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"STUDY OF FEEDING METHODS OF THE PRODUCTION LINES. DAB PUMPS S.P.A. CASE STUDY"

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Riassunto

La Lean Production è riconosciuta come un metodo organizzativo che si basa sul concetto del miglioramento continuo. In particolare, fornisce un insieme di principi e metodi che mirano a eliminare gli sprechi e a portare i processi aziendali all'eccellenza.

In questa tesi viene presentato il caso studio effettuato presso l’azienda DAB Pumps, un'azienda specializzata nel settore delle tecnologie per il trattamento e la gestione dell’acqua. L'obiettivo principale del progetto era la riduzione dello spazio di magazzino materie prime e semilavorati ed il relativo valore.

Nei capitoli successivi viene mostrato come attraverso l’applicazione della filosofia Lean, l’azienda sia riuscita ad ottenere maggiori performance. Dopo una prima fase di analisi, è stata fatta una mappatura del flusso attraverso dalla quale è subito emerso che la maggiore fonte di spreco era la mancata sincronizzazione delle linee lungo il processo di creazione del valore. La linea che produce semilavorati ragionava come reparto indipendente volto a raggiungere la massima efficienza, senza considerare la reale necessità di produrre o meno.

Nell’elaborato viene mostrato come attraverso l’applicazione del kanban si sia riusciti a sincronizzare le due linee di produzione, ragionando con un’ottica “pull” anziché “push”. Tenendo conto di tutti i vincoli attualmente presenti e oggetto dei successivi progetti di miglioramento, è stato fatto un dimensionamento del kanban in modo da garantire il continuo asservimento della linea a valle e, allo stesso tempo, controllare la produzione della linea a monte, evitando di creare un eccessivo magazzino di semilavorati.

Confrontando le performance ottenute nel 2021 prima del progetto con quelle del 2022 anno nel quale è stato implementato, viene messo in evidenza come attraverso l’applicazione dei principi e strumenti Lean, le aziende possano migliorare gradualmente le proprie performance.

Abstract

Lean Production is recognized as an organizational method based on the principle of continuous improvement. Specifically, it provides a set of principles and methods that are aimed at eliminating waste and bringing business processes to excellence.

This thesis presents the case study carried out at DAB Pumps, a company specialized in water treatment and management technologies. The main objective of the project was the reduction of raw material and semi-finished product warehouse space and its related value.

This thesis shows how through the application of lean philosophy, the company has been able to achieve greater performance. After an initial analysis phase, flow mapping was done which showed that the most significant source of waste was the lack of synchronization of lines along the value creation process. The line producing semi-finished products was acting as an independent department aimed at achieving maximum efficiency, without considering the real need to produce or not.

The thesis shows how through the application of the kanban it was possible to synchronize the two production lines, reasoning from a "pull" rather than a "push" perspective. Taking into account all the constraints currently present and the subject of the subsequent improvement projects, kanban sizing was done in order to ensure the continuous feeding of the downstream line and, at the same time, to control the production of the upstream line, avoiding the creation of an excessive stock of semi-finished products.

Comparing the performance achieved in 2021 before the project with the performance in 2022, year in which it was implemented, it is highlighted how through the application of lean principles and tools, companies can gradually improve their performance.

INTRODUCTION

In recent years, market volatility has forced companies to adopt production approaches and methodologies that are increasingly flexible, lean and resilient to unforeseen events. Lean Manufacturing, an approach originated in Japan to provide flexibility while maintaining business productivity, is among the most innovative business approaches in this regard. An increasing number of companies are taking part in this form of change, as in the case of DAB Pumps S.p.A., a multinational company that is a leading manufacturer of pumps for water handling and that is the case study in this thesis.

Lean Production is recognized as an organizational method that is based on the principle of continuous improvement. It provides a set of principles and methods that are aimed at removing waste and leading the company's processes to excellence. This thesis will show how some principles and tools of Lean Production were applied to improve the company's performance level.

The first chapter begins with a brief introduction to lean production and some historical insights into its evolution and diffusion in global business contexts. The chapter then continues with an in-depth study on Lean Management, the first focus is made on Muda, on waste, considered as the first enemy to be eliminated in order to increase the customer service level and increase the company's marginality. Eliminating waste from a lean perspective means giving business continuity. In the second part of the first chapter, all the principles of Lean Manufacturing are presented: value identification, value mapping, flow definition, implementation of Pull methodology, and pursuit of perfection. The principles are considered as a guideline to be followed in order to make the company totally connected with customer needs and flexible in the face of change. The chapter concludes with a focus on the Toyota Production System and all the tools used in lean.

The second chapter begins with a presentation of DAB Pumps S.p.A., the industry in which it is placed, products and markets in which it operates. The chapter then continues with a focus on the Hungarian subsidiary, the production site where the project was carried out, making mention of its history and products. The last part is about the MRP system and its application according to product types: make to order and make to stock products.

The third and final chapter is about the project carried out. Once the reasons for launching the project have been explained, the chapter continues with all the activities carried out by dividing them into two clusters: Core activities and Support activities. This phase of the chapter is considered the core phase of the thesis as all the analysis and implementation activities carried out during the project are detailed. The chapter and the thesis conclude with the results obtained from the implementation of the new method. The results compare performance between 2021 and 2022, the year in which the implementation of the project took place, in different perspectives. The first part presents the KPIs of Stock Cover and Stock Turn, the value of stock material, and the occupied warehouse space in the two years compared. It then continues with the results regarding the increase in production efficiency. The chapter concludes with an in-depth discussion of what were the improvements in terms of shop floor security.

CHAPTER 1

DEFINITION OF LEAN PRODUTION

In this chapter, the concept of lean manufacturing and its evolution over time will be introduced. The first part will explain the concept of lean production and explore the history of the Toyota Motor Company. In the second part, lean management will be analyzed in a more technical way. The main principles and tools that should be applied in companies to carry out the lean transformation will be explored in detail.

1. What is lean production?

The term Lean was first created by John Krafcik, an International Motor Vehicle Program (IMVP) master's student at Massachusetts Institute of Technology (MIT), in the mid-1980s and later introduced into management terminology by Womack, Jones and Roos within the book “The machine that changes the world” published in 1990.

The lean production approach is “lean” compared to mass production because it uses half human effort in the factory, half production space, half investment in tools, and half engineering hours to develop a new product in half time. This approach requires less than half the inventory at the production site and ensure greater and ever-increasing product variety (Womack, Jones and Ross, 1990). This definition was taken up six years later by Womack and Jones in the book Lean Thinking (1996), in which they specify how another goal of lean thinking is to try to get as close as possible to the customer's needs by trying to offer him exactly what he wants.

These definitions are the two basic pillars on which the lean model is based: the pursuit of efficiency with the aim of reducing production costs and the full satisfaction of customer needs. The latter point means greater ability to respond to market needs by offering more variety rather than a single, totally standardized product, as it was in mass production. In short, the lean model can be summarized as give to the customer in an efficient way what they want, when they want it, where they want it, and in the quantities they want it.

2. The Origin of Toyota Production System

Toyota's first model, the AA, was born in 1936 at the Toyoda Automatic Loom Works automotive division. Toyoda Automatic Loom Works was the company where the family based its main business related to the weaving industry. It had been founded in 1890 by Sakichi Toyoda (1867-1930), father of Kiichiro Toyoda (1894-1952). In 1937, under the leadership of Kiichiro Toyoda, the automotive division was made independent and took the name Toyota Motor Company.

Until the end of the Second World War, the production model was the American one: mass production. Thanks to the availability of energy and raw materials, it was possible to produce large quantities of consumer goods to be 'pushed' onto the market by putting supply before demand.

On the other hand, the post-war socio-economic context in Japan was totally different: the lack of capital in addition to the high production and raw material costs did not allow the application of the western economic model.

In the early 1950s, in Japan, economic conditions began to decline due to the introduction of economic devaluation policies. In Toyota Motor Co. the expected increases in production did not materialize and the crisis began. Kiichiro Toyoda retired in 1947 and turned the company over to Eiji Toyoda (1913-2013), with the goal of catching up with the American auto industry. During these years Eiji Toyoda was joined by Taiichi Ohno (1912-1990). Face with this problem Ohno realized the need for a radical change of strategy and decide to take a new path: put the customer and his satisfaction at the center and eliminate waste at all levels. He introduced the concept of Jidoka, or automation, inspired by the automatic loom invented by Sakichi Toyoda and combined it with the Just-in-Time principle developed by Kiichiro Toyoda. The Toyota Production System was born and has since been applied in all Toyota production plants (Bertagnolli, 2018).

A new model of industrial production was defined to meet the need for production flexibility while maintaining high company productivity. Production based on real demand from the market and no longer on supply as in the Fordist-Taylorist company.

The extraordinary results achieved through this new production philosophy led to the establishment of the Toyota Production System (TPS), an innovative methodology centered on the continuous hunt for waste and the importance of the involvement of everyone in the company.

The concept of Lean Production was born, a philosophy that completely changes the company's point of view and shifts the focus to the customer rather than productivity (Tekin et al., 2019).

Fig. 1 : *Lean production History*

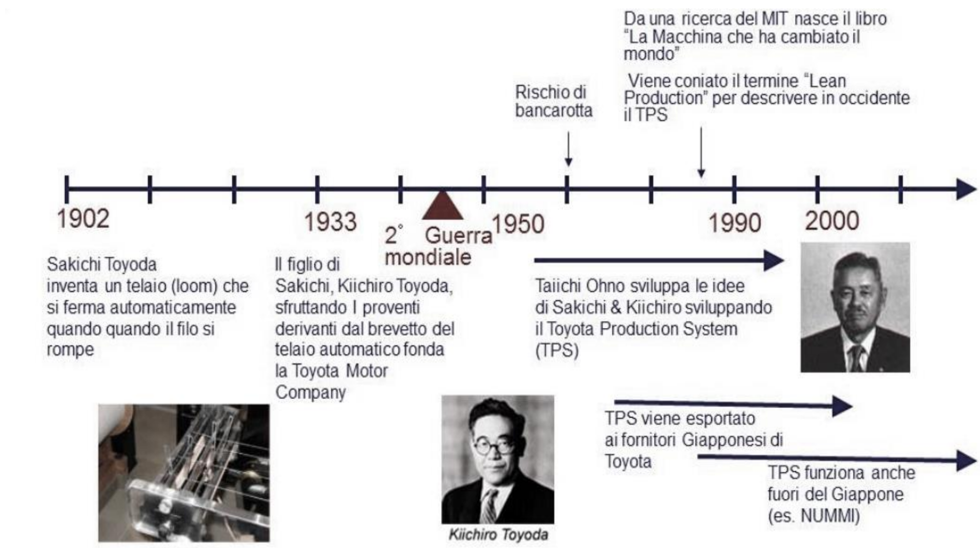

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Fig. 2 : *Difference between Craft, Mass and Lean Production*

	Craft Production	Mass Production	Lean Production
Focus	Task	Product	Customer
Operations	Single items	Batch and queue	Synchronized flow and pull
Overall Aim	Mastery of craft	Reduce cost and increase efficiency	Eliminate waste and add value
Quality	Integration (part of the craft)	Inspection (a second stage, after production)	Prevention (built in by design and methods)
Business Strategy	Customization	Economies of scale and automation	Flexibility and adaptability
Improvement	Master-driven continuous improvement	Expert-driven periodic improvement	Workforce-driven continuous improvement

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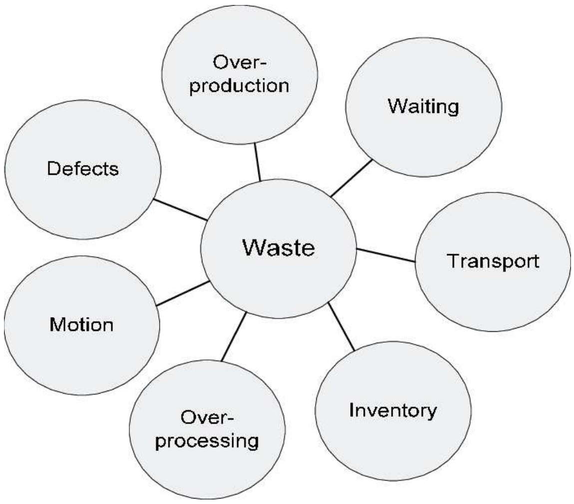
3. Lean Management

The term lean manufacturing refers to the set of methods and tools for building an efficient and effective organization to produce a product or service while maximizing resources. It is a management philosophy aimed at generating the maximum amount of value for the customer with the minimum amount of waste (Jackson et al., 1996). Waste is anything that does not add value to the product or service for the customer or that does not add value to the company as a whole. Value (Womack and Jones, 1996) and waste are the two core concepts of lean management. Lean management combines methods to optimize and improve processes. However, Lean is more than just a collection of methods and principles. Lean has mainly to do with the strategy and culture of a company (Bertagnolli, 2018).

3.1 *Muda*

The cornerstone of the Lean philosophy is the centrality of the customer and the value he perceives. According to this perspective, all activities that do not create value for the end customer are considered waste in Japanese Muda. Eliminating waste helps to reduce the customer's waiting time, cutting some of the production costs that are a significant part of the final price of the good or service and improving quality (Smith, 2014; Okpala, 2014; Bertagnolli, 2018).

