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"LEAN TRANSFORMATION OF A MANUFACTURING FIRM: THE CASE OF ELBI S.P.A."

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Firma dello studente

Alla mia mamma e al mio papà

Table of Contents:

Introduction

Today more and more companies decide to undertake a path of improvement of their performance following the principles of Lean Production. This new philosophy has spread in recent years as a result of the companies' need to be more competitive in a global market. How? By reducing costs, eliminating wastes and increasing process efficiency and productivity, paying greater attention to the customer's needs and the quality of the finished product. Implementing a Lean Transformation process that achieves the indicated benefits is challenging and requires the application of a right method, without which projects often fail or achieve very modest results. In this Thesis, we will discuss about the enforcement of Lean Production in a local manufacturing firm called ELBI S.P.A, based in Limena (PD). Over a period of six months, I collaborated with an external consulting company called KaizenKey s.r.l., dealing with the following three projects regarding Continuous Improvement:

1) **Improvement of Human Resources Management**

   What has been extracted from literature reviews on the Lean Transformation process, is that, despite the large number of tools and techniques used in order to achieve process optimization, there seems that People, who are going to be the ones who will lead the change, will significantly affect the desired result. The intention is to create what is defined as "*Total system*", encouraging a high degree of personal responsibility. For this reason, we developed a Skills Matrix of all the workers involved within the operative departments and we computed two final KPIs of polyvalence of each skill (hard and soft).

2) **Improvement of the Corporate Logistics Flows**

   The project concerned the definition of a new Internal Logistics that would guarantee a more efficient management of the flows of materials and information within and between the various departments.

3) **Improvement of Assembly lines by studying Cycle Times**

   The third project concerned the analysis of the Cycle Time of the assembly lines within the department M. This analysis aimed to define a new balancing and layout solution based on a redistribution of workloads. In doing that, we developed a Time and Methods framework, which is particular useful in order to calculate the Standard Cycle Time within the working cycle.

CHAPTER 1

LEAN PRODUCTION: ORIGINS AND PRINCIPLES

This chapter aims to illustrate the transition from the industrial production to that which is called Lean, highlighting the main principles and features that characterized this new philosophy.

1.1. The development of Industrial Production

From the end of the seventeenth century to today, the world has witnessed an incredible development of the Economic-Industrial system, moving from a predominantly agricultural and crafty arrangement to a much more contemporary one. This new system was featured by the use of highly automated machines and new energy sources, all accompanied by a strong component of technological innovation. More specifically, there have been four *Industrial Revolutions*, which have characterized the last two and a half centuries.

The *First* industrial revolution took place from 1780 to 1830 in England and spread, in the following century, to other European countries and the United States of America. This revolution envisaged a new industrial system with workers who were employed within the factories and the traditional energy sources, used until now, were replaced by the application of new ones. Some of these included combustible sources such as coal, which allowed the introduction of steam engines to the industrial system (Chandler, 1990). This engine represented the greatest technological foundation and its greatest expression in terms of organization known as the "factory system". This new arrangement concerned the entire production chain: on the one hand, the owners of the capital needed to invest in machines and to pay workers' wages and, on the other hand, the workers who sold their labor force. Subsequently, the "factory system" continued to expand within and even outside of Europe, radically turning in favor of new economic realities, such as Germany and the USA. The Industrialization process strengthened as a result of a close connection between science, technology and production.

This linkage set the scene for the beginning of the *Second* industrial revolution, which was established during the second half of the eighteenth century. During this revolution, there was a strengthening of several fields, such as energetic, electric, oil & steel and transportation. In addition, there was a significant progress in scientific research and medicine (Hughes, 1983).

In the years following the Second World War, the concept of the *Third* industrial revolution was introduced. This concept led to the discovery and adoption of new energy sources such as the atom, the solar energy and the wind. The driver of this revolution was the technological innovation that brought about the birth of PC, robots (through artificial intelligence and automation), the creation of the first spacecraft and satellites, and the shifting to renewable energy (Jeremy Rifkin, 2011). Within the industrial field, a new "Factory system" took place, known as *Post-Fordist*, in which the concept of assembly chain was overstepped by promoting a more automated one. Furthermore, the meaning of “Outsourcing” was introduced, with the dislocation of traditional companies in low-cost areas. In the past, as explained previously, Industrial Revolutions have allowed humans to no longer depend on their own strength and on animals, providing millions of people with digital skills and thus, making Mass Production effective.

Nowadays, the form of revolution that concerns humanity is the *Fourth* industrial revolution. This revolution is characterized by the presence of new technologies that connect the physical, digital and biological spheres to each other. Additionally, this connection brings consequences in all areas, mostly in the economic and productive fields, reaching out and even questioning the meaning of "human being". More commonly, it is referred to as "Industry 4.0", pointing out the trend of industrial automation that incorporates some new production technologies in order to improve working conditions, increasing productivity and production quality. Accordingly, advances in robotics through the use of artificial intelligence, nanotechnology, and material sciences will lead this era and profoundly change the functions of the modern economy (Uzair M. Younus, 2017). This transition is moving towards a concept of “Smart Factory” both in terms of production and energy. Regarding production, with new technologies that create a new sort of operator made by machines, tools and services, thanks to IT infrastructures and techniques which allow to integrate systems between different companies along the supply chain (from supplier to the customer). And in regards to energy, creating more powerful systems by eliminating energy waste.

Historically, *Industrial Production* has evolved parallel to *Industrial Revolutions*, through various stages of development and establishing, definitively, with the introduction of the machinery into the production process and the resulting foundation of the "Automatic Factory".

The first sweeping change concerns the transition from *Craft* to Factory production. Specifically, Craft production, refers to the manufacturing process completely carried out by man, the craftsman, with his hands, without any kind of machine or technology. This term is related to the work of highly skilled artisans who, working from home or in small workshops, are able to add value and a highly degree of variety to the product, in order to meet the requirements of the individual customer. This type of manufacturing process is prior to Industrial Revolution. The craftsmen followed the whole working cycle: from the idea, to that of procurement of materials and to the manufacture of the product, until the final sale of the good. Craft products have a high quality, because for an artisan it is possible to obtain certain effects or levels of detail using techniques which are unworkable in other kinds of production. Very low production volume and lack of economies of scale were the negative aspects of this labour technique.

A clear example of craft production concerns the Panhard & Levassor (P&L) company, car manufacturer, when Evelyn Henry Ellis, a member of the English parliament, decided to go there in order to buy a new car (Womack et al., 1990). The P&L's work force was composed by workers who were skilled craftsmen who produced cars in extremely low volumes. Once her particular instructions were understood, P&L decided to produce this car, aware of the fact that it could satisfy its consumer's need because every single component was made one at a time and it was simple to apply such requests. Finally, the car was ready for the delivery in June 1895, when Ellis became the first person to drive an automobile in England. After almost twenty years, several companies around Western Europe and North America began manufacturing cars in small volumes adopting craft techniques.

Overall, craft production had the following features: highly skilled workforce inside a decentralized organization, coordinated by an owner who kept in touch with everyone involved in the system. For all the following reasons, the drawbacks of craft production are equally obvious in hindsight. The production costs were high and they did not drop with volume, which meant that only wealthy people could afford such cars. There was a considerable lack in terms of consistency and reliability, which were elusive and each car produced was a prototype. Moreover, the individual craftsman did not have the resources to implement new innovative techniques in its production system, as real technological progress needed a broader context.

Despite these drawbacks, a small number of craft-production firms have survived until now. They try to focus on narrow market niches populated by potential buyers who wish to deal directly with the manufacturer, ordering highly customized products.

The auto industry, around 1920 after World War I, progressed to *Mass Production*, where Henry Ford found a way, based on the principles formulated by Frederick Taylor, pioneer of the “Taylorism”, to overcome the problems inherent in craft production with his Model T. The pillar of Mass production, unlike what many people still believe, the “moving assembly line2” is identifiable in the concept of “interchangeability” of components and the simplicity of attaching them to each other. All this made possible the configuration of what we call "Assembly Line". H. Ford was even able to modify and develop innovative designs in order to reduce the total number of parts needed during the manufacturing process and made them extremely easy to attach. Mainly, Mass production consists in the process of creating large quantities of standardized products, carried out by some type of mechanization as with an assembly line. The ultimate goal is to achieve high production volume through the use of a detailed organization of the materials flow within a division of labor.

Oppositely to craft production, where the product is produced in a single location or by a single operator who performs the various production phases from start to finish, in Mass production the entire process is subdivided into elementary activities entrusted to a predetermined work station. The operator has to perform only a small part, highly optimized, of the total processing. In the design phase of the assembly line, the cycle time of each station must be made equal or at least as close as possible to the cycle time of all the other stations, using appropriate groupings and subdivisions of the activities into more and more specialized fractions, so that the line is able to work without stops and overlapping. The first step to make the process more efficient was to deliver the parts to each work station, allowing the assemblers to stay at the same spot during the whole working cycle. This was made possible also because the parts were created to a standard design that could be used in different models following the standardization process. At the beginning of the process, the workers performed only a single task moving from a product to the next one around the assembly hall, but this implied the problem about “walking time”, where a worker was forced to move from an assembly stand to another one. In order to get over that problem, Ford introduced the “moving assembly line”, which brought the product past the stationary worker, giving the rhythm of production and of the single operator. Mass production makes possible the reduction of production costs thanks to economies of scale and allows an efficient use of “not particularly well-trained labor”. This lack of labor skills refers to the elementary nature of the repetitive activities entrusted to each operator, which makes training needs very limited. However, being based on the standardization of components and products on continuous line processes, the resulting system is inherently inflexible with high initial investment cost, which makes it suitable only to products whose demand is largely predictable. This system, which is characterized on large-scale batch production, dominated for several decades the car-manufacturing industries, being the only one adopted by the main manufacturers.

From the second half of the XX century, after post-war period, a set of new techniques and production principles based on Toyota's way of work began to spread in several western companies. Toyota invented an entirely new way to manage and plan their production. During the same time period, some Japanese producers, particularly in the manufacturing and automotive industries, were getting relevant market shares to western producers. The reason for this success was based on a profoundly different production approach to wastes, quality, customers and the role of workers. In brief, Toyota could better understand, compared to other companies, the importance of these new production-related concepts. And, thanks to the intuitions of Shigeo Shingo, Taiichi Ohno and others, Toyota developed a new production system considered an evolution of the "Fordist assembly line", capable of responding to the high variety of market demands while maintaining high quality standards and substantial production volumes. This emerging production system is called the *Lean Production.*

1.2. The Lean Thinking

The Toyota Production System spread as Lean Production, or LP, because according to John Krafcik, the inventor of this term, it "*uses less than anything*" compared to Mass production. As athletes undergo hard training sessions with a lot of devotion, commitment and discipline to reduce body fat and develop muscles, Lean approach also aims to reduce waste and improve processes by trying to establish the idea of continuous improvement within the corporate culture. LP is even present in the book called "The Machine That Changed the World", by scholars James P. Omak and Daniel T. Jones, in which they compared the production systems of the major US and European automotive manufacturers with that of Japanese Toyota, explaining its superiority to all others and defining it as "*an entirely new way of making things*", underlining how this was completely different from Mass production. This system can be depicted by using the TPS house, which is a graphical representation of the Toyota's tools that compose its production system (see Figure 1):

- The left pillar, *Just-in-Time*, is defined as the "right piece, at the right time, in the right quantity";

- The right pillar is identified with the term *Jidoka*, or intrinsic quality, or the adoption of machines able to identify situations of non-compliance on their own stopping immediately, avoiding the production of defective products;
- The highly motivated staff, who are entrusted with the task of improving continuously the process, represents the main pivot of the entire house. Unlike of the theories of H. Ford, according to which managers and engineers have to deal with the planning while the only occupation of the workers is to run their own work, Toyota's aim is different: encouraging operators in order to propose suggestions so that there is one constant review of their way of working and involvement in the process itself.
- At the same time, TPS needs a strong *Foundation*, in order to provide a base on which Just-in-Time and Jidoka can be implemented. This is achieved through stability and standardization of the processes.
- The final *Goal* of the house concerns on cutting costs and the reduction of the lead time while keeping the highest possible quality.

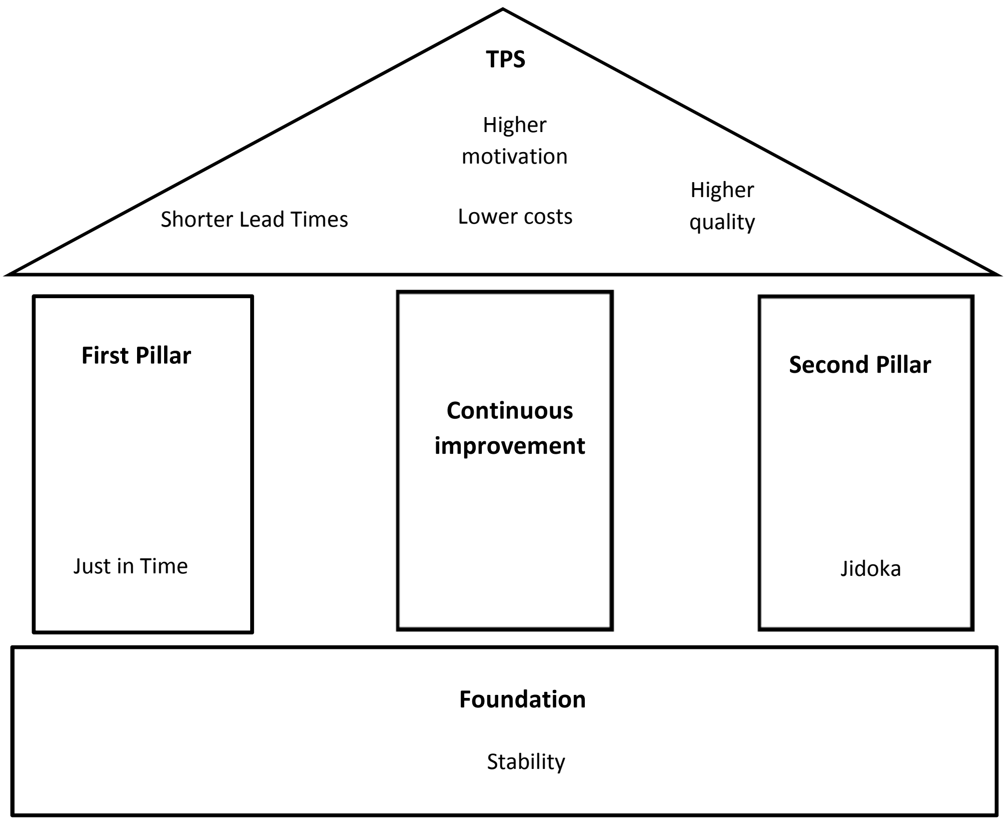


Figure 1: the TPS house

In the book *Lean Thinking* (by Womack and Jones, 2003), the authors use the term "Lean Thinking", in order to describe the ideology that drove Toyota to develop the TPS. Its roots are connected to the concept of "Continuous Improvement", an approach to be adopted with the aim to add value to the product and, simultaneously, eliminating waste. In order to carry on and keep LP, there are some principles useful for all companies that are implementing this change, which incorporate the overall ideas of this productive philosophy and are as it follows:

1) Specify the value for the customer;
2) Identify the flow of value;
3) Make sure that the value flow is free from interruptions;
4) Make sure it is the customer to request the value from the manufacturer (pull logic);
5) Pursuing perfection.

