incremento implementando cambios en su sistema productivo para poder satisfacerla. En este trabajo hemos tratado de encontrar una solución aplicando la filosofía Lean, concretamente, buscando aquellas técnicas que ayuden a mejorar la productividad en respuesta al incremento de la demanda. Para ello, se ha realizado una revisión no sistemática de la literatura, seguida de un análisis de los resultados obtenidos en dicha búsqueda. Se han descrito las principales técnicas y metodologías que potencialmente pueden ayudar a aumentar la productividad, como el Mantenimiento Productivo Total (TPM), Just in Time (JIT), Kanban, Kaizen, 5s, Value Stream Map (VSM) y Pull system. Posteriormente, teniendo en cuenta las limitaciones y características de la industria de la construcción naval, hemos intentado adaptar estas técnicas y ver si realmente podrían ser útiles para aumentar la producción en una industria específica como la de los astilleros de lujo. El resultado obtenido es que, aparentemente, estas técnicas no presentarían ningún problema a la hora de aplicarlas en este sector.

Abstract in lingua italiana

Negli ultimi anni, il settore della cantieristica navale di lusso ha registrato una crescita della domanda e i cantieri navali hanno dovuto far fronte a questo aumento implementando cambiamenti nel loro sistema produttivo per poterlo soddisfare. In questo lavoro abbiamo cercato di trovare una soluzione applicando la filosofia Lean, in particolare cercando quelle tecniche che aiutano a migliorare la produttività in risposta all'aumento della domanda. A tal fine, è stata effettuata una revisione non sistematica della letteratura, seguita da un'analisi dei risultati ottenuti in questa ricerca. Sono state descritte le principali tecniche e metodologie che possono potenzialmente contribuire ad aumentare la produttività, come la Total Productive Maintenance (TPM), il Just in Time (JIT), il Kanban, il Kaizen, le 5s, la Value Stream Map (VSM) e il Pull system. Successivamente, tenendo conto dei vincoli e delle caratteristiche dell'industria navale, abbiamo cercato di adattare queste tecniche e di verificare se potessero davvero essere utili per aumentare la produzione in un settore specifico come quello dei cantieri navali di lusso. Il risultato ottenuto è che queste tecniche non avrebbero apparentemente alcun problema se implementate in questo settore.

Abstract

During the last few years, the luxury shipyard sector has experienced a growth in demand, and shipyards have had to face this increase by implementing changes in their production system in order to satisfy it. In this work we have tried to find a solution by applying the Lean philosophy, specifically, by searching for those techniques that help to improve productivity in response to the increase in demand. To this end, a non-systematic review of the literature was carried out, followed by an analysis of the results obtained in this search. The main techniques and methodologies that can potentially help to increase productivity have been described such as Total Productive Maintenance (TPM), Just in Time (JIT), Kanban, Kaizen, 5s, Value Stream Map (VSM), and Pull system. Subsequently, taking into account the constraints and characteristics of the shipbuilding industry, we have tried to adapt these techniques and see if they could really be useful to increase production in a specific industry such as luxury shipyards. The result obtained is that these techniques would apparently not have any problems when implemented in this sector.

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Introduction

The luxury yacht building market has grown considerably in recent years, presenting shipyards around the world with both exciting opportunities and serious challenges. Shipyards have been forced to review and modify their manufacturing processes in order to effectively manage this boom due to increased demand.

Luxury shipyards, which historically have a reputation for fine craftsmanship and meticulous attention to detail, must find a balance between these ideals and the demands of increasing production and efficiency. The Lean concept presents a comprehensive framework of methods and ideas aimed at simplifying processes, eliminating waste and increasing productivity as a potential strategy to achieve this balance.

In this paper, we have tried to find a solution to this increase in demand by applying the Lean philosophy, specifically by looking for those techniques that help to improve productivity as a response to the increase in demand. To this end, a non-systematic review of the literature has been carried out, followed by an analysis of the results obtained in this search.

1. Research methodology

In this first section we will try to establish the basis of this work in order to be able to develop it afterwards. Firstly, we will define the purpose of this project and its objective, from which we will elaborate three questions that will try to be answered throughout the project, after being clear about the main objective and having defined the questions, we will move on to the core of it and we will carry out a review and discuss the most significant ideas obtained in this research.

The aim of this methodology is to gather evidence from a variety of viewpoints to create a study that will provide a comprehensive set of recommendations to help yacht manufacturers enhance their production methods and effectively meet the growing demand for luxury yachts.

1.1 Research objective

This thesis aims to identify which lean manufacturing techniques are most useful to meet the growing demand for yachts. Therefore, one of the first questions we should ask ourselves is, what are the main tools that companies could use to cope with the increase in demand, so that they can satisfy it.

Nallusamy conducted a study in which he faced the problem of increasing demand in companies using “Computer numerical control” (CNC) systems and carried out a study on increasing productivity in these companies, using lean manufacturing techniques, implying and asserting that lean manufacturing techniques are useful in increasing productivity. (Nallusamy 2016)

Sadiq, also pointed out the importance of proposing a solid strategy through the application of lean, in order to increase productivity and efficiency, and thus cope with the increased demand that manufacturing companies are experiencing in the 21st century. (Sadiq et al. 2021)

We can therefore establish a relationship between the desire to satisfy increased demand and a possible solution which would be to increase productivity.

