INSTITUTO POLITÉCNICO DE BRAGANÇA
Escola Superior de Tecnologia e Gestão

Maturity Assessment Of Lean Manufacturing Tools In Catraport With Data Visualisation Of Overall Equipment Effectiveness

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Master in Mechanical Engineering

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Dedication

To my dear father *Habib*, whose memory continues to inspire and guide me. Your values, wisdom, and love are deeply ingrained in my heart, and I dedicate this work to you with profound respect and everlasting gratitude.

To my dear mother *Neila*, for her love, sacrifices, and support in the most difficult moments, which are at the origin of my success, thank you for being the mother and the father. May God keep and protect her.

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To all my relatives who, actively or not, participated and helped in the accomplishment of this work.

It is with great pleasure, I dedicate this modest work to you.

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Resumo

Esta tese investiga a avaliação da maturidade da produção optimizada na fábrica da Catraport, que revelou desafios operacionais significativos devido a um sistema de empurrar e a uma gestão inadequada do armazém. As principais questões incluíam o excesso de stock, a falta de gestão visual, as ineficiências organizacionais, as preocupações com a segurança do transporte e as restrições de espaço, identificadas através de ferramentas como o diagrama de Ishikawa e a análise 5W1H. Foram formulados objectivos SMART para resolver estas questões, centrados na redução dos movimentos de contentores, na melhoria dos sistemas de prateleiras e etiquetagem, na implementação da gestão visual e no reforço das medidas de segurança no prazo de seis meses. Foram desenvolvidos um plano de ação detalhado e um diagrama de Gantt para uma implementação sistemática. O estudo também salientou que os dados médios semanais relativos à eficácia global do equipamento (OEE) têm limitações. Recomenda a passagem para a monitorização em tempo real e a utilização de tecnologias IoT da Internet das coisas e de sistemas SCADA de controlo de supervisão e aquisição de dados para uma melhor análise. Sugeriu a implementação de um sistema de relatórios visuais e de uma plataforma de dados baseada na nuvem para centralizar os dados operacionais, facilitando a análise das métricas de produção, manutenção e qualidade.

Palavras-chave: Lean mangement, PDCA, Ishikawa, 5W1H, OEE, SMART. .

Abstract

This thesis investigates the maturity assessment of lean manufacturing at Catraport factory revealed significant operational challenges due to a push system and inadequate warehouse management. Key issues included overstocking, lack of visual management, organizational inefficiencies, transport safety concerns, and space constraints, identified through tools like the Ishikawa diagram and 5W1H analysis. SMART objectives were formulated to address these issues, focusing on reducing container movements, enhancing shelving and labeling systems, implementing visual management, and strengthening security measures within six months. A detailed action plan and Gantt diagram were developed for systematic implementation. The study also highlighted that weekly average data for Overall Equipment Effectiveness (OEE) has limitations. It recommends moving to real-time monitoring and using internet of things technologies and Supervisory Control and Data Acquisition systems for better analysis. It suggested an implementation of a visual reporting system and a cloud-based data platform to centralize operational data, making it easier to analyze production, maintenance, and quality metrics.

Keywords: Lean management, PDCA, Ishikawa, 5W1H, OEE, SMART.

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Acronyms

This document contains some abbreviations which are defined here.

SOW	Scientific Organization of Work
WIP	Work in Process
OEE	Overall Equipment Effectiveness
JIT	Just In Time
TPS	Toyota Production System
QM	Quality Management
VSM	Value Stream Mapping
5S	Sort, Set in order, Shine, Standardize, and Sustain
PDCA	Plan, Do, Check, and Act
FIFO	First In First Out
5W1H	What, Who, Where, When, Why, and How
SMART	Specific, Measurable, Achievable, Relevant, and Time bound
KPIs	Key Performance Indicators
IoT	Internet of Things
SCADA	Supervisory Control and Data Acquisition
BI	Business Intelligence

Chapter 1

Introduction

At the beginning of the 20th century, a new system of work organization called Scientific Management emerged. It was based on a radical separation between the conception and execution of tasks, and the fragmentation of activities, leading to the specialization of workers assigned to a fixed workstation and elementary operation. This approach later evolved into large-scale production and mass consumption. In the face of increasingly fierce competition, globalization of markets, growing consumer demands, and an inability to raise prices, organizations are increasingly forced to improve their productivity, service, and quality. Employers seek ways to ensure the participation of experienced production employees who understand customer service needs. The evolution of organizational models tends towards the disappearance of supervisory personnel, compelling many organizations to seek new working methods. The Japanese were the first to realize this significant turning point and made efforts to move forward. For this purpose, the principles of a more flexible and streamlined management model were put in place to adapt companies to the turbulence of competition and the new demands facing organizations from all sides. This model is lean management. Indeed, improving quality and increasing productivity require the comprehensive application of its principles to better control production stages and ensure quality. It can be said that the winning company is the one that begins by mastering the principles of lean management and their application. Organizations are always searching for new ways to increase productivity and product quality while reducing costs. Currently, an organization's potential for success lies in its ability to have the right knowledge in the right place at the right time, hence the utility of having several reliable tools that can provide organizations with competitive advantages and open paths for performance improvement. It is recognized that the concept of Just In Time (JIT) manufacturing developed just after World War II in Japan within Toyota's automobile manufacturing plants. Workplace flexibility has been ensured through innovation in work organization, the valorization of human resources, and the ability to anticipate techniques to succeed in the face of evolving needs and markets. The principles brought by lean management are important levers for creating value and eliminating waste in any organization. This thesis explores lean manufacturing's history and its application within Catraport, examining its maturity level. Notably, warehouse operations face significant challenges due to limited space, requiring frequent container movements. This disrupts organization and hampers inventory management and order fulfillment. Additionally, the absence of robust visual management systems complicates product identification, leading to inventory errors. Transport issues and security concerns further compound these challenges. Addressing these issues is vital for enhancing productivity and leveraging lean management principles for operational excellence at Catraport.

1.1 Theoretical framework

Early 20th century, scientific management introduced a novel system of work organization, emphasizing the division between task conception and execution. This approach, later evolving into mass production and consumption, necessitated specialization among workers and fixed workstations. In the modern context, organizations face escalating competition, globalized markets, and heightened consumer expectations, compelling them to enhance productivity, service, and quality. Lean management emerged as a response, originating in Japan as a means to adapt to competitive turbulence. Its principles, aimed at improving quality and productivity while minimizing waste, have become crucial for organizational success. JIT manufacturing, a concept born in post-World War II Japan, further underscores the significance of flexibility and innovation in organizational processes. The principles of lean management serve as vital tools for value creation and waste elimination across diverse organizational contexts.

1.2 Objectives

This thesis aims to explore the history and application of lean manufacturing within Catraport, with a focus on assessing its maturity level. Specifically, it seeks to address the challenges faced by warehouse operations due to space constraints and frequent container movements, which hinder inventory management and order fulfillment. Additionally, it aims to tackle issues related to product identification, inventory errors, transport inefficiencies, and security concerns. By addressing these challenges, the objective is to enhance productivity and leverage lean management principles for operational excellence at Catraport. It explores also a data visualization of Overall Equipment Effectiveness (OEE), presenting some case studies and developing some solutions for improvement.

1.3 Document structure

In addition to this general introduction, this thesis is structured into 6 chapters:

Chapter 2: Literature review, explores lean manufacturing and provides an in-depth examination of lean manufacturing, its historical evolution, principles, tools and different type of wastes. It offers a comprehensive understanding of lean management's theoretical basis and practical implications.

Chapter 3: Maturity assessment of lean manufacturing in Catraport, this chapter includes a brief presentation of Catraport and focuses on assessing the maturity level of lean manufacturing implementation, presenting results that highlight the prevalent issues within the warehouse.

Chapter 4: Analysis and suggested solutions, this chapter examines the challenges faced by warehouse operations, including space limitations, inventory management issues, and transportation inefficiencies, offering a detailed case study of the Plan-Do-Check-Act (PDCA) cycle. This includes a deep analysis of anomalies using Ishikawa diagram and 5W1H, goal setting, action plan formulation, checking progress, and strategies for effective implementation.

Chapter 5: Results and discussion, this chapter shows the results of the analysis of the past section and explores data visualization techniques to present the OEE at Catraport. It provides visual understanding into equipment performance, downtime, and efficiency levels, facilitating a deeper understanding of operational dynamics and opportunities for optimization by suggesting some solutions for improvement within the organization.

Chapter 6: Conclusion, this chapter provides a comprehensive conclusion to the topics discussed in the previous chapters.

Chapter 2

Literature Review

This chapter explores how lean management came to be. It looks at its beginnings during times like Taylorism and Fordism, and how it grew into what is called Toyotism. It also shows how culture played a big role in shaping lean. It talks about the main ideas of lean, like reducing waste, and the tools it uses to make things better in factories.

2.1 History of lean manufacturing

A brand-new method of work organization known as scientific organization of work emerged at the start of the 20th century. Its foundation was a sharp division between the planning, carrying out, and finishing of tasks and the actions themselves, which resulted in the specialization of employees tethered to a stationary workstation and a simple operation. Lean manufacturing, lean production or often simply Lean, is a production practice that considers the expenditure of resources for any goal other than the creation of value to be wasteful and thus a target for elimination. From the perspective of the customer, 'value' is defined as the price for which the customer would be willing to pay for. The lean concept is not a new one, originating from the end of 19th century and the beginning of the 20th century, with the development of the production systems by Henry Ford and other producers. A brief overview over the evolution of lean management over the years is offered by figure 2.1. Key contributors to the evolution of the lean concept such as Eli

Whitney, Taylor, Gilbreth, Henry Ford, Shingo and Ohno will be mentioned and discussed in the following sections.

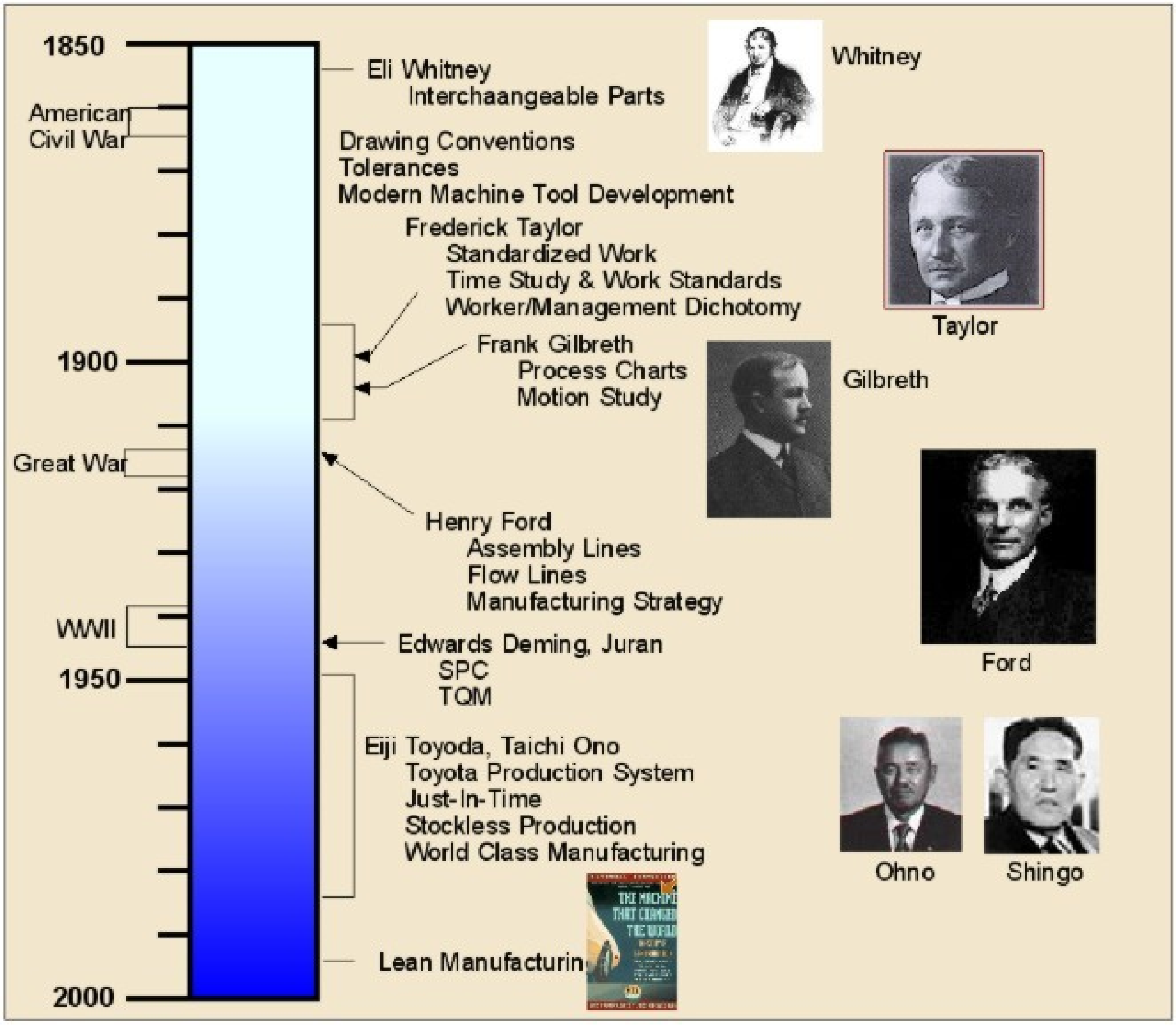

Figure 2.1: The evolution of the lean management over the years [1]

In today's competitive world, there are so many companies who actually develop their own area with few resources. At the end, they need more beneficial from the manufacturing of the product department. Means there are so many businesses, which opted few resources to get more benefits from it. One of the best ways to increase the effectiveness and efficiency of the product is to adopt the lean management technique. The manufacturing service, for profit, not for profit, education and health businesses can be improve through the help of this technique. There are number of businesses, which depend on the small industries. So the big industries are using fundamental components to define their importance in a different way. Different industries have been implementing the lean approach for producing better product in less time with fewer efforts [2], [3].

2.2 The roots of lean

Since the 1980s, numerous business models have emerged to guide managers in running their operations. While many of these models appeared conceptually sound, only a few offered sustainable and practical implementation strategies. Prior to this era, managers, consultants, and academics struggled with improving or replacing existing business processes, lacking a comprehensive toolbox for successful transformation. In the late 1980s, companies looked to Japan, a rising manufacturing powerhouse, for inspiration. Industry leaders like Toyota, Nissan, Sony, and Honda not only dominated the Japanese market but also expanded their influence in North America and Europe. This rapid ascent prompted other market players, consultants, and academics to study how these companies designed, implemented, and operated their manufacturing systems, eventually termed "lean production" processes. The origins of lean production can be traced to Western concerns about Japanese manufacturers, particularly in the automotive industry, gaining an insurmountable competitive edge. In response, academics and Western competitors embarked on benchmarking activities to uncover the secrets of Japanese success. The findings culminated in the publication of "The Machine that Changed the World" by Womack, Jones, and Roos in 1990. For Western manufacturers, this seminal work provided crucial insights into the Japanese model's efficiency, emphasizing reduced effort and resource utilization across the manufacturing cycle: less inventory, less space, and less capital investment [4].