1) Define the Value

The value is what really matters to the customer and takes on meaning only when it is expressed in terms of goods or services that a company offers, able to satisfy the consumer's need in a given time and at a certain price. The paying customer is, ultimately, the reason of existence for the company itself.

Therefore, in order to define which are the activities that add value, it is necessary to know what the customer gives value and understand what are the business conditions that allow to produce it. We need to focus on the features and key processes with the aim to improve them (it makes no sense to focus on what the customer does not consider added value). Finally, the customer becomes the reference point for the definition of waste: the consumption of resources, which occurs in relation to other purposes, is defined as *Muda*. This represents the main principle of Lean Thinking because it determines the success of the next four.

2) Identify the Flow of Value

The flow of value is made up of all Value-Added and Nonvalue-Added activities that allow a company's product or service to flow along the supply chain, starting from the “concept design”, passing through the development, transformation of raw materials in the finished product and finally arriving at the customer's distribution and payment.

It is important to map the flow of value, identifying where value is created and where it is not, in order to make sure that every single operation adds value to the product and, consequently, to the end customer. Subsequently, the entire value stream must be mapped and analyzed, trying to recognize all waste sources within the process. By doing so, three types of activities can be identified:

1. Activities that generate value (VA), for which I can transfer the cost to the customer and it would be willing to pay.
2. Activities that are necessary but do not create value (NVA), in fact they are not easily eliminated in the short term without a structural redesign in business processes (First type of waste).
3. Activities that are not necessary and that do not create value (NVA), therefore they can be eliminated immediately as they are clearly wasteful (Second type of waste).

3) Continuous Flow

To make the flow smooth, it is necessary to eliminate activities that do not add value, so that the product or service can flow continuously from the beginning to the end of the process. After defining the value and after the flow of value has been completely mapped and any kind of waste has been eliminated, the focus moves on the activities which create value (VA). The idea of Continuous Flow has led to the concept of One-Piece-Flow, which intends to establish the progress of semi-finished products in the production system following a continuous flow; the material crosses the departments in the quickest way and the inventories are reduced to a minimum level. The goal is to implement the solution closest to the continuous flow, characterized by:

- Minimum stocks
- Quick set-ups
- Immediate shipments
- Machine that are very flexible and synchronized in cycle times.

For these reasons, the manufacturing plant of a Lean firm can be characterized by a line layout where all the equipment are arranged sequentially, allowing the process to produce one single product at a time, without an intermediate stock of Work-In-Process between one productive stage and the next one. Furthermore, we can find Lean plants organized in cells, called “production islands”, in which there are all the materials and machinery necessary for the production of a single product or an entire family, having similar features.

4) *Pull Logic*

The principle of “*Pull*” logic indicates that no activity is performed until the customer downstream (both internal or external) has asked for it (as it is the customer to drive the market). In this way, the stock level and the capital equipment can be reduced. The pull principle emphasizes the importance of the customer-supplier relationship and considers the internal processes connected to each other. In fact each of them is "customer" of the upstream process and "supplier" of the downstream one.

The opposite logic is called “*Push*”, which means managing processes in advance of customer needs, according to which firms anticipate the entry of materials in the factory ensuring the delivery time required by the market. This prediction is determined by using what is planned on the basis of forecasts (triggered by MRP information systems) and, if these are incorrect, inventories are generated. According to the pull logic, the customer must request the material needed to meet the demand of the downstream process. On the other end, the supplier must have a stock of material, which is called "Supermarket", in order to satisfy the customer's request. This stock, once reached a minimum level needed to buffer possible demand fluctuation, must be restored to ensure the availability of material to the customer. This allows the flow of value to deliver the right materials, at the right time, in the right quantity, while keeping a minimized warehouse at the same time. To increase the overall level of efficiency, it is necessary to extend waste disposal and the introduction of this new production management to the entire supply chain.

5) *Perfection*

The continuous pursuit for *Perfection* is the essence of the fifth principle of Lean and, more generally, of the Japanese philosophy. The aim of Continuous improvement is based on the idea of ideally striving for perfection through small incremental steps, one after the other. Naturally, a system will never reach absolute perfection, but this continuous review of the processes, with the aim of eliminating waste and increasing efficiency, serves to guide the strategy both at the operational and the managerial level, in such a way as to never be satisfied of the objectives achieved, continuing to pursue an ever-increasing level of quality and productivity. The ideal perfection coincides with the complete elimination of waste, so that in this condition, all activities create value for the final customer. This tension is the goal to keep active a systematic process of improvement since perfection is not a static concept, but a dynamic one, because the value for the customer changes over time. Finally, this last principle is fundamental to maintain staff motivation high: without new goals and without new objectives to be achieved, the tendency is to settle down, considering the status quo as a non-modifiable situation, thus blocking the entire process of improvement undertaken.

CHAPTER 2

TOOLS AND TECHNIQUES OF THE LEAN PRODUCTION

The following Lean Tools and Techniques constitute the two pillars and the foundation of the TPS house. They represent key and necessary elements for the practical implementation of this new production philosophy, compared to the Five Principles, which serve to create the maximum value for the consumer. Moreover, it is important to know how they work, understanding their potential and how they could be applied and adapted to any business context.

2.1. First Pillar: Just In Time

Just-In-Time (JIT) is a production planning method that is based on the idea of producing only what is needed, when it is needed, and in the amount needed. It confers speed and flexibility to the logistics-production system and results in the progressive reduction of all types of waste by simplifying production processes (VijayR. Kannan, Keah Choon Tan, 2004).To do so, the firm has to be able to switch the production very quickly, leveraging on set-up time reduction and using specific techniques. In fact, its correct functioning depends strongly on the simultaneous application of all Lean principles, methods and techniques, as these confer the necessary stability to the system. The main operational elements of a JIT system are the following:

- Layout
- Kanban system
- Heijunka
- Single Minute Exchange of Die (SMED).

The advantages of JIT are many:

- Reduced the level of inventories and the Lead Time of the process
- Increased reliability and the level of customer service
- Reduced storage costs and inventory management.

The application of JIT requires a high degree of synchronization between the processes and, within the supply chain, between supplier and customer. In fact, a short delay in the procurement of materials or processing could give rise to a paralysis of downstream processes. It is equally significant to improve the efficiency of the system to prevent failures or stops affecting the continuity of the flow and to share, with every actor of the supply chain, the importance that the company has in creating value for the customer. Since customers are the ones who trigger the production, the firm has to become more flexible in adapting to the fluctuations in demand and it can do that especially through the flexibility of labor. Consequently, it is important to convince both the managerial class and the individual operators to work together, concerning this new mentality.

2.1.1. Layout

The layout of the production plants, hence, plays a fundamental role in achieving the goals of JIT. In relation to JIT logic, the arrangement of the machines and equipment should be modified and properly located to optimize the production flow. In *batch-and-queue* production the typical layout is *Functional* and the resources are grouped for reasons of practical proximity. In producing batches, every one of them is processed in a specific function or dedicated department and then, once the working cycle of the whole lot is completed, it is moved to another function or department for the next step.

This type of layout creates several drawbacks and waste such as:

- An increase in pipeline inventory
- Excessive handling of the material with significant transportation costs
- An increase in Lead Time
- Recurring Bottlenecks between the various departments involved in the production.

Contrarily, LP implies One-Piece-Flow production that requires a *Product layout* instead of a functional one. A second strategic aspect of JIT concerns to the flexibility of machines and of men to adapt to changes in demand. Moving from the utilization of *Big* machines that have long and complex setups, making big batches and quickly creating waste with the only purpose of getting "economies of scale"; to *Small* machines that allow simultaneous processing and they are easier to move and permit flexible scheduling options with quick set-ups.

With a Lean layout, having a *U-shaped* production line, product families are grouped within the work centers composed by machines and equipment. These categories are located sequentially around this type of cellular layout, along which the operators moved doing their job (see Figure 2). All these work centers share common process routings. In this way, this type of layout requires less in-process inventory, reduces the cost of movement being there less physical space and, consequently, it will be less material handling due to "U-shaped"; since the workers will have shorter travel distances with an increase in visibility and teamwork emphasis. Each operator can be assigned different tasks and, therefore, some of them can work on the same cell whereas others are assigned only one. While the production is running, the operators are performing some manual tasks and the machines, on the other hand, work automatically, performing different tasks. One of the most relevant features of this layout is that the entry and exit from the line, where the production begins and ends, are in the same area.

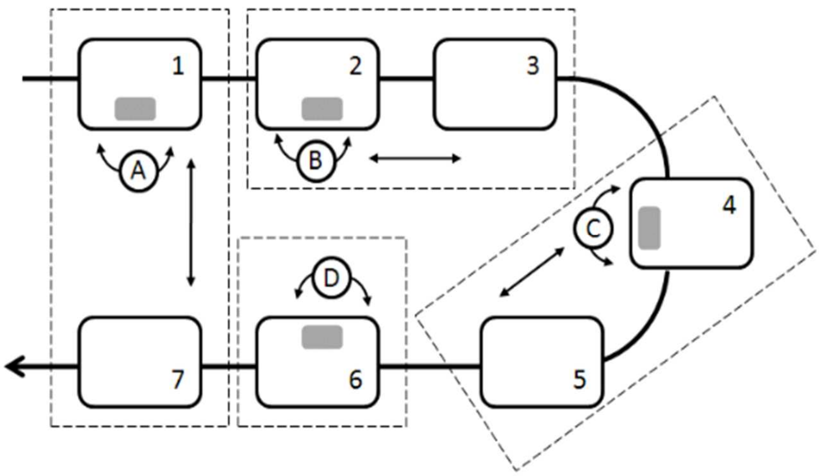


Figure 2: example of U-shaped production line.

2.1.2. Kanban system

Kanban, one of the most useful tools for applying JIT, is a controlling and signaling system which integrates, with the normal flow of materials (that goes from upstream to downstream), a flow of information that proceeds along the reverse path (from downstream to upstream), capable of triggering production based on the needs of final customer (see Figure 3).

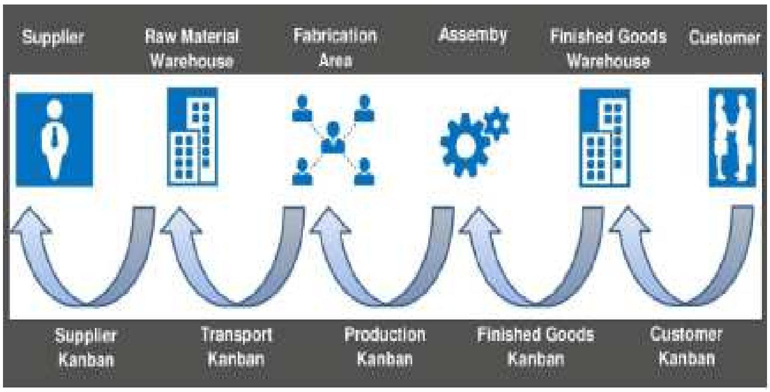


Figure 3: example of Kanban operating scheme.
Source: www.sixsigmatrainingfree.com

In Japanese, the word *Kanban*, stands for "card" or "signal" and each of them identifies a product, a component or a semi-finished product, indicating its origin and destination. Basically, they are used to link upstream and downstream divisions, which transmit a series of instructions, by communicating information on materials to be supplied or components to be produced. In fact, the demand Kanban is sent from the production stage to the upstream one, in order to signal which components are needed and it contains specific information (such as the name of the supplier, the customer, the code, the specific re-order quantity, the description and site). There are three types of Kanban:

1) *Move or Conveyance Kanban*, which is a "single card Kanban" that authorizes the movement of a piece between two contiguous processing cells: the downstream cell can take a piece to work with from the upstream one, only if there is a "Withdrawal Kanban" that signals the required delivery of parts to the next stage of production.
2) *Production Kanban*, which is usually associated with a Kanban system, composed by two cards, one for production and one for transportation, authorizes the upstream station to produce and replace the items consumed by the downstream customer.
3) *Vendor Kanban*, instead, signals to external suppliers the need for the required product to be shipped.

Generally, the number of Kanban card is related with the quantity of pipeline inventory, each Kanban is associated with a specific standard quantity/product and it is attached with fixed - sized container.

2.1.3. Heijunka

Heijunka is the Japanese word that means “*Leveling of production*”. It is a technique aimed in reducing the workload variability. Production can easily be leveled if the demand is constant or if a regular rhythm is maintained in the upstream processes so as to allow the same rhythm in the downstream as well.

This approach recommends to apply levelling on two aspects of production:

1) *Leveling of production by Volume*: by doing so, it would be necessary to produce following the long-term average of the demand and maintain an inventory proportional to the difference between the average demand and the peaks, thus ensuring the stability of the production process and the frequency of deliveries. Practically, everyday the system should process the same amount of a certain item (i.e. 20 items of product A, 30 items of product B and 15 items of product C), according to what was mentioned previously.
2) *Leveling of production by Product mix:* most of the time, production is a mix of different products with several processing steps. In the case in which the production line does not provide a single-product but a mixed-model, it is necessary to determine the optimal production sequence. The reduction of product changeover times, adopting SMED technique, allows to program smaller and smaller batches and increase flexibility to changes in demand fluctuation. In order to plan the production of products with different levels of demand, the “Heijunka box” is used, which is a visual control board that, taking advantage of the Kanban cards, keeps the workloads of the various stations constantly leveled for short increments of time, considering the product mix requested by the end customers. In this way, the mix of products are manufactured according to a specific sequence (i.e. A→B→C, where the system tries to complete one sequence every day by reducing lot size.