I would also like to reflect on a brief description of what is a possible definition of productivity, as it will be useful when trying to find the most efficient techniques to increase productivity. (Tangen 2002.) attempted to provide a good explanation of productivity and the implications it has inside a firm. Tangen defines productivity as the link between the results gained and the resources needed to produce these results.

In other terms, it refers to how well a business employs its resources to generate goods or services. Increasing productivity entails producing better outcomes with less resources, which might result in lower costs, more output, or better product quality.

For all of the above, the main objective of this project is to see if lean techniques focused on improving productivity are applicable to the luxury sector and specifically to the manufacture of yachts, since it is possible that due to the origin of lean manufacturing which was conceived in the automotive sector, a sector whose main characteristic is the high replicability and easy standardisation of products, companies may encounter difficulties when implementing these techniques, which is why, the research will try to examine the drawbacks of using these tools in these industries. To this end, the thesis will develop both an unsystematic search and review for investigating, in broad lines, which lean manufacturing tools are most commonly used in companies in various sectors and what could be the possible benefits and drawbacks. Then it will narrow down these techniques by focusing on luxury companies, in particular, the focus will be on providing, suggestions and insights to yacht manufacturers who aspire to improve their production methods and meet the growing demand, while taking into account the unique difficulties faced by the luxury yacht industries.

1.2 Research questions

In this section we will set out the questions that will be answered throughout the work, and which will be aligned with the objective of the work

- How may the application of lean manufacturing techniques could increase productivity and help meeting the demand?
- What techniques from lean manufacturing are most applicable to the luxury yachting sector to meet the increasing demand?

1.3 Unsystematic search

The purpose of this section is to justify and establish what will be the procedures and methodologies followed to achieve the objective of the project and the questions formulated above. As it has been established, the objective of the thesis is to try to cope with the increasing demand in the yacht sector by applying lean manufacturing techniques to improve productivity and to try to meet the increasing demand. As it is a very specific sector, at the time of searching for articles the offer was quite scarce, and quite unknown, that is why in order to try to understand these new applications of lean in the naval sector a non-systematic search has been followed to try to provide new ideas and perspectives that can be applicable to the yacht industry. Additionally, for the same reason as the previous one, snowballing technique has been followed. This is a sampling technique in which the articles found provide references to new articles in order to go deeper into a topic of interest, this technique is normally used when it is difficult to obtain information about a specific topic.

To carry out this search, broadly speaking, the tools used were the search engines Scopus and google scholar, together with keywords such as: Yachting, "Lean management", Lean, "Luxury yacht", "supply chain", "Lean and yacht", "increase productivity", "meet demand".

During the project, these two search engines have been used for various reasons, firstly, Google Scholar, as a first approach to a topic, because of its familiar interface and ease of use. Afterwards, when we wanted to have a deeper knowledge of a topic, we have searched in Scopus, because with its advanced search and using queries and its logical connectors, we are able to obtain articles on very specific topics. In addition, the content of Google Scholar and Scopus is drawn from reputable academic publications and conferences that adhere to rigorous peer-review procedures to guarantee the accuracy and validity of the study.

2. Results

This section will attempt to answer the questions and develop the objectives of the project mentioned. As mentioned above, since the subject is very broad and specific, articles about the topic are limited, a non-systematic review has been carried out. In addition, this section will also attempt to provide some background and possible uses of the information developed to guide future investigations and practical applications in the yacht manufacturing industry.

The structure of the project is the following: first, a brief overview of the origins of lean manufacturing, as well as a description of some of the most commonly used techniques in different industries, and then an attempt will be made to find possible relationships between the use of these practices and a possible improvement of productivity.

This will be followed by a description of the history of luxury, in particular the yachting sector, and a state of the literature on lean manufacturing and productivity improvement in the luxury sector, in particular the yachting sector.

2.1 Lean Manufacturing

In this section we will establish the basics and history of lean manufacturing, subsequently we will make a first approach to the lean manufacturing techniques most used in manufacturing companies around the world and which of them could make a significantly improvement in rising productivity. Finally, the main benefits and limitations of using lean manufacturing tools will be presented.

Before we begin to analyse in depth the techniques and applications of this work philosophy, I believe it is worthwhile to make a brief introduction to the philosophy and way of working of lean manufacturing.

Lean manufacturing, also known as lean production, is a form of management and production that originated at Toyota and was developed throughout the 20th century. The first signs and roots of lean manufacturing come from Sakichi Toyoda (founder of Toyota industries), when in 1926 he invented an automatic system for a weaving machine, which detected when a thread was broken, and automatically stopped the process. This was the first birth of the philosophy of lean manufacturing, with the invention of the term Jikoda (autonomous automation) which later became an essential part of the Toyota production system that we will talk about later.

Later in 1937, Sakichi Toyoda's son, Kiichiro, founded what is now known as the Toyota motor company, initially an expansion of his father's loom company. It was here that the philosophy of TPS and lean manufacturing came into its own. In 1945, after the Second World War, Japan was in a difficult economic situation and so Kiichiro and the engineers at Toyota came up with the term on which part of the Lean philosophy would be based, Just-in-time.

Just-in-time means that, in a flow process, the right parts needed in assembly arrive at the assembly line at the time they are needed and only in the quantity needed (*Taiichi Ohno 1978*).

In the following years, and especially during the oil crisis where all companies were suffering, at Toyota Motor Company, although profits suffered, higher profits were sustained in 1975, 1976 and 1977 than at other companies. The widening gap between it and other companies made people wonder what was going on at Toyota (*Taiichi Ohno 1978*).