Fig. 3 : *The seven wastes*



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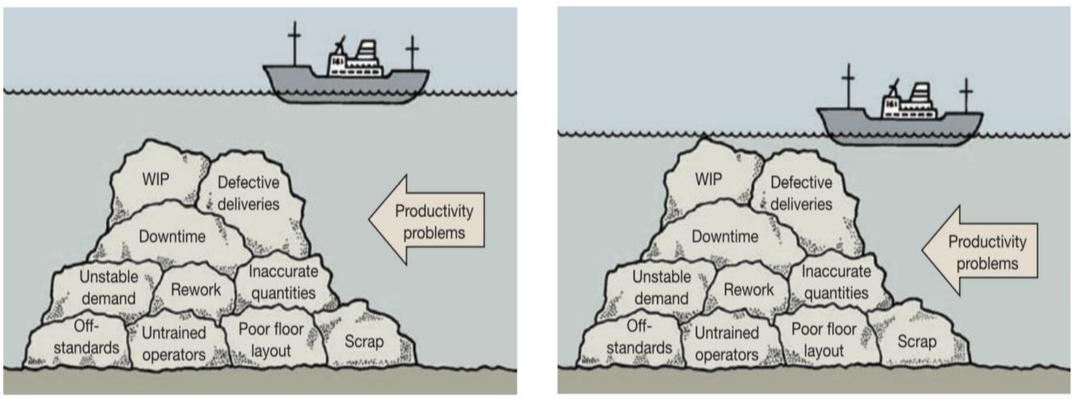
➢ ***Overproduction***

Overproduction is the main waste and the origin of the other types of waste, in particular inventory, defects and transport. Overproduction means producing more than customer's demand and more than the market can absorb. This pattern is typical of batch production, where the quantity of parts to be produced is calculated asynchronously with respect to the market demand in order to maximize the utilization of production facilities, rather than customer satisfaction (Ohno, 1988; Rewers et al., 2016; Bertagnolli, 2018; Jaffar et al., 2015).

➢ ***Inventory***

Inventory is an accumulation of materials (raw materials, semi-finished or finished products) or information waiting to be processed or shipped to the customer. In financial terms, it is a capital assets that could be invested differently in order to have a cash flow return. It takes up space, it is responsible for unnecessary handling that may damage the goods during movement, and it may be affected by obsolescence. Last but not least it covers quality problems: when we produce in batches, it is difficult to check all the single items and with high inventory it is difficult to identify quality problems. The reduction of inventory level can reveal the operations' problems (Ohno, 1988; Rewers et al., 2016; Bertagnolli, 2018; Jaffar et al., 2015).

Fig. 4 : *Inventory problems*



<u>*www.chegg.com*</u>

- ***Waiting***

Waiting is a problem related to an imperfect synchronization between different activities, caused by line balancing errors or poor planning quality. Waiting time, and therefore waste, refers to the situation in which there are staff members who are not carrying out any activity, because they are waiting for a previous operation to be completed or for material or equipment. It can also be considered as an operator overseeing the operation of an automatic machine without carrying out any operations. This time could be spent more productively (Ohno, 1988; Rewers et al., 2016; Bertagnolli, 2018; Jaffar et al., 2015).

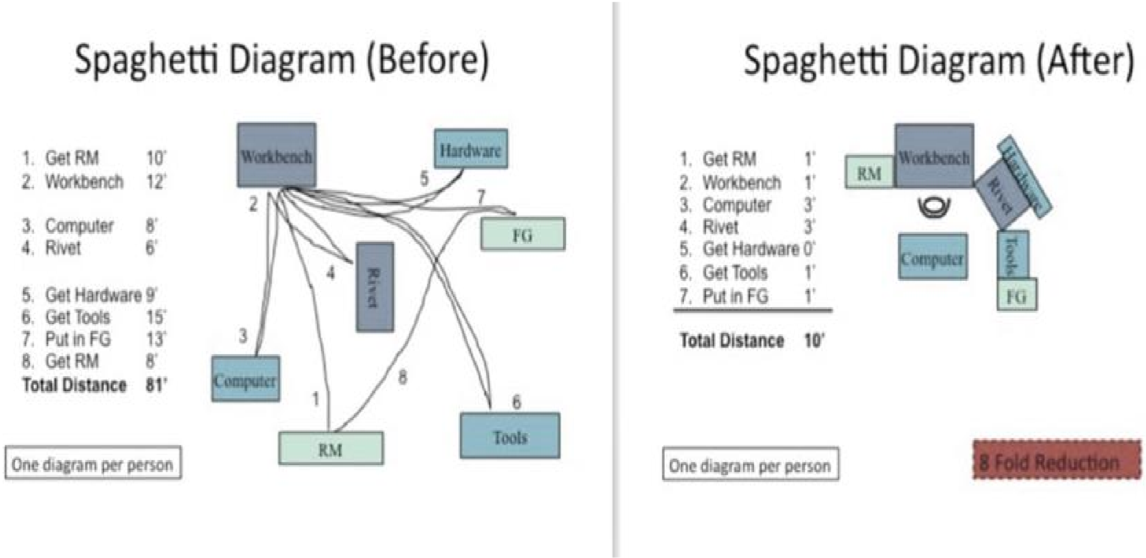
- ***Transportation***

Although all transport does not contribute to value creation, not all of it can be avoided. It is important to reduce them as much as possible. It is important to analyze the reason why transportation is required, seeking to reduce or eliminate the constraints that make it essential. Transportations are a waste of time, resources and a cause of physical damage to materials during handling (Ohno, 1988; Rewers et al., 2016; Bertagnolli, 2018; Jaffar et al., 2015).

- ***Motion***

Motion are the movements that an operator makes to perform his or her activities that do not generate any added value for the customer. It is related to ergonomic factors and safety in the workplace. Incorrect layouts of production lines, non-optimal distribution of materials and tools and poorly ergonomic workstations can generate unnecessary motions. It is necessary to analyze the movements of operators, machines and products within the production process to remove unnecessary motions and increase productivity (Ohno, 1988; Rewers et al., 2016; Bertagnolli, 2018; Jaffar et al., 2015).

Fig. 5 : *Spaghetti Chart*



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➢ ***Defects***

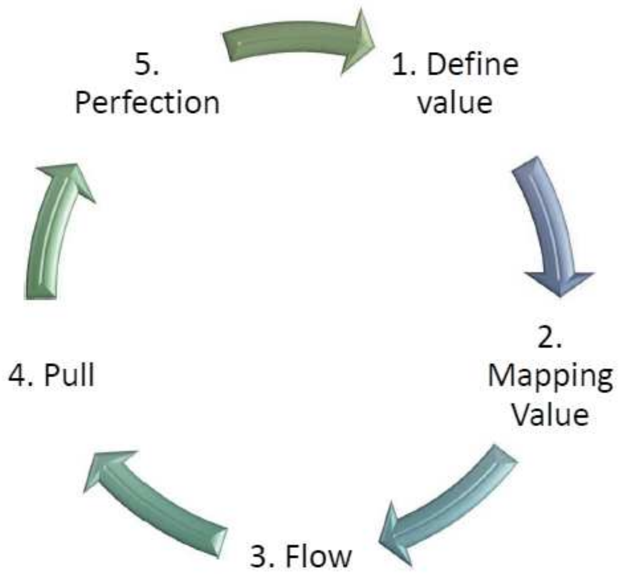
Defects are non-conforming features of a product. They can generate scrap, require rework or, in the worst case, reach the customer and cause dissatisfaction. It is imperative to identify the root causes of a defect in order to eliminate them and produce a compliant product (Ohno, 1988; Rewers et al., 2016; Bertagnolli, 2018; Jaffar et al., 2015).

➢ ***Process wastes***

Process wastes result from unnecessary activities that are carried out during the process that do not directly contribute to the value creation of the product. They may result from either lack of knowledge of the product actually desired by customers or inappropriate training of operators or lack of standard operating procedures ((Ohno, 1988; Rewers et al., 2016; Bertagnolli, 2018; Jaffar et al., 2015).

3.2 The five principle of Lean Thinking

Fig. 6 : *The five principle*



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- ***Value***

A cornerstone of lean thinking is the concept of value. Value is defined by the customer and it is achieved if it can meet the customer's needs (Womack and Jones, 1996).

It is created by the producer (Womack and Jones, 1996): a small amount of time and effort spent in an organization adds value for the end customer. It is therefore essential to clearly define the value of a specific product or service from their perspective, so that a step-by-step removal of all non-value activities or Muda can be carried out (Graziadei, 2006).

The most important objective in defining value, once the characteristics of a product have been identified, is the definition of the target cost. Rather than establishing the price of the product according to the market and figuring out how to produce it to optimize costs and create margins, through lean principles, costs are established first by trying to eliminate all MUDA: only then the price is established. The lower the Muda, the lower the costs and the higher the margins (Womack and Jones, 1996).

➢ ***Value stream***

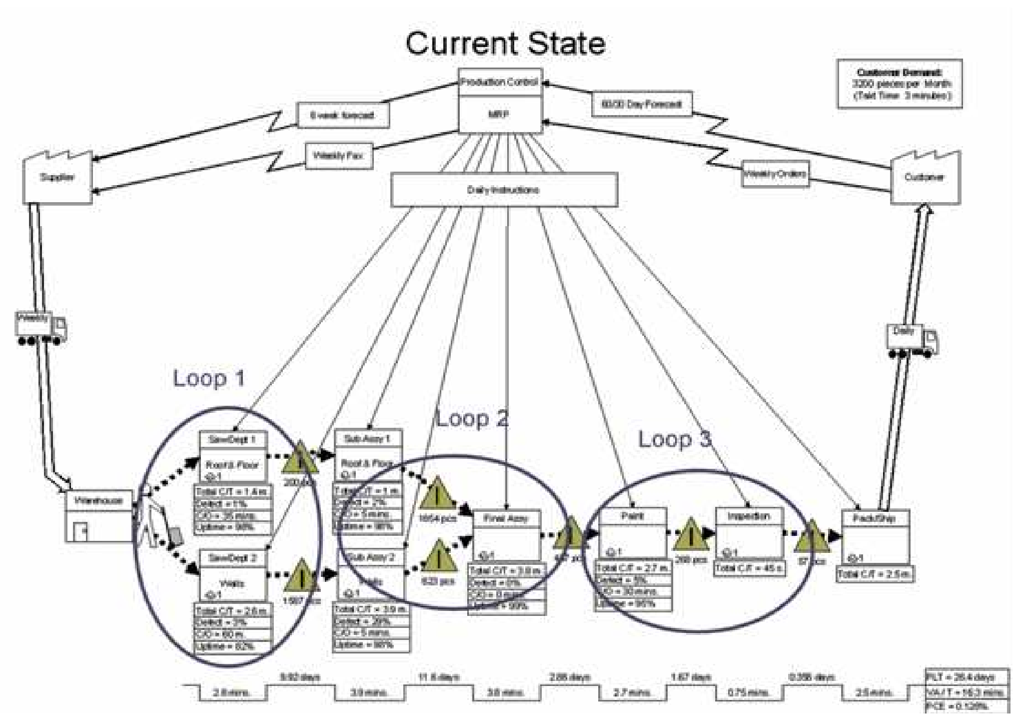
The second principle concerns the identification of value in the entire flow of product or service creation mapping all activities carried out.

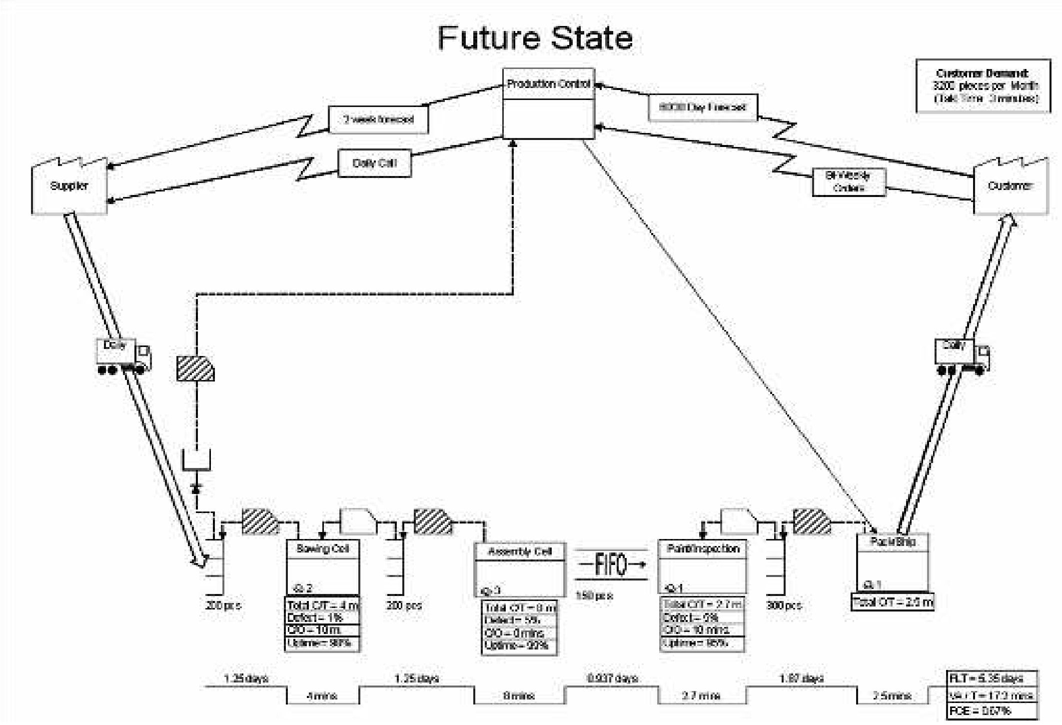
The value stream is the set of activities, both value-added and non-value-added, required for the product (good or service) demanded by the customer.

To most effectively perform activities mapping, the three fundamental processes of any industry must be considered:

- the definition of the product from conception, through detailed design and subsequent engineering, to actual realization;
- the management of information from receipt of order to delivery through detailed planning;
- the physical creation of the product or service delivered to the end customer (Womack and Jones, 1996).

Fig. 7 : *Mapping value – From current state to future state*





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Looking for value within the flow inevitably highlights significant amounts of waste, in the form of superfluous activities, repetition and errors, within the company and throughout the entire supply chain up to the end customer.