2.1.4. Single Minute Exchange of Die (SMED)

The SMED (Single Minute Exchange of Die) is a methodology introduced by Toyota company to reduce product changeover times. One of the longest setups that Toyota had to deal with was the replacement of the molds on the presses used to form the panels of the bodywork. Using Shingo’s techniques, an industrial engineer who worked as a consultant for Toyota, in 1971 molds’ changeover times were reduced from three hours to an average of three minutes. In recognition of these techniques, the term "Single Minute Exchange of Die" was coined, which means “*change mold in a single digit* ", in less than ten minutes and then expressible with a single digit.

Consequently, SMED became essential because if the product changes are too long then the tendency is to have batches too big before moving on to the next one. This creates several types of waste such as: “overproduction” because it is produced more than necessary, “higher inventory levels”, “yield losses” if the products are out of specification, and “lack of flexibility” in reacting to changes in customer needs. Changeover is an unproductive step of the process since it does not increase the added value of the product and absorbs labor and plant production capacity.

The purpose of this tool is to have a Quick Changeover (QCO), or to be able to quickly switch from one production to another in the same production plant. Four phases can be identified to implement SMED:

1) Measure and analyze changeover activities:

during this phase, all the necessary activities are carried out in order to critically analyze the current set-up process. Regarding the changeover activities, they can be either:

- “*Internal”*, which are those that can be performed only if the process has stopped
- “*External*”, which are those that can be performed when the process is still operating.

Specifically, in the analysis the following activities are executed:

- description of the tasks performed by each operator.
- timing detection taken to perform each operation.
- distinction between Internal and External activities, based on the aforementioned definition.
- listing of the tools used to carry out the various tasks and their location.

2) Separate external and internal activities:

in this phase, the goal is to completely separate the two type of activities, taking into account that:

- "*External*" activities include cleaning, handling of tools and components necessary to carry out the changeover, both in the initial phase of the process and during the final one.
- "*Internal*" activities, instead, should concern only the disassembly, the assembly, the centring and the adjustment of the equipment.

3) Change all *Internal* activities to *External* ones:

bringing the activities out of the product changeover time by taking "Internal" activities out of set-up operation can save a lot of time. Then, it must be analyzed whether or not it is possible to change the "*Internal*" activities in "*External*" ones. How? Pre-preparing the activities and the related equipment and making the changeover process more flexible by speeding up the required changes of equipment.

4) Practice changeover routines:

if several operators can carry out the activities simultaneously, the total time can be reduced without increasing the labor necessary for product changes. This final phase is aimed at optimizing the sequence and operational methods of "Internal" activities, both through technical solutions (developing methods and improving work equipment with standardization), and through organizational one (performing "Internal" activities in parallel).

2.2. Second Pillar: Jidoka

Jidoka represents the second pillar of TPS house. This Japanese word is generally translated with “Autonomation”, which identifies a technology that uses control systems to manage machineries and processes in order to stop the production whenever an abnormal condition or defects occur. It is extremely efficient because it helps to minimize defects before they reach the customer. In fact, the machines are able to stop automatically and the operators can fix the problem by interrupting the production process. Therefore, the simultaneous presence of appropriately trained operators is fundamental as they have the authority to stop the whole production process at the first critical signal (the term "*Automation with human touch*" is used for this reason). The goal is to reduce waste and defects by identifying the root causes of the problem, then making improvements in order to ensure that it does not occur again in the future. Jidoka enables to separate men and machine, making machinery free from the need to be constantly supervised by the operators, allowing workers to simultaneously control multiple production stations.

2.2.1. Poka Yoke

Poka-Yoke (in Japanese "fool-proof") is a *Visual Management* tool which prevents human errors in carrying out a production operation and aims to make assembly and manufacturing activities simpler and less error-prone even by less-skilled operators. This device is inexpensive and, through automatic inspection not based on human interaction, prevents defects by stopping and communicating a signal each time any anomaly is detected.

The inventor of this tool, distinguishes three types of Poka-Yoke (Shigeo Shingo, 1986):

1) C*ontact devices*: the physical characteristics of an object, such as geometry and color, allow to identify the correct position of grip, insertion or manipulation of the tool or subassembly and preventing them to combine incorrectly objects to each other, avoiding malfunctions caused by a wrong one contact.
2) *Fixed value devices*: check whether a certain number of operations has been carried out.
3) *Motion step devices*: check whether all steps of a given process were performed in their correct order.

Depending on the type of error that is committed, this technique is able to provide simple warnings or hinder the wrong action. Occasional errors deserve warnings, while common ones deserve checks or impediments. Poka-Yoke can be applied to different areas, but it works very well when you analyze manual operations for which are required adjustments and a constant supervision by the operator and where there is a strong staff turnover with a poor training thereof.

2.2.2. Andon

Andon is a type of *Visual Management* control, which is used as a system to inform operators, maintenance staff and management in general that there is a problem occurring in in manufacturing operations. It provides instant, visible and audible warning to the operations team that there is an abnormality within that area. This control is implemented through the use of two basic elements, which are the "Andon board" and the "Andon line or cord". These are located near the operator and every time the operator identifies a problem, he or she can activate manually the alert signal pulling the cord or the button. Once that is taken proof of the existence of the problem, a visual indication – commonly is a light (red if the line stopped, yellow if it calls for an help and green if everything is normal) which signals the production line status – specified in which workstation there is a need of help. At that point, a supervisor should come to the workstation to help out. Now, the goal will be to solve the problem and restore the operation of the process. If difficulties are found and the problem cannot be solved, additional help will be requested by pulling the Andon cord again. If at the end, the problem is not be solved then the line is stopped until the issue gets finally fixed.

2.3. Foundation: Stability

According to TPS house, it needs a strong foundation that is necessary for the implementation of JIT and the Jidoka. Stability implies that the process must be:

- "*Capable*", where the operators and machines do not produce defective products and do not make systematic errors.
- "*Available*", the operators work when they asked to do so and the machines work when they are expected to do it.

In order to give stability to the entire process, several tools must be used.

2.3.1. Standardized Work

The *Standardization of work* is a method in which all the essential procedures required to perform a specific job or task are defined, codified and shared within the company.
We can talk about Standard Operating Procedures (SOP), indicating the document where, in detail, are indicated, in succession, the operations with their specific instructions and the way in which they must be carried out, following the so-called "best practices".
At the same time, it forms the basis of an approach that can be developed and which allows the Continuous Improvement. There are three components needed to achieve standardization:

1) the *Takt Time*, which represents the time needed to produce a single component (or the entire product) in such a way as to satisfy the customer's request. For instance, it represents the speed that the production process should have to meet the demand.
2) the *Cycle Time,* which is the time required to complete the cycle of an operation.
3) the *Standard Work In Progress* (SWIP), composed by the standard inventory needed to keep the process operating smoothly.

2.3.2. 5 s

5S is a systematic and repeatable methodology to optimize working standards and improve operational performance. The goal is to eliminate all the wastes and everything related, which are not functional to the activity performed. This technique requires the involvement of the all staff and, once entered into the attitude of each person, it is understood as a normal practice to be performed. The 5S is even a "zero investment" tool that has a strong return in terms of quality and productivity and it can be applied to the company as a whole.
More specifically, the five S's are:

1) *Seiri* – Separate, which consists in identifying all that is necessary for daily work, separating it from tools that are used less or even never. By eliminating or storing what is not essential, the impact that the useless equipment can have on everyday work can be reduced.
2) *Seiton* – Tidying, where it is necessary to arrange in a functional way what has been kept, optimizing the use of space, defining the exact position of each object and coding it appropriately in such a way as to allow a reduction in the time of material research.
3) *Seiso* – Cleaning, keeping the workplace clean allows the operator to check and fix the tools provided by the company, in order to guarantee the right functioning of them. A clean and tidy environment also allows to bring out inefficiencies.
4) *Seiketsu* – Standardize, defining repetitive and consolidated rules to continue the standardization of resources and production spaces, adopting standard procedures.
5) *Shitsuke* – Support, ensuring that the four previous steps are applied with commitment and perseverance over time in all company departments, by supporting the Continuous Improvement point of view.

2.3.3. Total Productive Maintenance (TPM)

The TPM is a set of principles and practices aimed at increasing the performance of machines improving the methodology, organization and planning of the maintenance process. It aims at optimizing the effectiveness of manufacturing equipment and tooling, reducing at minimum machine failures and emergency maintenance.

It is based on the teamwork activities and involves all levels of the organization: from supervisors to operators, passing through the production managers. TPM requires operators and maintenance staff to work together, on a daily basis, on routines of maintenance - like cleaning, oiling and visual inspections – to prevent failures, to improve the OEE (Overall Equipment Effectiveness) and to extend the life cycle of the equipment, by using preventive maintenance. Some of the most important elements of the TPM are (I.P.S. Ahuja, J.S. Khamba, 2008):

- *Preventive maintenance*: maintenance performed at regular time intervals based on a schedule designed to avoid stops or breakdowns before they occur.
- *Predictive maintenance*: maintenance that uses tools to analyze the "state of health" of the machines and try to anticipate when the machine is about to break, in order to intervene by arranging it before it happens.
- *Failure maintenance*: the repair of the machine after a fault.
- *Corrective maintenance*: arrangement to the machinery to reduce the frequency of micro-stops and faults and reduce the timing of action in case of breakage.
- *Autonomous maintenance*: maintenance performed by organized teams of operators in complete autonomy compared to other technicians and engineers involved in the maintenance department.

2.4. The final goal: Cost, Quality, Time and Motivation

In relation to the TPS house, its roof represents the final aims of the entire Lean system. Manufacturing products with the lowest possible *Costs*, ensuring an excellent level of *Quality* that meets the expected standards and delivering them to the customer by reducing the *Lead Time* as much as possible, is what Lean is supposed to do. At the same time, there must be a highly motivated staff who participates in Lean projects and can promote Continuous Improvement in the whole company. TPS aims to achieve all these goals simultaneously and, for this reason, Lean strategy is driven by the two pillars, Just in Time and Jidoka.

2.5. Continuous Improvement (the Third Pillar)

As previously explained in the description of the TPS house (Figure 1, Chapter 1), there is a third pillar, the *Continuous Improvement*, which is understood as the main pillar of LP.In Japanese, it is defined as “Kaizen” and intended as a culture of sustained improvement targeting the elimination of waste in all systems and processes of an organization. It involves everyone (from operators to managers) and implies a limited investment (Nadia Bhuiyan and Amit Baghel, 2005). If taken individually, the changes made by the Kaizen are modest and incremental, however, over time, the cumulative improvement can be very wide.
Unlike *Kaikaku*, which is a Japanese word that means “breakthrough”, Kaizen is a reversible methodology and, therefore, it is a low risk method, in fact you can always go back to the old operating modes since no high costs were incurred. To properly implement a Kaizen strategy, managers must take into account the following concepts (Masaaki Imai, 2015):

1) kaizen and Management
2) processes and results
3) keep the improvement through the PDCA cycle
4) quality first of all
5) talk with the data
6) the downstream process is the customer.

The first step is up to the management that must express its commitment to draw up and spread a clear strategy in which an implementation plan is defined with precise deadlines.

1) *Kaizen and Management*: within the Continuous Improvement methodology, Management has two main functions: “Maintaining” and “Improving”. *Maintenance* is intended as compliance with operational, technological and managerial standards, while *Improvement* refers to the activities aimed at raising the level of standards in force (see Figure 4).

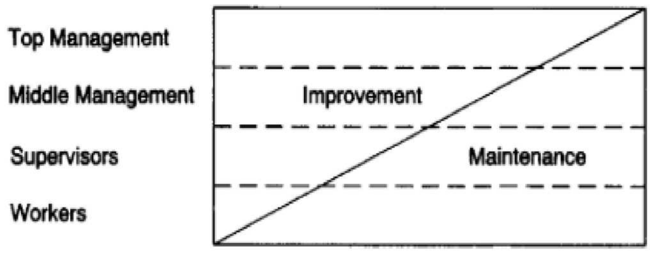


Figure 4: division of tasks in the corporate hierarchy.
Source: Masaaki Imai (2015) Gemba Kaizen, Franco Angeli.

The improvement can be split in two types: Innovation and Kaizen. The *Innovation* allows us to obtain a considerable leap onwards by doing significant investments in new technologies, thereby generating a change of direction. Instead, the goal of *Kaizen* is to focus on incremental improvement measures of modest size, exalting the moral of the workers, by promoting the team-work approach with a full involvement of the people, supported by training and effort of the entire staff (see Figure 5).

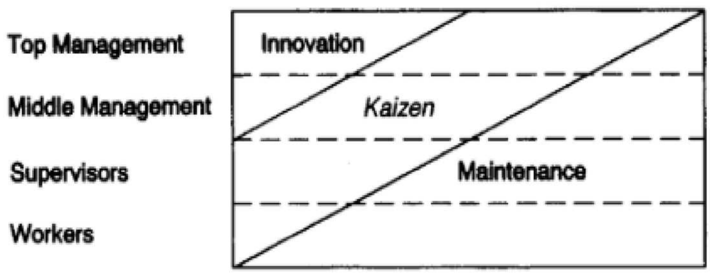


Figure 5: differentiation of types of improvement.
Source: Masaaki Imai (2015) Gemba Kaizen, Franco Angeli.

2) *Processes and results*: very often, Kaizen strategies do not provide the desired results because companies do not focus on *processes*. If the processes are not improved, the *results* will not change and will remain the same. Therefore, it is necessary to focus on the key activities that generate value for the customer. Therein, it must be a convinced adhesion on the part of the Management, for two main reasons: to show all workers the importance of improvement projects and sustain the initiatives over time, avoiding the risk of failure due to a decrease in staff motivation.

3) *Keep the improvement through the PDCA cycle*: the *Plan-Do-Check-Act* cycle, or Deming cycle, is an iterative method consisting of four steps, used as a tool to preserve the Continuous Improvement of products and processes. It was made popular by the famous "guru" of the quality, W.E. Deming, and lays its foundations on the "scientific method" because, compared to it, its main principle is the repetitiveness of the cycle: once the hypothesis is confirmed or rejected, a new iteration of the cycle allows to further extend the knowledge, bringing us closer to the goal, typically the perfection of the process or product. Using of the PDCA cycle means continuously looking for better methods of improvement (M. Sokovic, D. Pavletic, K. Kern Pipan, 2010).

   The four phases, in which the improvement process is divided, are the following (see Figure 6):

   1) *Plan*: during this phase the objectives to be reached are defined, all the data related to the problem in question are collected and, based on these, the main causes to be removed are identified. Then is necessary to formulate an action plan to solve the problem.
   2) *Do*: the managers put into practice the actions envisaged, possibly within the agreed time, and they collect the data to be analyzed in the following two phases.
   3) *Check*: the implemented solutions are subjected to a constant control over time, in order to verify the results and the sustainability of what has been achieved. The data collected in the previous phase are studied and compared with the predetermined goal, checking every deviation between what is planned and how the improvement actions were actually implemented.
   4) *Act*: if the previous phase ("Check") shows that the action implemented is an improvement compared to the current standard, then this becomes the new one standards for how the organization should act ("Act") in the future. In the hypothesis that checking phase does not show an improvement compared to the previous standard, then this standard remains in force.