Eventually, given the growing popularity of the Toyota production system, it culminated in the publication of the book *The Machine that Changed the World* by Womack, in which he finally coined the term Lean Production.

Since then, many industries around the world have adopted the ideas of lean manufacturing. The concept has been applied outside manufacturing to fields such as healthcare, software development and services, with adjustments and adaptations to suit specific situations.

To cope with changing customer expectations, new technologies and global supply chain issues, new ideas and techniques for lean manufacturing are now being created. The lean mindset continues to prioritise the fundamental ideas of reducing waste, increasing efficiency and empowering workers.

This shows how the use of lean isn't limited to the manufactory area of the company but can be applied to an entire enterprise and all its areas such as: product development, marketing, sales, service, accounting and other white-collar job (Holweg & Pil, 2001).

2.1.1 Basic pillars of lean manufacturing

Before delving into the applications and tools used in the main lean manufacturing techniques, it must be understood that: The concept of lean manufacturing might look easy but its implementation is not an easy task. The introduction of lean manufacturing into an organisation tends to change its working culture (Gupta and Jain 2013).

Therefore, Womack and Jones, in their book *Lean Thinking*, set out a number of basic and necessary principles:

- **Identifying value:** The first of the principles that Womack and Jones defined was that of "value". Womack and Jones defined it from the perspective of the consumer, i.e. to eliminate or reduce all those production activities that do not directly increase the value proposition for the consumer. (Hines, Holwe, and Rich 2004; Nithia, Noordin, and Saman 2015).
- **Value Stream Mapping:** Is a tool used to give a graphical view of the workflow of material, information, and the activities involved in a production process, and to find value and non-value added activities in the making of the final product (Hines, Holwe, and Rich 2004; Nithia, Noordin, and Saman 2015)
- **Establishing Flow:** Flow refers to the importance of creating a continuous flow of work, without bottlenecks or interruptions.
- **Pull:** A pull system refers to the fact that, in a production process, it is the final stages of the process that pull and require materials from the others, i.e. it is the customer or the demand that establishes how production will be, in order to avoid overproduction or unnecessary stocks or inventories (Taiichi Ohno 1978).
- **Kaizen:** Term, which in Japanese means continuous improvement. This principle highlights the need for continuous efforts to discover and reduce waste, optimise processes, and improve overall performance. (Gupta and Jain 2013).

Although it may seem a first sight, that these concepts are abstract and have little to do with the subject of the project, whose objective is to help shipyards to improve their productivity, the reality is that these 5 concepts are basic to really implement a lean system in a company and will help to improve efficiency. For example, (Palange and

Dhatrak 2021), argued that it is observed that VSM technique is commonly used, for reduction in cycle time, lead time and resolving bottleneck issues. Moreover (Singh, Singh, and Singh 2018) also concluded that implementing a kaizen culture leads to improved productivity and efficiency in organisations.

2.1.2 Most used tools in lean manufacturing for productivity improvement

Lean Manufacturing has proven to be an effective practice for increasing productivity and efficiency in manufacturing companies. Numerous tools that are often used in this industry have been developed as a result of its emphasis on waste reduction and process improvement. This section, will investigate a number of popular lean manufacturing tools and evaluate their effectiveness in improving productivity. To guide our selection process, we have focused on the study of lean manufacturing techniques commonly used in a variety of industries. This choice is motivated by the main objective of the project, which is to meet the growing demand in the yachting sector, which requires a fast and efficient increase in production. As a result, it is believed that the techniques most widely used are the ones that will have the greatest impact in the production system and will offer the fastest implementation.

The first article analysed is (Vasudev Krishnan, C. Mallika Parveen *Comparative Study of Lean Manufacturing Tools Used in Manufacturing Firms and Service Sector 2013*) in which 180 companies were analysed, of which 79 companies were from India, 65 from China and 36 from Malaysia. The results obtained in the paper by (Vasudev Krishnan, C. Mallika Parveen) are illustrated in Figure 2.