The flow analysis shows three types of activities:

- activities that create perceived value for the customer;
- non-value-added activities in the processes that are necessary for the end customer, Muda Type One;
- non-value-added activities in the processes, but these activities are unnecessary for the customer, Muda Type Two (Womack and Jones, 1996).

Analyzing the entire value stream means looking beyond the company and not only within its boundaries. The value stream map (VSM) is the graphical representation of all activities needed to manufacture a product. It contains all actions, value-adding and non-value-adding, which are carried out and it provides a complete overview of all process steps without any boundaries (Bertagnolli, 2018). The collaboration of all parties involved to make the entire value stream flow and reduce waste is called Lean Enterprise (Womack and Jones, 1996).

The goal of this activity is to map the flow by drawing the "current state map", study how to reorganize activities, how to eliminate non-value-added activities, how to eliminate Muda, and finally draw the "future state map". The objective is not to transfer Muda to another player in the supply chain, but to eliminate it (Graziadei, 2006).

- ***Flow***

Once the value has been defined and the various steps that constitute the flow have been identified, the remaining steps must be recomposed into a continuous flow that can proceed without impediments or interruptions (Womack and Jones, 1996).

The application of the flow concept inevitably leads to a critical review of the principles on which the organization is based. In particular, core processes are cross-functional, so divisions between offices and by batches must be avoided. In fact, tasks can be performed more accurately and efficiently if the product is processed continuously from raw material to finished product (Womack and Jones, 1996).

Things work better by focusing on the product and its needs rather than on the company and its equipment: functional organization and barriers between functions are challenged. Changes to the layout of offices and departments in order to ensure a continuous flow are part of this logic (Bertagnolli, 2018). These aspects can have a great impact on process flow, value-added activities and elimination of waste. As a result, it is possible to highlight differences between overall process time and the sum of 'value-added' time.

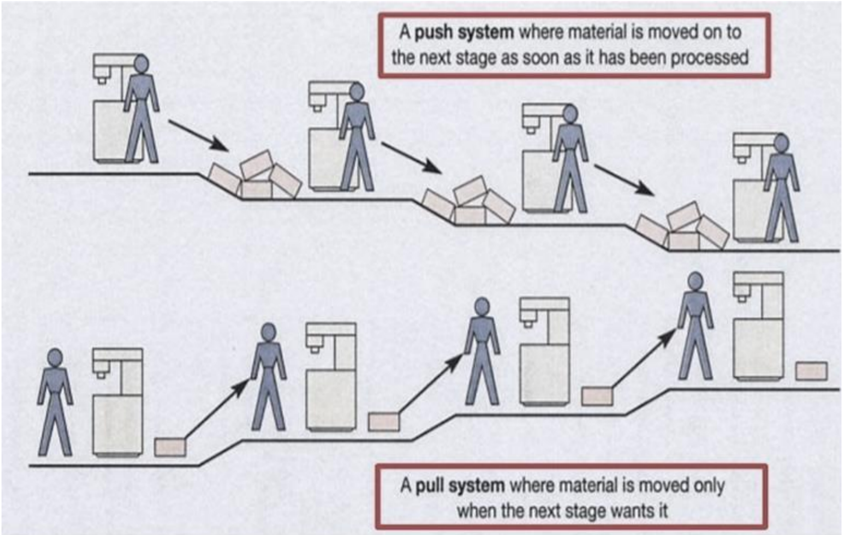
- ***Pull***

Low quantities and high product variety are the main characteristics of the new market: it must be the end customer who pulls the production flow (Bertagnolli, 2018).

The reduction of lead times and the increased flexibility resulting from the elimination of waste allows the introduction of 'pull' logic to replace 'push' planning. The aim is to make and produce exactly what the customer wants, when he wants it. As a consequence, customer demand becomes much more stable if customers feel that they can get what they want immediately and if companies stop conducting periodic discount campaigns aimed at placing already manufactured goods (Womack and Jones, 1996).

The reduction of time required from design to product launch, from sale to delivery, from raw material to customer is the first visible effect of converting departments and batches to teams of product and flows ((Womack and Jones, 1996).

Fig. 8 : *Push vs Pull system*



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➢ ***Perfection***

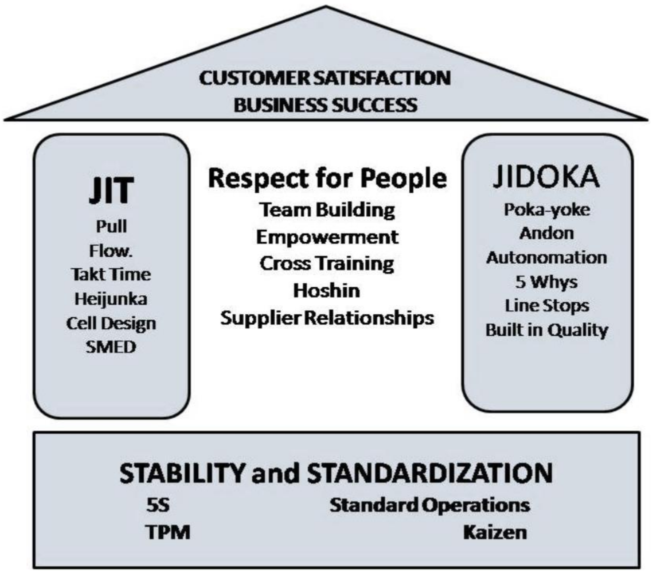
As lean techniques are applied along the entire value stream, one gets closer and closer to the customer's wishes. Nevertheless, the process of reducing effort, time, space, costs and errors never ends.

Continuous improvement is the ideal goal of pure value creation. Eliminating Muda represents an ongoing challenge to be faced in the day-to-day life of the company.

3.3 Toyota production System (TPS)

The lean production temple was first illustrated by Liker (2003) to describe the goals, principles and most common tools of lean. On the roof are goals such as achieving the best quality, lowest costs, shortest lead times, and highest safety. The two pillars on either side show the fundamental principles upon which lean production is based and the tools used to achieve them. The left pillar represents the Just-in-Time principle while the right pillar represents Jidoka (Bertagnolli, 2018). People are at the center of the lean house concept, as they are able to see waste and solve problems leading to continuous process improvement. The foundation of the house represents the stability of the temple so that the pillars stand upright and consists of tools such as 5S, standardized work, TPM and Kaizen (Thakur, 2016)

Fig. 9 : *Lean production temple*



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3.3.1 Just in Time (JIT)

Just-In-Time means producing only what is needed, when it is needed, and in the quantity needed, at every stage of production (Ohno, 1988).

The synchronization of activities between supplier and customer reduces the risk of producing components that will not be used and reduces the accumulation of material awaiting processing, thus eliminating warehouse space in the factory.

There are several benefits that result from the application of JIT:

- Reduction in the order to payment timeline: companies often have cash flow problems as they have to purchase large quantities of raw materials before production and before the payment by the customer.
- Reduction in inventory costs.
- Reduction in space required.
- Reduction in handling equipment and other costs: handling large batches requires special equipment. Reducing batches simplifies operations and reduces associated costs.
- Lead time reductions.
- Reduced planning complexity: using pull systems, such as kanban, can radically simplify planning.

- Improved quality: reducing batches and reducing handling often has an impact in terms of quality.
- Employee empowerment: a key point of JIT is the involvement of employees in the design and application of the system (Fullerton et al., 2001).

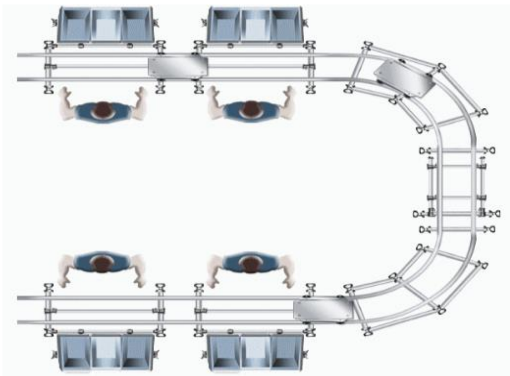
From a management point of view, this is an ideal although difficult condition to achieve. It involves connecting several processes, any problem occurring upstream will stop the production line or change the production plan. Problems are quickly highlighted (Alarcón, 1997); this is often considered a negative aspect of JIT, as any problem often has an immediate impact on the entire production process. However, this is the perfect way to ensure that problems are highlighted and resolved immediately when they occur (Ohno, 1988).

➢ ***Layout***

Closely related to waste reduction is layout (Arunagiri et al., 2014). A well-designed layout reduces transport and waiting times, ensuring a continuous flow of activities with consequently shorter delivery times. The layout should be reorganized to minimize the route of components and materials. U-shaped flow is the most common flow configuration to implement (Bertagnolli, 2018):

- the footprint is minimal;
- increases visibility;
- reduces the distance between different stations;
- components can be fed from outside the production line;
- transparent and open communication within the work cell is easier.

Fig. 10 : *U-shaped layout*



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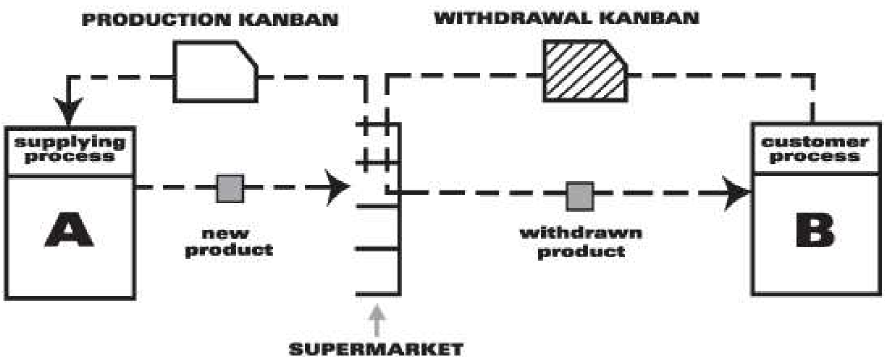
➢ *Kanban*

Kanban in Japanese means ‘visible part’, as opposed to the traditional push system, where material is pushed according to a schedule (MRP), with ‘Kanban cards’ products are pulled through the production process (Kumar et al., 2006).

Fig. 11 : *Kanban card*

Each process step has to start production only on input from the following step (Rahman et al., 2013). Demand is based on consumption of a «controlled inventory» (Junior, 2010) that is called “supermarket” located between the processes (Bertagnolli, 2018). If the downstream process does not consume, the upstream process does not produce.

Fig. 12 : *Supermarket*



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➢ ***SMED (Single Minute Exchange of Die)***

Reducing batch sizes necessarily requires a reduction in machine set-up times to maintain process efficiency. The Single Minute Exchange of Die (SMED, Shingo 1985), are all those activities implemented to have a Quick Change-over (QCO), in other words, to be able to switch quickly from one production to another in the same machine (Bertagnolli, 2018). Shingo describe the SMED as a four main steps (McIntosch et al., 2000):

- Starting state: internal and external set-up conditions are not distinguished;
- Phase one: separating internal and external set-up activities;
- Phase two: converting internal to external set-up activities;
- Phase three: improving all aspects of the set-up operation.

The challenge is to implement process in which set-up operations must be standardized and properly documented. This enables production workers to follow the procedures of a given process, resulting in reduced and optimized set-up time (Moreira et al., 2013).

➢ ***Takt time***

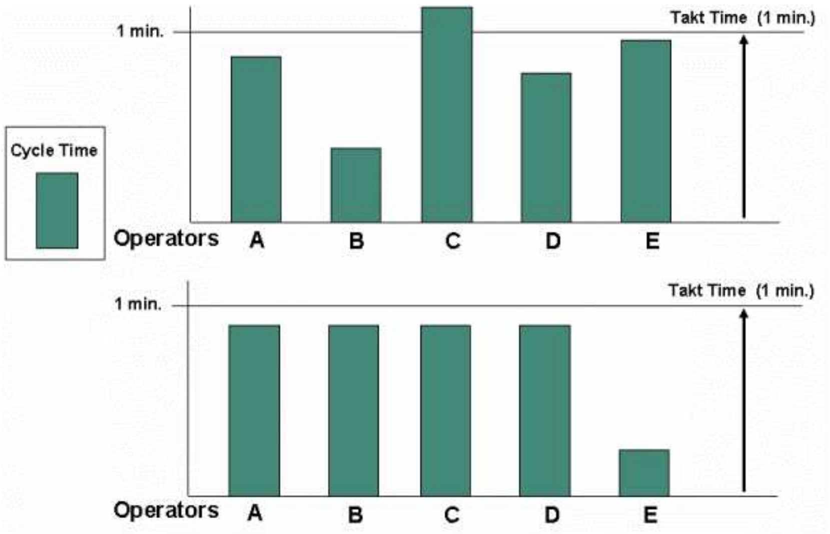
In production, the term Takt Time is referred to the speed at which products are produced. It is the rate at which a product or service must be completed to satisfy customer demand (Ali et al., 2014).

Fig. 13 : *Takt time calculation*

$$\text{Takt time} = \frac{\text{Total Available Production Time}}{\text{Average Customer Demand}}$$

The objective is to balance the production line according to takt time to guarantee the required production without increasing the value of the stock. Stations that have a cycle time greater than the takt time, called constraints, do not allow us to maintain the production pace required by demand. Stations that have a cycle time much shorter than the takt time create excess stock (Linck et al., 1999).