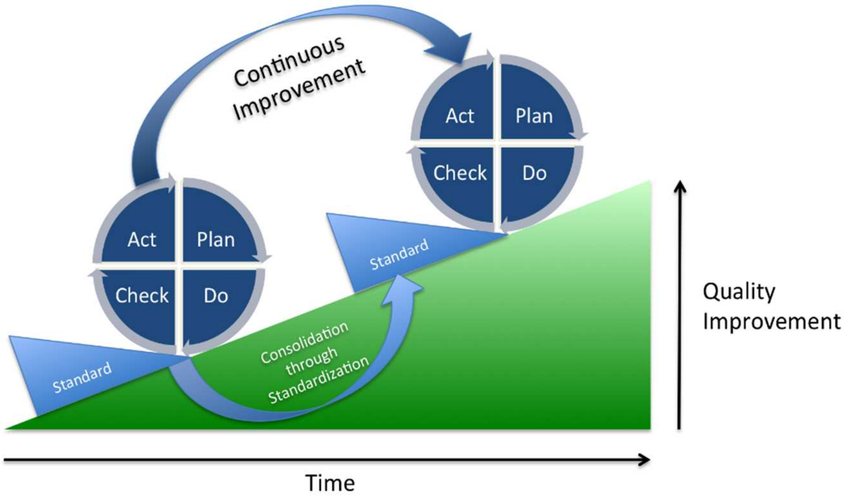


Figure 6: the PDCA cycle process.

Source: https://en.wikipedia.org/wiki/PDCA

4) *Quality first of all:* if the quality of a product does not meet the requirements, the company is not competitive, despite low prices or short delivery times. Precisely for this reason, one of the basic technique of Kaizen philosophy is the *Total Quality Management* (TQM), which is delegated to the entire organization. TQM's activity is not limited to quality control carried out in production, but constitutes a global strategy to help the managerial class to increase competitiveness and profitability by improving all aspects of business management. It means the objective of the company to improve the features of a product in numerous ways: in terms of performance, reliability, adherence to specifications, durability, usability, service and perceived quality.

5) *Talk with the data*: the improvement to be achieved goes through Problem Solving approach; according to that, Kaizen is a problem-solving process. Trying to solve a problem without starting *Data* means relying on subjective feelings, often coming to wrong conclusions. Improving, instead, means moving from the current state to the future state, achieving the desired goal, and so this can not be done if the performance is not measured objectively. The quality and reasoned collection of data represented a fundamental point in the implementation of the Kaizen in the company.

6) *The downstream process is the customer*: a process consists of a sequence of activities whose ultimate goal is to create value for the customer, transforming raw materials and information into finished products or services. Each process has its own supplier and its customer and the downstream process must always be considered as a *Customer*, whether it is internal or external to the company. This is very important because supplying a defective or low-quality piece to an internal customer means ultimately transferring it to the final one. Only when all the people working in the company are conformed to this principle, it is possible to maximize the value offered to the consumer.

2.6. Value Stream Mapping

Value Stream Mapping (VSM) represents the process of collection of all the activities required to bring a product through the main flows, from raw materials to the final customer, passing through the intermediate transformation and assembly processes (Rother and Shook, 1999). The analysis of the flow of value is based on the overall optimization of the whole system, and not only of the single process: the goal is to eliminate all wastes without removing value to the product, increasing exponentially the efficiency of the process. The whole process and the respective flow of information and materials are represented graphically with the use of some predefined symbols and icons. Thanks to the VSM, two process maps are performed:

1) *Current State Map* (see figure 7)*:* this first outcome concerns a description of how the process is currently organized. The current process is analysed starting from the customer and going backward, identifying any potential value leak. The identification of wastes passes through their measurement adopting some significant indicators such as: set up times, cycle times, inventory levels, machine efficiency indexes, delivery times, quality performance and many others. In order to map the flow of materials, the main production phases, the time and the number of people working for each workstation are determined first. Subsequently, the quantity of stock materials is defined along the process and where the defects cause return flows. On the other hand, to highlight the flow of information, it is necessary to calculate the processing time and order fulfilment (both for suppliers and for customers) with reference to the functions involved. Necessary modifications and changes to fix some aspects of the current operations will be part of the Future State Map.

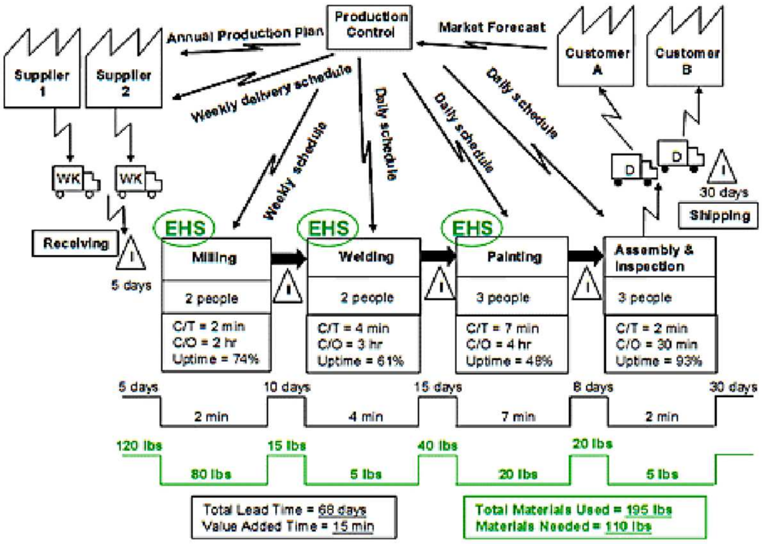


Figure 7: example of Current State Map

Source: www.leanmanufacturing.it

2) *Future State Map* (see Figure 8): this second outcome shows how the system should look after all the inefficiencies and wastes have been removed. This future map depicts an ideal state of operations and it helps the development for the application of the Lean techniques. This final state will be the current goal and it requires a proper implementation of specific Lean tools.

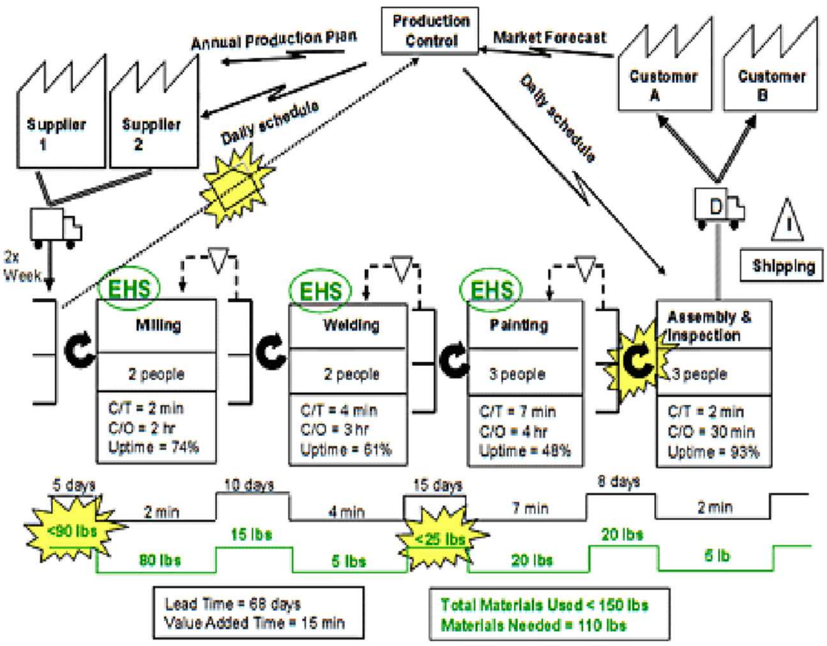


Figure 8: example of Future State Map

Source: www.leanmanufacturing.it

2.7. Wastes: Muda, Muri and Mura

In compliance with what has been said before, Value represents the point of departure and arrival of Lean Production philosophy. Specifically, the corporate organizational structure should be managed and adapted only around processes that create added value to the customers. As a result, the main goal of any organisation must be to focus its efforts and resources only on what has value and deliver it to its final customers (Mossman, 2009). For this reason, preserving value activities means that companies have to eliminate within their processes, any kind of waste that consumes resources but does not add any value to the product (Nicholas, 1998). As we see, waste plays a central role in Lean management.

In Japanese, “waste” is translated into Muda and it is related to every action done by a company that a customer is not willing to pay for (Pieńkowski, 2014). It is not the only type of waste that can be performed by the company; there are other two types of waste called Muri and Mura.

2.7.1. Muda

Taiichi Ohno, during his period of work in Toyota, identified seven types of Muda. Lean Production’s techniques listed so far have precisely the objective of identifying these wastes and, in case it is not possible to completely removed all of them, at least reduce them considerably. The following wastes are suggested by (Womack and Jones, 2003):

1) *Over-production*

It means producing a large quantity of goods compared to what the customer actually has requested or, even better, before the actual order is recorded by the supplier. Basically, it follows Push Logic and, for this reason, it is an obstacle in reaching the final goal of the TPS house because it absorbs time, efforts (in terms of energy) and, generally, unnecessary expenses. Moreover, this waste tends to hide production problems, as well as causing other types of Muda, since Overproduction must be stored, moved, etc.

2) Waiting

This Muda occurs when operators lie idle because there are goods that are not moving along the process or because they are waiting for information to be delivered or tools or machines to be available. Obviously, this time, which is spent waiting, does not generate value. Rather, it reduces productivity and increases costs related to the process.

3) *Transportation*

It is related to all the movements of material, parts and products from one place to another, without it being necessary and so without adding any value. Excess transportations can be due to poor layouts and organization of production, characterized of large batch sizes and multiple storage locations.

4) Over processing

it is due to the fact that more resources are used than those actually needed to perform an activity. These unnecessary and not value adding activities bring inefficiencies and are extremely costly and time consuming. They can not be put into the final selling price of the good, because customers are not expected to appreciate them.

5) Inventory

Stocks, in the form of raw materials, semi-finished or finished products, represent a capital that has not yet produced earnings for the company or generated value for the customer.
Inventories are likely to hide problems and defects along the supply chain, making them more difficult to be discovered and solved.

6) Motions

They are related to unnecessary movements performed by workers or machines,
like moving from one workstation to another because of a poor workstation layout, or looking for parts, documents or tools. Generally, they cause a decrease in the efficiency of the process and additional costs because workers do excessive walking.

7) Defects

They are errors, imperfections or non-compliance which lead the product to be out of the standard specifications. Even the re-working and the returned goods that not satisfied customer requirements are considered defects. When you are producing defects you are wasting financial resources and time, decreasing the overall quality of your operations.

2.7.2. Mura

The waste Mura means "*unevenness*" or "*inconsistency*" and it is indicates the fluctuations in demand and workload. Such variations within the production process are not due to the final customer but by the firm itself. It is important to keep under control these variations in production schedule by adopting Production Levelling technique such as Heijunka.

2.7.3. Muri

The waste Muri means "*unreasonableness*" or "*overburden*". It reveals when a company overloads its operators and machines under unnecessary performances or, more often, dangerous activities. Loading excessively working staff, for example by making workers forced to work at an unsustainable rhythm and in a non-ergonomic place, could lead to more or less serious injuries and, consequently, to people's absenteeism and to a potential reduction in motivation. The same reasoning can be applied to machinery: excessive wear can cause wasted time due to fixing or maintenance.

CHAPTER 3

ELBI S.P.A

In this chapter, I will present ELBI S.P.A., the company in which this work of analysis and improvement was performed in the field of Operations management based upon the principles of Lean Production. More specifically, the company will be described both from the historical point of view and from the various production processes that characterize the business in which it operates.

3.1. The History

In 1965, a group of four people who were selling expansion tanks through subcontracting operations originally founded ELBI S.P.A. in a garage.

From 1970 to 1990

In the early 1970s, the founders decided to purchase a vast warehouse and there was a subsequent displacement, with a growth to 50 employees, at Vigodarzere plant. Furthermore, there was an expansion of the range of products offered to hot water cylinders and central-heating boilers. In the early 1980s, after a sudden expansion in the North African foreign market and having overgrown the capacity of the Vigodarzere plant, ELBI S.P.A moved to Limena, where its current plant is still present. This change of location came along with a new factory acquired after a bankruptcy of a previous one, thus expanding its production capacity. A few years later, ELBI S.P.A began producing surge tanks and diaphragm expansion tanks, those with membrane. The business model of that time was based on economical savings for large-scale production.

From 1990 to 2000

In the early 1990s, the company started a new production line processing *Plastic* material, adopting rotational-moulded polyethylene technology, manufacturing tanks for the *Thermohydraulic* division. The goal was to reduce production costs by working plastic instead of iron, but such strategy did not work, because there were some obvious problems in manufacturing and regarding the properties the product itself.

Therefore, the management decided only to start the production of tanks for the containment of drinking water, not under pressure with rotational-moulded polyethylene. In the same years, Elbi of America, Inc. based in Houston, Texas, was founded. This choice was a result of an attempt to enter the American market more firmly given the need to acquire ASME's certification in order to operate in United States; the only way to afford it was to found a company in the abovementioned country. Initially, this new company played the role of simple marketing and sales activities, learning about the cultures and mentalities of a vast and complex business like the American one.

In 1994, the *Green System* business sales division was established, which deals with the production and distribution of pots for plants and flowers made of rotational-moulded polyethylene technique. The know-out and the raw material used were the same ones of the tanks, but what changed was the type of mold. The company, in this way, entered in a new market, the gardening and green furniture one, first in Italy and immediately afterwards even abroad.

In 1996, Elbi of America switched from the mere import-export business of products coming from China, U.S.A. itself or Italy, becoming officially the production headquarters for the fixed-diaphragm tanks (D series), thus bringing production closer to the target market. Towards the end of the 1990s, the third commercial division of the company, called *Ambiente*, took place, which deals with the design and production of containers and bells, always manufactured with rotational-moulded solution, for the collection of solid urban waste, and to market a wide range of accessories for urban hygiene and decor.

From 2000 to Today

In the early 2000s, there was the acquisition of the French-owned Lander company specializing in the field of environment. The acquisition brought home a new business dealership, involving urban supplies, and two related main contracts, one for the Florentine market and the other for the Roman one.