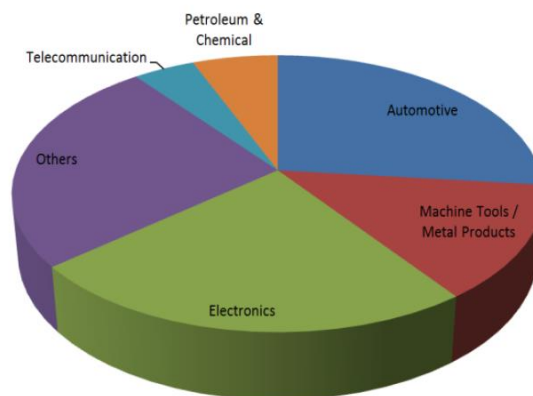


Figure 1: Classification of manufacturing firms based on similarity of products

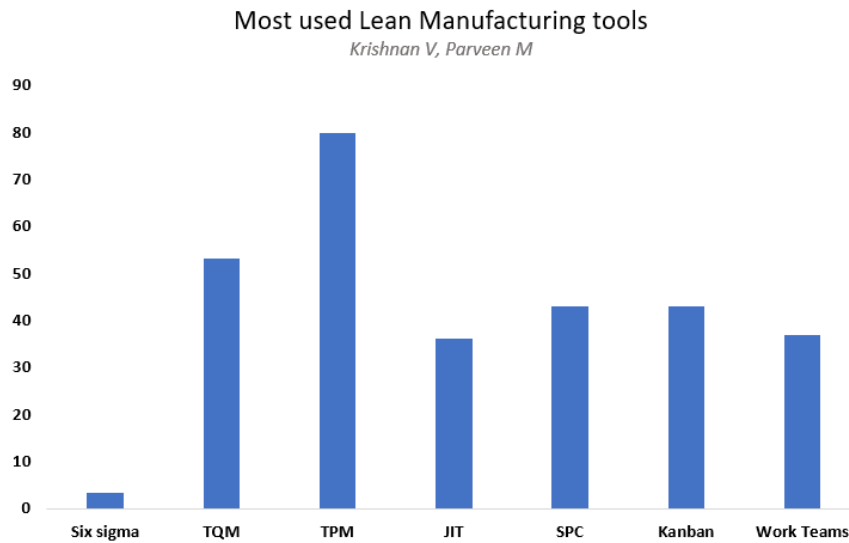
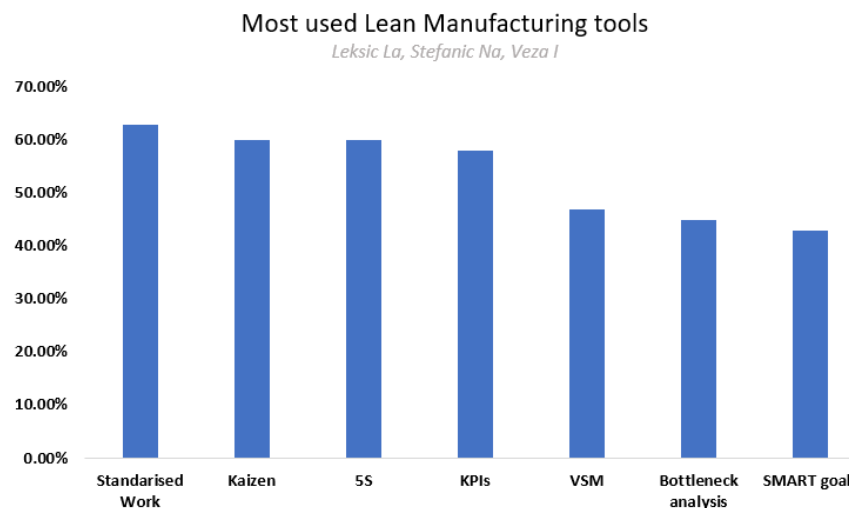


Figure 2: Percentage adoption of lean tools in manufacturing firms

The results obtained in the paper by Vasudev Krishnan, C. Mallika Parveen were Six sigma 3.3% Total quality management 53.3% Total productive maintenance 80% Just time 36.11% Statistical Process Control 43% Kanban 43% Work Teams 37%.

The second paper analysed was (Leksic, Stefanic, and Veza 2020) where a total of 63 Croatian companies were analysed, the results obtained from the analysis were: Standardised work 63%, Kaizen 60% 5S 60% KPIs 58% VSM 48% Bottleneck analysis 45% SMART goals 43%.



The last paper
manufacturing

Figure 3: Most used lean manufacturing techniques

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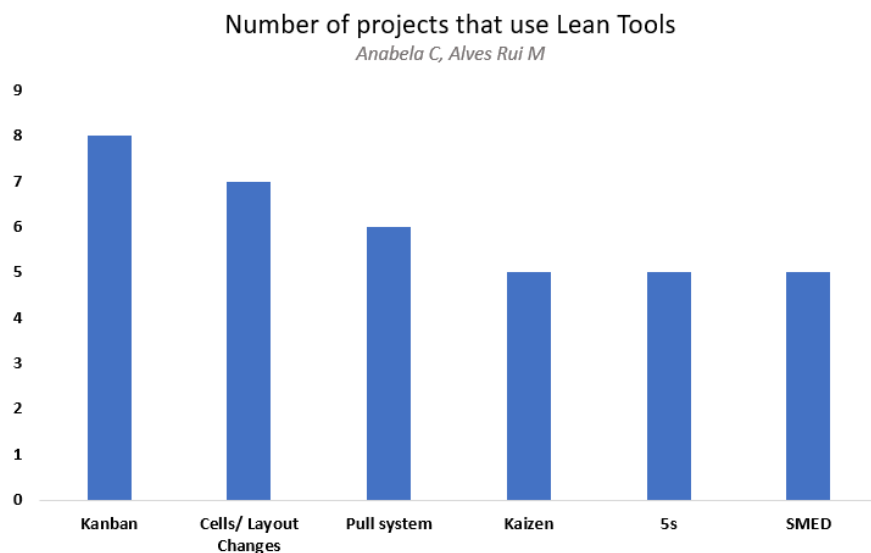


Figure 4: Lean tools applied in the projects

After analysing several articles that have tried to answer the question of which lean manufacturing techniques are the most used in manufacturing industries, we will now try to establish which of the most used techniques are the ones that could implement the greatest benefits in terms of increased productivity.

From the previous studies it is derived that the most used tools by the companies are: Total Productive Maintenance (TPM), Just in Time (JIT), Kanban, Kaizen, 5s, Visual Stream Map (VSM), and Pull system. We will go on to analyse them, trying to see what their main applications are and how they can help to improve productivity.

Firstly, Total Productive Maintenance (TPM), broadly speaking, is a crucial element that aims to cut down on waste, errors, and equipment downtime. It involves machine preventative maintenance and self-maintenance understanding.