Fig. 14 : *Cycle time balancing*



imt.uoradea.ro

➢ ***Heijunka***

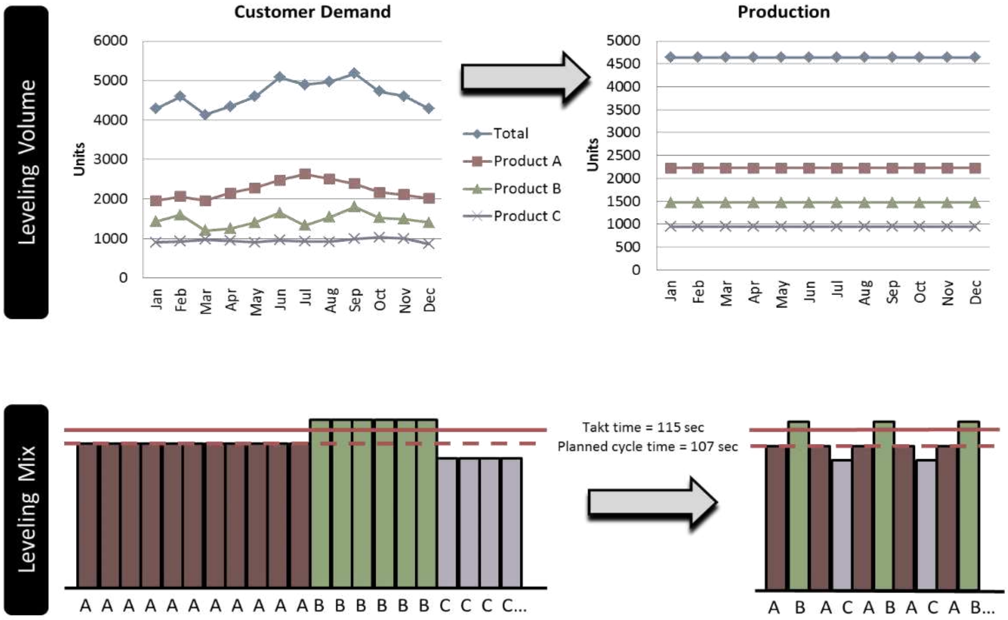
The basis of lean production is to level the workflow to optimize the production line (Koch, 2008). Heijunka is the term to define the production levelling that balances the workload within the production cell while minimizing supply fluctuations (Rewers et al., 2016).

The main goal of Heijunka production are:

- levelling production volume;
- levelling production mix.

The first one means to distribute production equally over a given period. The latter means to balance the distribution of the mix to be produced in a given period (Koch, 2008).

Fig. 15 : *Heijunka*



www.talcottridge.com

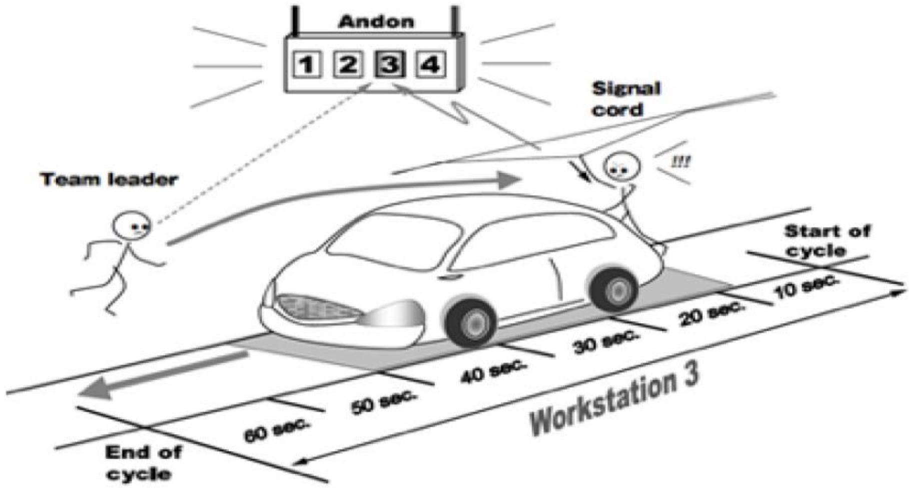
3.3.2 Jidoka

The concept of Autonomation or Jidoka was born with Sakichi Toyoda. He invented a weaving loom that could stop when it detected a thread break. In this way, a single worker was able to control several machines, as the operator only had to intervene in case of exceptions. Autonomation with a human touch, one of the important parts of the Toyota Production System (Bertagnolli, 2018).

The principle of Jidoka can resumed into a few simple steps:

- discover an abnormality;
- stop the production;
- fix immediately the problem;
- investigate and correct root cause.

Fig. 16 : *Jidoka*



www.lean.org

- ***Built-in Quality***

Inspection does not improve the quality, nor guarantee quality. Inspection is too late. The quality, good or bad, is already in the product. Quality cannot be inspected into a product or service; it must be built into it.

EDWARDS DEMING, *Out of the crisis.*

Built-in quality is a practice that aims to solve quality problems before they become large-scale problems. Rather than relying on quality inspections to detect defects after the production, Built-in quality aims to catch defects as they emerge, helping organizations avoid problems such as rework, wasted raw materials or customer dissatisfaction (Bertagnolli, 2018).

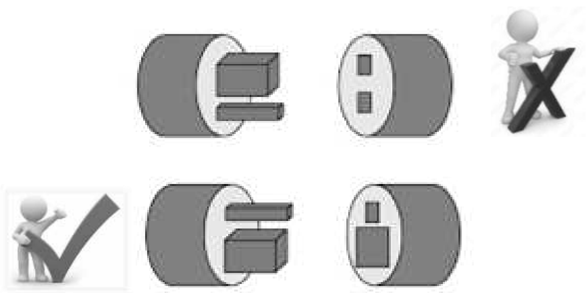
- ***Poka Yoke***

Poka Yoke is a tool that helps prevent the creation of defects during the production process (Rewers et al., 2016). It means 'error-proof' and is used to avoid mistakes so as to guarantee a production status of 'zero defects' (Dudek-Burlikowska et al., 2009).

Poka-Yoke is focused on continuous improvement already at the industrialization stage in order to:

- ensure a reliable and repeatable manufacturing process;
- minimize quality problems in the finished product;
- reduce or eliminate rework;
- avoid investing large sums of money with complex control systems.

Fig. 17 : *Poka Yoke*



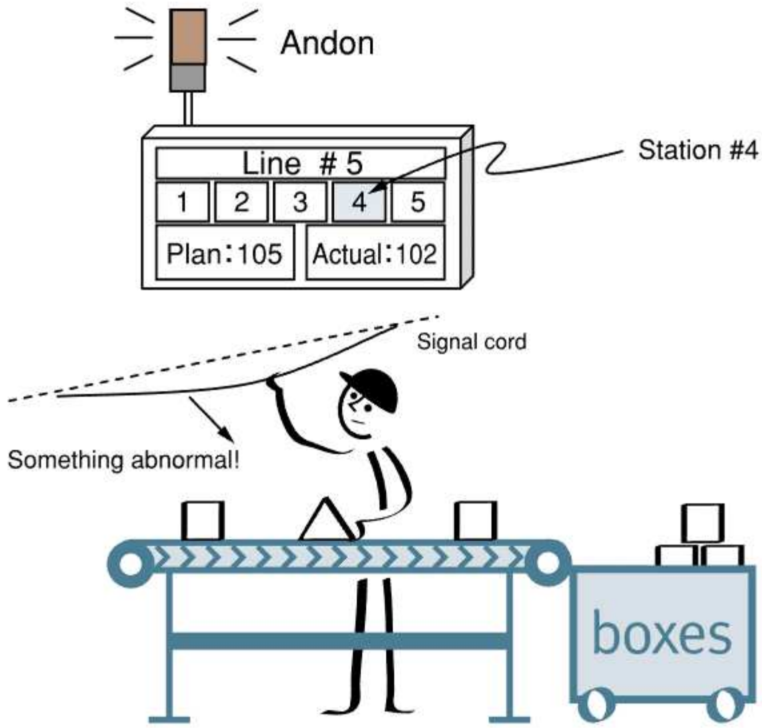
leansisproductividad.com

➢ ***Andon signal***

Andon is an information tool which provides instant, visible and audible warning to operators that there is an abnormality within that area. The alarm is connected to the production system from which it collects data in real time. If necessary, the alarm can be activated either manually by the operator or automatically by the production system itself.

The Andon system allows operators to identify and take action on a process problem or quality issue, such as an interruption in production or the production of non-conforming products (Bertagnolli, 2018).

Fig. 18 : *Andon signal*



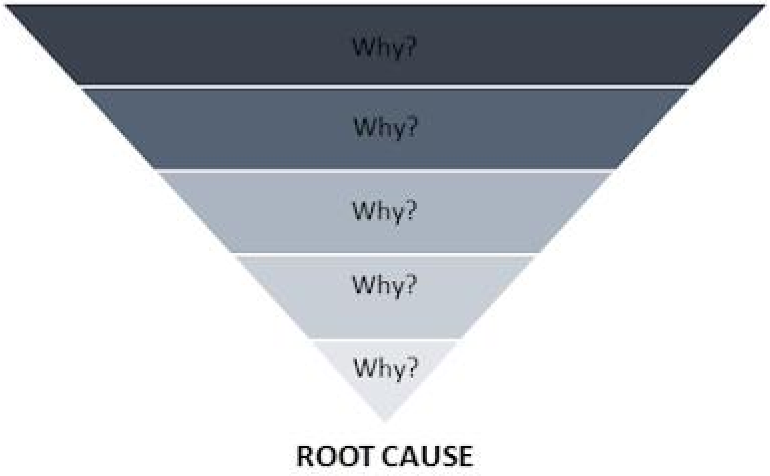
www.lean.org

- ***5 whys analysis***

Unexpected problems arise in any team or process. However, problems are only symptoms of deeper issues. Solving a problem quickly may be a convenient solution, but it does not protect the work process from recurring errors.

The “5 Whys” method helps discover the root cause of a problem by asking 'why' five times. This questioning technique is a powerful tool for root cause analysis (Andersen, 2006).

Fig. 19 : *Root causes analysis*



cx-journey.com

3.3.3 Stability

At the foundation of TPS is the concept of stability. A process is stable when production deviations are minimal and therefore under control. Continuous improvement generally aims to reduce variation by stabilizing processes. Stability means predictability. Predictability facilitates planning.

➢ ***Standardization work***

Work standardization is based on the analysis and definition of Standard Operating Procedures (SOPs) for performing tasks and processes (Thakur, 2016). The best practices are detailed to define who performs the task, what is needed to complete the task, when the task should be performed, and how to perform it (Bertagnolli, 2018).

➢ ***5S method***

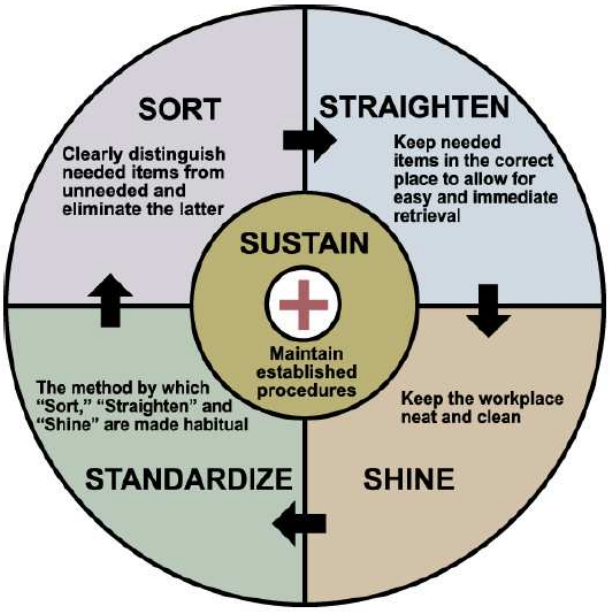
5S provides a practice of optimizing the conditions of the work environment. it is a quick and easy method to implement and allows the work environment to remain organized, clean and safe at all times.

The 5S method is based on five steps (Omogbaia et al., 2017):

- Sort (Seiri): eliminate anything that is not needed in the workstation.

- Set in order (Seiton): place something in a specific location in order to find it immediately when needed and avoid wasting time in searching.
- Shine (Seiso): keep the workplace clean.
- Standardize (Seiketsu): define the rules for keeping the workstation free of unnecessary objects, tidy, clean. Eliminate the risk of clutter.
- Sustain (Shitsuke): follow the previously established rules and encourage staff to respect them so that the 5S method becomes a routine.

Fig. 20 : *The Schematic Diagram of 5S principles*



www.ijstr.org

➢ ***TPM (Total production maintenance)***

Maintenance must ensure equipment availability in order to produce products at the required quantity and quality levels.

The changing needs of modern manufacturing and high operating costs have forced a review of the role of improved maintenance management. However, strategic approach to improve the performance of maintenance activities is to adopt and implement TPM strategic initiatives over traditional reactive and fire-fighting maintenance approaches (Ahuja et al., 2008).

TPM promotes proactive and preventive maintenance of equipment and it highlights maintenance as a necessary part of the business. It is aimed at improving the competitiveness of organizations to maximize operational efficiency and includes a powerful approach to changing the mindset of employees. Empowerment of operators becomes essential as the distinction between the maintenance and production roles is narrowed (McKone et al., 1999).