In 2001 a new production facility was opened in Modugno, in the south of Italy, mainly dedicated to the manufacture of products made of rotational-moulded technology. The plant is equipped with two ovens for rotational molding and a machinery for polyethylene extrusion and pulverizing.

Since 2006, ELBI S.P.A. has become a distributor for *Playground* division, offering a range of equipment for parks and schools for children within 18 months to 16 years of age. In 2007, the *Living* business unit division was born, driven by the garden market, with products developed by prestigious architects and designers, always made with polyethylene materials and intended to the furniture market.

In 2008, ELBI S.P.A. entered in the well-being market, becoming an Italian distributor, with an offer of innovative well-being track consisting of several sporting gears for athletes or sportsmen. The 2008 is also the year of the restyling of the Green System Division, with the advent of new design products for the furniture market comes the need to create a new image, expressly dedicated to this new target. The new brand, *21st*, wants to be the expression of a renewed image of both the traditional offer, the Garden one, and the new products under the Living division. This new collection is described as *"a fresh, modern, contemporary image that looks to the future with curiosity and dynamism"*.

In 2014, ELBI S.P.A. decided to acquire a company, based in the American territory that so far was its supplier, in Los Angeles. The purpose of this acquisition was for the company to expand its presence in the US market with a sales company specialized in selling products for the connection of the gas. Approximately a couple of years later, in 2016, a new subsidiary was founded in Philadelphia. The goal was to become a leader in the eastern part of the U.S., both at the level of distribution and brand awareness.

Today, ELBI S.P.A. is a company that makes *differentiation* its strong point. The variety of its products, which include very different technologies and know-outs, imposes a very flexible organizational structure, both from a commercial and a productive point of view. For this reason, ELBI S.P.A. is implementing new solutions in its Operations management, through the use of Lean Manufacturing techniques trying to optimize process efficiency. At the same time, at the commercial level, ELBI S.P.A. presents divisions that work independently taking care of the relationship with the customer, following the specific needs of the reference market.
The goal, for the next years, is to increase its revenue with a penetration strategy into emerging markets, such as South America and Asia. Another approach could be to develop new synergies through the acquisition of strategic companies, setting up new production and/or commercial subsidiaries, expanding the action range being more present globally.

3.2. The Products

Nowadays, ELBI S.P.A. concentrates its activities in four distinct *Business Divisions*, whose products are manufactured according to strict quality, process and control criteria, and they are as follows:

1) Thermos-hydraulic: its product range includes one of the most exhaustive offerings regarding thermos-hydraulic market:

- *Hot water cylinders*: these are suitable for the installation in civil and industrial systems and for the production and storage of hot water for hygienic-sanitary purposes thanks to their features of functionality and reliability.
- *Expansion tanks for heating*: are products designed to absorb the volume change of water or of other liquids, therefore they allow the correct working of a heating plant during all its operative phases.
- *Bladder autoclaves for sanitary water*: its function is to sustain system pressure by feeding additional water into the system at the required pressure.
- *Multifunctional tanks for heating and hot water*: these are designed to be fitted both into sanitary system as expansion tanks, in order to absorb the water expansion volume generated by a variable temperature, and as tanks for cold water sanitary systems as well.
- *Tanks for solar systems*: these solar panels work with higher temperatures compared to those of conventional systems.

- *Polyethylene tanks for underground and above ground:* these are for underground use only if they follows these specifications: storage of water or other liquids and rainwater recovery.
- *Cold-water tanks (galvanized and/or glass lined):* these could be galvanized or glass lined tanks with cold water or compressed air.
- *ASME tanks*: these are suitable for use in commercial and industrial fresh potable hot water applications or in hydronic heating systems where they keep the system pressure below the relief valve setting preventing, in this way, dangerous pressure build-up.

2) Garden 21st Art: this division is composed by four different categories:
    1) *Terra collection*: it reproduces the tradition of ancient art of Tuscan terracotta handmade. A collection that translates and delivers knowledge, memories and traditions to the present. A journey through time and space.
    2) *Fiore collection:* it represents the innovation of design, a process of research of new shapes in continuous evolution that flourish in a new style: fresh, sober, original. A continuous, slow and silent evolution: life flowing while progress advancing.
    3) *Nude collection*: elegance and simplicity are the fundamental characteristics of this collection. Thanks to the wide choice of sizes and the variety of colors offered, the vases of the Nude collection are ideal to furnish both outdoor and indoor environments.
    4) *Pet collection*: shapes and structures, materials and colors designed for the maximum comfort of our great animal friends. That is why thinking about their comfort and the functionality of the objects necessary for their well-being is a serious matter.

3) Living 21st Art: the aim of 21st division is to "explore". In fact, its collaboration with the main Italian designers allows it to extend the boundaries, changing the perception and developing creativity. Since collaboration drives knowledge, Living 21st represents a collection of landing points discovered and marked on new art maps. The depth of this research also depends on the combination of materials, colors, shapes, images and density. It offers a wide range of products like: seating and tables, furnishing and bookshelves, coloured and lacquered pots and, eventually, light and lamps.
4) Ambiente: the range of products included in Ambiente division is composed by 2 and 4-wheel containers up to 2,000 liters of capacity, stationary containers up to 3,200 liters, a complete range of bells for separate waste collection from 2,000 to 3,500 liters of capacity, a large series of urban furniture baskets and, at the end, two domestic compartments. In addition, there are also semi-buried and buried bells with volumes included between 2,500 and 5,000 liters. All products comply with European standards and duly certified.

3.3. Production processes

The production processes, given the wide range of products offered, are very different from one to another. Metal processing currently accounts for almost 70% of production activities, where technologies are used for stamping, cutting and bending sheet metal, welding of carbon steel and stainless. There are even activities in the processing of plastic and painting, ending with the assembly and packaging of the final products.

Basically, in ELBI S.P.A. there are six departments where the main processes take place, while some products or components are purchased externally or, sometimes, some of them undergo some modifications that are outsourced and then return to the company carrying out the processing cycle.

The business model used mainly by ELBI S.P.A. is the one called *Make-to-stock*, producing goods in huge quantities for the warehouse on the basis of sales forecasts, thus working on production lots and always keeping a stock of finished product available. On the contrary, for some markets the *Make-to-order* principle is applied, where orders are initially collected and, as a result of them, production is performed, because these are diversified from the earliest stages of processing and their production cannot start until the order of the consumer has been acquired.

In order to better understand the several production processes that characterize ELBI S.P.A.'s operations, below there is a description of the work carried out in each of the company departments. The company has six different production departments, which are as follows:

- Department B and Department C

  The department B together with the department C are the suppliers of the department M, where all the mechanical processes that lead to the creation of the semi-finished product are carried out, starting from the raw material, which is mainly composed by sheet metal. In these departments, we can find *Expansion tanks*, which are divided into two product lines coded ERCE and DV, and *Autoclaves* that fall into the product line coded AFV, AC and AF.

  The department B consists of two sub-departments, called "*B low*" and "*B high*".

1) In the "B low" department, the whole range of rectangular flat tanks is produced (all the litres). The phases of the manufacturing process are as follows:

- *Pressing*: in this phase, starting from the sheet metal, two caps of the same size and height are pressed, using mechanical processing. One of them has a larger hole, in which the spacer pipe will be subsequently welded, instead, the other one presents a smaller hole, since it will be threaded and it will be inserted the valve and the membrane.
- *Drilling and welding of the spacer pipe and thread for valve insertion*: the operators, who collect the caps that have completed the first processing, carry out these activities, unlike the pressing, manually. The cap in which there is the spacer pipe represents the "air" side, while the other one where there is the membrane will represent the "water" side.
- *Membrane clamping*: in this step, the membrane is hermetically inserted inside the cap through an automated process and then set by the operator. In this department are also produced AC2, AC5 and AC8 product codes. Their processing are practically the same as those previously listed, yet they require one more step: the mold undergoes a modification inside a trimming machine that is used to polish the sheet. The first cap will have a flange, instead of a spacer pipe.

  Then, they are welded in the same line where the 8-liter rectangular tanks are produced. There is also the 5 and 8-liter line, where the entire process from pressing to clamping is completely automated. This product has a "valve" side and a "spacer pipe" one. Regarding the ER and DV products, there is also a 24 liters line.

Furthermore, 24-liter STPs are also produced, which are water-cooled tanks, having in both cups the spacer pipe but processed in the same way as the 8 liters. Then, there are AC25, AF25 (with 16 bar pressure) that have the flange and the GPM model which has an horizontal shape and further processing such as manual welding of some accessories in a line apart.

2) In the "*B high*" department, there are five presses devoted to the production of: AS25 and AF60, which work like an AC25 and they are characterized by two spherical caps rather than rectangular. AFV, ERCE and DV product lines between 100 and 150 liters, which undergo the same processing as the previous ones. ERCE and DV product codes suffered one more step that is the membrane clamping, instead the AFVs did not. The department C provides the same activities of that B, with in addition the production of the hose clamps for both of them. The hose clamps are produced in two different lines, one from 8 to 24 liters and the second from 50 to 500, by a machine and, subsequently, automatically welded. Then, they are distributed to the two departments based on what it is needed. In this department, the first type of press ranges from 200 to 500 liters and the others from 12 liters to 80. ERCE, DV and AFV product codes of such liters are made here.

The processing of the ERCEs takes place in this way:

- Two caps are pressed, the first without the edge, in which there will be the hole for the spacer pipe, while in the other it will be the edge and the hole for the valve insertion.
- Once the caps have been made, the base is welded and hermetically the membrane is clamping with the use of the hose clamps already produced, which serve as support.
- Once membrane clamping, the circumferential welding is applied, giving life to the raw product, which has thus completed the working cycle.

The processing of DVs is different because, they are all pressed with the edge and then sent to "*topratura*" process externally and when they come back all the other caps, without edge, are pressed and then, they follow the same stages of the ERCEs.

The processing of AFVs, instead, is still different. Two caps are pressed, the first without the edge, in which there will be the hole, oblique and not vertical for the valve insertion, while in the other it will be the edge and the hole for the flange. Once the caps have been made, in this case there will be no insertion of the membrane and of the flange

which will be assembled in the department M. There will be the welding of the base and the circumferential one.
These processing are valid for all products within the range mentioned above, except for the 80 liters. Regarding the ERCEs model, only the caps without edge are produced, those where the spacer pipe will be welded. Then, these caps with the edge and the hole for the insertion of the valve will be pressed and, simultaneously, the previous ones are clamped with their respective membranes. About the AFV, caps are pressed one with the edge and the other without in succession; this change according to the type of press.

- *Department M*

In this department are assembled all the products that come out from the departments B and C. There are, in total, six assembly lines, divided into two blocks according to their capacity (in liters): on one side we have B1 and B2 and, on the other side, there are D, E, F and G. In the first two, B1 and B2, all the products (expansion tanks and autoclaves, spherical or rectangular) from 2 to 30 liters are assembled, while from D to G only the ones from 35 to 500 liters.
This department also includes the painting process that works as a link between the raw product, from department B or C, and the assembled one.
There are two painting systems, accessible from both departments. The painting handles the raw product, which is a semi-finished one. Each process can work with only one color at a time, therefore, simultaneously, the entire system work with two colors. Generally, different colors are used: blue, red, white and gray. Red is for the ER product line, blue for the AFV, white for the DV, while gray is used for some specific markets or for a certain type of customer. The difficulty lies in better managing the painting chain, planning the production, trying to minimize color changes. The chain is loaded and unloaded manually.
There are two loading areas, one between departments B and M and the other between departments C and M, where all the raw products are collected and secondly, according to what is planned and required by production and based on the what is actually available, the painting chain is fed, composed by hooks on which the products are hung up. Once the product completes the painting process, it is manually removed from the hook and brought to the assembly lines or, if it is comprised between 2 and 30 liters, deposited in a cage. All the tanks or autoclaves from 200 to 500 liters decrease the

production capacity of the chain since, given their considerable size, they occupy the space of two hooks. For example, immediately after a 300 liter expansion tank there will be a free hook. For this reason and for the fact that we work in production batches, the overall production capacity of the painting chain is never fully exploited.

- Department A

In department A there is the production of the raw bladder autoclaves for sanitary water, the hot water cylinders, the ASME tanks, the glasslined cylinders up to 5000 liters and the cold water tanks galvanized. The processing within the department A begins with the production of the coils and of the tube sheets, in stainless steel. The activities are as follows:

- *Bending of tubes, assembly, rolling, welding and testing*: there is the processing of coils, which are worked on a line and modified and assembled according to the required size and after, they are coiled, giving them spiral shape (there are more than 50 different types coiling). Later, they are taken to another line where the sleeves, the tie rods and all that is needed to be anchored on the ferrule are welded.
- *The next step is the "plasma"*: it is an automated machinery supported by a programmable logic controller (plc), based on three axes (forward, backward and the force regulator), in which the ferrules are drilled. Subsequently, the processing of the ferrules takes place, which are initially worked manually and after, they undergo a longitudinally calendering process, giving them the cylindrical shape. Then, depending on the type of product, a coil or a cylinder (externally purchased) or even both are inserted.
- *Now, it is the turn of the funds*: they are purchased externally and worked at the basement level or by welding them the sleeves or the flange, before being inserted on the product.
- *Later on, there is the circumferential welding and testing:* those are the last steps of the processing, where, first, the flange, the sleeves or pipes could be applied, depending on the product type and secondly, the raw product is finally tested: filled with water, brought to the necessary atmospheres and tested.

Once the test has been completed, they are stored in a transitory warehouse where they will then be brought to painting or glazed (in the department R) or galvanized externally. The products that undergo the galvanizing process come back to the department A, where a further finishing process is performed on the threads and then, they are moved to the finished products warehouse.

- Department R

This department is, for some products, the consumer of that A. According to that, the products that arrive here are still raw and they will be either glazed or insulated or will undergo either the processes or even none of them if not the installation of the membrane for compressed air. The vitreous enamelling or glazing processing and the insulation one are performed on those products that must contain water, being used for heating systems. The enamelling treatment makes the cylinder suitable to contain hot water for sanitary purpose and resistant to corrosive phenomena. It takes place inside the product through special oven and it is divided in two lines, according to the product capacity: from 100 to 1000 liters, where the surface is washed then glazed and, once out of the oven, if necessary, is insulated. Regarding the insulation process, there are three different types:

1) The first involves the use of a mold in which polyurethane is inserted and, once the process is over, it is finished by applying an aesthetic cover (in some of them, the coil is even inserted), packaged and brought into the finished products warehouse.
2) The second involves the use of a particular type of sponge (only for tanks that work with water at high temperature) and another type of polyurethane, which is processed at a different density.
3) A more compact type of polyurethane characterizes the third one and it is dedicated for tanks that work with water at a lower temperature.