Although it may seem that machine maintenance may not be directly related to improving productivity or efficiency, but rather to cutting waste, it can be an important tool for companies, in (Goshime, Kitaw, and Jilcha 2019) authors highlighted how cleaning, lubrication and routine inspections of industrial equipment would keep breakdowns and unnecessary stoppages at bay, keeping machines operational for longer, and thus resulting in higher production in the long run.

Moreover, even if it is a bit off the subject, which is the improvement of productivity to satisfy an increase in demand,(Leksic, Stefanic, and Veza 2020) concluded from their study in several companies, that TPM was one of the most powerful tools of lean, and that companies should apply this technique at the end of their transition to lean, in order to be able to cut waste as much as possible, and as has already been argued above, this cutting of waste can also lead to an improvement in productivity or work efficiency.

Secondly, we have, more than a tool itself, one of the most important philosophies applied in lean manufacturing, we are talking about Just in Time (JIT), which could be defined as manufacturing correctly what is necessary in the necessary time.

In (Sadiq et al. 2021) stated that JIT is a philosophy that identifies and eliminates all forms of waste, promoting continuous improvement. All of the above would result in reduced costs, improved productivity and improved quality, resulting in improved customer satisfaction.

The authors comment that Japanese companies have worked on the concept of JIT to make it a pivotal point in trying to meet customer demand with minimum effort and minimum delay, also stating that this practice ensures a significant increase in the quality of the products and the work of the employees.

Thirdly, the next tool to be discussed is Kanban. Kanban is a Japanese manufacturing method that consists of continuous delivery of materials and parts based on visual cues and demand signals. In(Palange and Dhattrak 2021) authors saw that by employing Kanban System could smoothen the process, reduction of cycle time, efficient utilization of machine. In addition in (Wakode et al. 2015) the writers studied the impact that applying kanban method could have on improving the productivity on companies and conclude that not only could kanban be a great tool for productivity improvement but also for reducing wastes and helping achieving just in time.

Fourthly, we have Kaizen, which is a Japanese term and philosophy to refer to continuous improvement as a result of involving all parts of a company, appreciating even the smallest of improvements and promoting continuous improvement into the future (Palange and Dhattrak 2021)

(Singh, Singh, and Singh 2018) conducted an analysis of the benefits that kaizen could have on a company and concluded with 14 benefits including: extent of improvement in competitive image, improved customer relation, reduction in scrap, improvement in productivity, reduction in inventories, increase in profit, improvement in overall equipment effectiveness.

The 5S approach is a system for creating and keeping a tidy, effective, and secure workplace. Sort, Set in Order, Shine, Standardize, and Sustain are the five "S" principles.

In the article (Ruiz et al. 2019) the authors applied lean manufacturing techniques to a medium-sized textile company that was having problems with productivity and meeting demand. The main tool applied was 5S. As a conclusion of the application of 5S in this company, they managed to satisfy the demand from 37% to 86%. They also improved the cycle time by 76%.

To continue, we have Visual Stream Mapping (VSM) is a world-renowned graphical tool that helps to clarify and analyse the workflow and to find the value-added and non-value-added activities that contribute to the final product.

In (Palange and Dhattrak 2021) They conducted a case study in which they applied VSM to a plastic bag manufacturing company, VSM tools eliminated non-value adding activities reducing the cycle time. TAKT time was reduced from 46.6 min to 26 min. The number of rolls produced increased from 28 to 50 per day.

Apart from the fact that VSM can help all of the above, in (Nallusamy 2016) the authors highlighted the opportunity that VSM can give a company to also apply other lean manufacturing improvement techniques, as VSM offers a simplified, graphical overview of a company's workflow and this can help to identify weak points where different lean techniques can be applied.

Lastly, we have the pull production system. It means that a production line will not start up unless it has received an order, so it will be the customer who pulls the production.

In (Gupta and Jain 2013) a case study was shown where the traditionally adopted 'push' (based on forecast demand) system was replaced with a 'pull' (based on actual demand) system for obtaining a smooth and synchronized system, so that products were to be produced with the right timing and in the right quantity.

The application of pull may not have a direct implication on improving the efficiency and productivity of a company, but it is certainly an interesting tool to consider because it reduces unnecessary inventories, and this can help to improve the overall welfare of a company (Palange and Dhattrak 2021)

2.2 Lean in Luxury and Yachting industry

After establishing the basics of lean manufacturing in the previous chapter, and which are the main techniques most used in industries, as well as the implications of these techniques when it comes to improving the productivity of a company, in this section we will focus on studying which of these techniques are valid for application in the luxury sector and shipyards. To do this, we will first make a brief introduction to luxury companies, in particular, to those involved in the construction of yachts, and we will establish the main characteristics of this sector, which will later help us to decide whether the techniques selected in the previous section can help to satisfy the demand and increase the production of a company.

2.2.1 Concept of luxury and introduction to the yachting sector

The word "luxury" comes from the Latin "luxus", meaning "gentle or extravagant way of life", "magnificence" or "opulence" (from the Oxford Dictionary of Latin by Dubois et al., 2005), or from the Latin "luxuria", meaning "excess". The word "lux" refers to the original luxury items, which included jewellery and precious stones.

The luxury manufacturing sector has its roots in ancient civilisations when talented craftsmen produced fine jewellery, such as those made in ancient Egypt or in China for the imperial court.