2.3 The history of industrial production: Taylorism, Fordism, Toyotism

2.3.1 Taylorism

Taylorism is the science of dividing specific tasks to allow employees to complete assignments as efficiently as possible. The practice of Taylorism was first developed by Frederick Taylor who desired to obtain the most efficient practices in the workforce [5].
The principles of Taylorism:

- The best one way,
- Double division of work(vertical and horizontal),
- Performance pay and time control,
- Coordinating work through functional hierarchies.

2.3.2 Fordism

The Ford T was invented by Henry Ford (1863 - 1947), founder of the company of the same name, in 1908, taking the principles of Taylorism or Scientific Organization of Work (SOW) and adding other concepts [6].
The principles of Fordism:

- Standardization,
- The assembly line,
- Increasing workers purchasing power.

2.3.3 Toyotism

Toyotism is a form of work organization designed to reduce production costs, avoid overproduction, cut lead times and produce the best possible quality. Based on JIT production and new management rules. It's an improvement on the two previous modes of organization Taylorism and Fordism [7].

2.4 Different strategy of production

Production strategies can be categorized into three distinct types. Each type has its own unique approach and set of practices, advantages and disadvantages.

2.4.1 Push system

The push-type system can be described as a top-down planning system because all production quantity decisions are derived from forecasted demand in the master production schedule. The system produces as many parts as previously forecasted. The parts are released to the next station as quickly as possible to avoid starvation at the downstream stations. This characteristic enables the system to reduce delivery lead time since many semi-finished or finished products are available. Medium to large variation of demand may not cause any chaos because semi-finished products are kept at each station. The push-type system is better for planning and controlling production activities. However, it causes high volume of Work in Process (WIP), both in the form of semi-finished and finished products. As a result, the system suffers from high inventory holding cost [8].

2.4.2 Pull system

The pull-type system drives productions based upon customer demand (as opposed to forecasted demand). Each station can be viewed as an isolated station with its own supplier (the upstream station) and its own customer (the downstream station). When a customer order is placed, it will be fulfilled from the finished product inventory. As soon as the finished product is pulled from this inventory, a signal (or kanban) is generated to trigger production of the upstream station in order to replenish the finished product inventory. Similar procedures take place until the first station, where it pulls raw material from the raw material storage. The pull-type system can reduce WIP significantly. However, the system may not work well in an environment with medium to large demand variation because there is not enough semi-finished inventory kept. This in turn may result in a significant back order. In addition, the pull-type system often has longer delivery lead time than that of the push-type system, thus higher delivery late penalty costs [9].

2.4.3 Hybrid push/pull

The hybrid push/pull system is recently introduced. This system compromises the conflicting performance characteristics from both push- and pull-type systems so that a better system performance can be anticipated. This hybrid system is commonly found in any assemble-to-order environment. In this environment, raw material can be transformed into common semi-finished products at a point where next downstream operations are controlled by customer orders. Therefore, the production of the earlier upstream stations is controlled by push-type production, while the production of the later downstream stations is controlled by pull-type production [10].

2.5 Overall Equipment Effectiveness

The OEE metric has been long used for determining the productivity of machines in manufacturing systems. Centered on Total Productive Maintenance principles, the OEE metric is the product of a machine's availability, performance, and quality. Each of these three factors are typically calculated from different sets of information. With the abundance of data obtained from the production floor nowadays resulting from the ongoing technological advancements, important information related to the OEE metric and its factors could easily be overlooked [11]. To this end, this work proposes an Industry 4.0 perspective for presenting OEE data, allowing better visualization and analysis. As an implementation, data from a single machine within a short period of time in a practical industrial setting was used. Based on the performed analysis, recommended actions were

provided to improve production efficiency and reduce quality issues [12].
OEE is the product of 3 other simpler indicators:

OEE= Availability * Performance * Quality [13].

2.6 The evolution of lean management – a cultural trace

The evolution and history of lean management can be traced back using different determinants. Nevertheless, the following sections focuses on offering a cultural standpoint of the history of lean management over the years.

2.6.1 The American contribution

Eli Whitney's introduction of interchangeable parts marked a significant step in the development of Lean production and JIT principles. While Whitney gained fame for inventing the cotton gin, his advancement of interchangeable parts proved to be more pivotal for industrial evolution. Although the concept of interchangeable parts predates Whitney and can be traced back to Chinese emperor Qin Shi Huangdi in 221 B.C., Whitney refined it in 1799 when he secured a contract from the U.S. Army to produce 10,000 muskets at an unprecedentedly low cost of 13.40 Dollars each [14].

The adoption of interchangeable parts by companies like Cadillac and Chrysler led to increased production volume and speed. However, until 1850, armories faced challenges in producing standardized metal parts due to limitations in technology, resulting in significant manual effort to ensure accuracy. It wasn't until the late 1890s that the approach to production began to change with the emergence of industrial engineers like Frederick W. Taylor.

Taylor's focus on individual worker analysis and job methods resulted in the development of time study and standardized work, which he introduced as part of Scientific

Management or 'Taylorism'. Despite facing criticism for his scientific approach to management, Taylor remained dedicated to improving economic efficiency, particularly in productivity [15]. Frank Gilbreth further contributed to lean history with motion study and process mapping, aiming to reduce worker's movements and standardize processes [16], [17]. Gilbreth's wife, Lilian Gilbreth, introduced psychology into the field, studying worker motivation and its impact on processes. Together with other contributors, including Taylor, the Gilbreths emphasized the importance of eliminating waste, a foundational principle to JIT production and Lean methodologies.

Henry Ford's introduction of the Model T revolutionized production with its efficient assembly line, reducing the time to produce a car to just 93 minutes by 1910. Ford's management approach was heavily influenced by Taylor's scientific management theory. However, despite Ford's success, his production system faced challenges from future Japanese competition, signaling the need for further evolution in production methodologies.

While Ford's achievements inspired competitors, many failed to replicate his methods due to their inability to grasp the fundamental principles behind his approach. Ford's legacy lies not only in his groundbreaking production techniques but also in the enduring principles that continue to shape modern manufacturing processes.

2.6.2 The Japanese contribution

While Ford's mass production system thrived during America's economic growth, Toyota Production System (TPS) proposed an alternative approach focused on maximum economic efficiency with minimal resources. TPS aimed to eliminate waste, encompassing activities that didn't add value to the product, such as overproduction, stocks, transport, waiting time, stocking space, maintenance/errors, and supply time. The TPS principle centered on continuous improvement of standards.

Ford relied on industrial engineers to define work standards, while Toyota empowered workers in Gemba (the production area) to alter standards [18]. Taiichi Ohno, Shigeo Shingo, and Eiji Toyoda developed TPS between 1948-1975, originally known as JIT

Production [4].

The Japanese automobile industry faced challenges against American dominance until the introduction of the Enterprise Law in 1936, which supported Japanese truck producers like Toyota, Nissan, and Isuzu. Toyota aimed to adapt the American mass production system but encountered resistance from employees still loyal to traditional production techniques.

Toyota's pivotal moment in Lean concept evolution came from internal productivity improvement efforts after World War II. Combining Taylorism elements with specific company strategies, Toyota focused on production flow, multitasking, and system establishment. The company overcame challenges such as overproduction and waste, which threatened bankruptcy, by delivering automobiles to the American army during the Korean War.

Toyota further progressed with the arrival of Quality Management (QM) pioneers in Japan: Edwards W. Deming (1950) and Joseph M. Juran (1954). Deming introduced Statistical Quality Control and the 'Deming circle': Plan, Do, Check, and Act, laying a solid foundation for Japanese quality standards [19].

Juran, the second player on the Japanese quality scene, made his appearance in 1954 bringing essential contribution in the areas of:

- Defining the QM System, which is a basic requirement for every company producing material goods and services,
- Using the Pareto principal in control quality. It must be remembered the Pareto principal was created in 1906 by the Italian Vilfredo Pareto who observed that 20% of Italy‘s population owned 80% of its territory,
- Non-quality cost study: 'Juran Trilogy' defined quality components like planning, control and quality improvement [20].

At the end of the 1950s, Toyota introduced a stock gestation system named Kanban, in translation 'card', which was supposed to reduce the waste created in stocks [18].

As a result of the TPS success, Toyota was supposed to invade the American automobile market and place themselves amongst top companies like Ford and General Motors. Another factor that contributed to Toyota‘s company development and the LEAN Management, was the Japanese engineer Shigeo Shingo. Shingo created the SMED method and the ’Non-Stock Production’ system. This system was created in 1975 and means cutting the strings of the stock products and the necessary space and their cost [21].
Single Minute Exchange of Die is a method applied for the first time in Toyota Company and follows a reduction in the setting time of equipment. The method was successful, with the setting time being reduced from 1-2 hours to just a few minutes. Related to this method is the ’six Sigma’ concept developed by Motorola in 1985, which came to the world‘s attention in 1995 when it was introduced by General Electric company via Jack Welch. Six Sigma improves process quality by identifying and eliminating defections.

2.7 Principles of Lean

Atkinson (2010) proposed that the central theme for lean is to exploit customer value through reducing the wastes that are generated within an organization. In essence, lean attempts to generate more value for its customers, whilst utilizing less resources. The lean ideology develops from an attempt to widen the organizations’ remit by attempting to persistently improve the customer value (Clarke 2011). In order to achieve this, the organisation has to alter its focus from vertical transformations to a situation where by the products of the complete value streams flow horizontally across the various functions towards the customer. The literature, Bicheno and Holweg (2009), Camp (2013), Womack and Jones (2005), and Marksbury (2012), is abundant, suggesting that there exist five essential principals to lean, namely:

1. Identify the customers and specify the value, clearly define value for a product in view of the customer’s perspective; targeted attempts to waste reduction can occur,

2. Proceed to categories and map the value stream which essentially comprises of all

the collective activities used to deliver the end product,

3. Improve the flow by eradicating the waste which assists to reduce the lead time of delivery,

4. Be responsive to the customers' demand schedules,

5. Improve the flow by eradicating the waste which assists to reduce the lead time of delivery,

6. Continuously pursue perfection.

The figure 2.2 shows the principles of lean by presenting the methodology and the customer needs .

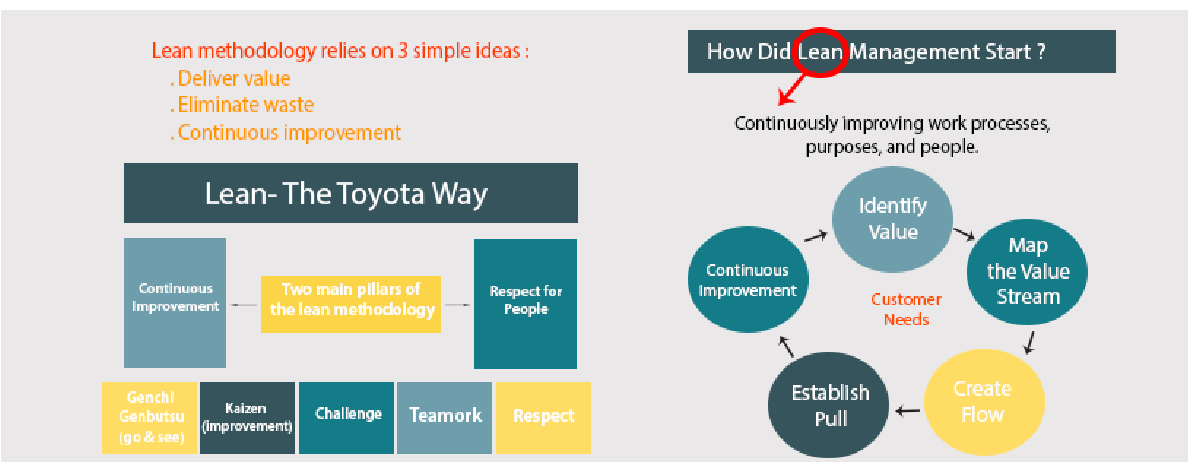

Figure 2.2: Principles of Lean

One considers that the a prominent and overall challenge faced by lean organizations is to develop a culture which assists to both generate and maintain a long-term obligation from senior management towards the entire workforce [22].

2.8 Different types of Wastes (Muda)

2.8.1 Definition

The aim of lean is to abolish the waste from the production process. It is very important to identify the eight waste before digging it. Waste is in the least action or activity that will not enhance any cost to the product, or we can say, waste is any unwanted process that will reduce the value of the product and customer do not want to pay for that.Taiichi Ohno identified the initial seven types of waste that was called Muda in japan [21]. Transportation, inventory, movement, waiting, overproduction, over-processing and defects are seven types of waste identified by Taiichi Ohno. The acronym "TIMWOOD" also applies to them. The eighth waste wasinvented by western industries in 1990s, and that was unused of workers talent or ‘Skill’of workers was later added. Therefore, "TIMEDOWN" [23] is generally referred to as the 8 wastes [24] as represented in the figure 2.3.

Figure 2.3: The 8 wastes of lean Muda [25]

1. Defects: The product is not manufactured as per the specifications and tolerances

given by the customer. Those products are rejected in quality inspection and consider as waste. Product/material will reject when the product/material is not suitable for use. Due to defective product/material it will loss of money and defective piece will not be reused [26]–[28].

2. Overproduction: Excess of production over consumption. In market demand is less compare to the consumption, but industries are manufacture more to reduce the manufacturing cost. In this case inventory cost is increase and money is also block. So, it is considered as a waste. Overproduction means manufacturing additional goods via a 'push production mechanism'. Three countermeasures to develop overproduction. Firstly, by use of 'Takt Time' confirms that the production rate among workstations is continue. Secondly, reducing idle time like loading and unloading, setup times. Thirdly, reduce the WIP by using a pull or 'Kanban' system [29]–[31].

3. Waiting: These are time delay and idle times during which value is not added to the product. If the machines, men, and material wait it is waste of these resources and it demoralizes the employees. The waste of waiting includes [27], [28]:

   - Operator is waiting for his turn and not receive material on time,
   - Machines are idle due to line unbalance.

4. Transport: Unwanted movement of the product during manufacturing. It is caused due to unplanned layout and product are unnecessary move from one workstation to other. In addition, excessive movement causes fatigue, wear and tear of product and equipment's [32], [33].

5. Inventory: refers to the surplus stock of materials, products, or components that are not being used, are defective, or are no longer needed in the production process, representing a type of inefficiency within a business operation. This includes excess raw materials, WIP, finished goods, obsolete items, and defective products. Waste inventory is caused by overproduction, poor demand forecasting, inefficient processes, supplier issues, and quality problems, leading to increased storage costs,

tied-up capital, risk of obsolescence, and reduced efficiency. Strategies to reduce waste inventory involve JIT production, improved demand forecasting, Lean manufacturing principles, effective supplier management, and stringent quality control measures.

6. Motion: Workers are moving from one workstation to the other workstation without necessity and the manufacturing lead time is increase. This type of unwanted motion is considered as waste. Any excessive movement of workers, vehicles, or machinery requires waste in motion. Running, raising, reaching, bending, stretching, and shifting are part of this. To improve the working conditions for workers and improve health and safety standards, repetitive motion activities should be eliminated. Some motion countermeasures consist to make sure that the tools material is place near machinery in well organized manner.

7. Extra processing: Increases machining time, material handling time and add more process steps. Due to over processing the cost of the product is increased that will pay by the customer. For reducing over processing on products, consider standard job specifications for manufacturing. Prior to starting work, always think to the customer and produce product quantity as per the requirements of the customers and try to reduce the unnecessary operations and manufactured quantities where it is required [29], [31].