Nowadays, there is a new type of polyester insulation, which is mandatory for the European market of the thermo-hydraulic division, and it is exclusively for Class C products (hot water boilers up to 2000 liters). ELBI S.P.A. purchases such type of insulation externally and it applies directly to the surface of the product.

- Department P

This department carries out all the processing of plastic for the Garden, Thermo-hydraulic, Ambiente and Living divisions. This process provides processing of a particular plastic materials, called polyethylene that is purchased externally or shipped from Modugno. The “raw materials warehouse” of ELBI S.P.A. supplies this department only with small metal parts and accessories necessary for processing. There are seven ovens that work with molds of different sizes, in fact some of them are specific for certain types of product. The product manufacturing mainly focuses around the processing of the oven and it is divided into the following phases:

- Loading phases, where initially the operators fit the molds and insert the polyethylene necessary for processing. Some molds can be sandblasted before being assembled.
- Once the product has finished the cooking, which takes place at a temperature between 260 and 300 degrees and lasts between 14 to 30 minutes, depending on the type of product and, therefore, the mold used, the next step is the cooling, which also fluctuates from 14 to 30 minutes.
- The last step is the unloading of the product from the oven, where it is subsequently finished (through deburring, labelling and checking the quality of the product at the visual level), if provided, it is drilled, and the sleeves are inserted (only for the products of the thermo-hydraulic division). Eventually, they are storage outside the department, while those of the Living, Garden and Ambiente division are move to the finished product warehouse specific to this business.

Instead, some products are manufactured starting from polypropylene, which is, compared to polyethylene, much rigid and tends to deform less easily during the cooking process.

CHAPTER 4

LEAN TRANSFORMATION

In this chapter I will briefly explain what is meant by Lean Transformation and I am introducing the three projects carried out.

4.1. Literature review

Nowadays, in order to be competitive in a global market, many organizations are transforming more and more moving from a traditional management approach to a Lean one. In relation to what happened several decades ago in Toyota and properly in the automotive industry, this success serves as a benchmark that companies continually seek to imitate in achieving similar and satisfying outcomes. Developing a Lean transformation process that achieves the expected goals is not easy and it needs the application of a precise method, without which such projects often fail or get very modest results. Although there are many techniques and tools that can be adopted by those who decide to undertake a Lean transformation path, many organizations struggle to attain successful implementation. To understand better the failure mechanisms and some crucial success factors of Lean transformation, it is important to take into account the following question: "Which are the key and critical stages of the Lean evolution?" It requires a complete commitment from the top management, but the biggest challenge is to involve the middle management and workers and make them aware that there is a need for change and the effectiveness that Lean Production can have. As already mentioned, for many companies the major objective of a Lean transformation is in the search of a competitive advantage without managing human and relational aspects or developing an organisational learning process by improving the use of the broad skills within the workforce. For this reason, it is not only primary to implement Lean techniques inside business processes, but an organisation's culture needs transforming as well. In fact, the inability in establishing a lean organizational culture and the lack of people support, not provided by management, are often a significant failure in the implementation of this philosophy (Sanjay Bhasin, 2012; Sim & Rogers, 2009).

Successful Lean Transformation focuses on the relationship between human resources and performance management practices. Those organizations that dismiss the value of people, as a key driver, can get stagnant results (Liker & Hoseus, 2008). As we know, Lean Thinking is a set of principles, methods and tools for the Continuous Improvement of processes in organizations: it is a philosophy, an organizational approach, which consists of doing more with fewer resources, involving always everyone. It is strictly based on the management of human resources, which is the most relevant aspect, since the business climate influences the results achieved by companies and often compromises them. A real cultural transformation capable of producing a radical change in workers, which produces great operational and economic benefits, summarized in:

- improvement in the quality of service;
- improvement in the quality of the product;
- improvement of process efficiency.

A Lean business transformation process consolidates its success if the change of people, and the way in which they "face" their work, becomes a goal and not just a result.

The Continuous Improvement is the real method that underlies the change. It enters in daily working life of each employee, automatically influencing the way of thinking, operating and reacting. Consequently, a new culture of innovation and learning, both in management and within the various departments of the organization, is established.

Some scholars point out the fact that inadequate change management techniques together with a lack of expertise to shift corporate culture can trigger a collapse of Lean transformation (Liker & Hoseus, 2010; Saurin, Marodin, & Ribeiro, 2011).

The challenge that companies are dealing with concerns mostly the aspect linked to the importance of motivating and supporting their workers. They will lead the implementation of the Lean and decree its success or failure. Leaders are also needed and the company must set up some communication channels *ad hoc,* so that all staff are highly motivated and confident about the path taken. (Fiona Keru Mwacharo, 2013).

4.2. Lean Transformation in ELBI S.P.A.

An external consulting company, called KaizenKey srl, carried out the transformation process in Elbi spa, which started around February 2016. Their intervention, with the use of workshop activities, led to an increase in know-how on Lean techniques within the company and, to a subsequent improvement in the optimization of production processes.

These workshops are focused and structured team-based projects adopted to improve a work area and achieve specific goals.

The first analysis carried out by KaizenKey srl lasted few days, in order to understand the state of the company. Basically, the analysis consisted in mapping some of the major processes, measuring a sufficient number of data that allow to propose an improvement project that does not cover many years on, but it is essential to plan the first two workshop activities and then proceed with the involvement of the company's key resources, according to its needs.

The *First* workshop began in March 2016, where it was decided to focus on the Finished Product warehouse of the thermo-hydraulic division. A Value Stream Mapping of the main processes within the warehouse was performed and, starting from a current situation characterized by a *Push* control logic, there was an increase regarding the availability of the material and an optimization of the order fulfillment. The final result was achieved thanks to the transaction to a *Pull* concept, triggered by the customer, with the introduction of Kanban system.

The *Second* workshop was related to the creation of trolleys composed by specific materials for the procurement of the assembly lines by Kanban system and subsequently extended to the management of all membranes used in the departments B, C and M. These trolleys are brought by the logistic service to the operators, who work in the department M.

The first two workshops completed the initial analysis. Afterwards, it was decided to develop a new project from November 2016 to December 2017 with more continuity and a strong structure. In order to start with this new long-term plan, KaizenKey srl analyzed and developed, at the macro level, a new functional organization chart.

During the previous workshops some problems have emerged concerning: the lack of clarity on the different roles of people (who does what and for what is accountable); the lack of someone who would be support KaizenKey srl during the path of change; the absence of a Logistics manager and a Production planning department that was not widely managed and structured.

Generally, at the organizational level there was a strong gap of definition of responsibilities. With the implementation of this new organizational chart, the role of each actor has been defined, empowering him or her and creating the conditions for a future efficient organizational management.
The next workshop took into consideration the commercial Back office on the definition of standard procedures regarding the fulfilment of a shipping order. One of the goal was to increase the reliability on delivery times. Before doing this workshop there was a complete separation between what is the order confirmation and the fulfilment of the same, since the back office worked passively. Specifically, it received the orders that were loaded on the specific date requested by the customer, directly confirmed and then turned to the production planning staff and the shipping office who had to work hard in order to have everything available for such date (goods and trucks for shipments). The problem was that those dates were not respected with consequent delays and losses in turnover related to the non-delivery and dissatisfaction of the final customer. Today, instead, with the benefit provided by the analysis carried out during the workshops, the Back office has an active role. In particular, it receives the order from the customer, inserts an order proposal within the working day which is immediately transmitted to the Production planning department that has one day to confirm it or not, based on the availability of the material, considering the Lead Time and if some purchase is needed. At the beginning of the third day, a confirmation of the order is sent back from the Back office to the customer, according to the delivery date entered by the Production planning staff. The customer has 24 hours to make some complaints, otherwise it is considered approved.
Subsequently, we moved to the Department A with a new workshop concerning the management of bottoms surface rounded. They were directly purchased externally or by subcontracting arrangements with very long throughput time and the result that they did not arrive on time thus generating a problem in terms of missing. There was the risk of buying too many materials or, on the contrary, not having what it is needed. After an accurate analysis of the different types of these raw materials, the three major suppliers of Elbi and after having established a new warehouse management on this product, KaizenKey srl introduced the Kanban system regarding the bottoms surface rounded. With this new methodology, a framework contract is defined, where the purchase price is fixed, while deliveries and withdrawals are based on the effective consumption. In addition to the bottoms surface rounded, the Kanban logic has been brought on the three divisions of finished products as well.

During my internship period in Elbi, from July 2017 to December 2017, I had the opportunity to collaborate with KaizenKey srl on three different Lean Transformation projects, which will be presented and discussed here below.

4.3. First project: Improvement of Human Resources Management

What has emerged from the Literature review regarding the implementation of a Lean Transformation turnaround is that, despite the large number of techniques and tools available used to achieve process optimization, there seems that People, who are going to be the ones who will lead the change, will significantly affect the desired result. One of the major pillars, according to Lean philosophy, regards the “Involvement of everyone”. The intention is to create what is defined as “Total system”, encouraging a high degree of personal responsibility, engagement and ownership of the job, through a concept based on “Respect-for-humans”. Every process and, in parallel, everyone in the organization are considered an essential part towards Continuous Improvement. The organization chart, designed previously, responds to the managerial level (being functional) and, for this reason, the need to develop a mapping skill of all the workers involved during the year 2017. This went to completion of the previous organization chart, having in this way an overall analysis of the company concerning Human Resources management and their skills.

4.3.1. Analysis

The analysis began with the development of a Skills matrix, which is a simple visual management tool aims in controlling and monitoring of skill levels. It displays all tasks and skills required to work in a predetermined area and it is also used to aid human resources planning. We have performed a skills matrix for every departments, as well as those of production and warehouse, and then we have computed an analysis based on the results obtained. The aim of this project was to understand the real productive capacity of each individual worker, related to the different activities carried out in the department of belonging. Afterwards, we have calculated a KPI of polyvalence for each department. Furthermore, it was important to comprehend the sensitivity of the department head in assessing and managing the human resources for which he is accountable. In order to fulfil the research objectives, a *qualitative analysis* method has been implemented.

It consisted of interviews made to each individual worker and then compared to the thought of the department head, interviewed as well. None of the department heads was interviewed in order to assess his level of competence, because they are assumed to be able capable to execute independently all the activities conducted in the department, having a KPI of polyvalence around 100%. Instead, before starting the interviews, we have faced with all the department heads in order to get an idea on what are the main activities and the macro processing areas of each department. In this way, we have defined the so-called *Hard skills* and for each of them, a value between 1 and 5 was assigned during the interviews, based on the answers given by any individual worker, according to the following classification (see figure 9):

- **5:** completely independent (coach)
- **4:** quite expert (developer)
- **3:** normal (practitioner)
- **2:** little experience (learner)
- **1:** never done (untrained).

Analysis					
Hard Skills	**1**	**2**	**3**	**4**	**5**
Dolly operator					
Internal movements	**X**				
Transfer to PRO and Shipping area	**X**				
C/SC external painting line	**X**				
Transfer from B to C	**X**				
Internal painting (with powder)					
Load painting line					**X**
Planning the right mix for the painting line	**X**				
Color changeover and start-up	**X**				
Unload of the painting line and products handling					**X**
Assembly of expansion tanks					
Insertion of the valve			**X**		
Pre-charge of the product			**X**		
Testing			**X**		
Labelling and packaging			**X**		
Assembly of autoclaves					
Insertion of membrane and flange			**X**		
Insertion of the valve			**X**		
Pre-charge of the product			**X**		
Testing			**X**		
Labelling and packaging			**X**		
Assembly of ASME tanks					
Insertion of membrane and flange			**X**		
Insertion of the valve			**X**		
Pre-charge of the product			**X**		
Testing			**X**		
Labelling and packaging			**X**		
External painting (with liquid)					
Painting	**X**				
Painting to PRO					
Machine operator and loading	**X**				
Unloading	**X**				

Figure 9: example of a Skills Matrix of worker 1 in the Department M (Hard skills).

Figure 9 describes an example of Skills Matrix used for evaluate the workers within the department M, regarding the analysis of the Hard skills. The structure of the matrix is very simple: on the rows, there is the list of all the *Activities*, which are 25 in total, and the *Macro-processing areas*, which are 7 in total (from being a "*Dolly operator*" to work on "*Painting to Pro*"), while, the skill level related to each activity is highlighted on the columns. According to the answers, a synthetic KPI is calculated corresponding to the value reported in the Skill matrix for a given worker-activity or worker-macro area combination. Obviously, the higher the KPI, the greater the skills of the individual worker will be (see Figure 10).

	HARD SKILL LEVEL	5	20	125		% AVERAGE ON THE MACRO AREA	% AVERAGE ON THE TOTAL DEPARTMENT
Internal movements	1	20%	5%	0,8%		Dolly operator	
Transfer to PRO and Shipping area	1	20%	5%	0,8%		20,0%	3,2%
C/SC external painting line	1	20%	5%	0,8%			
Transfer from B to C	1	20%	5%	0,8%			
			20				
Load painting line	5	100%	25%	4,0%		Internal painting	
Planning the right mix for the painting line	1	20%	5%	0,8%		60,0%	10%
Color changeover and start-up	1	20%	5%	0,8%			
Unload of the painting line and products handling	5	100%	25%	4,0%			
			20				
Insertion of the valve	3	60%	15%	2,4%		Assembly of Expansion tanks	
Pre-charge of the product	3	60%	15%	2,4%		60,0%	10%
Testing	3	60%	15%	2,4%			
Labelling and packaging	3	60%	15%	2,4%			
			25				
Insertion of membrane and flange	3	60%	12%	2,4%			
Insertion of the valve	3	60%	12%	2,4%		Assembly of autoclaves	
Pre-charge of the product	3	60%	12%	2,4%		60,0%	12%
Testing	3	60%	12%	2,4%			
Labelling and packaging	3	60%	12%	2,4%			
			25				
Insertion of membrane and flange	3	60%	12%	2,4%			
Insertion of the valve	3	60%	12%	2,4%		Assembly of ASME tanks	
Pre-charge of the product	3	60%	12%	2,4%		60,0%	12%
Testing	3	60%	12%	2,4%			
Labelling and packaging	3	60%	12%	2,4%			
			5			External painting	
Painting	1	20%	20%	0,8%		20,0%	0,8%
			10			Painting to PRO	
Machine operator and loading	1	20%	10%	0,8%			
Unloading	1	20%	10%	0,8%		20,0%	1,6%
					FINAL KPI OF OPERATOR 1	50%	48,8%

Figure 10: calculation of the KPI of polyvalence of Worker 1 in the Department M (Hard skills).