Luxury producers arrived in Europe and became popular during the renaissance, during which time many luxury brands emerged and gained popularity. The world of luxury goods manufacturing boomed during the industrial revolution, during the 18th and 19th centuries. Luxury goods became more widely available, thanks to increased company capacity and mass production, yet companies that made products by hand remained exclusive and expensive. At this time, companies such as Tiffany and co or Hermes emerged.

During the 20th century, luxury manufacturing companies became global and brands such as Chanel, Gucci and Dior emerged at this time, during which time luxury

companies not only focused on the manufacture of clothing, but also diversified their products, even making brands an indication of standard in society.

Currently the luxury sector is very diversified, and not only encompasses the companies of Rome but also has several sectors, such as luxury automotive, restoration, art, or in the case that concerns us in this project Luxury yachts.

Luxury shipyards are those that custom build premium yachts for a clientele that demands the latest technology, craftsmanship and advanced yachts. In this context, some of the most important shipyards are: Ferreti, Hanse yachts, Pardo yachts etc.

2.2.2 Lean manufacturing in yachting companies

It has been seen that lean manufacturing is not a philosophy that is very widespread in the luxury yacht building industry, which is why, in this section, we will first discuss whether or not lean can be applicable in luxury shipyards, and to do so we will comment on the main characteristics of this industry and whether it is possible to adapt lean to these characteristics. Then, in a more specific and pragmatic way, we will go on to analyse the techniques described above in the lean manufacturing section, so that they can be of help to companies wishing to enter the world of lean and increase their productivity and efficiency.

2.2.2.1 Characteristics of the luxury shipyard manufacturing industry

Firstly, I would want to comment some insights of the type of production strategy shipyards follow. In this particular sector "Make to order" (MTO), used in the context of shipbuilding and the yachting industry, refers to a manufacturing approach in which shipyards produce a yacht just when it's ordered by a customer and defines its specifications. This indicates that neither pre-built nor stocked boats or yachts exist; rather, each boat is individually designed and constructed only once a buyer has placed an order.

In the article (Sharma and Gandhi 2017) they comment on some of the limitations or specific characteristics that shipyards have. In this work, they comment on how shipyards are still today an industry that is not very technologically developed or is in its infancy, and therefore there are still very traditional ways of manufacturing, in which there is a lack of specialisation or standardisation in the processes, as well as the difficulty in automating processes.

In (Ponticelli et al. 2013) state that shipyards are known for creating intricate, specialised and one-of-a-kind ships. The rigorous engineering and systems integration involved in these projects adds to their overall complexity. In addition, the handling

of massive and expensive components throughout the production process increases the logistical and financial complexity of the shipyard's operations.

The yacht building business, according to the authors of (Phogat 2013) is known for its high level of customisation, as each vessel is built to the owner's specifications. Due to state-of-the-art technology and luxurious features, the components of yachts are huge and complicated. The construction of yachts requires complicated engineering, and their size increases the difficulty of the job.

2.2.2.2 Applicability of lean manufacturing techniques applied in shipyards

Therefore, having seen in the previous section, which are the characteristics of the luxury boat manufacturing industry, in this section we will review the techniques described in section 2.1.2 in which we analysed the most used techniques in the industries, which could help to improve productivity and help companies to meet the demand.

In Article (Phogat 2013) the writers examine the methods that are frequently used in the shipbuilding industry and consider how lean concepts may be applied there. In this article it was analysed how much lean is applied in Japanese, Norwegian and US shipyards. Firstly, they focused on the implementation of the pull system and Just-in-Time (JIT), emphasizing how well-established these practices are in Japanese shipyards. The yacht manufacturing model, which is highlighted by the writers, is dependent on client orders; as a result, ship building doesn't start until the customer placed an order. Because of this, this industry finds use for both JIT and the pull system. In addition, the writers highlighted that the Japanese shipbuilding industry improved its productivity by 150% when they started implementing some of the lean principles.

The authors also examine in the same study the procedures used in shipyards in Norway and the United States. Surprisingly, it was found that both nations have incorporated 5S concepts into their manufacturing and warehousing operations, despite the relative lack of awareness of the lean mindset in both locations. This demonstrates the value of the 5S methodology as a key element in increasing productivity and efficiency in these shipbuilding industries.

In the article (Lang et al. 2001) an empirical study was conducted on whether the implementation of lean manufacturing techniques can help shipyards to be more competitive and improve their production. The authors emphasised that in order to start applying the lean philosophy in a company from scratch, the most important thing is to have a global vision of the state of the company, which is why they used a Value Stream Map to be able to know the current state of the shipyard and to be able

to apply lean manufacturing principles. In order to do this, the authors first advise to carry out a VSM in two parts. The first part is a current state map, which focuses on the main sources of waste. Subsequently, a future state map will be carried out in which the focus will be on more specific lean manufacturing techniques that will improve the overall efficiency of the company.

Despite a lack of literature specifically dealing with Total Productive Maintenance (TPM) at shipyards, certain articles—such as those cited in (Storch and Lim 1999; Tan et al. 2020) emphasize the need of reducing machine failures throughout the shipbuilding process. The significance of developing a preventive maintenance system to guarantee uninterrupted output and cost savings in shipyard operations is implied by these references.