The main guiding principles on which a TPM project is based are:

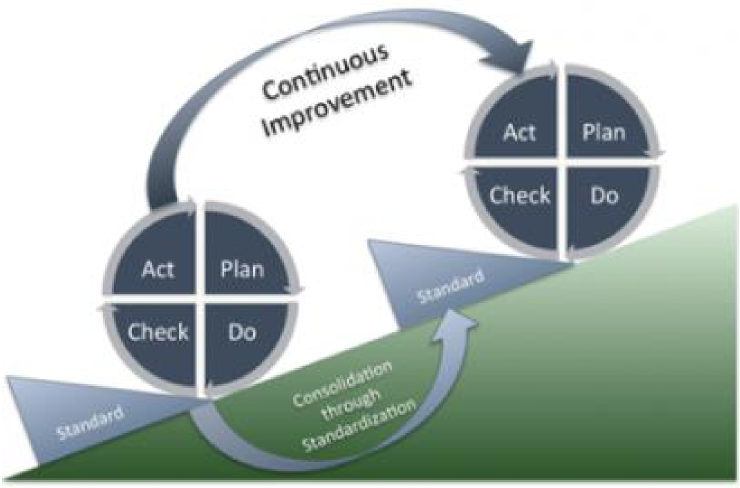
- Monitoring and improving Global Plant Efficiency. Overall Equipment Effectiveness (OEE) is the ratio between the time during which the plant produced "good parts" and the time during which the plant was engaged (Almeanazel, 2010).
- Developing autonomous maintenance. Autonomous maintenance involves production employees in cleaning, maintenance activities in order to avoid failures and breakdowns in order to keep the plant in its optimal condition.
- Developing preventive maintenance. Through preventive maintenance activities, it is possible to anticipate and prevent the occurrence of failures, avoiding production stoppages.
- Developing quality maintenance. Initiate a process of constant analysis of breakdowns and production losses in order to identify technical changes and improvements to plants (Jain, et al., 2014).
- Early Equipment Management. This principle involves the proper selection, design, and commissioning of facilities in order to avoid maintenance costs as much as possible in their life cycle (Suzuki, 1994).

➢ ***Kaizen***

Kaizen is composed of the two Japanese terms "kai" for change and "zen" for the better. In the occidental business language, Kaizen is translated as continuous improvement. In contrast to kaikaku where the existing is not optimized but fundamentally challenged, kaizen strives to continuously improve processes, services and products in small steps through employee involvement. Kaizen optimizes processes, kaikaku questions them and radically redesigns them (Bertagnolli, 2018).

The most frequently used model of achieving and monitoring continuous improvement processes is the Deming’s Cycle or PDCA cycle. PDCA is an abbreviation of the terms: plan, do, check and act. It means that every improvement activity must start with a planning phase, must be put into practice, must be tested and confirmed and then move on again to a new planning phase in a continuous cycle. Deming's cycle is a dynamic model, it is infinite (Soković et al, 2009).

Fig. 21 : *Continuos improvement and Deming's Cycle*



www.eqmc.it

3.3.4 Importance of people

Employees should not be considered a resource, employees are people and cannot be compared to any other material resource. While machines depreciate and lose value, people learn and create an increase in value. Through their learned skills, they constitute long-term corporate value.

In the lean philosophy, it is very important how the work of a leader is evaluated. The leader is not just measured by results, he is measured by the trust he enjoys among his employees. If a manager advances his employees, he benefits and the entire company benefits. A leader must act as a role model and must transmit the values on which the organization is based (Bertagnolli, 2018).

The organization as a whole must have the attitude, culture and capabilities at all levels to achieve continuous improvement and sustain itself into the future. This requires the commitment of all members by removing obstacles that delay, prevent or inhibit improvement. People need to be aware of what needs to change and why, so communication, transparency and role models are key to engagement (New, 2007).

4. Conclusions

In this chapter, a general focus on lean production was made. After an overview of its evolution, the principles and tools used in companies were discussed. Considering the contents of the chapter, we can deduce that the main objective of lean management is to reduce waste and give the best possible service to the customer. The next chapter will present the company where the project was carried out and where some of the above-mentioned tools were applied.

CHAPTER 2

DAB PUMPS S.P.A.

Compared to the previous chapter where the principles and tools of lean production were presented in a theoretical manner, this chapter will present the company in which the project was carried out. The first part presents the company in general, some figures and in particular its evolution. The chapter continues with a focus on the Hungarian plant, the plant in which the project was carried out, and finally a presentation is made of the ERP used and its features.

1. DAB Pumps s.p.a.

Founded in Mestrino (Padua) in 1975, DAB is a company specialized in the industry of water handling and management technologies.

Developed within the industrial tissue of the Northeast of Italy, DAB is now a multinational company employs around 1,700 people worldwide in production site and sales subsidiaries.

With 6 production sites: four in Italy (the headquarters in Mestrino, Bientina, Castello di Godego and Val Liona), one in Hungary (Nagykanizsa) and one in China (Qingdao), 12 sales offices around the world, 7 local representative offices and 28 sales agencies in the Italian territory, in 2022, about 2.7 million pieces were produced with a turnover of 430 million.

Fig. 22 : *Production site and sales subsidiaries*

www.dabpumps.com

1.1 Company's history

DAB was founded in December 1975 as the business unit of a group of four companies that were respectively involved in stainless steel stamping, blanking of sheet metal, die-casting of casings and winding of motors, and moulding of plastic components for pumps. In a few years, DAB realized that the markets would turn towards the domestic pump, so through the integration of its production forces, it succeeded in producing the *Jet* pump.

Being a market leader in cold water pumps, it made its first acquisition, Vema, in 1985, with the aim of differentiating production. Begins production of heating pumps, centrifugal pumps and vertical pumps.

The nineties were the years of globalization, a policy that was implemented through the strengthening of the global sales network with the opening of 6 sales branches in Belgium, Holland, the United Kingdom, Switzerland, Austria and the United States, as well as, in 1996, through the entry into the most important multinational group in the pump sector (Grundfos) with which DAB is still in a separation strategy, a regime that guarantees full autonomy in the management and development of the business.

With the aim of completing its Know-How, the second wave of acquisitions occurred from 1998 to 2009. Companies such as Leader Pumps (plastic moulding), TESLA (submersible motor technology), Brisan (submersible pumps for agriculture and gardening), Wacs (electronics) and Alma (wastewater drainage) thus joined the DAB Group. The path of acquisitions ends with the creation of the DAB Water Technology Group (DWT Group), a financial holding company that owns all the companies.

Today's Dab has a customer-centric approach and a growth strategy that takes advantage of innovations and new digital technologies, the Esybox range, Dab's patented autoclave system, and the D-Connect remote control are examples.

Fig. 23 : *DAB in the world*

www.dabpumps.com

1.2 Products and markets

DAB provides technological solutions that ensure reliability and efficiency to optimize the energy consumption in domestic and residential, civil, commercial applications and in irrigation systems for agriculture.

In the domestic and residential sectors, principal applications are for heating, air conditioning, water supply, pressurization, irrigation and gardening, rainwater utilization, drainage, sewage collection and disposal, and circulation and filtration of water in swimming pools. Similar applications are also provided in the civil and commercial sectors particularly in large circulation systems for heating and air conditioning, pressurization in water supply systems, firefighting, and wastewater disposal. In agriculture, DAB provides pumping solutions for underground water extraction, irrigation, energy-efficient submersible pumps and motors.

Fig. 24 : *Products and segments*

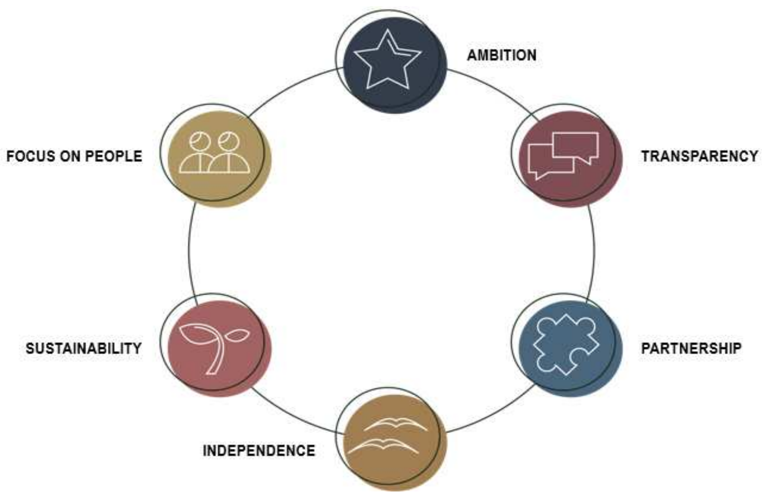
www.dabpumps.com

1.3 DAB values

Main values at DAB Pumps include sharing a culture of innovation and growth based on people, technology and the environment. Digital transformation, smart solutions and flexible work are part of the business model.

Great focus is placed on sustainability, thanks to a program of activities such as the installation of photovoltaic panels and rainwater recovery systems, from 2015 to 2022 CO^2 emissions have been reduced by 45.2% and water consumption has been reduced by 47.6%.

Fig. 25 : *DAB values*



www.dabpumps.com

2. DAB Hungary

DAB started building the production site in Hungary, in Nagykanizsa in the province of Zala, in 2013, initially with 5,000 square meters of plant, divided between an office area and the production area.

Once the factory was ready, the first productions to be moved were the submersible pumps (Verty Nova, Nova-Feka, BVP, etc.) and shortly afterwards the surface pumps (Jet, KPF and KPS, Jetcom, etc.) together with the painting plant and a machine for the mechanical machining of the pump bodies.

Following the construction of an additional 5,000 square meters of plant and with a view to optimizing flows, the winding department for electric motors, motors mainly used in the production of surface pumps produced in the Hungarian factory, and the line for encapsulating motors used in submersible pumps, also produced in Hungary, were moved to DAB Hungary. During this period, a new line for the production of the new mechanical circulator (VA Evo) was also built in Hungary, with the intention of bringing production closer to the main market still active for that type of product, i.e. Russia, where, unlike in the European Community, the obligation to install energy-saving electronic circulators is not yet in force.

In this way, 2019 arrives, when the construction of the last part of the building (an additional 5,000 square meters) takes place, in view of the new productions to come to this plant, in particular for the new production line of the Grundfos SCALA pump and a new injection moulding department for the production of plastic parts. As can be seen from the evolution of this production site, improved flows are at the heart of DAB's relocation strategy.

The plant, which is now 15,000 square meters, has thus grown from 12 employees employed in 2013 to 260 in 2021, about 20 of whom are employed in the offices (logistics, procurement, scheduling, HR, and administration) and the remainder in the production departments. Today this plant produces about 550,000 pumps per year and 600,000 electric motors.

2.1 The Scala System

The Scala was one of the last production lines to be installed in the Hungarian factory in 2019. It is a compact, fully integrated and self-priming water system for increasing pressure in domestic applications, in single and two-family houses and flats.

It is a make-to-order product, i.e. it is only produced at the customer's request and not to fill stock in the warehouse. As will also be discussed in more detail in the next section, make-to-order products have a longer lead time for delivery to the customer than make-to-stock products because the component purchasing and assembly phase begins once the customer's order is received. Scala's finished product codes, compared to other MTO products, are fairly standardized, so it was possible to include a sales forecast plan in order to call up the components needed for assembly in advance and shorten the lead time for delivery.

The forecasting part in DAB is managed through the use of an MRP (Material Requirement Planning) which will be presented in the next section.

Fig. 26 : *Scala System*

product-selection.grundfos.com

3. Material Requirements Planning (MRP)

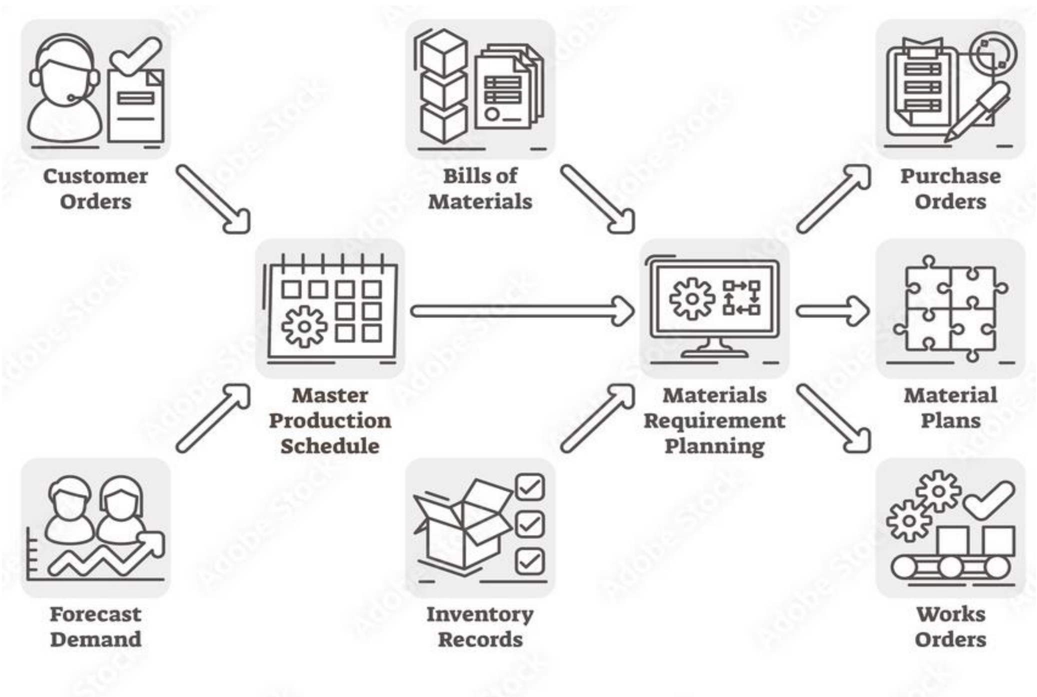
Enterprise resource planning (ERP) systems are software packages that provide cross-functional integration of information across business process steps (Klaus et al., 2000).

The term Enterprise resource planning (ERP) was coined in 1990 by The Gartner Group. ERP evolved from the material requirements planning (MRP) systems of the 1970s and MRP II manufacturing resource planning systems of the 1980s (Nazemi et al., 2012).

Material requirements planning (MRP) is a system designed for manufacturing production planning. It identifies the materials required, estimates the quantities, determines when the materials will be needed to meet the production schedule and manages the delivery schedule with the aim of meeting demand and improving overall productivity (Hasanati et al., 2019).