In the Figure 10, we observed that the Worker 1 got a final KPI of **50%**, which is calculated from the average of the individual KPIs of each macro-processing area.
For example, the KPI of "*Assembly of expansion tanks*", equal to 60%, is calculated according to the average of Hard skill level related to the answer given by Worker 1 and compared with the maximum achievable, which is level 5 (being a coach).
Secondly, we calculated, for the "*Assembly of expansion tanks"*, the percentage concerning its weight on the total maximum assumable level of polyvalence of the entire department. In order to do that, we took into account the level of each of these five activities (within this macro processing area), and compared them to the total maximum number of polyvalence achievable (equal to 125, given by the multiplication of 5 - our benchmark - with 25 - the total number of activities in this department). In this way, we got a KPI equal to 12% specific to this macro processing area. However, the overall KPI of the whole department is equal to **48,8%.**
The same reasoning has been applied to all the workers in the department M (27 workers), thus having a two final results concerning the *Global average polyvalence level*, completing the analysis related to the Hard skills (see figure 11).

	FINAL KPI OF THE DEPARTMENT M	
HARD SKILLS	52,61%	58,71%
Dolly operator	37,50%	6,00%
Internal painting	46,61%	7,46%
Assembly of Expansion tanks	79,29%	12,69%
Assembly of autoclaves	72,43%	14,49%
Assembly of ASME tanks	72,43%	14,49%
External painting	30,00%	1,20%
Painting to PRO	30,00%	2,40%

Figure 11: Final KPIs of the Department M (Hard skills).

From the table above, we observed two KPIs equal to **52,61%** and **58,71%** respectively**.**
The *First* one concerning the average of all the macro-processing areas within the department and the *Second* is related to the total level of polyvalence compared to the maximum achievable, as already mentioned previously.
The following radar chart (see Figure 12) highlights the distribution level of the Hard skills among the different macro-processing areas. The highest polyvalence index is obtained in the areas related to *assembly* skills, in fact this is the main activity performed in the department M. The other macro-processing areas, like *Dally operator* and *internal or external Painting,* got an average KPI around 36%, less than half of that of assembly.

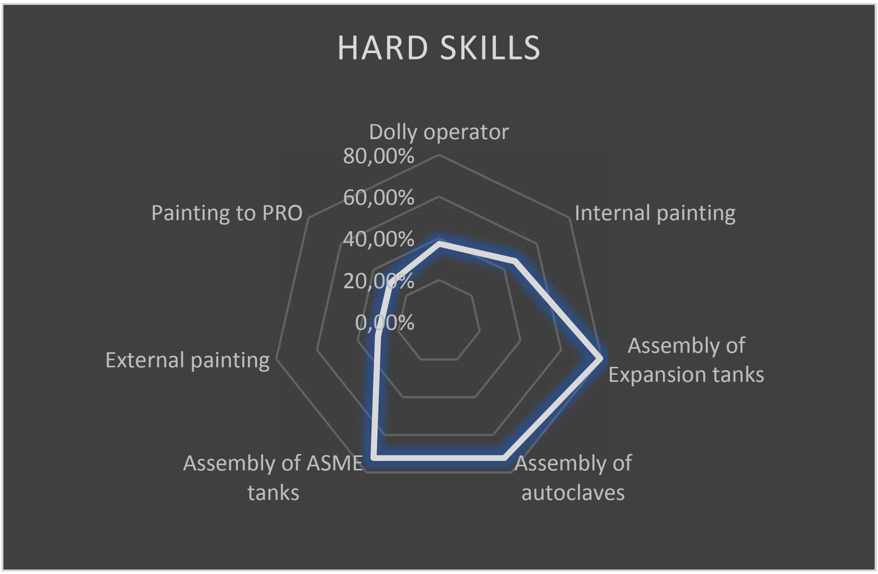


Figure 12: radar chart about KPIs distribution of the macro-processing areas-

In order to get a general framework of the overall current level of each individual worker, we also developed a *Soft skill* KPI, composed by the following (see figure 13):

1. Collaboration
2. Sense of belonging
3. Ability to work in a team
4. Having clear the role
5. Ability to make a decision
6. Motivation
7. Serenity
8. Problem solving capacity.

For each of these categories, in the same way as for Hard skills, a value between 1 and 5 was assigned during the interviews. Specifically, a level 5 on *Problem solving capacity* refers to the ability of finding and solve a problem in the shortest possible time without immediately asking for any help or unnecessarily bothering a colleague, wasting further time. On the other hand, a level 1 on *Having clear the role* means that the specific worker has not clear what and how he or she should perform his or her own work, as he or she is not aware of what are the main priorities. Getting a good score in each of these skills demonstrates strong interpersonal, cognitive, accomplishment and managerial skills by workers, a favorable condition for implementing and supporting a Continuous improvement over time.

Soft skills	1	2	3	4	5
Collaboration		X			
Sense of belonging		X			
Ability to work in a team			X		
Having clear the role				X	
Ability to make a decision	X				
Motivation	X				
Serenity		X			
Problem solving capacity	X				

Figure 13: example of Skills Matrix of Worker 1 in the Department M (Soft skills).

In the Figure 13 is described an example of Skills Matrix used for evaluate the workers within the department M, regarding the analysis of the Soft skills. We examined 8 different softs skills with a final KPI calculated in accordance with the value reported in the matrix for each given skill. Obviously, the higher the KPI, the greater the skills of the individual worker will be (see Figure 14).

	SOFT SKILL LEVEL	BENCHMARK
		5
Collaboration	2	40%
Sense of belonging	2	40%
Ability to work in a team	3	60%
Having clear the role	4	80%
Ability to make a decision	1	20%
Motivation	1	20%
Serenity	2	40%
Problem solving capacity	1	20%
	FINAL KPI OF OPERATOR 1	40%

Figure 14: calculation of the KPI of polyvalence of Worker 1 in the Department M (Soft skills).

In the Figure 14, we observed that the Worker 1 got a final KPI of 40%, which is calculated from the average of each individual KPIs compared to the benchmark of 5 (the highest level desirable). At the end, the Worker 1, after being interviewed, obtained two conclusive KPIs: **50%** for the Hard Skills and **40%** for those Soft.

The same reasoning has been applied to all the workers in the department M (27 workers), thus having a final result concerning the *Global average level*, completing the analysis related to the Soft skills (see figure 15 and 16).

	FINAL KPI OF THE DEPARTMENT M
SOFT SKILLS	65,63%
Collaboration	71,43%
Sense of belonging	60,00%
Ability to work in a team	62,86%
Having clear the role	92,14%
Ability to make a decision	52,14%
Motivation	61,43%
Serenity	69,29%
Problem solving capacity	55,71%

Figure 15: Final KPI of the Department M (Soft skills).

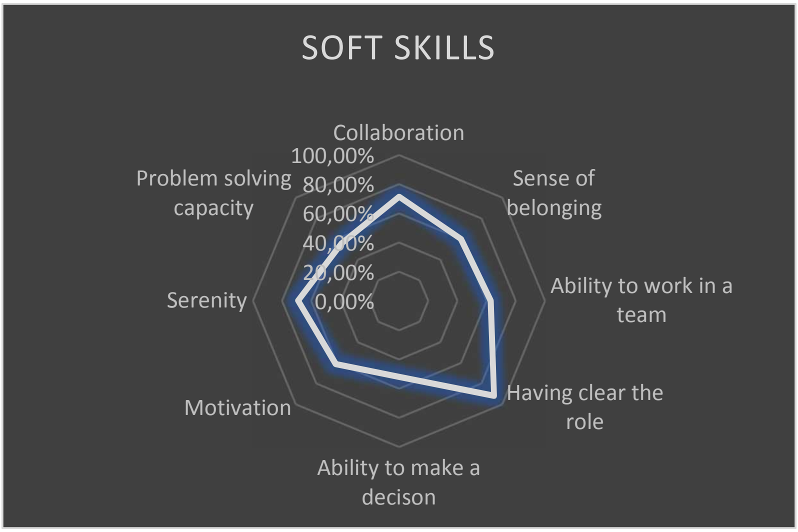
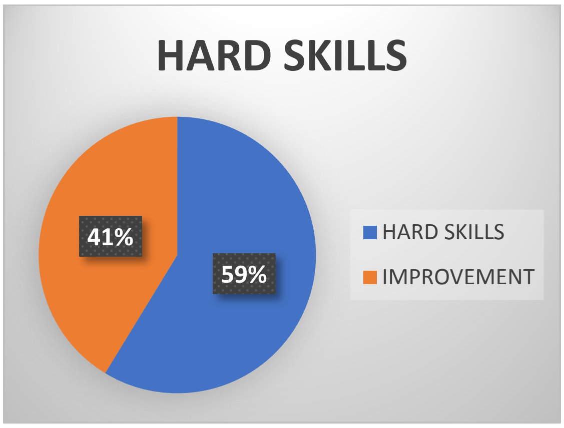
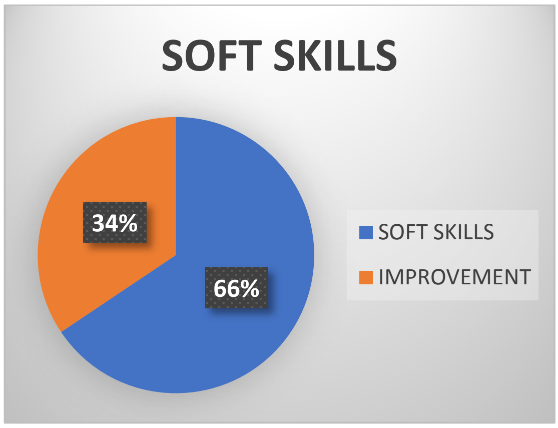


Figure 16: radar chart about KPIs distribution of each Soft skills in the department M.

In total, the department M got two final KPIs equal to **58,71%** for the Hard skills and **65,63%** for the Soft ones.





In addition to the questionnaires made for Hard and Soft skills, we carried out two other questions to deepen the engagement: "What do you think about the company?" and "What would you suggest or improve within the company?"

Each worker's answers to these questions were grouped into five macro areas providing the following results (see Figure 17 and Figure 18):

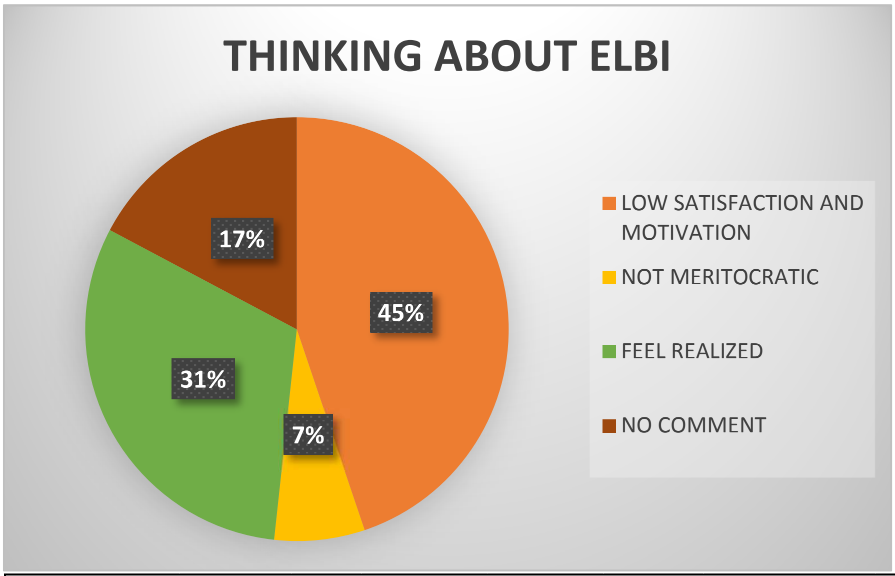


Figure 17: Analysis regarding the "Thinking about Elbi" in department M.

THINKING ABOUT ELBI (%)				
SOLID	FEEL REALIZED	NOT MERITOCRATIC	LOW SATISFACTION AND MOTIVATION	NO COMMENT
3%	30%	7%	43%	17%
33%		50%		17%

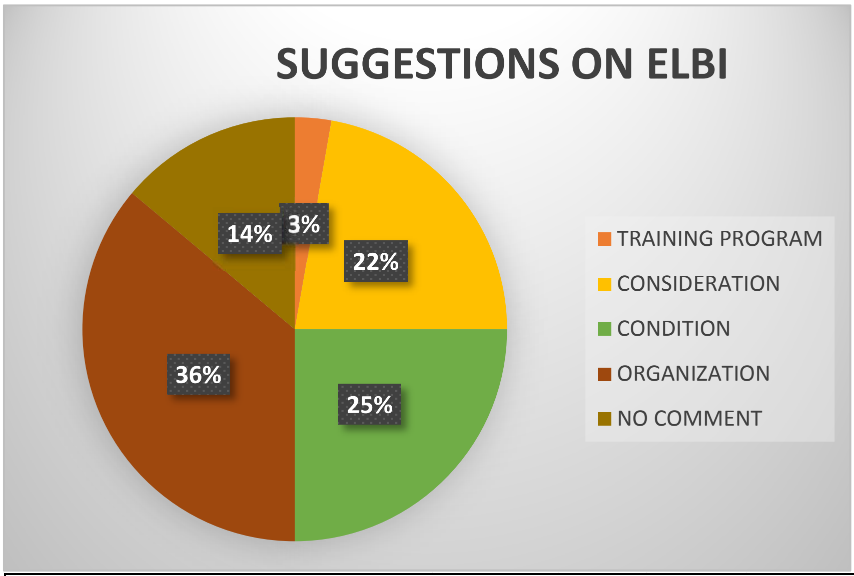


Figure 18: Analysis regarding the "Suggestions on Elbi" in department M.

SUGGESTIONS ON ELBI (%)				
TRAINING PROGRAM	CONSIDERATION	CONDITION	ORGANIZATION	NO COMMENT
3%	22%	25%	36%	14%
3%	47%		36%	14%

As we can observe from the above pie charts, only a third of the workers of the department M feel fully satisfied and have a positive consideration about the company.

On the other hand, half of the workers complains about business management, which is not based on meritocracy and, overall, it feels generally dissatisfied and not motivated to achieve company goals. A significant data is certainly the 17%, which evidences that a part of workers did not want to express any thought on the company. It would be meaningful to understand how this 17% is subdivided. For instance, who preferred not to comment because the judgment was negative and who, instead, has not commented for a complete disregard such as not caring about the company but only of its own employment status. In any case, we can assume that almost 60% of the workers in the department M do not have a positive thinking about the company.