8. Non-utilized potential: This waste was not developed by Toyota, this 8th waste, the waste of human skills, is well known to many individuals. Also explain as no utilization of manpower skills, creativity, efforts consider in the 8th waste. This waste is developed when management not identify the skills of his workers in the organization. Employees is just following the boss order and do work as per the boss instructions. It is very difficult to optimize the process without taking help of frontline workers. This is because the worker who perform the job on shop floor is recognize the problems first and he has the solutions for that problem [24].

2.8.2 Identifying and eliminating the 8 wastes

Perceiving that they exist and giving a proficient system to characterizing them is the initial step to slashing waste. Value Stream Mapping (VSM) is a tool of Lean Management to assess the current state and to design a likely state. This outlines the progression of information and substance as they emerge. VSM is an effective strategy to plan the process involved, outwardly show the connection manufacturing process and to recognize non-value added and value-added activities. Utilize the VSM to characterize waste and proceed in view of the end client. Work in reverse to the beginning of the production process from the end client. Record cases of the eight waste in the process and construct a methodology to eliminate or limit them. Keep on provoking the staff to discover more waste and reliably build up their strategies. Draw in with and bring out their thoughts for change from the forefront staff. They will grow more trust in their critical thinking abilities as the group keeps on limiting efficiencies and waste decrease turns out to be important for their regular everyday practice after some time.

2.9 Lean tools and techniques

Lean tools and practices are fundamental for eliminating inefficiencies and optimizing workflow, leading to improved productivity and higher customer satisfaction. By fostering a culture of continuous improvement and waste reduction, organizations can achieve greater operational excellence and sustainable growth.
Implementing lean principles empowers organizations to adapt quickly to changing market demands, enhance employee engagement, and drive innovation for long-term success. They could be classified into 5 different families:

- Customer relationships,
- Supplier relationships,
- Human resources,

- Manufacturing planning and control,
- Process and equipment.

The figure 2.4 shows us the different techniques of lean manufacturing each one of them belonging to his family.

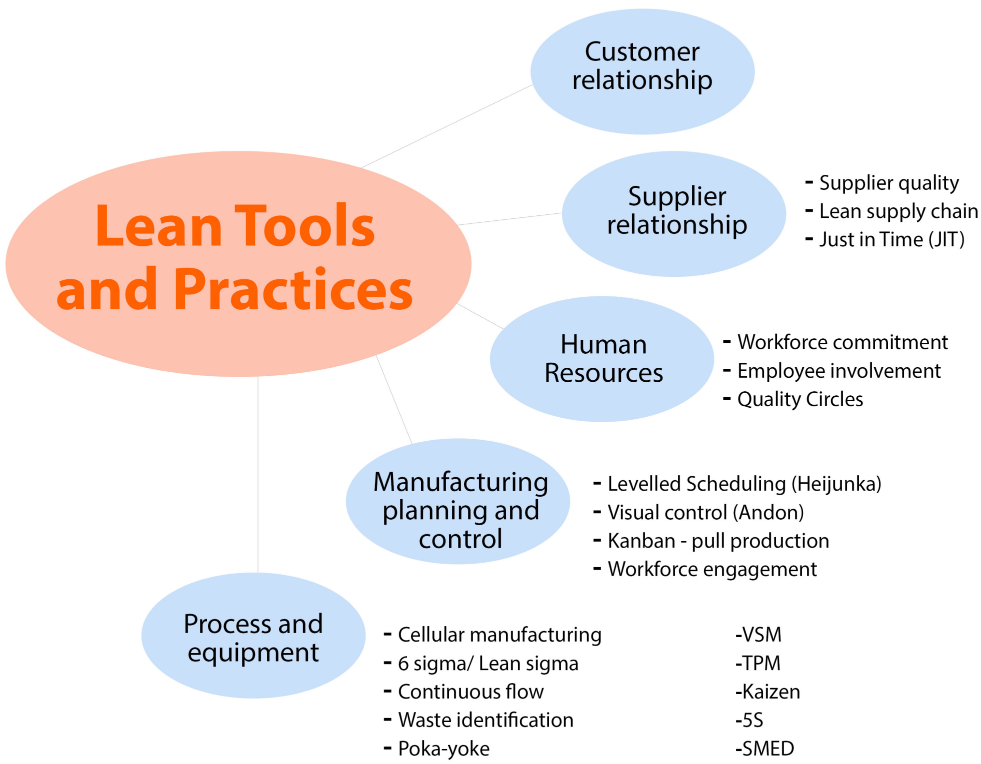

Figure 2.4: Lean manufacturing tools and practices.

2.9.1 5S

Is a methodology used to organize and improve the efficiency and effectiveness of a workplace. The term '5S' refers to the five Japanese words that describe the steps of the methodology: Seiri (Sort), Seiton (Set in order), Seiso (Shine), Seiketsu (Standardize), and Shitsuke (Sustain). The goal of 5S is to create a clean, organized, and standardized workplace that minimizes waste and improves safety, quality, and productivity.

Steps

1. Seiri (Sort): This step involves sorting through all items in the workplace and removing any unnecessary or unused items. Only essential items are kept, and the rest are either discarded, recycled, or relocated to a more appropriate area.

2. Seiton (Set in order): After removing unnecessary items, the next step is to organize the remaining items in a logical and efficient manner. This step involves identifying specific locations for each item and labeling or marking those locations to make it easy to find and return items to their proper place.

3. Seiso (Shine): This step involves thoroughly cleaning and maintaining the workplace. This not only ensures that the workplace is free from dirt and debris, but it also helps identify any defects or maintenance issues that need to be addressed.

4. Seiketsu (Standardize): Once the workplace has been sorted, organized, and cleaned, the next step is to create standard procedures and guidelines to ensure that the workplace remains organized and efficient. This includes creating standard operating procedures, visual management systems, and implementing regular audits or inspections to ensure that the workplace is consistently maintained.

5. Shitsuke (Sustain): The final step of 5S involves making the 5S methodology a part of the organizational culture. This step involves continuous training and education of employees, regular monitoring and review of the 5S system, and incorporating 5S principles into everyday work practices. By making 5S a part of the company culture, the benefits of 5S can be sustained over the long term.

It's important to note that 5S is not a one-time event but rather a continuous improvement process that requires ongoing commitment and dedication from all employees to sustain its benefits over the long term [34].

2.9.2 Kaizen

It is a Japanese term that means 'continuous improvement' or 'change for the better'. It is a philosophy and methodology that focuses on making incremental improvements in processes, products, and services to improve quality, reduce waste, and increase efficiency. Kaizen is based on the belief that small, continuous improvements can add up to significant improvements over time. The kaizen approach involves the entire organization, from the top leadership to frontline employees. It encourages everyone to identify and eliminate waste in all aspects of the organization, including manufacturing, service, and administrative processes.

Steps

Kaizen involves several key principles, including:

- Standardization: Establishing standard processes and procedures to eliminate variability and improve efficiency.
- Continuous improvement: Making small, incremental improvements to processes and procedures on an ongoing basis.
- Respect for people: Treating all employees with respect and involving them in the improvement process.
- Waste elimination: Identifying and eliminating waste in all aspects of the organization.
- Customer focus: Focusing on the needs and expectations of customers and striving to exceed their expectations.
- Teamwork: Encouraging teamwork and collaboration to achieve common goals.

Kaizen can be applied to any process or activity in the organization, and it can be implemented through a variety of tools and techniques, including VSM, 5S, and visual management. The goal of kaizen is to create a culture of continuous improvement and to empower employees at all levels of the organization to make changes that improve quality, reduce waste, and increase efficiency.

2.9.3 Kanban

Kanban is a project management methodology that uses visual cues and a physical or digital board to visualize the progress of work items through various stages of a workflow. The word 'Kanban' is a Japanese term meaning 'signboard' or billboard', and this methodology was originally developed by Toyota as a way to improve manufacturing efficiency. In a Kanban system, work items are represented by cards or sticky notes, which are moved across a board with different columns representing different stages of the workflow. The visual nature of the board makes it easy for team members to see at a glance what tasks are in progress, what tasks are next, and what tasks are completed. This promotes transparency, collaboration, and efficiency in the team's work processes. Kanban can be used in a variety of contexts, from software development to marketing to healthcare. Its simplicity and flexibility make it a popular choice for teams who want to improve their project management processes.

Steps

- Identify the workflow: Identify the steps that a work item goes through from start to finish. This could be anything from a software development process to a marketing campaign,
- Create a board: Create a board with columns representing each step in the workflow. This can be a physical board (e.g., a whiteboard or a bulletin board) or a digital board (e.g., Trello, Asana, or Jira),
- Add cards: Add cards or sticky notes to the board, with each card representing a work item. Include important information such as the item's name, description, priority level, and deadline,

- Set WIP limits: Set WIP limits for each column. WIP limits help prevent team members from taking on too many tasks at once, which can lead to bottlenecks and delays,

- Move cards: Move cards across the board as work items progress through the workflow. Team members should update the cards regularly to reflect the current status of each item,

- Hold regular meetings: Hold regular meetings to review the board and discuss any issues or updates. This can be a daily stand-up meeting or a weekly retrospective.

Continuously improve: Continuously improve the workflow and the board based on feedback and observations. Experiment with different WIP limits, column labels, and card designs to find what works best for the team.

2.9.4 Value stream mapping

A VSM is a visual tool used to analyze and improve the flow of materials, information, and activities required to deliver a product or service to customers. It is a lean manufacturing technique that helps to identify waste and inefficiencies in a process by mapping out the steps involved in creating and delivering a product or service. A VSM typically includes information on the process steps, cycle times, inventory levels, and the flow of information and materials through the process. By analyzing this information, teams can identify areas of improvement and implement changes to streamline the process, reduce waste, and increase efficiency. VSM is commonly used in manufacturing, but can also be applied to other industries such as healthcare, software development, and service industries.

Steps

- Identify the process: Define the process you want to map, including the start and end points, and any steps in between,

- Gather data: Collect data on the process, such as cycle times, lead times, and inventory levels. This can be done through observation, interviews, and data analysis,
- Create a current state map: Draw a map of the current state of the process, showing the flow of materials and information, as well as any bottlenecks, delays, or waste,
- Analyze the current state: Review the current state map to identify areas for improvement, such as reducing waste, shortening cycle times, or improving quality,
- Create a future state map: Based on the analysis, create a map of the future state of the process, showing the ideal flow of materials and information, and how waste will be eliminated,
- Develop an action plan: Determine the steps needed to move from the current state to the future state, including changes to the process, equipment, and resources needed,
- Implement the changes: Implement the action plan, making the necessary changes to the process, and monitor the results to ensure they are achieving the desired outcomes,
- Continuously improve: Regularly review the process and make improvements to further reduce waste, improve quality, and increase efficiency.

2.9.5 Lean maintenance

Lean maintenance is a maintenance strategy based on the principles of lean manufacturing. It focuses on eliminating waste, reducing downtime, and improving equipment reliability through a systematic approach to maintenance. The key principles of lean maintenance include:

- Continuous improvement: Like other lean strategies, lean maintenance is based on a continuous improvement process, where small changes are made over time to improve the maintenance process,

- Value: Lean maintenance focuses on providing value to the customer by maintaining equipment in a way that maximizes uptime and reliability,
- Flow: Lean maintenance seeks to create a flow of work that minimizes waste and reduces downtime by improving the reliability and efficiency of equipment,
- Pull: Lean maintenance seeks to create a pull-based system where maintenance work is triggered by equipment performance, rather than by a pre-determined schedule,
- Standardization: Lean maintenance focuses on standardizing maintenance procedures to ensure consistency and efficiency in the maintenance process,
- Visual management: Lean maintenance uses visual tools to help identify problems, track progress, and communicate information about the maintenance process [35].

2.9.6 PDCA

The Plan-Do-Check-Act (PDCA) method for controlling and improving the management process supply chain or the company's habits consists of repeating four steps. In other words, there are 4 phases used in this method to pay attention and adjust the deviations that might occur with the main goal of being better in business processes. The PDCA process ends with the Planning, Conducting, Testing, and Implementation steps also known as the Deming Phase. Deming developed the plan do check action cycle as a four-stage repetitive problem solving [36]:

1. Plan: Plan consists of setting goals and processes to achieve specific results.
2. Do: This step for involving people and executing the plan.
3. check: The inspection process stages have been monitored and evaluated according to specifications
4. Act: In the fourth step, actions are taken to improve results and meet or exceed specifications.

In general, PDCAs in the manufacturing industry are applied to reduce waste (waiting time, idle, failure, defects, etc.). However, a literature review will be conducted to describe the application of PDCA in several sectors other than manufacturing that can also reduce waste, or improve quality, etc., with a quantitative or qualitative research approach. The concept of PDCA cycle produces several actions to correct corrective, temporary, and permanent. Corrective and continuous actions consist of eliminating the root cause. Interim measures to correct and correct problems[37].

2.10 Conclusion

To sum up, this chapter talked about how Lean Manufacturing grew over time. It shown where it started and how it changed into what it is now. By focusing on reducing waste and always trying to improve, Lean helps businesses work better. It's not just about using tools, it's a way of thinking. By embracing Lean, companies can keep up with changes and do well in the manufacturing world. In Catraport they have implemented just the techniques showed and defined on the this element.

Chapter 3

Maturity assessement of lean manufacturing in Catraport

3.1 Catraport delineation

Catraport Lda, was founded on July 21, 2015 and began operations in 2017. It is a metalworking company dedicated to the production of cold cast parts, by industrial stamping processes for the automotive industry. The company, based in Bragança, Portugal, in the Mós industrial estate, as shown in figure3.1, has belonged to the P&C Automotive group since 2016 and aims to be a benchmark company for this group, which operates worldwide. To achieve this, it uses the most modern equipment, technologies and procedures to produce cutting-edge components, satisfying the group's needs while empowering the company. Its main shareholder, CATRA SPA, located in northern Italy, was founded in 1979, and its core business is sheet metal stamping, plastics stamping, tool and mold production, welding, component assembly and painting. Its final output is 70% for the automotive sector and 30% for other sectors that use this type of input. CATRA SPA operates according to the JIT philosophy, with a strict quality policy and quality, management and environmental certifications.

Figure 3.1: Catraport, Lda.

3.1.1 Company structure

The company's facilities, as drawn in figure 3.2, may be separated into three main sectors for the purposes of this study: (i) the production sector, (ii) the inventory and dispatching sector, and (iii) the disk storage sector.