3. Discussion

To begin the analysis of the results, I would like to return to the research questions or objectives stated at the beginning. The overall objective of this thesis focuses on assessing the feasibility of employing lean manufacturing methodologies to cope with the emerging increase in demand for yachts in shipyards. To this end, we asked two essential questions. The first focused on whether the implementation of lean manufacturing practices in a company would have positive results for its productivity, eventually enabling the company to meet the growing demand. The second question explored the applicability of these techniques in the niche of luxury shipyards, considering the specific attributes of this industry. The points presented above will be discussed below.

After having established the research objectives and questions, several articles were analysed to try to answer these questions, firstly to see if lean manufacturing could be of help to respond to the incipient increase in demand, It has been analysed papers and looked at which lean manufacturing techniques were most widely used in companies around the world, concluding that Total Productive Maintenance (TPM), Just in Time (JIT), Kanban, Kaizen, 5s, Visual Stream Map (VSM), and Pull system were the most widely used. Of these techniques, the only one that we could say, that is not specifically a tool in itself, is Kaizen, which as we have seen during the work, can be likened more to a philosophy of work, in which certainly can be based much of lean, and continuous improvement, as mentioned in the article (Palange and Dhattrak 2021), Kaizen, is a key pillar of lean manufacturing since as discussed in this article, the philosophy of continuous improvement should be applied at all levels of the company, so that the whole company, improves in altogether, and that this way of working and implementing changes, serves as a basis for the application of the tools that are necessary for a company, to improve its productivity and efficiency. Personally I think that the kaizen philosophy is a necessary tool if a company wants to improve, because it is easier to make small changes and implement them over time than to make big, sudden changes.

Along with the Kaizen philosophy, in literature we also find nowadays a tool used to know what is the current state of a company and to know where improvements can be made and where bottlenecks or unnecessary expenses are occurring, this tool is called Value Stream Mapping. (VSM). I believe that companies that wish to start improving their processes, but perhaps do not know where to start, VSM can be a very useful tool, as it offers the possibility of knowing in a simple way what is the overview of a company or a production process and know its limitations, and thus know where to put the focus of attention, and for the case at hand, where we can apply modifications and implement improvements to increase the productive capacity of a company and meet the demand.

On the other hand, another technique that it should be prioritise when trying to implement lean in a company would be TPM or Total Productive Maintenance. In the article(Leksic, Stefanic, and Veza 2020) classify this tool as one of the most important when initiating a transition to lean. This statement is due to the fact that a system of failure prevention and maintenance of the tools and machines used in a productive process is basic for a company and for the correct functioning of the same, since many times more time is spent repairing a big problem than carrying out the correct maintenance.

Thirdly, in the articles studied, importance is also given to the implementation of 5s, which as we have seen is a lean tool used to provide a method for creating, maintaining and managing an effective working environment. As with the lean tools mentioned above, at first glance they do not seem to be specifically focused on improving the productivity or efficiency of a company, but they do play a secondary and essential role in making work effective. In the case of 5S it is not complicated to understand that a clean and tidy working environment motivates people to work with a better attitude and productivity, since the employee focuses on working and performing their tasks and not on fighting with the mess of their workplace. All this is also corroborated in the article (Ruiz et al. 2019) mentioned in previous sections, where the application of 5S achieved a noticeable improvement in productivity and a higher percentage of demand was met.

Finally, we have chosen to bring together the last 3 techniques and discuss them as a whole, as they are closely related to each other, and the concepts they deal with go hand in hand with each other. We are talking about Just in Time, Kanban and the Pull Production System. Firstly, the pull production system, as we have seen, is a system that starts up work according to consumer demand, and which is normally applied together with kanban, which is an indicator used by pull systems to show the demand for supplies or work. And by using these two previous tools we could obtain in a productive process the so-called Just in time, which is nothing more than having what

is necessary at the right time. These three tools when applied correctly do have a direct impact on the productive system of a company, improving efficiencies and helping to meet the demand of a company as reflected in the articles of (Ramirez-Peña et al. 2019; Sadiq et al. 2021).

We will then go on to discuss whether the above techniques can be of use when applied to the shipbuilding industry and shipyards, and thus help them to meet the increase in demand. The analysis will be divided into two parts, firstly, the feasibility of applying these techniques, taking into account the particularities and limitations of the yacht building sector, and secondly, some general recommendations about other ways in which shipyards can improve and perform their work more efficiently.

First of all, focusing on the specific techniques that have been mentioned, we are going to make an introductory mention of those that are unanimously the easiest to apply, putting ourselves in the shoes of a shipyard that wishes to start using lean. These include Total Productive Maintenance, 5S, Visual Stream Mapping and Kaizen. We will start by discussing the Kaizen philosophy. It has already been said several times during this project that continuous improvement is not a tool, but a way of working and a work philosophy, which is necessary when implementing lean in a company. Particularly, referring to the case of lean implementation in shipyards, in the article (Prause 2017), the authors conducted several case studies in which they asked themselves what level of lean existed in the North German shipyards. They found for the particular case that the level of kaizen in these shipyards was very low, and that they had not stopped to think about it, however, they also comment that the companies they asked did not raise any objections about employees participating in the process of continuous improvement. Therefore, even if continuous improvement is not a popular improvement strategy among shipyards, it could be argued that it can be a valuable tool, if a company wants to impose changes or its ways of doing things, because as mentioned above, it will always be easier to apply constant and a priori small changes, than sudden and big changes.