The ability to forecast and plan material and component requirements is of critical importance for effective production and stock management (Jonsson et al., 2015). Stock usually represents a significant cost in business operations and it is one of the most important factors in profitability. Without MRP it is impossible to manage stock effectively so that the right amount of the right items are available at the right time. Excessive stock is costly, but insufficient stock can cause inventory depletion, which is often the main cause of production interruptions, shipping delays, additional costs, and customer service failures.

Fig. 27 : *Material Requirements Planning*



stock.adobe.com

3.1 Production planning in DAB Pumps

To be able to explain well how production planning takes place, it is necessary to highlight the difference between make-to-stock and make-to-order products.

- ***Make to stock***

MTS products are generally standard products (Adan et al., 1998) and as the name implies, they are produced to be stocked and made immediately available to the customer as soon as an order is placed. One of the main features of MTS is rapid delivery, having large stocks of finished products means being ready for mass distribution at the exact moment when there is demand. Stock levels are set based on sales forecasts, and production is activated only to restore inventory. MTS systems are also known as push systems, characterised by short delivery times, high storage costs and limited flexibility with regards to customisation (Peeters et al., 2020).

For this type of product, forecast plans are used to predict the quantities of components needed in advance and to facilitate capacity management. However, as the value of stock is one of the most important parameters to keep under control in order to have working capital available, doing MTS means making very accurate sales forecasts. Having higher plans means having more finished product and more raw materials in stock ready to be processed and therefore more financial immobilization.

- ***Make to order***

As opposed to make-to-stock, production does not take place to restore inventory but is activated only when an real customer order is placed, it is known as pull system (Peeters et al., 2020).

Generally, make-to-order products are expensive products with low volumes and fluctuating demand. This management mode makes it possible to minimize inventories of high-value finished products and special components, while maintaining a minimum inventory of raw materials and semi-finished products in common among several finished products with the advantage of being able to use them on different orders as needed.

On the customer's side, there is the advantage of being able to customize the product to exactly meet their needs but the disadvantage of long lead times (Zaerpuor et al., 2008).

In this case, production is scheduled only in the short term, a daily beat is defined, and production capacity is saturated day by day according to components availability.

4. Conclusions

In this chapter, the company in which the project was carried out was presented in order to better understand the company environment and to contextualize what will be presented in the next chapter. In the first part, its evolution was presented so its DNA, the context in which the company operates, products and markets, and the values on which the strategy is based. In the second part, a focus was made on the Hungarian plant, the one where the project was implemented, and the company's ERP system. In the next chapter we will look at all the analyses and activities that were carried out for the realization of the project.

CHAPTER 3

STUDY OF FEEDING METHODS OF THE PRODUCTION LINES. DAB PUMPS S.P.A. CASE STUDY

The content of this chapter concerns the project carried out in DAB Hungary with the goal of optimizing flows regarding the latest added lines, Scala and Injection molding department. It began with a presentation of the starting state and the reasons that led us to investigate the topic: the latest plant expansion has revealed several critical issues related to the material flow into the plant. The central part concerns the core project, all activities were explained, dividing them into core and support activities. The chapter then closes with the results part.

1. The reasons behind the project

The project was developed in Hungary, at the Nagykanizsa plant. The main objective was to reduce the warehouse space occupied by raw materials and semi-finished goods and the related stock value. Focusing on the plastic injection moulding department, it turned out that although it produced 99% of the codes for the Scala System line, it was totally unaffected by fluctuations in demand. Production was scheduled to ensure full utilization of machine capacity, producing more material than necessary.

Before starting with the analysis of the graphs and KPIs, it is important to understand the variables that have been taken into account. The first variable is the planned output, a theoretical output that is monthly provided based on long-term forecasts. It is the most important input as it is the starting point for all evaluations, especially for the creation of the scheduled production plan used to define the optimal amount of stock to be produced. The second variable is the output actually produced. It is visible only after it has occurred and shows how much production was in line with forecasts. Through this variable, it is possible to calculate what the optimal stock amount should have been in the analyzed period and consequently the delta with the actual stock amount. The third variable is the target stock. Considering all the constraints currently in place in production, in particular the difficulty of making quick set-up changes, as a first step we set a target stock of 20 days based on the amount of demand. Initially, considering 20 days was seen as a very good improvement as we started from an average stock level of more than double that.

Analyzing the charts, it is clear that in 2021 the value of the stock was above the ideal value. The graph in Table 1 shows the trend in stock coverage. Considering the stock coverage in relation to planned production, it can be seen that for the whole of 2021, the value of the stock was almost double the ideal value. The result is even worse when considering actual production. In this case, the amount of stock is more than double in all quarters, with some peaks even close to three times the optimal value. Comparing the stock had during 2021 with the target, maximum 20 days of coverage, it can be seen that throughout 2021 the stock was higher with some peaks of 60 days of coverage.

The same result is visible also in the Table 2 in terms of the stock turn index. Despite the company's target of a rotation index of 1, in other words, to rotate all stock at least once a month, in 2021 it had been consistently lower with negative peaks of 0.37 when calculated on actual output and 0.55 on planned output.

These initial analysis also revealed another important issue, the significant difference between planned and realized output. This difference is due both to forecasts that are not entirely in line with actual demand, and to unforeseeable events like downtime due to breakdowns, component shortages, absenteeism and other variables.

It was from these initial analysis that arose the need to open a project to keep production and consequently the stock value of plastic components under control.

Table 1 : *Stock cover 2021: starting state*

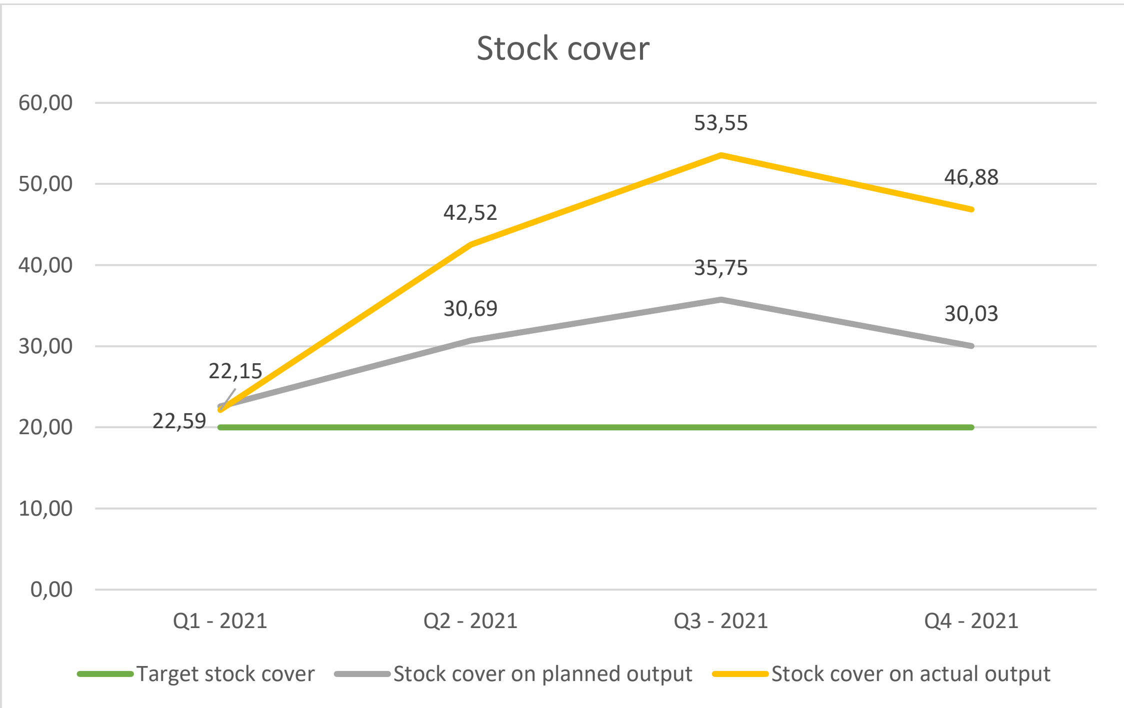
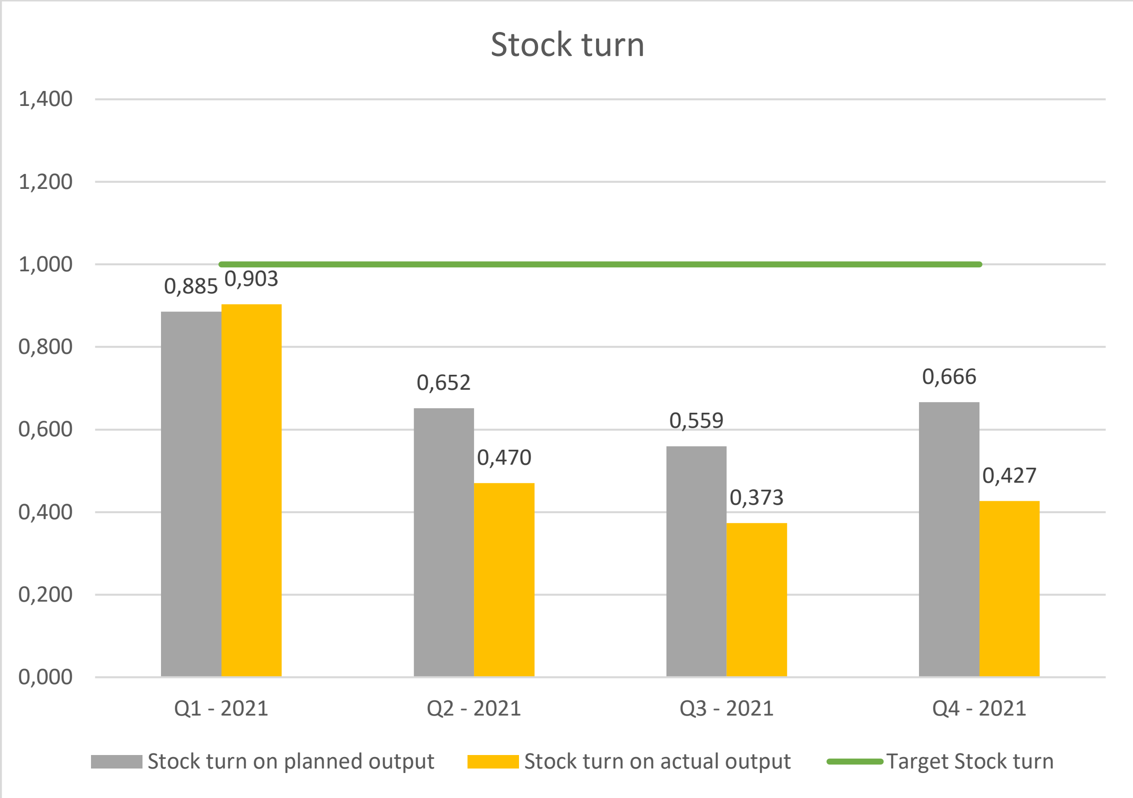


Table 2 : *Stock turn 2021: starting state*



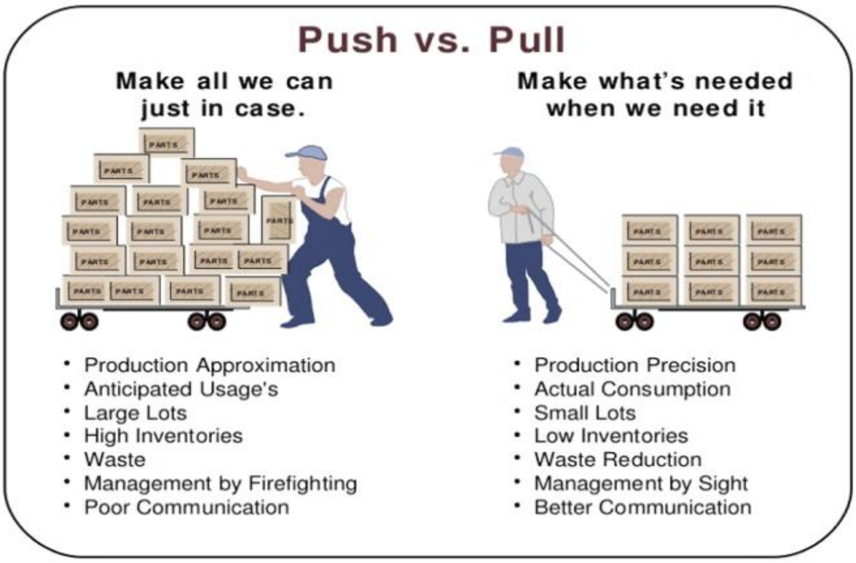
2. From PUSH to PULL

The aim of the project was to link the production of plastic components to the demand in the Scala department. Synchronizing the two production lines will allow us to reduce the space occupied in the warehouse and reduce the financial immobilization.

Switching from PUSH logic to PULL logic has improved communication between the two production lines and enabled more accurate and timely production, based on the real consumption of the downstream line and not on the saturation of the machines.

The tool identified to ensure proper interaction between the two departments was the kanban. Through the implantation of this tool, production in the plastics department took place only on input from the downstream line. In this way, production is activated when the material already produced is consumed and not to saturate the machines.

Fig. 28 : *Push vs Pull*



medium.com

3. Implementation of the project

In order to fully understand how the project was implemented, it is necessary to distinguish the activities carried out. The first category, identified as Core Activities, represents all the main activities aimed at the realization of the project. The second, Support Activities, concerns all those related activities aimed at ensuring the reliability and resilience of the project.

3.1 Core activities

The Core Activities are divided into two phases, the data analyses and the implementation of the new method.

The analysis phase started with the study of the two production lines, the gathering of all info regarding products and processes, analyses of material flows and the link between the two departments. The second phase, the implementation phase, involved the creation of production plans schedule, the study and implementation of kanban and the reallocation of space reserved for material.