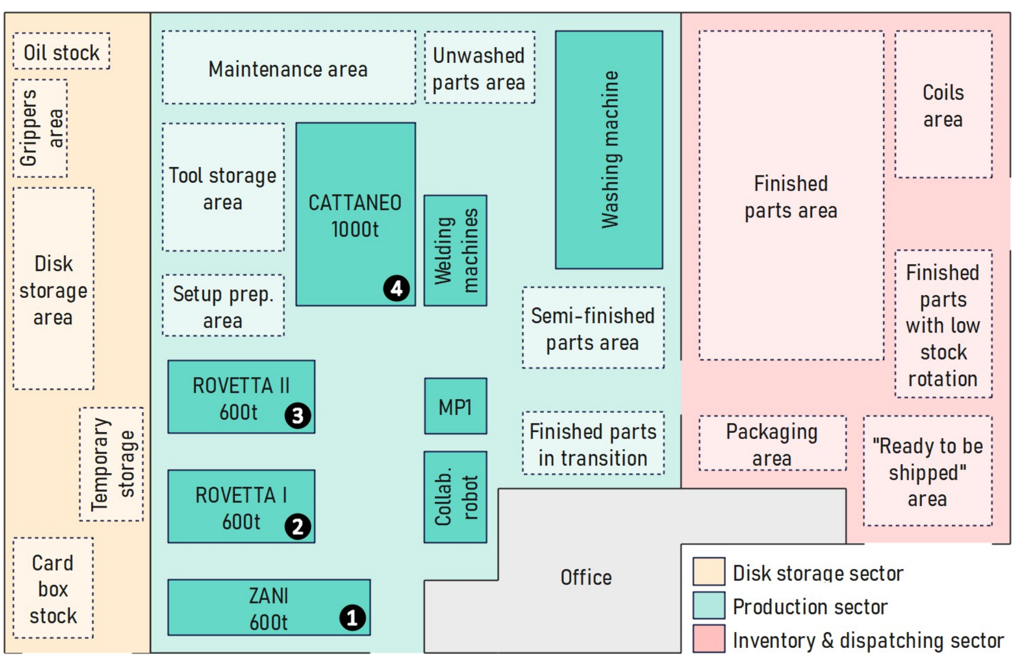

Figure 3.2: Company structure [38]

The company has four progressive hydraulic presses in its production sector: (1) Zani

600 tons, (2) Rovetta I 600 tons, (3) Rovetta II 600 tons, and (4) Cattaneo 1 000 tons. A certain variety of products can be produced by one press, but its capacity is restricted, and certain items can be produced by using numerous machines. Despite this, the suggested framework does not have to allocate items to a specific press as the corporation already knows which machine (first choice) is most efficient for each product based on unitary prices and productivity rates. Only in the event that the primary machine needs maintenance or breaks down is the backup machine (second choice) utilized. Because of the requirement for large production volumes, a restricted number of machines, and lengthy setup periods, the company's approach depends on inventory management to handle unforeseen demand. The figure 3.3 shows the equipment that the organization uses, as well as the cold stamping sub-sector named from the left to the right.

Figure 3.3: Rovetta I, Rovetta II, and Catteneo

3.1.2 Manufacturing process

Using one of the semi-automatic progressive hydraulic presses, cold metal stamping is the main method used to make all goods, completed or unfinished. To put it briefly, cold metal stamping is a transformation process in which a room-temperature metal sheet is compressed between two dies to take on an imposed shape. The stamping tool, or set of dies, in a progressive hydraulic press is used to form the metal in successive die stages. The robotic arms that move the WIP product from one stage to another are connected to semi-automation. The operation of a semi-automatic progressive stamping hydraulic press is summed up in figure 3.4.

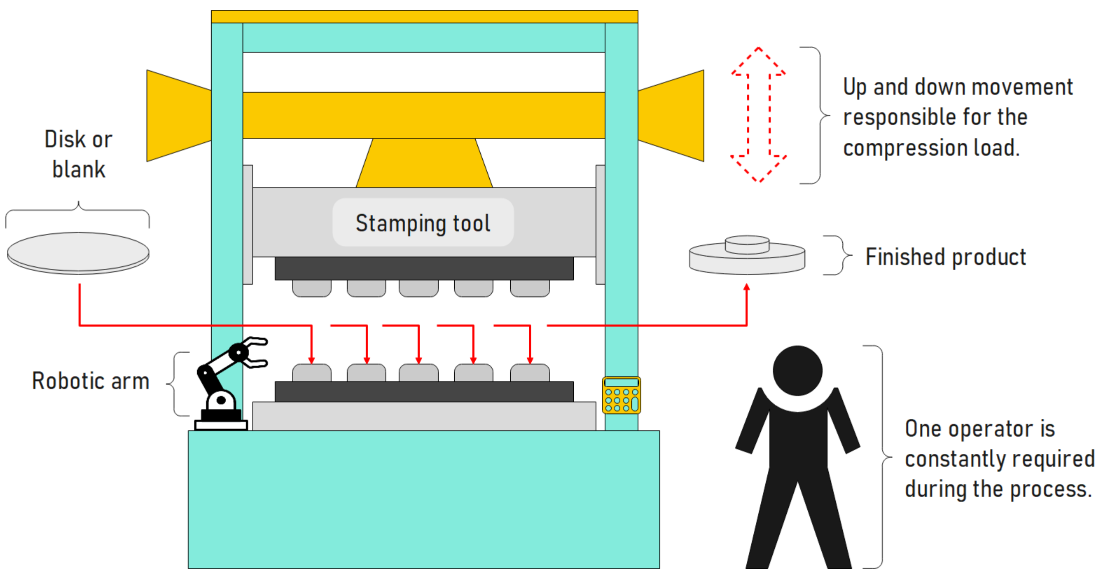

Figure 3.4: Working principle of a progressive stamping hydraulic press[39]

3.1.3 Storage process

The process takes place after the parts have been removed from the finished goods area and placed in the packing station, placing the parts in KLT cardboard boxes as in the example in figure 3.5, in the quantities corresponding to each part number and customer. Once packing is complete, the load is placed in the packing station in the shipping preparation area. Shipping involves moving the packaged loads from inside the warehouse and placing them on the truck in the loading and unloading area. Finally, shipping involves moving the packaged loads from inside the warehouse and placing them on the truck in the loading and unloading area. All movements are carried out using a forklift truck. The company has two types of forklift with different characteristics: the bigger one does not circulate inside the warehouse for reasons of safety and space. But only makes small movements in the entrance area furthest from the employees, for example in the reel storage area and in the area of loads ready for dispatch, The smaller one for the circulation inside the factory to move boxes during the process. A figure outlined in the Appendix A showing the structure of the warehouse.

Figure 3.5: Dvneo project KLT units

3.2 Maturity assessment in Catraport

It is crucial to remember that other manufacturing companies will find it difficult to quickly implement what Toyota has accomplished. Adopting lean principles is indeed a challenging endeavor, as many businesses have noted implementation issues. [40]. Bhasin [41] assert that social and management concerns are the primary causes of the obstacles to lean implementation. Organizations differ in a variety of ways, which can result in the development of unique strategies, routes, focuses, and management practices. It is also possible for organizations to attain varying degrees of manufacturing performance. [42]. Undoubtedly, Toyota's use of lean methodologies has resulted in exceptional performance. However, as [43] points out, there might be hazards to business continuity if it is not carried out methodically and with caution. As a result, effective organizational growth and competitive tactics are crucial components of every work that is completed. Determining the maturity level of lean development techniques is crucial for describing step-by-step procedures, guiding the organization towards achieving maximum leanness, and improving manufacturing business performance [44]. Consequently, as was previously said, it's critical to precisely describe each maturity level within the milestone qualities that are being evaluated, such as their tactical and strategic nature [45].

3.2.1 Lean maturity assessment models in the manufacturing industry

Conducting an evaluation is essential to the establishment of any world-class manufacturing principles and ensures a smooth implementation process. The literature that has recently been published shows that academics, researchers, and business professionals are very interested in maturity models and evaluation methods. [46]. Lean assessment models are often developed using the theory of evolution to outline the progressive modifications that must be made in order to assist firms in reaching their performance goals and the highest possible degree of leanness. In order to depict the current condition, the weaknesses are identified and the improvement chances are prioritized within the developmental phases and roadmap, taking into account the complexity and nature of the parameters being analyzed. [47]. On the basis of that, lean assessment may assist in generating a clear image that highlights the critical success elements and directs organizations in the proper path for creating strategic initiatives that will lead them to become lean. [48]. In responding to this lean effort, Capgemini [49] defines maturity level of lean deployment in two stages: taking control and creating excellence as shown in figure 3.6.

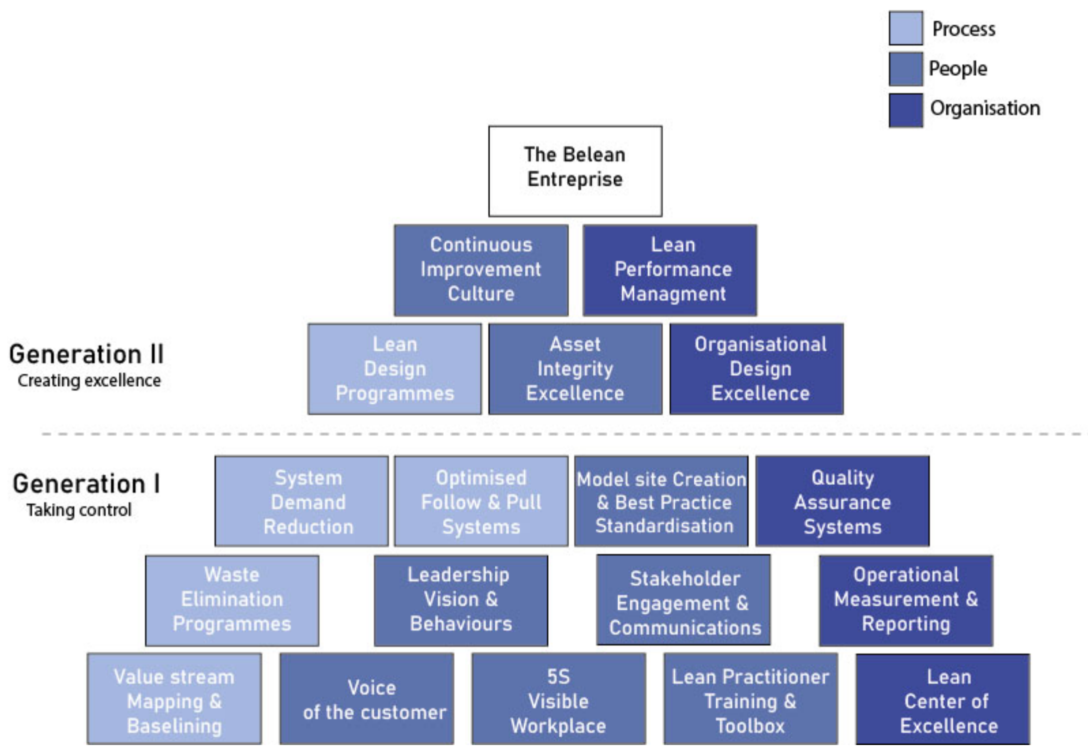

Figure 3.6: Two levels of lean deployment [49]

Lean implementation is a gradual process in order to shape the organisational culture. Therefore, the maturity assessment models need to be implemented gradually, and step-by-step, following the evolution of lean change to achieve the next level of lean status. The mind-set of lean in an organisation is to change the management focus from everyday tasks that consume their attention to a way of optimising the resources. This includes the flow and manufacturing cycles that are intertwined with technology, assets or facilities, cooperation between cross functional departments as well as the customers.

A logical model of lean evaluation is proposed by [50], and it is structured into steps that are separated into five maturity levels: reactive, formal, deployed, autonomous and way of life. The model includes five milestone attributes: strategic deployments, value stream, people, the application of tools and techniques to suit circumstances, and extended enterprise to describe the position of the organisation along the road map of lean implementation as shown in Table 3.1.

Table 3.1: Lean maturity assessment levels [50]

Milestone attributes	Maturity level index				
	Reactive	Formal	Deployed	Autonomous	Way of life
Ways of working	-Reactive approach	-Formal structure	-Goal oriented	-Managed autonomy	-Daily habit of CI
Associate autonomy	-Little/no	-only specialists	-Selected teams	-Majority involvement	-Full empowerment
Share best practice	-Involvement	-Team learning	-Value stream learning	-X-process learning	-External learning
Strategy deployment	-Adhoc learning				
Value stream					
People					
Tools and techniques					
Extended enterprise					

3.2.2 Analysis of existing situation

After visiting Catraport, discovering the manufacturing process (the workstations-the warehouse-the office of logistics...) and after viewing the follow-up documents of the continuous improvement.

It's necessary to know the lean culture and philosophy of the workers, the efficiency of the techniques of lean manufacturing implemented in the workspace, the degree of respecting the working process and make the evaluation of the maturity to know the flow rate.
After scheduling a meeting with the group responsible of the continuous improvement and the workers, it was agreed that it's important to know the level of maturity assessment to increase the flow rate.
Starting with the evaluation lean flow technology to know the assessment of the lean culture as shown on the next part.

3.2.3 Assessment results

Audit checklist

This audit checklist is a document used to conduct a structured audit of the program of lean manufacturing methods implemented on the factory. This simple form guides us through the various steps in evaluating the workshop according to lean manufacturing principles. Using a series of questions, It assess the progress of the project. As represented in the figure 3.7

E JUST IN TIME

	E.1 STOCK LEVELS
	Mass production philosophy. Products are manufactured on the basis of sales forecasts, then stocked before being sold.
	Manufacturing is triggered solely based on sold products, independent of a coherent planning with production cycles, and then stored until the delivery date. Safety stock of finished products and raw materials is in place to cope with rejection rates.
	Manufacturing is triggered based on sold products, but distributed on an annual basis. Excess components and raw materials are stored to benefit from volume effects when ordering.
3,2	Manufacturing is triggered based on sold products, but distributed on a semi-annual basis rather than according to the requested delivery date by the customer. Components and raw materials are ordered and supplied based on the actual production needs.
	The entire production is triggered solely based on customer demand. Components and raw materials are ordered and supplied just-in-time.
	E.2 PULL FLOW SYSTEMS - KANBAN
	Production is planned, with no direct link to customer demand.
	Production is planned and varies according to customer demand.
1,6	Kanban is used to help manage production.
	Kanban is used to launch the production of finished products.
	Kanban is used to launch the production of finished products, and to place orders with all suppliers.
	E.3 LOAD SEQUENCING AND BALANCE
	The notion of standard work is non-existent. Workloads and work-in-progress vary on a daily basis and for each operation. The distribution of tasks is not balanced.
	The Takt-Time is unknown. The workload is better balanced but does not allow for absorbing mix variations. Tasks are allocated, but only to relieve congested processes or bottleneck stations. Buffer stocks are present between workstations.
	The workload is balanced based on monthly smoothing of demand. Objectives are set to reduce inventory levels. Trainings are conducted to increase operators' flexibility.
3	The workload is balanced based on weekly smoothing of demand. Work-in-progress is maintained within calculated quantities. Operators are trained to work on upstream and downstream positions to regulate the production flow.
	Lines and cells are sequenced daily to optimize the distribution of customer demands. Work-in-progress is calculated and monitored. Operators are capable of working on immediately upstream and downstream positions. Workload is balanced across the entire factory.

Figure 3.7: Checklist example.

This checklist contains 8 categories, for each category there is scopes of which we have to choose which option works with this case.

After evaluating, a grouped histogram has been extracted and is represented on the figure 3.8.