Regarding the use of a Machine Maintenance System or TPM, as with continuous improvement, there is not much literature or interest in this lean tool, however, obviously, shipyards that want to maintain certain quality standards and be consistent in their manufacturing show interest in keeping their machinery running at full capacity and without sudden stops. As mentioned in the articles (Storch and Lim 1999; Tan et al. 2020) where they refer to the need to work towards avoiding downtime due to tool failures to a greater extent. It is therefore trivial to deduce that a system that tries to avoid sudden machine stoppages by means of simple maintenance is very beneficial for the productivity of a company, since the time "lost" in the maintenance

of the machines will always be shorter than that of a stoppage due to mechanical failure of the same.

Contrary to what happened with TPM, 5S is a tool that is used and valued among shipyards. Specifically in the article (Phogat 2013) the authors talk about the implications of lean in Japan, USA and Norway. They stress that, although in Japanese shipyards, lean is more than implemented and widespread, in Norway and the USA it is not so widespread, however, 5S is a tool that is used and well known in the shipyards of these countries and does not present any impediment.

Another tool that could be applied initially in shipyards is Value Stream Mapping. This would be used as a background to focus our efforts on the improvement of any part of the production process of a company, VSM would be a tool for general visualisation of the state of a production process. This tool would not imply any difficulty when applying it in a shipyard, as seen in the article (Lang et al. 2001) where the authors conducted an empirical case study where they successfully applied VSM in a shipyard, obtaining as a result improvements in efficiency and reducing waste in production.

Afterwards, having analysed VSM, TPM, 5S and kaizen, as tools that are easy to implement and necessary in the initial phase of transition towards becoming a lean company, we will go on to analyse more specifically the techniques related to production processes, such as the pull system, kanban and Just in time, remembering that we are studying the application of these techniques with the objective in mind of improving the productivity and efficiency of the company in order to satisfy the increase in demand in the sector.

As mentioned in previous sections, these three are closely related, as they are three ways of achieving the same objective. As for the pull production system, it has been previously mentioned, as it is a way of manufacturing in which production begins when the order is received by the customer, in order to save inventory and reduce stocks. Specifically, in this case, most of the shipyards in the world work in this way: Make to Order.

Therefore, if a pull production system is applied in shipyards without problem, they should also try to produce following the JIT system of producing what is needed only when it is needed. To achieve this, lean traditionally employs the use of the kanban tool is used to achieve JIT in manufacturing companies (Wakode et al. 2015). However, for the case at hand, applying kanban directly in luxury shipyards might have some difficulties. Given the current characteristics of the shipbuilding sector, most of them, either because they are traditional in their way of manufacturing or because of the diversity that characterises the sector, shipyards often lack standardisation in

manufacturing processes, which is a necessary element when applying kanban. One of the factors for which there is low standardisation in the shipyards is that generally yachts are highly customisable and there are many optional elements that change according to each client, so that practically every yacht that is manufactured is different from the previous one, making it difficult to achieve the desired standardisation in order to be able to apply kanban.

To ensure that each yacht produced is as similar as possible to each other. The articles (Ponticelli et al. 2013; Wong 2021) state that shipyards can employ a tool called “postponement” to reduce variability and standardise as much as possible, defining postponement as: A strategy employed by yacht builders to intentionally delay making supply chain decisions until the last moment. This involves keeping generic specifications and items in stock and assembling components on the finished yacht only when customer demands are confirmed. The authors also comment that through postponement, companies have additional time to modify products to meet customer demand.

Therefore, to conclude the discussion of results, the main tools that luxury shipyards can apply to respond to the incipient increase in demand have been answered during the discussion, always taking into account the particularities of this sector and considering the limitations in terms of the quantity of existing articles. With all this information, shipyards wishing to enter the world of lean manufacturing will have information that will serve as a starting point to improve the performance of their processes.

4. Conclusion

This paper has tried to respond to the need of luxury shipyards to cope with the increasing demand for yachts. For this purpose, from a theoretical point of view, we have tried to respond by applying lean manufacturing techniques to improve the productivity of the shipyards in order to meet the growing demand. Therefore, first of all, it has been discussed which lean techniques, according to the literature, can help to improve productivity in the context of a growth in demand. Then, the characteristics of the luxury shipyard sector have been presented and, among the selected techniques, the benefits that this sector can obtain from these techniques have been seen. These techniques include Total Productive Maintenance (TPM), Just in Time (JIT), Kanban, Kaizen, 5s, Value Stream Map (VSM), and Pull system.

From a theoretical point of view, one of the main limitations encountered when answering the questions posed in the thesis is the scarcity of information and the limited number of articles related to the application of lean manufacturing in the luxury shipyard sector. Moreover, for the analysis of the techniques, the project has analysed only the most used ones, so not all the existing techniques have been covered. So the conclusions drawn in this work have these limitations.

From a production point of view, it has been shown that some of the lean manufacturing techniques could have certain limitations when applied, such as the Kanban System, which, due to the variability and lack of standardisation characteristic of the naval sector, could have difficulties when it comes to its implementation. However, some possible solutions to this problem have also been offered, like “postponement” or encouraging companies to standardize their processes.

Future developments from this research could be directed firstly to further investigate the implications of lean in the luxury yacht manufacturing sector to facilitate the analysis of such techniques and promote the use of lean in the marine sector. Secondly, this proposal would need further research to provide more certainty, in particular, a case study would help to specify the necessary guidelines for the application of lean techniques and their implications for productivity improvement and the implications they may have on demand satisfaction.

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