➢ *Material flow analysis*

The analysis phase began with a study of the starting state of the two production lines. The initial objective was to understand the main characteristics of the two areas and their linkage. Starting with the downstream line, the volume and demand characteristics were analyzed. The Scala System is a special production line because although it is a make-to-order product, it is still managed with forecast plans. This type of management was possible because 90% of the components are the same for all finished products, consequently the forecast plan helps to recall the necessary components. It was through the forecasts, the quantities produced in the last years and the historical trend of demand fluctuation that the first considerations were made and the tools needed to put the two departments into flow were identified.

The second step was to analyze the upstream production line, the plastic injection moulding department. Starting from the demand, the amount of plastic components to be produced was calculated and compared with the real production capacity of the department taking into consideration all constrains. Mould-press association was the main constraints: presses cannot be equipped with all moulds as different tonnages are required depending on the size. Tonnage is one of the measures by which presses are classified; it is the calculation of the clamping force that the machine is able to exert during the injection process.

Table 3 : *Material flow analysis*

Mould information — Coeff. of use — Demand

SCALA1													
Machinery		Cod	Descr.	Cycle Time	Nr. Cavities	Number of pumps per shot	pcs/Hour	pcs/1 Shift	coeff. of utilisation	Where used n° of FP	Tot. Year cons.	Average monthly cons	St. dev.
D - 500t.		60 xxxxx	Code 1	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
D - 500t.		60 xxxxx	Code 2	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
D - 500t.		60 xxxxx	Code 3	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
D - 500t.		60 xxxxx	Code 4	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
A - 350t		60 xxxxx	Code 5	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
A - 350t		60 xxxxx	Code 6	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
A - 350t		60 xxxxx	Code 7	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx

- ***Definition of production plan schedule***

Once the analysis phase was completed, the implementation phase began. Taking into account all the data obtained in the first phase, a production scheduling plan was developed to ensure the proper supply of components.

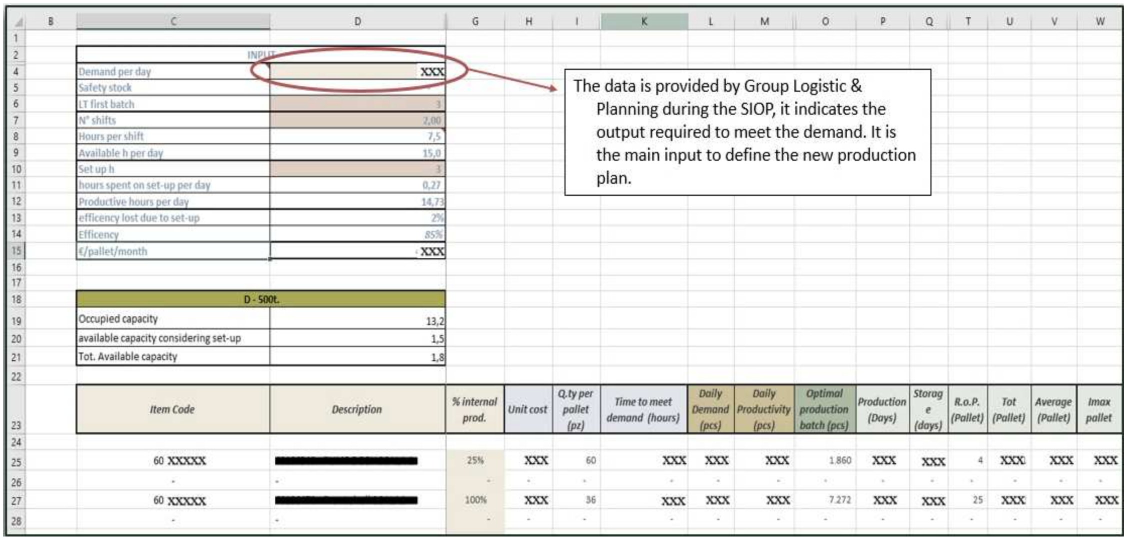
The template is divided into three macro areas: the inputs or general information, information on the codes to be produced and the results.

Starting with inputs, the most important is the "Demand per day", it is referred to the market demand for finished product and it is considered the most important information since it indicates the production pace. Among the other parameters there are the machinery set-up times, the material cooling times, safety stock and number of shift set. Machine set-up times were considered fixed: no SMED activities were run at this early stage of analysis with the aim of reducing set-up times. Also considered fixed were the material cooling times, "LT first batch" in the template. These are caused by the nature of the material: with the tools currently available, several days are required before the plastic part cools completely and can be assembled on the finished product without deformation. On the other hand, variable inputs include safety stock quantity and number of shifts set.

Once the inputs and code information, such as cycle time, have been entered, initial considerations can be made regarding the production capacity required. As demand changes, the amount of hours required per press and consequently the number of shifts needed change. These variations lead to analyses on make-or-buy strategies: in some cases there are some moulds also available from external suppliers and the company can decide the quantity to produce internally and the quantity to purchase. The real challenge in the scenario where the demand changes, is to decide if it is cheaper to modify the number of shifts on a press or if it is better to purchase externally.

The first result obtained, once all necessary considerations have been made, is the production sequence to be run on that machines, the optimal production batch and the time required to produce that quantity.

Table 4 : *Production plan template*



INPUT	
Demand per day	XXX
Safety stock	
LT first batch	3
N° shifts	2,00
Hours per shift	7,5
Available h per day	15,0
Set up h	3
hours spent on set-up per day	0,27
Productive hours per day	14,73
efficency lost due to set-up	2%
Efficency	85%
€/pallet/month	XXX

The data is provided by Group Logistic & Planning during the SIOP, it indicates the output required to meet the demand. It is the main input to define the new production plan.

D - 500t.	
Occupied capacity	13,2
available capacity considering set-up	1,5
Tot. Available capacity	1,8

Item Code	Description	% internal prod.	Unit cost	Q.ty per pallet (pz)	Time to meet demand (hours)	Daily Demand (pcs)	Daily Productivity (pcs)	Optimal production batch (pcs)	Production (Days)	Storage (days)	R.o.P. (Pallet)	Tot (Pallet)	Average (Pallet)	Imax pallet
60 XXXXX	[redacted]	25%	XXX	60	XXX	XXX	XXX	1.860	XXX	XXX	4	XXX	XXX	XXX
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
60 XXXXX	[redacted]	100%	XXX	36	XXX	XXX	XXX	7.272	XXX	XXX	25	XXX	XXX	XXX
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

➤ ***Kanban sizing***

The kanban has been identified as the tool to activate production. It is managed with the reorder point, the molding of a component should not be run until the downstream production line has consumed all the material up to that point. By using this tool, management of short-term demand fluctuations is improved and overproduction is avoided. Differently from the production scheduling plan discussed earlier, which is based on a monthly definition of demand, the kanban allows reactivity to daily fluctuations. A production shutdown of the downstream line immediately slows production in the plastics department as well, because the material is not consumed and thus no new production is started.

For proper functioning of the kanban with reorder point, the last step concerned the definition of the stock areas dedicated to each code and the sharing of all necessary information to the operators. The definition of the floor areas was implemented to set order and consequently allow operators to exercise immediate visual control regarding the stock level of each code. The information in the tables, on the other hand, indicates the quantities to be produced, when to start production, and the maximum space that can be occupied by that code. This information is updated periodically as the daily production required changes according to the production scheduling plan seen in the previous paragraph.

Fig. 29 : *Kanban tables*

3.2 Support activities

Support activities were crucial to ensure the reliability of the new method. Connecting production lines and reducing buffers between processes exposes the company to a higher risk of production stoppages due to unforeseen events. The goal of these activities was to minimize such unforeseen events and ensure the continuous running of the plastics department. A production stoppage in the plastics department consequently means a production stoppage on the Scala System production line.

- ***Mould maintenance***

Mould overhaul and repair was the first support activity performed during the project. Some molds had small defects that increased the likelihood of producing scraps or, in other cases, increased cycle time as they required additional steps performed by hand once they left the machinery. These repairs made it possible to start from an ideal situation by having more reliable equipment.

➢ *Maintenance plan*

The analysis and revision of the maintenance plans allowed to implement new procedures with the aim of preventing unexpected breakages and extending the life of the mould.

The maintenance plans were divided into first and second level plans.

At this stage of the project, the focus was on first level maintenance, the maintenance that is carried out periodically by the department's operators. All forms containing the activities to be performed on each mould and the frequency with which they are to be carried out were shared with the department heads and an archive was created to collect the results. The objective of this archive, together with the mould breakage archive which we will see in the next section, was to collect as much information as possible and to improve maintenance plans in the future.

The second level plan, on the other hand, concerns the maintenance and inspection of more specific components that cannot be carried out by production line operators and therefore delegated to external specialists. The objective of the second level plan was to define the inspection activities to be carried out and their frequency. It is very important to have a plan because this maintenance is performed externally and requires planning and building up stocks to avoid downtime.

Table 5 : *Maintenance plan template*

DAB WATER•TECHNOLOGY

Piano di manutenzione Mould
Maintenance Plan

-A.9

[redacted]
Updated by

[redacted]
Updated on

Per Piano di Manutenzione dello stampo si intende l'elenco di quelle operazioni che è opportuno fare preventivamente durante la vita ordinaria dello stampo al fine di preservarne l'efficienza e la sicurezza. Essendo azioni preventive devono essere pianificate

"Maintenance Plan" means the list of those actions to perform during the life of the mould in order to save its efficiency and safety. Being planned actions, their due date must be foreseen (as number of shots or months of life of the mould).

Nr. / No.	Descrizione Attività di Manutenzione / Maintenance Activity Description	Quando? / When?
1	PULIRE GLI ESTRATTORI, CONTROLLARE CHE NON PRESENTINO SCHEGGIATURE O CHE SIANO DEFORMATI (*). AL TERMINE DEL CONTROLLO LUBRIFICARLI CON OLIO.	Sempre (dopo) ogni lotto di produzione
	CLEAN THE EXTRACTORS, CHECK IF SOME SCRATCHES OR DEFORMATION. AT THE END OF CHECKING, LUBIRCATE THEM BY OIL.	Every Production Batch
2	PULIRE I MOVIMENTI, CONTROLLARE CHE NON PRESENTINO SEGNI DI USURA E CHE SI MUOVANO CORRETTAMENTE (*). INOLTRE CONTROLLARE IL POSIZIONAMENTO DEL GRANO A SFERA O ALTRO POSIZIONAMENTO. AL TERMINE DEL CONTROLLO LUBRIFICARE	Ogni lotto di produzione
	CLEAN THE SLIDERS, CHECK IF ANY WEAR MARKING AND NO PROBLEM ON THE MOUVEMENTS. BESIDES THAT, CHECK THE POSITION OF NUT BALL OR OTHER POSITIONS. AT THE END OF CHECKING, LUBRICATE PROPERLY	Every Production Batch

➤ ***Historical failure database and Spare Parts***

The failure history database was created in order to record all production stops due to mould breaks. In this form, the department leader records the type of breakage, the mould components involved and the time required for repair. The objective of creating this database was to understand if there is a correlation between the most frequent breakages and the components, in order to be more precise in first level maintenance activities and to focus on the necessary spare parts to be kept in stock. There are two levels of analysis, one concerns components that can be replaced with first level maintenance by the operators, the other concerns more complex components that are replaced by external specialists. The advantage of having these components in stock is to reduce maintenance and repair time in case of mould breakages.

3.3 Ongoing activities

In addition to the main activities already carried out to implement the project, others were planned with the aim of improving reliability and flexibility.

Currently, the focus is on teaching operators to work in both departments and on reducing machine set-up times. Both ongoing activities will help to be more responsive to changes in demand, avoiding production stoppages or overloading of stock.

4. Project results

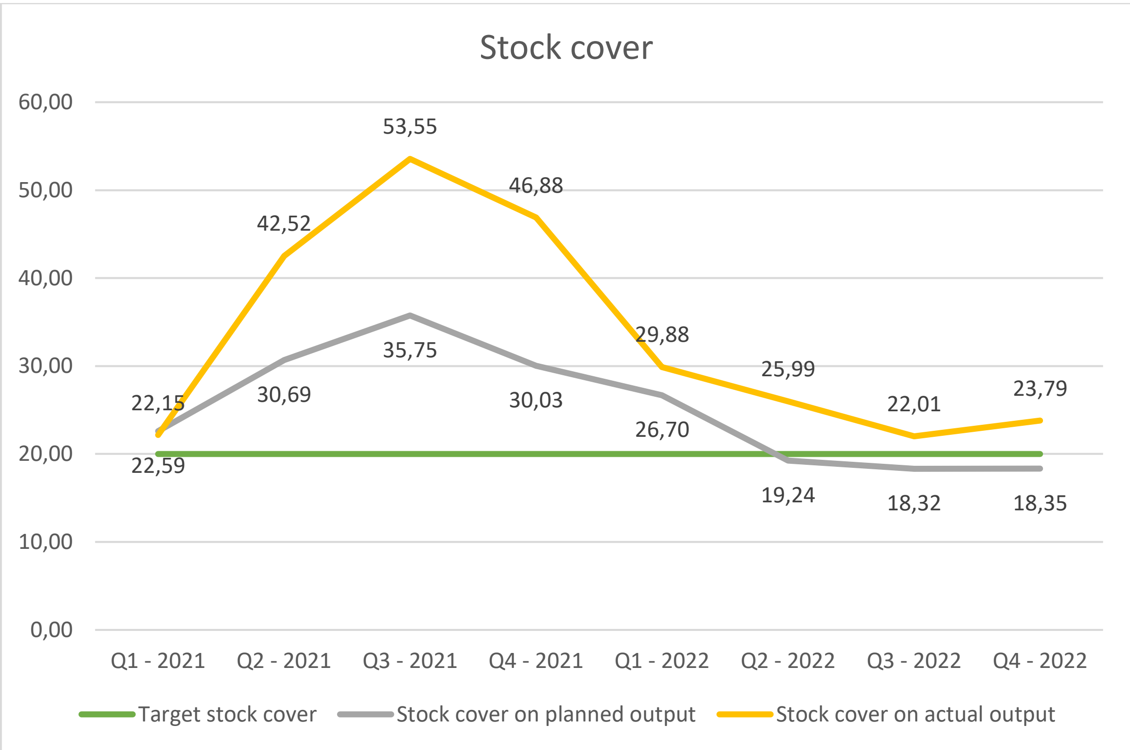
The project started at the end of 2021 with the aim of reducing the stock value and saving space in both internal and external warehouses. After an initial theoretical analysis phase and after identifying the kanban as the best tool to ensure a controlled flow between the two production lines, the first implementations on the gemba began in early 2022.