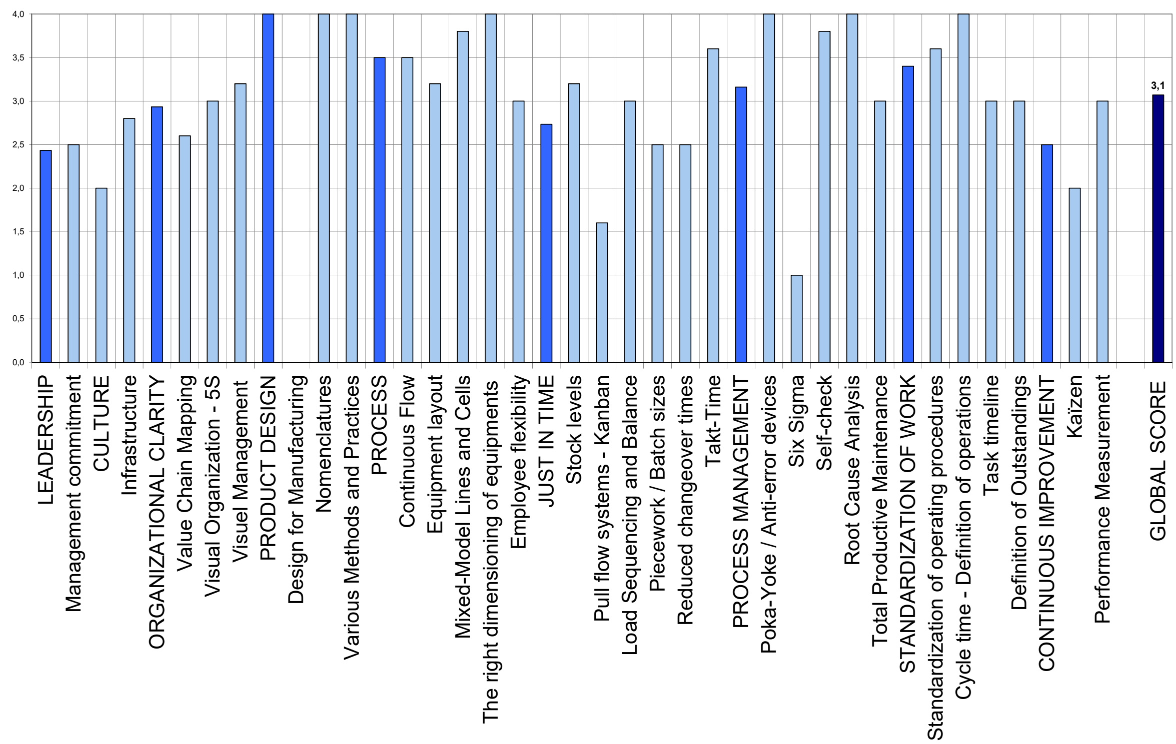

Figure 3.8: Histogram of lean flow evaluation

This histogram can show that there is a defect on six sigma and Kan-ban. To solve this problem, it needs to analyze the operation and approach of these methods to understand where is based the anomaly and to try to suggest some ideas to make them more efficient. Lean six sigma is a methodology combining Lean principles and six sigma strategies to streamline processes, minimize waste, and enhance quality within an organization's infrastructure. It focuses on continuous improvement, data-driven decision-making, and reducing variability to achieve efficient operations and customer satisfaction. Catraport is not able at the moment to implement the infrastructure of lean six sigma, so it was agreed to work on pull system Kanban.

3.3 Conclusion

In conclusion, the utilization of lean maturity assessment models in the manufacturing sector holds immense potential for driving operational excellence and fostering a culture of continuous improvement. According to analysis of various models and the assessment results, it gained invaluable insights into the organization's strengths, weaknesses, opportunities for advancement and where it can be the intervention.

Chapter 4

Analysis and suggested solutions

This chapter introduces the concept of processes and their improvement, focusing on the PDCA cycle. Processes are the backbone of organizations, ensuring things run smoothly. The PDCA cycle, is a method for fixing problems and making improvements. During this chapter it will be explored each step of this cycle and discuss techniques for identifying, solving issues and suggestion of ideas for improvements.

4.1 PDCA cycle

4.1.1 Plan

Problem Description:

Catraport factory are encountering challenges related to limited space within the warehouse, which significantly impacts on the operational efficiency because of the use of the push system production strategy. The constrained space necessitates frequent movement of containers to adhere to the First In, First Out (FIFO) principle and maintain warehouse organization. Additionally, the absence of effective visual management systems results in instances of using incorrect products, leading to operational disruptions and potential errors in order fulfillment.

1. Limited Space Impacts:

One major hindrance to the day-to-day operations is the warehouse's restricted space. Where it is forced to often transfer containers in order to access products in accordance with the FIFO principle, due to the constrained location. In addition to taking up important time, this frequent handling raises the possibility of errors in order fulfillment and inventory management procedures.

2. Organizational Challenges:

   Space constraints make it more difficult to keep a warehouse environment clear and orderly. The regular shifting of containers throws off the established structure of the organization and makes it difficult to find and retrieve inventory goods that are needed. Consequently, this affects the capacity to accurately and promptly fulfill orders, which in turn affects overall customer satisfaction and operational performance.

3. Lack of Visual Management: The lack of a good visual system exacerbates the problem of limited space. Without clear signs and markers, it's difficult for warehouse workers to find quickly what is needed, and consequently increase the chances of choosing the wrong container and wasting precious time. This creates unnecessary losses and disrupts the flow of goods.

4. Transport Challenges: Trucks circulating in the warehouse create additional problems. Blind spots are present and drivers are unable to see people circulating around them. This can lead to accidents and injuries. It's very important to solve these problems to create a safe environment, moving the products easily around the warehouse.

5. Security Considerations:

   Trucks moving around in the warehouse represents a hazard without unconsciousness driving. To fix this, it is needed to have strong security rules and make sure everyone knows about them. This will help keep everyone safe during operations.

To summarize, addressing the combined challenges of limited space, organizational inefficiencies, lack of visual management, transport concerns, and security considerations at Catraport factory is paramount to enhancing productivity, optimizing resource utilization, and ensuring seamless order fulfillment processes.

Problem analysis:

- Ishikawa analysis:

  Also known as a 'fishbone diagram' or 'cause-and-effect diagram', this tool is a visual diagram, it's also a visual method for finding the causes of an identified effect. The idea invented in this diagram as represented on the figure 4.1

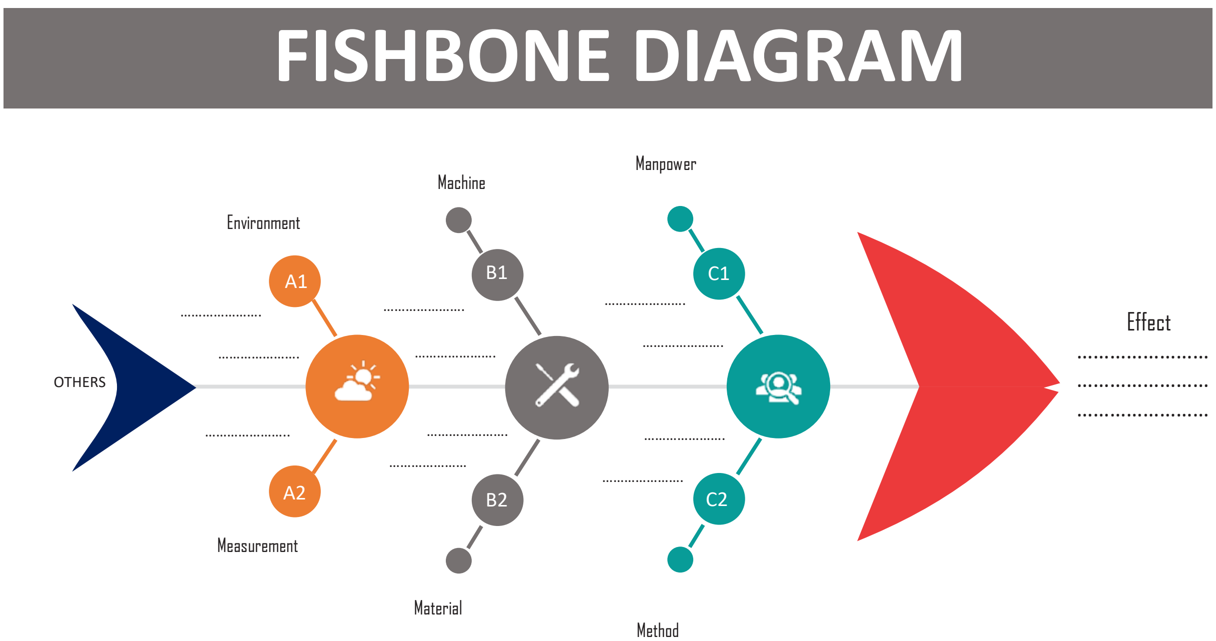

Figure 4.1: Ishikawa diagram developed

The figure represents a skeleton of a fish above, where it is divided into 5 parts:

- The head represents the problem or effect, e.g., lack of visualization,
- The bones represent different categories of potential causes,
- The symbol 1 represent the cloud and the sun, it refers to the environment and the measurement,

- The symbol 2 represent a screwdriver and the flat spanner, it refers to the machine and material,
- The symbol 3 represent a group of people with a magnifying glass, it refers to the manpower and the method.

These causes are grouped into 6 different categories: Environment by describing the factors related to the place where the process operates, measurement by mentioning the elements that have a connection with how the procedure or results are measured, material by precising the components, suppliers or initial materials that are utilized in the process as well as their connected factors, machine by presenting the factors related to the equipment and technology used in the process, manpower by describing the elements related to the human resources involved and method by mentioning the factors used in the processes and procedures.

The ishikawa diagram shown on the figure 4.2 represents the causes and effect of 'limited space' anomaly. The diagrams of the other anomalies are showed on the Appendix A.

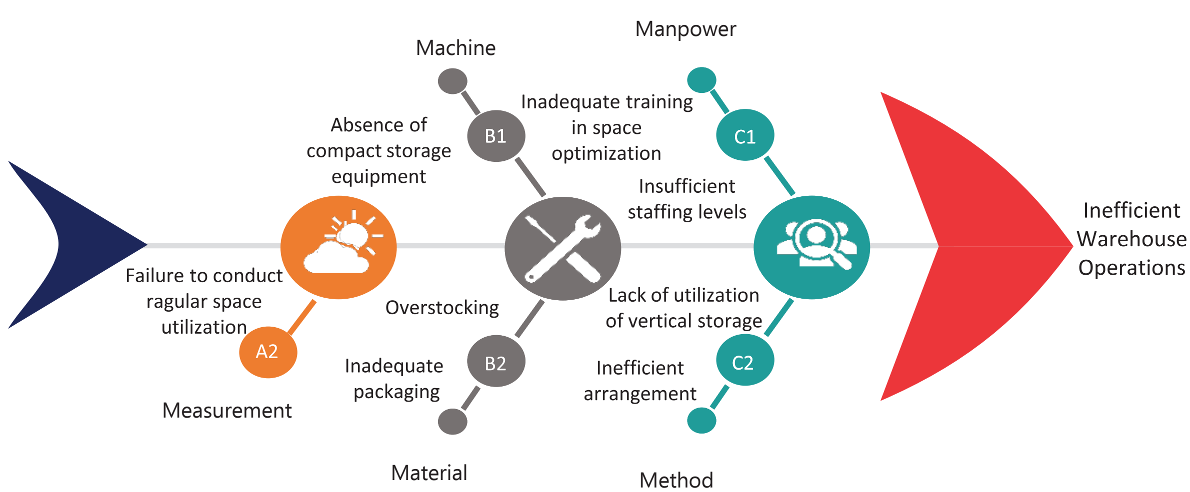

Figure 4.2: Ishikawa of limited space

These causes are grouped into 5 different categories: Manpower, Method, Machine, Material and Measurement. For the environment it can be neglected depending on the workplace situation.

This causes is extremely pertinent since it deals directly with the problem of space constraints. Frequent evaluations of space usage help in locating inefficiencies and potential improvement areas.

- 5W1H analysis: The 5W1H questioning method allows us to describe a situation by answering the following questions in a general way. As represented on the Tables 4.1 and 4.2 below.

Table 4.1: 5W1H Questions

5W1H	Description	Question
What	Description of the problem, task, activity	What are the specific challenges faced by the Catraport factory regarding limited warehouse space, organizational inefficiencies, lack of visual management, transport concerns and security considerations?
Who	Description of people involved, stakeholders, interveners	Who is responsible for managing warehouse operations at the Catraport factory?
Where	Site description	Where within the Catraport factory are these challenges most pronounced?
When	Description of the moment	When did the challenges related to limited space and organizational inefficiencies become apparent?
Why	Description of reasons, causes, objectives...	Why has the Catraport factory encountered these challenges and what are the underlying reasons contributing to each issue?
How	Description of methods, manners...	How are employees currently managing the constraints posed by limited warehouse space and organizational inefficiencies?

Table 4.2: 5W1H Analysis

Who?
Warehouse or logistics manager is responsible for managing warehouse operations at Catraport factory.

What?
-Limited warehouse space necessitating frequent container movements to adhere to FIFO principles. -Organizational inefficiencies due to the non constant movement of containers, distrupting the established organizational structure. -Lack of visual management systems leading to difficulty in identifying correct products promptly. -Transport concerns such as blind spots and lack of awareness leading to safety hazards. -Security considerations arising from the movement of trucks within the warehouse, potentially creating vulnerabilities and safety risks.

Where?
Challenges are most pronounced within the warehouse premises of Catraport factory.

When?
Challenges likely became apparent as operational demands increased or during changes in inventory management processes.

Why?
-Increased operational demands and limited physical space within the warehouse. -Inadequate organizational strategies to manage inventory and warehouse layout efficiently. -Lack of visual management systems to streamline product identification. -Insufficient training or awareness programs regarding transport safety and security protocols. -Ineffective communication channels between warehouse personnel and management regarding operational challenges and solutions.

How?
-Implementing manual inventory management techniques to track product movement and ensure adherence to FIFO principles. -Making ad-hoc adjustments to the warehouse layout to accommodate changing inventory requirements. -Relying on memory or traditional labeling methods to identify products location within the warehouse. -Employing cautionary measures when navigating transport vehicles within the warehouse premises, though these measures may be insufficient in addressing all safety concerns. -Adhering to basic security risks associated with warehouse operations.

These problem-solving tools enable to identify faults and analyze them in order to find the right solutions and make it easier to improve our warehouse.

Defining objectives (SMART):

Smart goals are objectives developed to effectively lead efforts and monitor progress. They are specific (goal should be clear and specific, avoiding ambiguity), measurable (goal should be quantifiable so that progress can be tracked and evaluated), achievable (goals should be realistic and achievable within the constraints of resources, time, and other factors), relevant (objective should be aligned with broader goals and priorities) and time-bound (objective should have a specific time frame or deadline for completion). They support people or groups in defining their goals, comprehending how to get there, and determining success within a predetermined time range [21]. The figure 4.3 is representing the characteristics of the objective smart as illustrated below.

Figure 4.3: SMART goal design used

The SMART goal shown on the figure 4.4 represents the causes and effect of 'limited space' anomaly. The SMART goals for the other anomalies are represented on the appendix C.

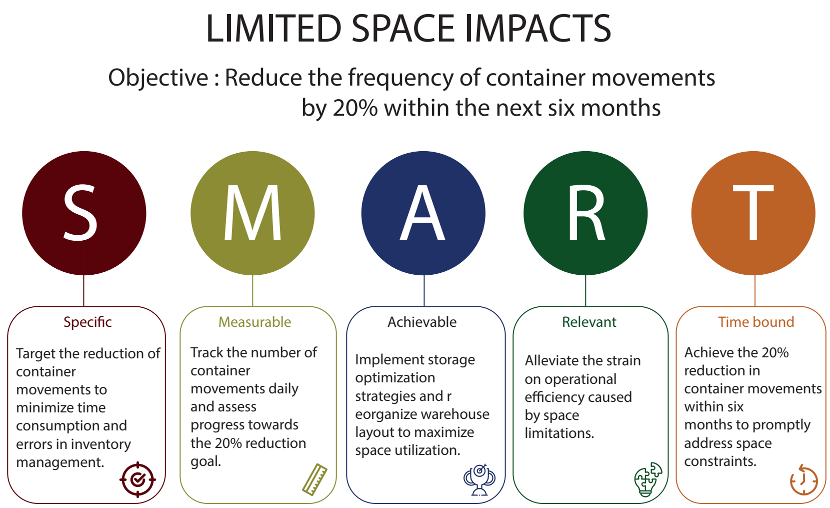

Figure 4.4: SMART goal of limited space

This objective focuses on improving operational efficiency by reducing container movements by 20% within six months, leading to cost savings, streamlined processes, and reduced wastes.

Drawing up an action plan:

Developing an action program within the framework of the PDCA cycle means reviewing the current situation, defining clear and specific goals, determining what measures are necessary to achieve them, and who will be responsible for this. In addition, it needs to specify the time frame, list the necessary resources, develop control methods, draw up a list of tasks and share them with all interested parties to get feedback and suggestions for improving the document. After brainstorming with all team members responsible, it was collectively concluded to propose improvement ideas, as outlined in the figure below, aimed at addressing the anomalies identified.

Figure 4.5: Action Plan

4.1.2 Do

Implementation of defined action plan:

After drawing up an action plan, it’s crucial to establish a strategy before commencing implementation. One effective method, as depicted in the Appendix C Gantt chart diagram, is to visually organize and schedule tasks over time.

The Gantt chart diagram, named after its creator Henry Gantt, is a visual representation of project tasks and their scheduled durations over time. It utilizes bars along a timeline to illustrate task durations, dependencies, and deadlines, providing project managers with a clear overview of project progress and resource allocation.

Collection of relevant data and information:

This step includes obtaining data related to the processes targeted for improvement, acquiring information about the current state of affairs such as performance metrics or customer feedback, and securing any additional resources necessary for implementation. It's crucial to ensure that the collected data is accurate, reliable, and directly pertinent to the goals outlined in the planning phase. By completing this task diligently, organizations lay the groundwork for informed decision-making and successful execution of improvement initiatives.

Application of changes or solutions:

This step is the application of the action plan suggested using the Gantt chart diagram, where teams execute strategies outlined to address identified issues or achieve defined objectives. Effective communication, coordination, and collaboration among team members are vital during this phase to ensure smooth implementation and mitigate potential disruptions, such as through regular meetings to assess progress, address challenges, and adapt strategies as necessary. By diligently applying changes or solutions and leveraging tools like the Gantt chart, organizations can initiate tangible progress toward improvement, laying the groundwork for subsequent evaluation and refinement in the PDCA.

4.1.3 Check

In this step, it is necessary to examine how it did compared to what was aimed for, identify why there are differences, and verify if the data aligns with the initial expectations. This process aids in making better decisions and enhancing operational efficiency.

4.1.4 Act

In this step, it is necessary to review the results of those changes or improvements. Any variances from what was expected should be further analyzed to determine the reason and whether corrective action is required. The decision maker should then determine whether the standard should be implemented, if modifications are needed and turn again the PDCA.

4.2 Project closure

After completing the PDCA cycle, all necessary changes were implemented and tasks were standardized. Following this, a thorough evaluation was conducted to determine if the predefined goals were achieved. Additionally, the new workflow was analyzed to ensure its efficiency and sustainability. The figure 4.6 represents a document can be visual guide for the tool used.

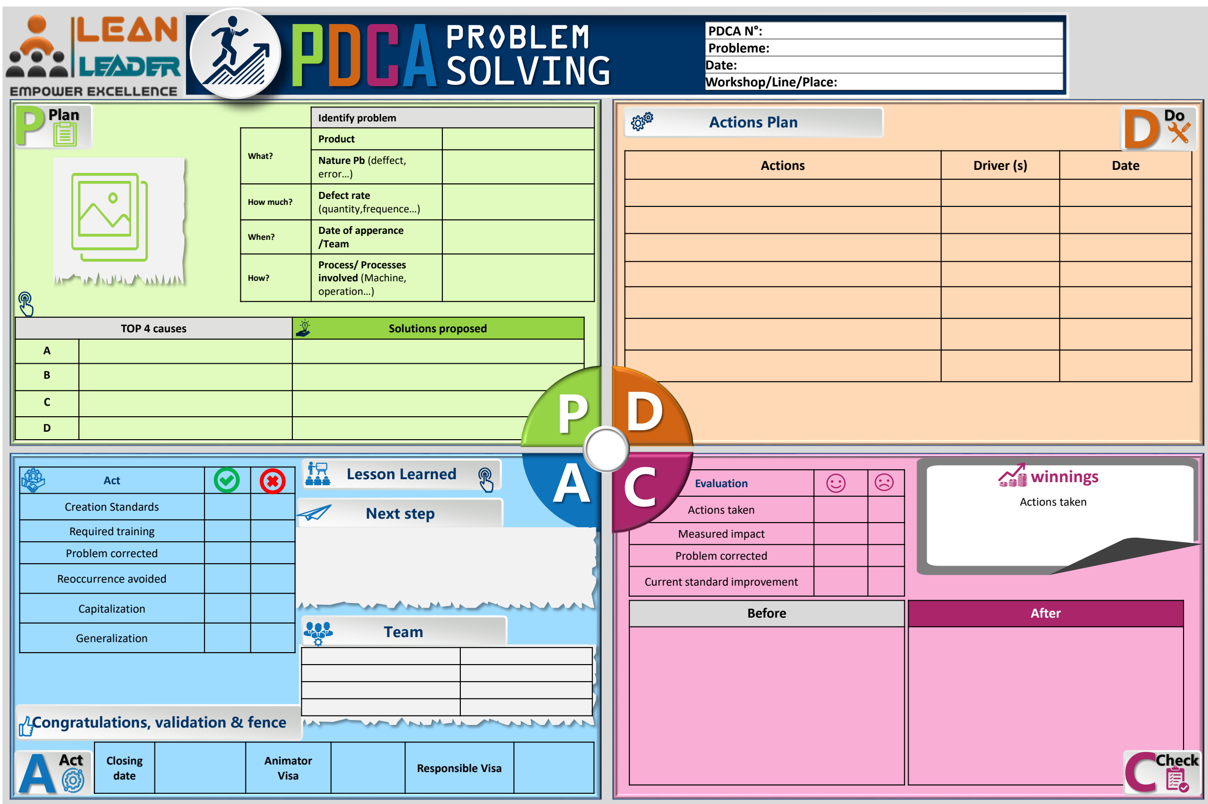

Figure 4.6: PDCA reporting exemple

This document serves as a comprehensive report detailing the PDCA implementation cycle for this specific project. It aims to provide a visual standard for understanding each phase of the cycle and the corresponding improvements achieved.

4.3 Conclusion

This chapter has delved into process improvement methodologies, with a focus on the PDCA cycle. By analyzing anomalies, suggesting an action plan, and outlining the other steps. The factory now has to choose the perfect time to implement this case study with with great care respecting all the instructions.

Chapter 5

Results And Discussion

5.1 Warehouse improvement

The previous sections explained how to do the diagnostic of the problems encountered using Ishikawa diagram. During this analysis, It turns out that all the problems has common point which is the lack of visual management that impact on the organization and the process approach inside the warehouse. This causes problems like moving containers around and making mistakes in finding and picking items, the waste of the time during this unjustified movement also for finding the container wished and the accidents that might happen because of the lack of awareness indications. To fix this problems, it was defined some goals:

Reduce containers movement decreasing it by 20% in six months: for reducing containers movement, implementing visual management techniques like color coded labels, clear signage can streamline the organisation. Using visual indications helps employees to quickly find, retrieve products with less container movement by clearly indicating the place of each container and systematically organizing storage spaces.

Find the container wished easier reducing the recuperation time by 30% the next 6 months: to find the container wished easier, vba excel integration and visual identification like matrix system increase the inventory management approach. This step helps to truck easily the inventory and reducing the waste of time.

Reduce mistakes by 25% the next 6 months: for reducing the mistakes, the implementation of Poka Yoke failure analysis helps to identify and prevent errors. Installing shelves with the visual indications implementation like signs, markers and potency helps workers to pick up the right items and reducing mistakes.

Enhance warehouse security measures within six months: for improving warehouse security, implementing a visual identification system using clear and easily recognizable visual cues. This system will help identify authorized personnel, monitor access points, and deter unauthorized individuals from accessing restricted areas. Visual identification, such as color-coded badges or uniforms, enhances security protocols by ensuring that only authorized individuals can access sensitive areas, thereby reducing safety risks and improving security.

Determining the causes, effects and goals for each anomaly helps outlining the other steps in the PDCA cycle, such as developing the action plan presented, implementing the improvement ideas, applying the changes, checking them against the objectives set, and reviewing the results.

5.2 Data visualisation of OEE improvement

5.2.1 Power BI software

Power BI (Business Intelligence) is a business analytics reporting tool introduced by Microsoft to create interactive business reports. It incorporates several analytics features to provide business insights across an organization. Prior to Power BI, end-users were dependent on information technology staff and database administrators for creating business reports and dashboards. Now, end-users can create business reports and dashboards on their own with the help of Power BI. The Power BI Datasets feature allows users to represent data and create visualizations based on the data[51]. The concept of Power BI process is illustrated in 5.1.

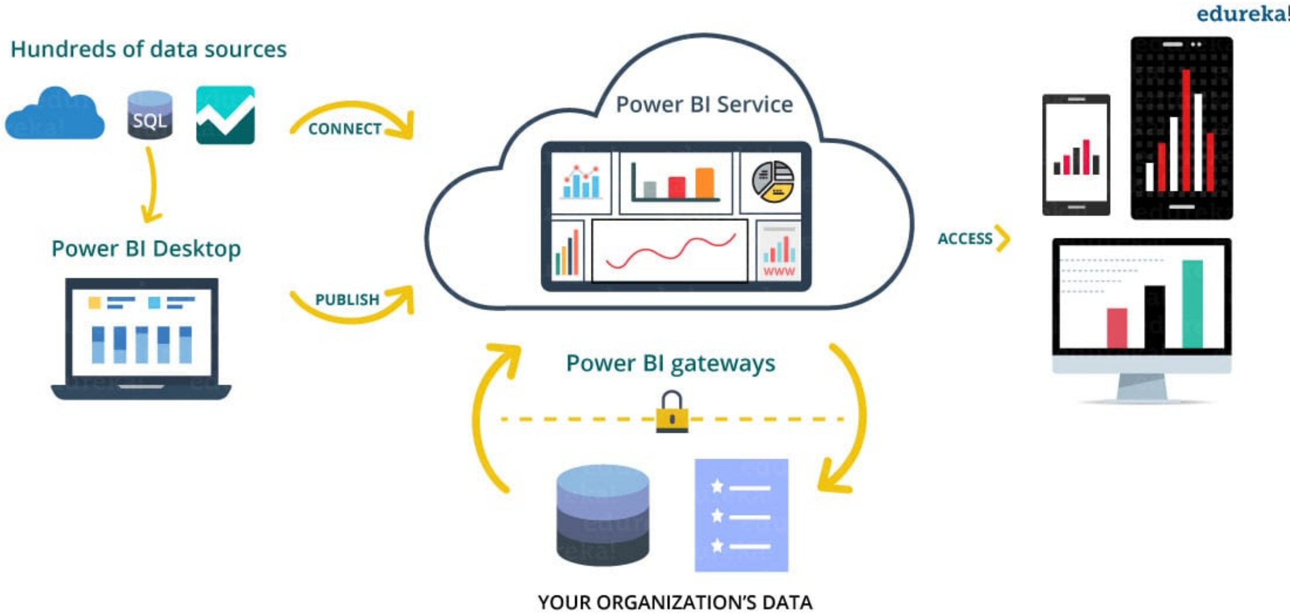

Figure 5.1: Power BI process [52]

5.2.2 Data Integration

Data preparation

In this Power BI data visualization, data integration from an Excel file serves as the backbone for the dashboard design. The Excel file provides understanding into manufacturing operations, featuring the Key Performance Indicators (KPIs) such as the sum of registered hours, operating hours, sum of savings, and average OEE.

Technologies

The resulting dashboard showed on the figure 5.2 offers a comprehensive view of machine productivity and financial performance within the manufacturing environment. This integration facilitates informed decision-making and optimization strategies to enhance operational efficiency and cost-effectiveness.

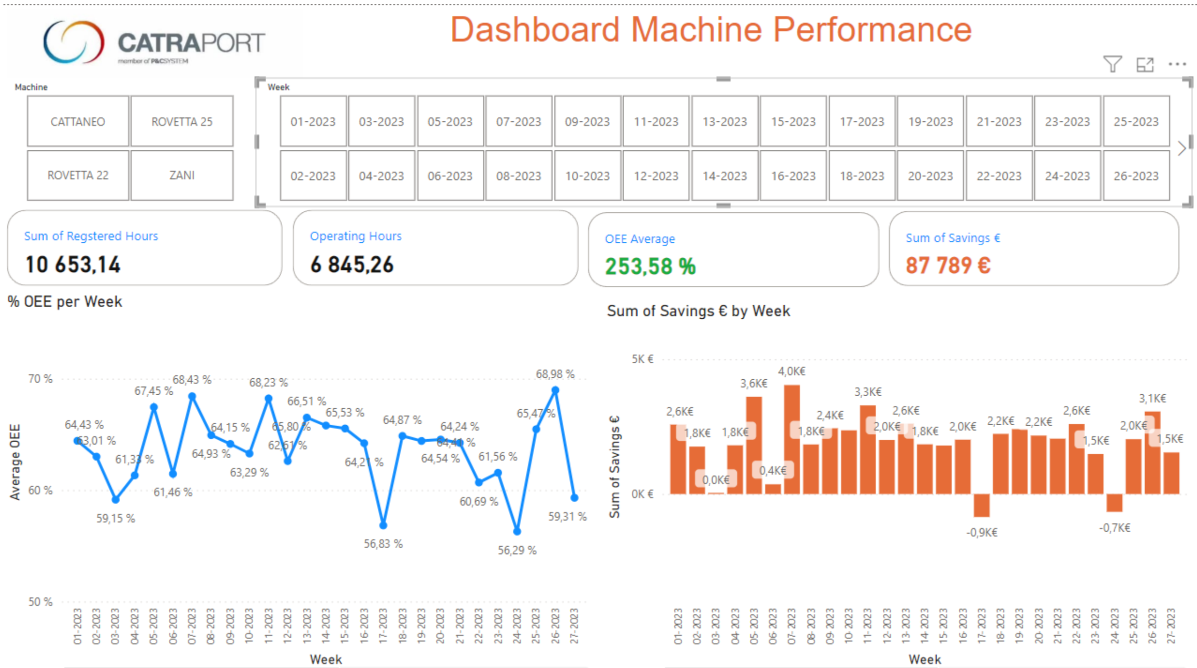

Figure 5.2: Dashboard Machine Performance

KPIS used

The KPIs applied in the data visualization include the sum of registered hours, operating hours, sum of savings, and average OEE. These metrics enable a focused analysis of machine productivity and financial performance, aiding in informed decision-making and optimization strategies within the manufacturing environment.