4.1 Stock reduction

Once all the analyses were done, among the first actions performed in early 2022 was to slow down the production pace of the plastic molding department in order to consume the excess stock in the warehouse. Instead of working at full capacity, the department worked at 20% of its capacity for a given period in order to have an initial situation where the stock was as much in line with demand as possible.

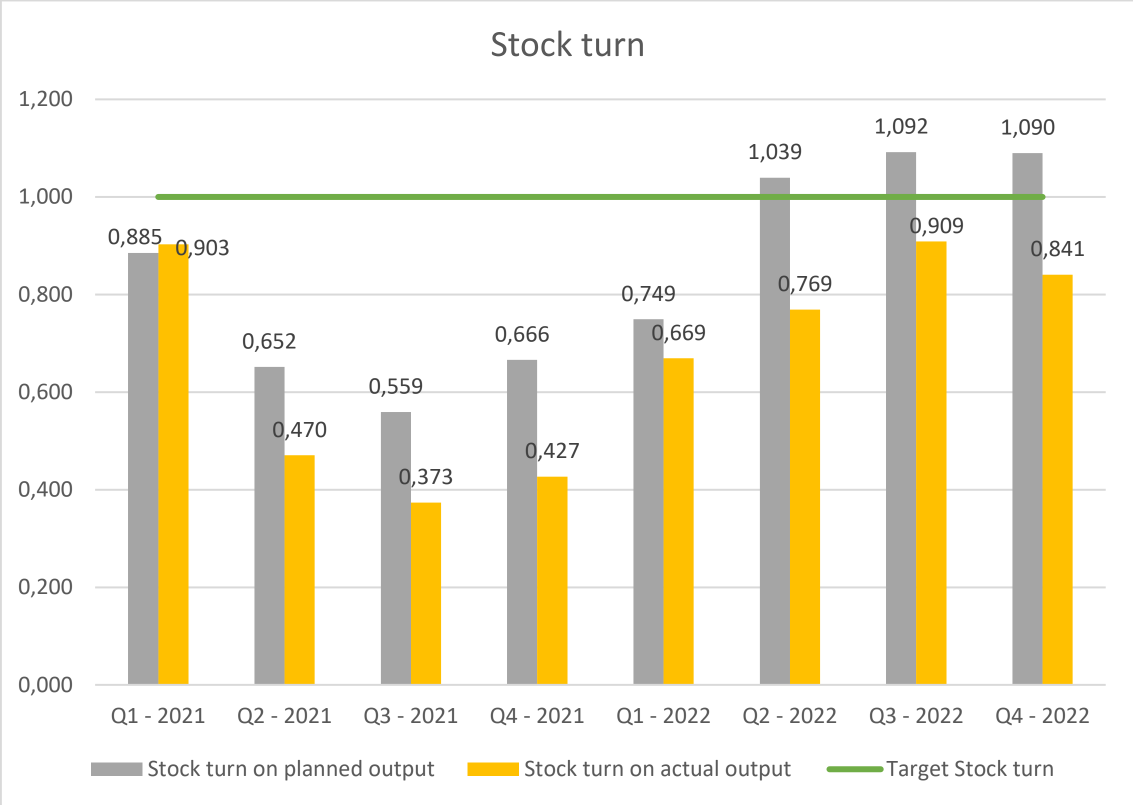
Analyzing the KPIs, the chart in Table 6 shows that from the first quarter of 2022, the stock coverage related to planned output began to decrease until steadily falling below 20 days, below the ideal stock level. Even more important is the result achieved in relation to real output, stock coverage has decreased significantly getting closer and closer to the target. The significant decline occurred from the fourth quarter of 2021 to the first quarter of 2022, period in which the most effective actions were implemented. During this period the average coverage went from 47 days to 30 days, reducing the stock value by about 28%. From the second quarter of 2022 until the end of the period analyzed, the level of stock coverage on planned output has always been below target, with an average level of coverage of about 18 days and a gap of only 5 days from stock turn on actual output. The reduction of the gap between planned output and realized output shows us how all the actions carried out in the project have increased the reliability of planned output, the input through which the whole pattern is set.

Table 6 : *Stock cover trend 2021-2022*



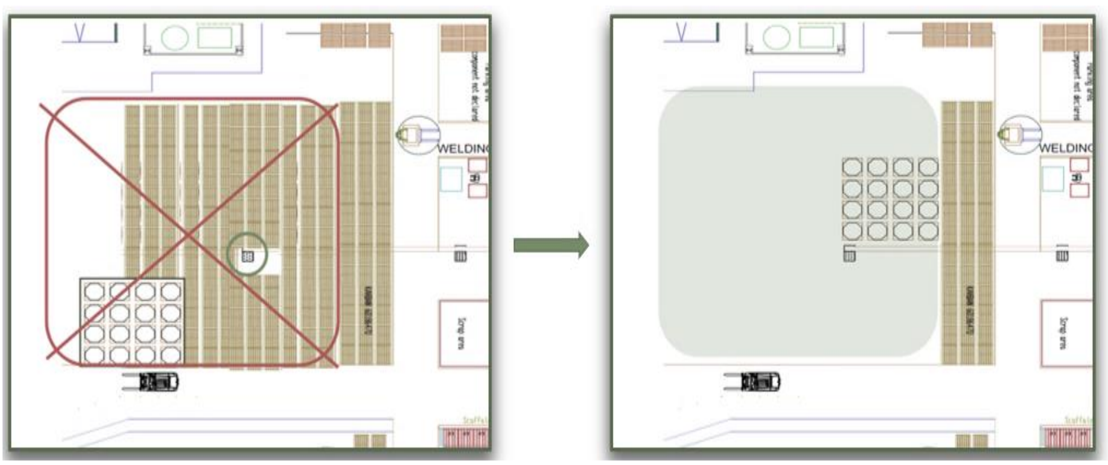
The same result is also shown in terms of the stock turn index. In this first phase, the goal was to ensure the rotation of all stocks at least once a month. As can be seen in Table 7, this goal was achieved, in one year this index gradually increased from a 0.55 on planned output and a 0.37 on real output in the third quarter of 2021 to a 1.09 on planned output and a 0.9 on real output in the third quarter of 2022.

Table 7 : *Stock turn trend 2021-2022*



The effectiveness of activities has not been slow to show the first improvements in terms of occupied warehouse space, from a peak of 660 pallet spaces occupied in the third quarter of 2021 to about 270 at the end of 2022. As can be seen in figure 37, the emptied area contained more than 300 pallets. According to lean principles, this area was then allocated to activities that could add value to the company.

Fig. 30 : *Occupied storage space: before and after*



4.2 Financial results

In terms of financial aspects, the impact of the activities carried out generated considerable benefits. The first and most significant was the reduction of the stock value around EUR 130,000 in total over 12 months. Starting from a value of EUR 202,000 in the third quarter of 2021, we were able to gradually reduce to a value of about EUR 75,000 at the end of 2022. However, in a market where growth and recession phases follow each other, a reduction in stock value frees up the cash needed to improve flexibility, to change strategy quickly and to react to new requirements. This reduction in value also provided benefits in terms of savings reducing the implicit costs of maintaining inventories. The implicit holding costs are identifiable in the costs associated with the capital investment in inventories and not identifiable through a cash outflow. To calculate these costs, it was taken into account: the total value of stocks produced in 2021, EUR 2,362,937, and that of stocks produced in 2022, EUR 1,834,949; the average storage period (stock coverage), 43 days in 2021 and 27 days in 2022; and an annual interest rate of 5.5%[1] applied to obtain a loan. The result was a reduction of the cost of the required capital from EUR 15,201 incurred in 2021 to a cost of EUR 7,412 in 2022.

In addition to the reduction of the stock value, there are also savings from the reduction of the space occupied within the warehouses. Considering the cost of a pallet place at 4.5€ per month, the average cost of storage at an external warehouse, the average cost of storage went from about 2,200€ per month in 2021 to about EUR 1,600 in 2021, about EUR 600 saved by the company every month. Taking the third quarter of 2021 as a reference point, the period in which the most critical issues emerged that led us to open the improvement project, we went from about 660 pallets to 270 at the end of 2022. Considering the two time frames rather than the average decrease between 2021 and 2022, the savings are around EUR 1,800 per month. While the storage cost per month was EUR 3,000 in the third quarter of 2021, it was reduced to EUR 1,200 at the end of 2022.

Reducing the value and quantity of unnecessary stock has also generated savings in terms of reducing warehouse administration costs, reducing the risk of obsolescence and especially energy costs. Whereas before the project the moulding machines were in continuous operation, at capacity saturation, from 2022 onwards moulding is only made upon request of the downstream line.

[1] Banca d'Italia : Harmonized interest rates for non-financial companies.

4.3 Improved order management and efficiency

The new method, while working with the goal of reducing production batches compared to the past, also unexpectedly provided benefits in terms of production efficiency and number of orders handled.

Previously, production orders were created with very large quantities to optimize department efficiency while minimizing setup time. However, the analysis performed revealed some inefficiencies present in this method: as a matter of fact, there was an alternation of large orders and very small orders . The causes of these inefficiencies resulted from unplanned depletion of some components for which a machine set-up needed to be changed immediately. These unexpected set-up changes led to a loss of machine utilization optimization, which affected the efficiency of the department and the number of orders to be handled.

Standardizing batches and synchronizing the two production lines, we estimated that about 40% fewer orders would have been handled in the past two years. As a result, resources dedicated to planning in the plastics department could have been freed up, allowing them to spend only half as much time on the department as before. The same result also applies to the management of changeovers. The 40% reduction in orders also translates into a reduction in the number of machine set-ups and, consequently, a gain in departmental efficiency.

4.4 Increased safety

Setting up order and dedicating well-defined areas for material, as well as providing visual control over the volume of stock, has also brought benefits in terms of safety.

Reducing the amount of material stored and reorganizing the space has resulted in a substantial reduction in the movement of material, a reduction in the risk of pallets falling, increased visibility and consequently greater safety for the operators in the plant. The reduction in the number of pallets has also ensured a reduction in the plant's fire load since it is plastic material stored inside wooden pallets.

Fig. 31 : *Defined storage areas and illustrative tables*

5. Conclusions

In this chapter we examined the application of some of the principles and tools of lean production at the Hungarian plant of DAB Pumps. In particular, we analyzed the application of the kanban method to the Scala System and plastic molding production lines to ensure continuous and optimized flow. Finally, it was highlighted how the application of this tool produced significant results in terms of space utilization, decreased stock value, and increased efficiency and safety.

Table 8 : *Results*

	Units of measurement	2021	2022
Stock value	€	202.000 €	75.000 €
Implicit costs of maintaining inventories	€/year	15.201 €	7.412 €
Cost of storage	€	2.200 €	1.600 €
Production efficency	Compared to 2021	-	↑
Energy cost	Compared to 2021	-	↓
Safety	Compared to 2021	-	↑

CONCLUSIONS

The project was kicked off at the end of 2021 with the aim of reducing the value of stock, saving space in internal and external warehouses and increasing communication within the internal value chain.

After an initial phase of theoretical analysis and after the implementations on the gemba, the first results were seen in the second quarter of 2022. It was clear that due to the improved communication between the different segments of the value chain and the implemented methodologies, there was in the short-term an immediate improvement in performance. The improvement of financial performance through the reduction of financial fixed assets and occupied space, especially rented external warehouses, was among the first results. Immediately afterwards, it was seen how the reduction in stock also showed up many inefficiencies that had previously been hidden by overstocking.

Closely related to the reduction of stock in the warehouse is the improvement of safety conditions within the production area, thanks to greater visibility and the reduction of the quantities handled daily by forklift trucks. Although the main focus was strictly on reducing stock and increasing safety, the project also helped to increase production efficiency. Contrary to what was initially thought, the reduction in the quantity of batches produced did not lead to a reduction in efficiency, rather it resulted in a reduction in sudden mould change due to unforeseen and unplanned material requirements.

In addition to the financial and performance effects, the project was very impactful in terms of staff awareness. The increased communication between the different areas also resulted in greater awareness by operators of their role in the value chain and consequently greater proactivity and more collaboration in seeking improvement actions for the entire process. One of the goals was precisely to encourage change from below and not to force it. Change must be down-top and not top-down.

Very important was the cooperation between the different departments during the implementation process. Although the core activities mainly involved Production and the Production Planning department, there were several supporting activities that enabled the implementation and ensured the resilience of the project. Among the most important were the activities carried out in collaboration with the R&D and the Process Engineer department in setting maintenance plans and spare parts for the moulds.

Very important are also all the inputs left over, or next steps for improvement. Among the most important of these is staff flexibility between production lines. Having operators capable of working on multiple assembly lines allows for greater flexibility as demand changes. In other words, with operators' flexibility, it is possible to balance lines maintaining efficiency without necessarily saturating the production capacity of departments even when it is not necessary. Another improvement left for the second step is the implementation of SMED or set-up time reduction. It will provide more production flexibility, batch reduction, and consequently it will allow even more reduction of stock in the warehouse.

In conclusion, the results obtained and the analysis performed in the paper can be a good starting point for future projects that could lead to further improvements in performance, allowing the company to gain a competitive advantage over competing companies.

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