5.2.3 Deployment

In the deployment phase, it presents the learnings from the Power BI dashboard developed. The use of the info from the Excel file to make real changes in how things run in the factory. The aim is to make machines work better and save money. By focusing on things like how long machines are on, how well they work, and how much we save, by making the factory run smoother and cost less. This deployment phase is all about making smart moves to help the factory grow and do better in the long run.

5.3 Case studies

Using the OEE weekly average strategy, while simplifying reporting and reducing administrative effort, results in delayed detection and response to problems, as well as a less accurate view of performance issues. This can obscure patterns and evolution's, making it more difficult to diagnose and resolve specific problems quickly. As a result, operational responsiveness and agility are reduced, which can hamper continuous improvement initiatives, employee engagement and decision-making based on up-to-date data. In addition, this can have a negative impact on maintenance planning and inventory management, leading to less optimal production efficiency overall. A figure 5.3 outlined below shows the OEE average of 'Zani' during 8 weeks.

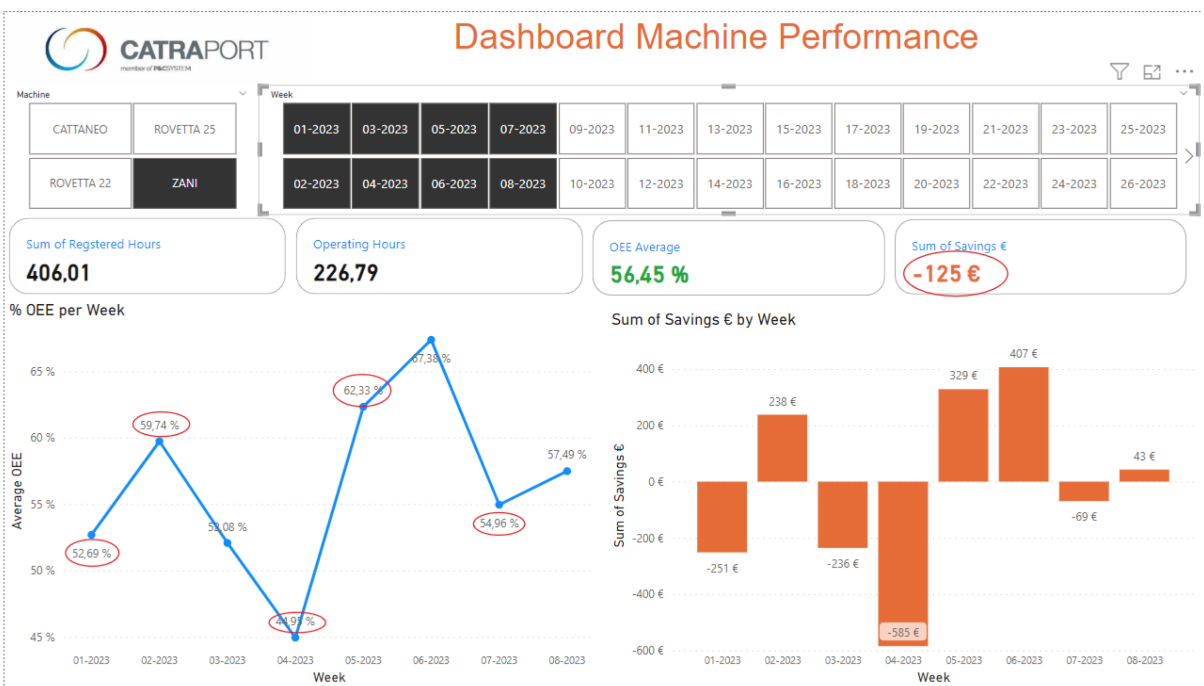

Figure 5.3: Visualization of 8 weeks average of Zani

The above figure shows the instability of the variation in the OEE average every week, due to several factors. For example, the value of the average OEE of the machine Zani in the first case fell from 59.74% to 44.95% in just two weeks. This fluctuation of average during this 8 weeks impact a deficit of -125€. For the second case the average fell from

76,19% to 48,14% in one week and 65,19% to 48,41% in the same term. This fluctuation of average during this 8 weeks impact a deficit of -425€as represented in the figure 5.4.

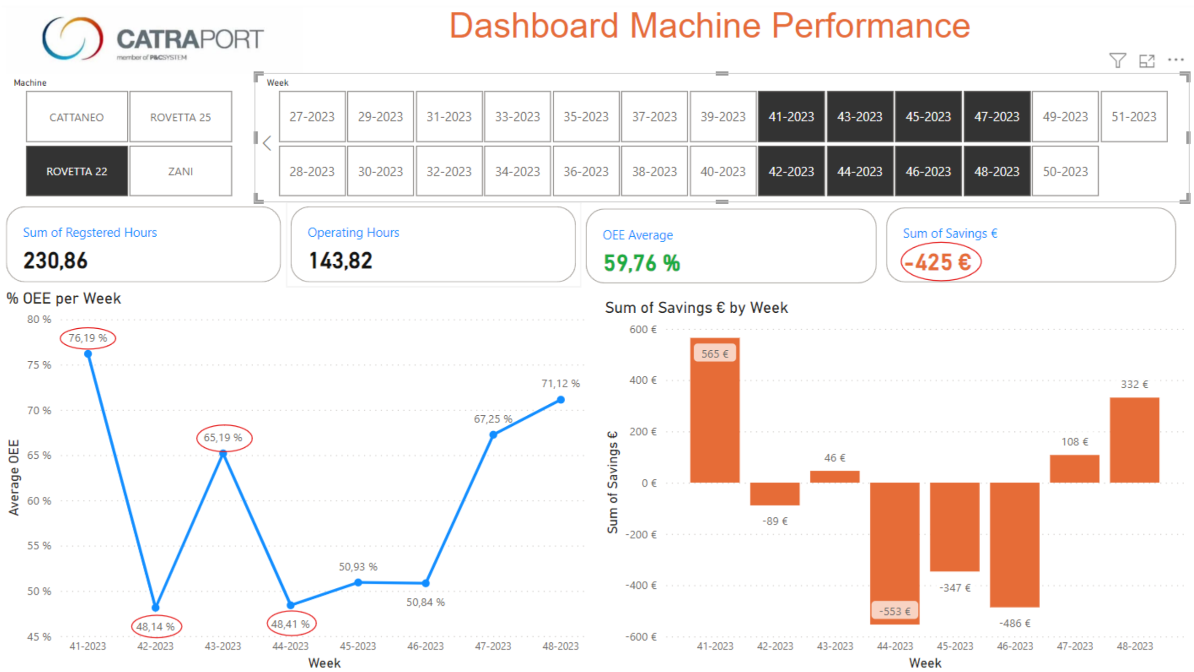

Figure 5.4: Visualization of 8 weeks average of Rovetta 22

The factory currently lacks a comprehensive database to accurately track and analyze these issues. Without detailed data, it is challenging to pinpoint the exact causes of the performance drop during this period. The absence of a centralized database means that historical data on machine performance, maintenance records and quality control measures are not readily available. This lack of information makes it difficult to implement targeted improvements or predict and prevent future issues.

5.3.1 Solutions for improvement

In order to enhance Overall Equipment Efficiency and transition to real-time monitoring, it is necessary for the factory to use Internet of Things (IoT) sensors and Supervisory Control and Data Acquisition (SCADA) systems. These technologies will enable the continuous collection and analysis of data. A consolidated cloud-based data platform will merge machine performance, maintenance records, and quality control data, allowing for predictive analytics to facilitate proactive maintenance. The implementation of real-time dashboards and automatic alerts will enable prompt action to be taken in response to any problems that arise. Additionally, the integration of communication tools will improve collaboration among team members. Implementing continuous staff training and embracing Lean techniques will provide continued enhancements, resulting in improved maintenance planning, efficient inventory management and increased production efficiency. By shifting to real-time monitoring and data management, the factory can expect to see significant improvements in OEE and overall production efficiency. The proposed implementation of IoT sensors and SCADA systems would allow for continuous data collection and analysis, facilitating immediate detection and response to issues. A centralized cloud-based data platform would enable comprehensive tracking of machine performance, maintenance records, and quality control data. This approach would support predictive maintenance, potentially reducing unexpected downtime. Real-time dashboards and automated alerts would enhance operational responsiveness, while integrated communication tools would improve team coordination. Continuous training and the adoption of Lean practices would drive ongoing improvements. These changes are anticipated to optimize maintenance planning, improve inventory management, and ultimately increase production efficiency.

5.4 Conclusion

This chapter summarizes the results obtained from the previous analysis of warehouse inefficiency and discusses the objectives set for improvement. It also presents the development of a new dashboard showing the OEE visualization, investigates two case studies of the weekly average OEE, and suggests some improvement ideas.

Chapter 6

Conclusion

In conclusion, the maturity assessment of lean manufacturing methods at Catraport factory has revealed significant operational challenges exacerbated by the use of a push system and inadequate warehouse management practices. The identification of root causes through the Ishikawa diagram, 5W1H highlighted issues such as overstocking, lack of visual management, organizational inefficiencies, transport safety concerns, and limited space constraints.

To address these challenges, a structured approach was undertaken, beginning with the formulation of SMART objectives tailored to each identified anomaly. Goals included reducing container movements, enhancing shelving and labeling systems, implementing visual management solutions, and strengthening security measures within a six-month timeframe. These objectives were supported by a detailed action plan and Gantt diagram to ensure systematic implementation and effective time management.

Furthermore, the analysis of Overall Equipment Effectiveness underscored the limitations of relying on weekly average data for performance monitoring. Fluctuations in OEE averages over an 8 weeks period highlighted the need for real-time monitoring capabilities and predictive analytics to optimize maintenance planning and minimize production downtime. Proposed solutions involved leveraging Internet of Things technologies and SCADA systems to enable continuous data collection, analysis, and proactive decision-making.

The implementation of a visual reporting system and a cloud-based data platform was recommended to centralize operational data and facilitate comprehensive analysis across production metrics, maintenance records, and quality control measures. These advancements are crucial in enhancing operational efficiency, improving inventory management, and fostering a culture of continuous improvement and collaboration among team members.

In conclusion, the journey towards optimizing warehouse operations at Catraport factory exemplifies the transformative impact of strategic analysis, targeted interventions, and technological innovation. By addressing identified challenges systematically and leveraging advanced monitoring and analytics tools, the factory is poised to achieve sustainable improvements in productivity, resource utilization, and customer satisfaction. This holistic approach not only enhances operational excellence but also positions Catraport factory for long-term success and competitiveness in the manufacturing sector.

Therefore, it is suggested that future work involves monitoring the implementation of the action plan presented, improving it until it can fully replace the current procedure. Finally, it is suggested to improve the OEE efficiency by analyzing the current method and implementing the new developed tools to have a solid data, to prevent the problems and improving communication between factory's departments.

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Appendix A

Warehouse structure

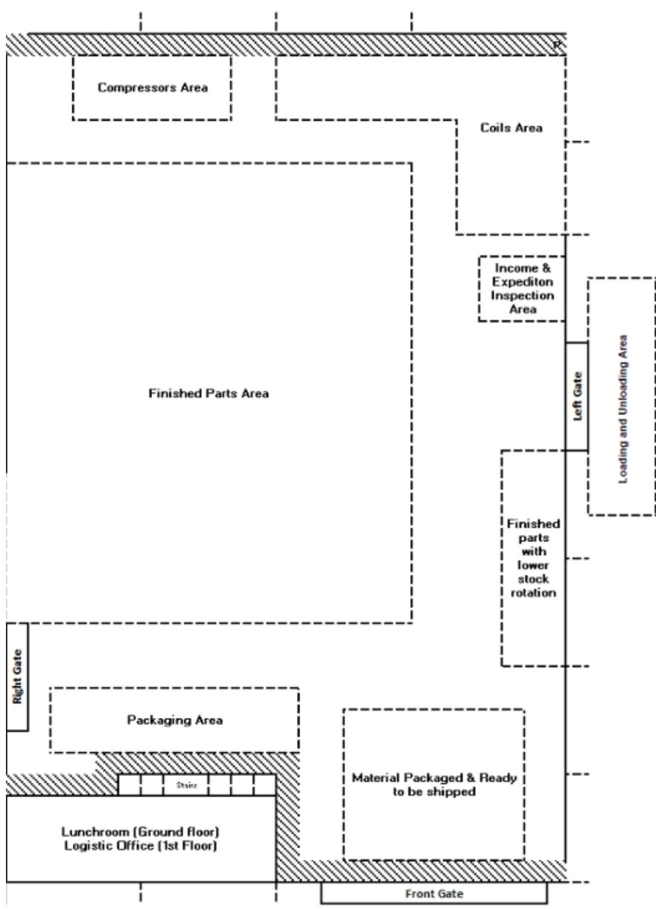

Figure A.1: Warehouse organisation

Appendix B

Ishikawa's analysis

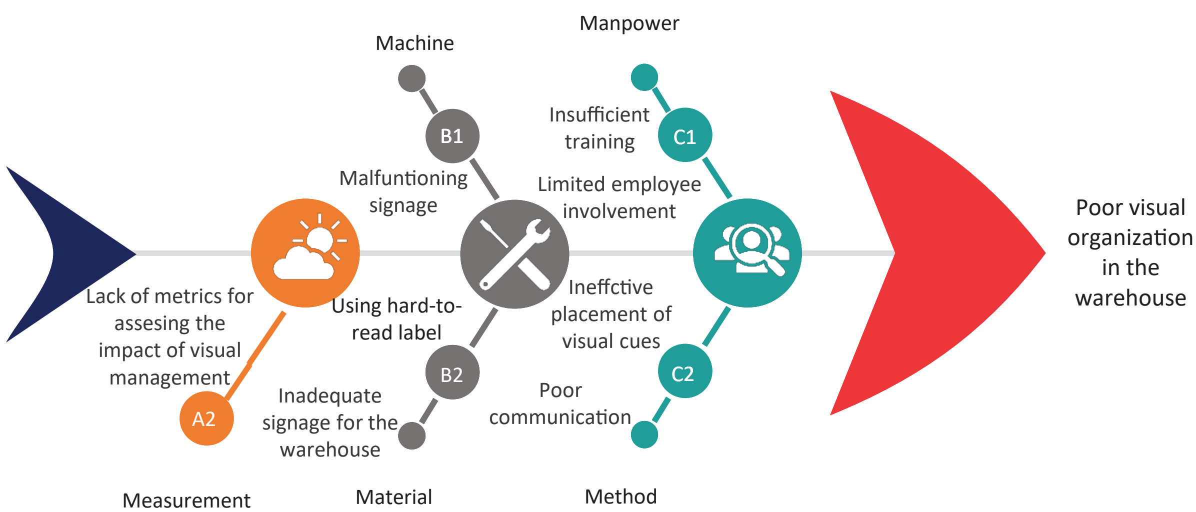

Figure B.1: Ishikawa lack of visual management

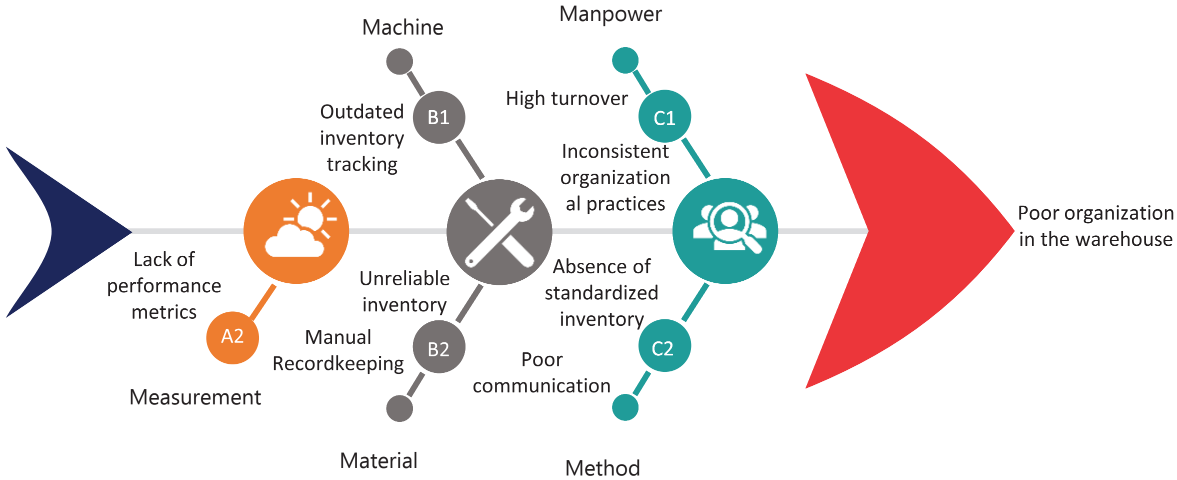

Figure B.2: Ishikawa organizational challanges

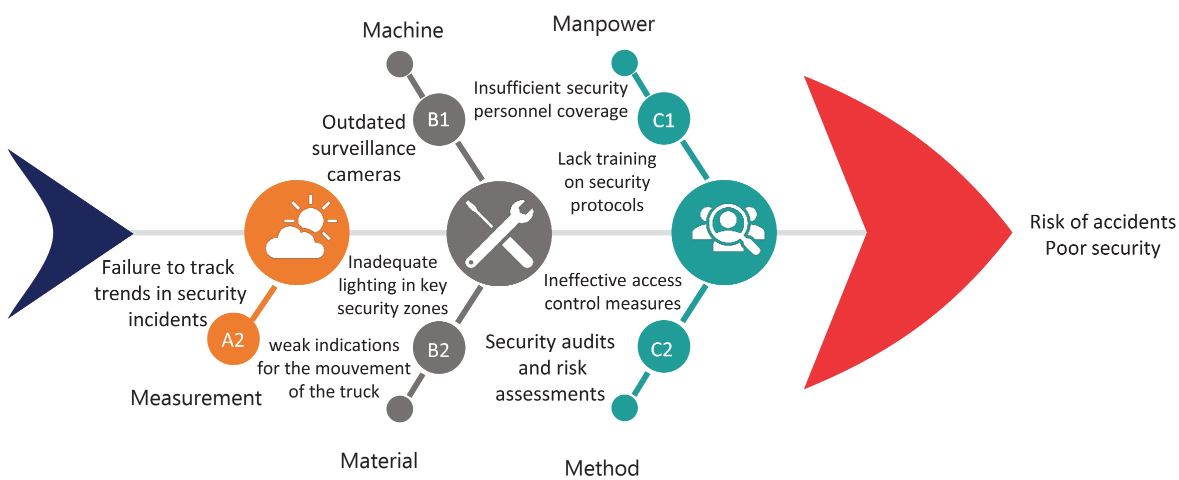

Figure B.3: Ishikawa Security considerations

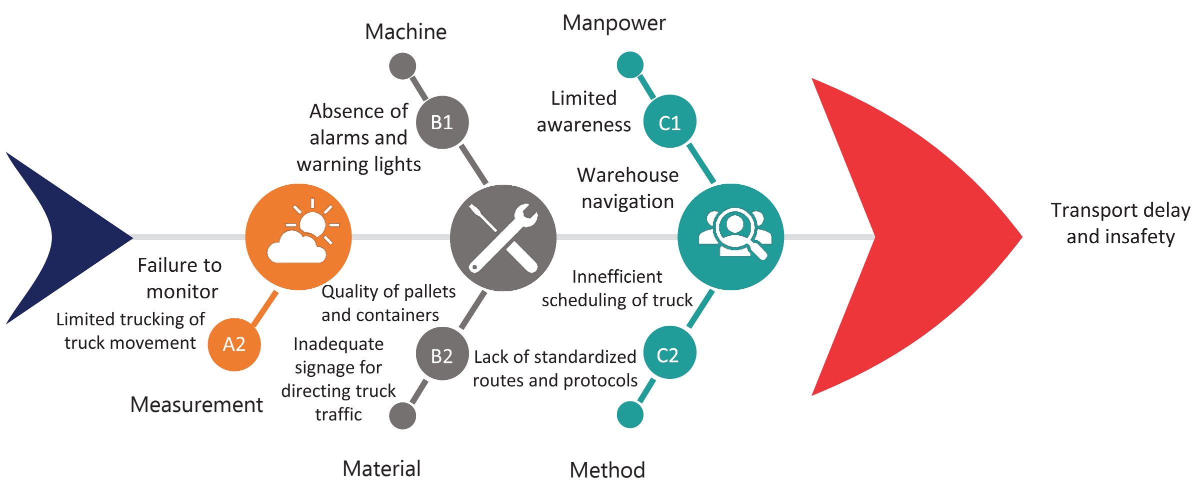

Figure B.4: Ishikawa Transport challenges

Appendix C

SMART goals

Figure C.1: Objective goal of lack of visual management

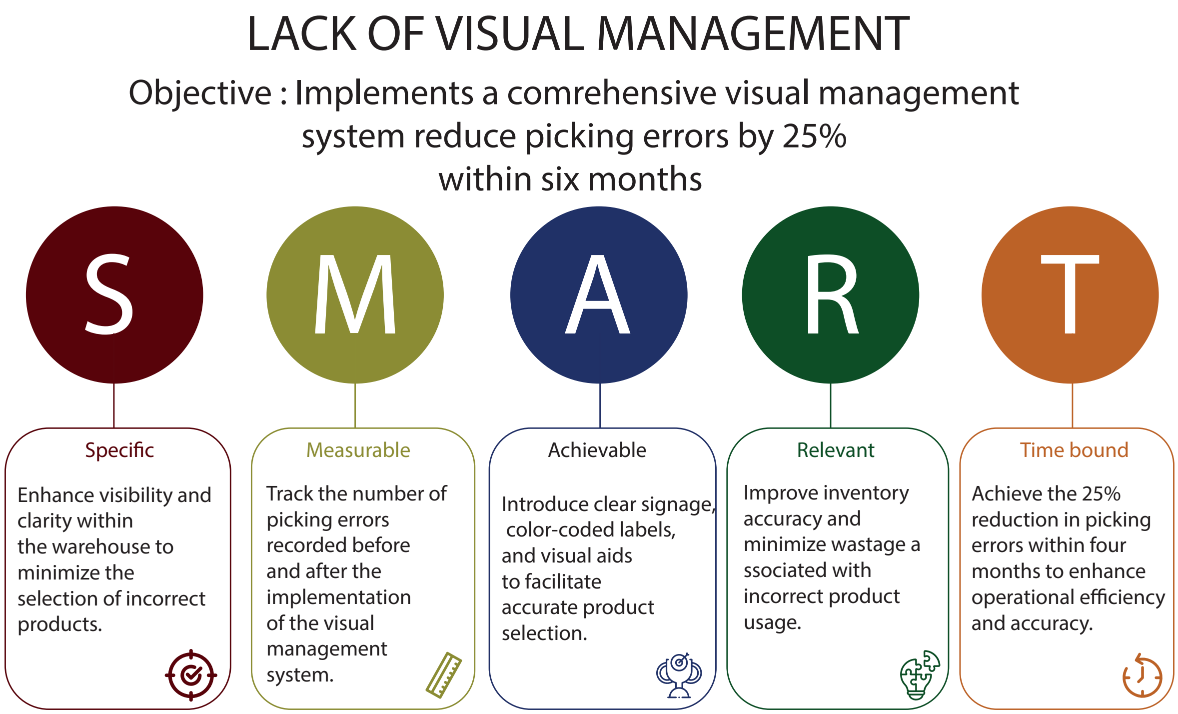

Figure C.2: Objective goal of organizational challenges

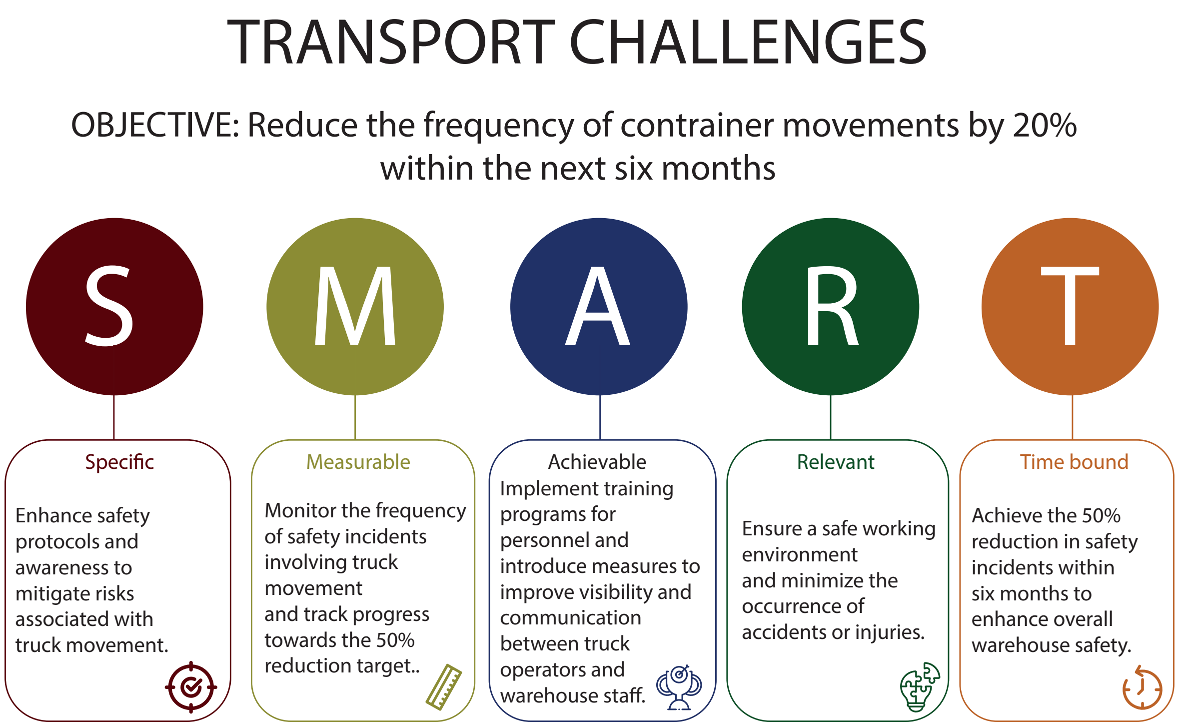

Figure C.3: Objective goal of security

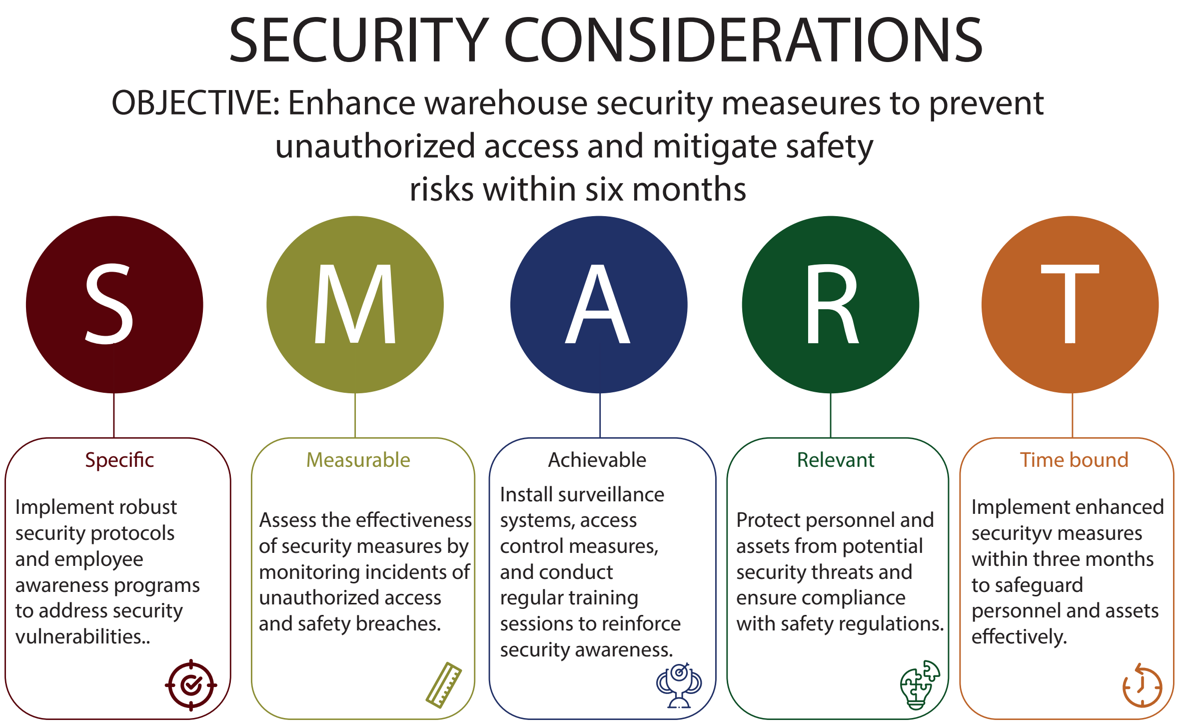

Figure C.4: Objective goal of transport challenges

Appendix D

Action Plan

Figure D.1: Action Plan

Project Name: Action plan Updated on:

Dept: Logistics **Past Due** 05/04/2024

Due Soon

Tasks	Statut	Start Date	End Date	Duration	Progress%	Responsibility	Comments
Visual identification system for containers				0			
Visual identification system for security				0			
Alarm system installation				0			
Floor markings				0			
Signboards implementation				0			
Asaichi system				0			
Develop VBA Excel for storage				0			
Training session				0			

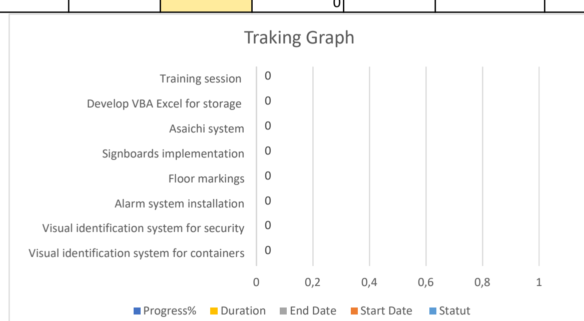

Figure D.2: Gantt Chart diagram for action plan