Regarding the potential corrective actions that have been suggested, we note that there is a very low percentage that requires intervention in terms of personal training and growth courses.

However, about half of the workers has expressed a desire to see their condition improved, referring to the place and the way in which the work is carried out. They asked for a greater consideration that goes far beyond what is the simple daily work, since the most of them perceives the company as distant and barely present. A little more than a third complains about problems in the organization, referring to a misalignment between what must to be done and how it should be as well as in terms of responsibility between the different actors within the department. Even in this instance, there is a percentage of abstainers equal to 14% who preferred not to comment on this issue.

Subsequently, after having collected all these data for each workers and computed the final KPIs, we interviewed the department head of the department M and compared the two evaluations, first for the Hard and the second for the Soft skills (see Figure 19).

HARD SKILLS	WORKERS	DEPARTMENT HEAD	DIFFERENCE
Dolly operator	**37,50%**	**28,89%**	**-8,61%**
Internal painting	**46,61%**	**32,59%**	**-14,01%**
Assembly of Expansion tanks	**79,29%**	**47,41%**	**-31,88%**
Assembly of autoclaves	**72,43%**	**46,67%**	**-25,76%**
Assembly of ASME tanks	**72,43%**	**29,63%**	**-42,80%**
External painting	**30,00%**	**25,93%**	**-4,07%**
Painting to PRO	**30,00%**	**23,70%**	**-6,30%**
AVERAGE	**52,61%**	**33,54%**	**-19,06%**

SOFT SKILLS	WORKERS	DEPARTMENT HEAD	DIFFERENCE
Collaboration	**71,43%**	**47,41%**	**-24,02%**
Sense of belonging	**60,00%**	**53,33%**	**-6,67%**
Ability to work in a team	**62,86%**	**45,93%**	**-16,93%**
Having clear the role	**92,14%**	**44,44%**	**-47,70%**
Ability to make a decision	**52,14%**	**31,85%**	**-20,29%**
Motivation	**61,43%**	**48,15%**	**-13,28%**
Serenity	**69,29%**	**52,59%**	**-16,69%**
Problem solving capacity	**55,71%**	**30,37%**	**-25,34%**
AVERAGE	**65,63%**	**44,26%**	**-21,37%**

Figure 19: Comparison between workers and department head on Hard and Soft skills KPIs.

In the above tables, the KPIs with the highest and lowest value, in relation to what emerged from the analysis based on the answers given by the workers, are highlighted in blue, while those in red are the values with the most significant difference between what was initially detected and what emerged after the interview with the department head.

As we can observe, the final KPI for the Hard skills provided by the department head is 36% less than the one emerged from the analysis with the workers (52.61%), while for the Soft skills there is a lower difference, but still substantial, equal to 33% less. In both cases we have a strong reduction with the main differences in "*Assembly activities*" regarding Hard skills and in

"*Having clear the role*", as of Softs ones. With these last data, the analysis of department M can be considered concluded.

All this evaluation method was carried out for all the Production departments of Elbi (including the raw materials and the finished products warehouses), by comprising a total amount of 137 workers and other 8 departments (see next figures).

Moreover, for each department we have calculated the *average age of the workers*, the *average level of remuneration* and the *average work seniority*.

- Department A

HARD SKILLS	WORKERS	DEPARTMENT HEAD	DIFFERENCE
Dolly operator	**40,38%**	**32,38%**	**-8,00%**
Bottom surface rounded	**77,62%**	**34,29%**	**-43,33%**
Giving the spiral shape to coils	**38,48%**	**33,33%**	**-5,14%**
Assembly	**57,69%**	**48,57%**	**-9,12%**
Rolling and welding	**59,05%**	**43,81%**	**-15,24%**
Testing	**61,90%**	**31,43%**	**-30,48%**
Warehouse management	**32,86%**	**28,57%**	**-4,29%**
AVERAGE KPI	**52,57%**	**36,05%**	**-16,51%**

SOFT SKILLS	WORKERS	DEPARTMENT HEAD	DIFFERENCE
Collaboration	**78,10%**	**67,62%**	**-10,48%**
Sense of belonging	**66,67%**	**65,71%**	**-0,95%**
Ability to work in a team	**64,76%**	**52,38%**	**-12,38%**
Having clear the role	**98,10%**	**77,14%**	**-20,95%**
Ability to make a decision	**60,00%**	**39,05%**	**-20,95%**
Motivation	**64,76%**	**47,62%**	**-17,14%**
Serenity	**78,10%**	**71,43%**	**-6,67%**
Problem solving capacity	**63,81%**	**38,10%**	**-25,71%**
AVERAGE KPI	**71,79%**	**57,38%**	**-14,40%**

- Department B

HARD SKILLS	WORKERS	DEPARTMENT HEAD	DIFFERENCE
24LT - 25LT - 8LT	66,86%	72,00%	5,14%
100LT - 150LT- 60LT	40,57%	33,33%	-7,24%
AVERAGE KPI	53,71%	52,67%	-1,05%

SOFT SKILLS	WORKERS	DEPARTMENT HEAD	DIFFERENCE
Collaboration	81,33%	81,33%	0,00%
Sense of belonging	76,00%	58,67%	-17,33%
Ability to work in a team	73,33%	69,33%	-4,00%
Having clear the role	88,00%	76,00%	-12,00%
Ability to make a decision	44,00%	45,33%	1,33%
Motivation	58,67%	61,33%	2,67%
Serenity	72,00%	76,00%	4,00%
Problem solving capacity	57,33%	42,67%	-14,67%
AVERAGE KPI	68,83%	63,83%	-5,00%

- Department C

HARD SKILLS	WORKERS	DEPARTMENT HEAD	DIFFERENCE
11/12 LT - 18LT- 35/50 LT - 80 LT	58,19%	71,76%	13,57%
200/300/500 LT	50,63%	58,82%	8,20%
Hose clamps	57,25%	44,71%	-12,54%
AVERAGE KPI	55,36%	58,43%	3,07%

SOFT SKILLS	WORKERS	DEPARTMENT HEAD	DIFFERENCE
Collaboration	72,50%	81,18%	8,68%
Sense of belonging	78,75%	76,47%	-2,28%
Ability to work in a team	52,50%	74,12%	21,62%
Having clear the role	93,75%	77,65%	-16,10%
Ability to make a decision	57,50%	55,29%	-2,21%
Motivation	71,25%	74,12%	2,87%
Serenity	70,00%	77,65%	7,65%
Problem solving capacity	66,25%	51,76%	-14,49%
AVERAGE KPI	70,31%	71,03%	0,72%

- Department R

HARD SKILLS	WORKERS	DEPARTMENT HEAD	DIFFERENCE
Glazeling processing for products >1000 lt	**40,00%**	**37,14%**	**-2,86%**
Enamelling processing	**56,79%**	**40,00%**	**-16,79%**
Glazeling processing for products <1000 lt	**49,87%**	**42,86%**	**-7,01%**
Insulation process	**59,29%**	**50,00%**	**-9,29%**
Finishing	**62,14%**	**54,29%**	**-7,86%**
Warehouse management	**60,95%**	**52,86%**	**-8,10%**
AVERAGE KPI	**54,84%**	**46,19%**	**-8,65%**

SOFT SKILLS	WORKERS	DEPARTMENT HEAD	DIFFERENCE
Collaboration	**77,14%**	**81,43%**	**4,29%**
Sense of belonging	**61,43%**	**68,57%**	**7,14%**
Ability to work in a team	**71,43%**	**78,57%**	**7,14%**
Having clear the role	**82,86%**	**85,71%**	**2,86%**
Ability to make a decision	**54,29%**	**74,29%**	**20,00%**
Motivation	**67,14%**	**71,43%**	**4,29%**
Serenity	**78,57%**	**70,00%**	**-8,57%**
Problem solving capacity	**61,43%**	**74,29%**	**12,86%**
AVERAGE KPI	**69,29%**	**75,54%**	**6,25%**

- Department P

HARD SKILLS	WORKERS	DEPARTMENT HEAD	DIFFERENCE
Production/Oven line	**72,41%**	**55,17%**	**-17,24%**
Garden finishing	**71,95%**	**46,21%**	**-25,75%**
Tanks finishing	**69,66%**	**59,31%**	**-10,34%**
Membranes	**54,90%**	**29,66%**	**-25,24%**
DAB and Lowara assembly lines	**43,45%**	**37,93%**	**-5,52%**
Purification assembly	**30,80%**	**29,66%**	**-1,15%**
Dolly operator	**42,41%**	**37,93%**	**-4,48%**
Warehouse management	**31,72%**	**62,07%**	**30,34%**
AVERAGE KPI	**52,16%**	**44,74%**	**-7,42%**

SOFT SKILLS	WORKERS	DEPARTMENT HEAD	DIFFERENCE
Collaboration	75,71%	70,34%	-5,37%
Sense of belonging	60,71%	66,21%	5,49%
Ability to work in a team	68,57%	62,07%	-6,50%
Having clear the role	90,71%	67,59%	-23,13%
Ability to make a decision	53,57%	57,93%	4,36%
Motivation	71,43%	63,45%	-7,98%
Serenity	74,29%	63,45%	-10,84%
Problem solving capacity	57,14%	60,00%	2,86%
AVERAGE KPI	69,02%	63,88%	-5,14%

- Raw materials warehouse department

HARD SKILLS	WORKERS	DEPARTMENT HEAD	DIFFERENCE
Receiving the raw materials	86,67%	90,00%	3,33%
Supply departments/materials handling	93,33%	100,00%	6,67%
Collecting stuff for the consumers	93,33%	100,00%	6,67%
Relationship with the suppliers	83,33%	50,00%	-33,33%
Administrative management	66,67%	60,00%	-6,67%
Warehouse management	71,67%	100,00%	28,33%
AVERAGE KPI	82,50%	83,33%	0,83%

SOFT SKILLS	WORKERS	DEPARTMENT HEAD	DIFFERENCE
Collaboration	100,00%	100,00%	0,00%
Sense of belonging	100,00%	100,00%	0,00%
Ability to work in a team	73,33%	100,00%	26,67%
Having clear the role	73,33%	100,00%	26,67%
Ability to make a decision	80,00%	100,00%	20,00%
Motivation	100,00%	100,00%	0,00%
Serenity	80,00%	100,00%	20,00%
Problem solving capacity	80,00%	80,00%	0,00%
AVERAGE KPI	85,83%	97,50%	11,67%

- Finished products warehouse (Thermos-hydraulic division) department

HARD SKILLS	WORKERS	DEPARTMENT HEAD	DIFFERENCE
Warehouse management (IN)	**66,11%**	**57,78%**	**-8,33%**
Warehouse management (OUT)	**80,00%**	**66,67%**	**-13,33%**
Office	**32,67%**	**35,56%**	**2,89%**
Transportation Ambiente and Garden divisions	**36,30%**	**22,22%**	**-14,07%**
Customer complaints	**83,33%**	**55,56%**	**-27,78%**
AVERAGE KPI	**59,68%**	**47,56%**	**-12,13%**

SOFT SKILLS	WORKERS	DEPARTMENT HEAD	DIFFERENCE
Collaboration	**80,00%**	**84,44%**	**4,44%**
Sense of belonging	**62,22%**	**77,78%**	**15,56%**
Ability to work in a team	**68,89%**	**77,78%**	**8,89%**
Having clear the role	**91,11%**	**82,22%**	**-8,89%**
Ability to make a decision	**62,22%**	**60,00%**	**-2,22%**
Motivation	**60,00%**	**77,78%**	**17,78%**
Serenity	**60,00%**	**82,22%**	**22,22%**
Problem solving capacity	**62,22%**	**62,22%**	**0,00%**
AVERAGE KPI	**68,33%**	**75,56%**	**7,22%**

- Finished products warehouse (21st/Garden/Ambiente divisions) department

HARD SKILLS	WORKERS	DEPARTMENT HEAD	DIFFERENCE
Warehouse management (IN)	**76,67%**	**73,33%**	**-3,33%**
Warehouse management (OUT)	**77,78%**	**66,67%**	**-11,11%**
Dab and Lowara product management	**95,56%**	**80,00%**	**-15,56%**
Office	**20,00%**	**20,00%**	**0,00%**
Management with other departments	**60,00%**	**100,00%**	**40,00%**
AVERAGE KPI	**66,00%**	**68,00%**	**2,00%**

SOFT SKILLS	WORKERS	DEPARTMENT HEAD	DIFFERENCE
Collaboration	60,00%	73,33%	13,33%
Sense of belonging	46,67%	60,00%	13,33%
Ability to work in a team	53,33%	66,67%	13,33%
Having clear the role	100,00%	80,00%	-20,00%
Ability to make a decision	40,00%	60,00%	20,00%
Motivation	53,33%	66,67%	13,33%
Serenity	60,00%	86,67%	26,67%
Problem solving capacity	53,33%	60,00%	6,67%
AVERAGE KPI	58,33%	69,17%	10,83%

Overall *Thinking about Elbi* and *Suggestions* for improvement:

THINKING ON ELBI (%)				
SOLID	FEEL REALIZED	NOT MERITOCRATIC	LOW SATISFACTION AND MOTIVATION	NO COMMENT
12%	36%	3%	24%	25%
48%		27%		25%

SUGGESTIONS ON ELBI (%)				
TRAINING PROGRAM	CONSIDERATION	CONDITION	ORGANIZATION	NO COMMENT
2%	26%	25%	23%	24%
2%	51%		23%	24%

	DEPARTMENT	HARD SKILLS WORKERS	HARD SKILLS DEPARTMENT HEAD	HARD SKILLS DIFFERENCE	N° of macro - processing areas	N° of activities	SOFT SKILLS WORKERS	SOFT SKILLS DEPARTMENT HEAD	SOFT SKILLS DIFFERENCE	N° of workers
PRODUCTION DEPARTMENTS	A	52,57%	36,05%	16,51%	7	29	71,8%	57,38%	14,40%	21
	R	54,84%	46,19%	8,65%	6	34	69,3%	75,54%	-6,25%	14
	M	52,61%	33,54%	19,06%	7	17	65,6%	44,26%	21,37%	27
	C	55,36%	58,43%	-3,07%	3	22	70,3%	71,03%	-0,72%	16
	B	53,71%	52,67%	1,05%	2	14	68,8%	63,83%	5,00%	15
	P	52,16%	44,74%	7,42%	8	19	69,0%	63,88%	5,14%	29
	AVERAGE	**53,54%**	**45,27%**	**8,27%**	**6**	**23**	**69,14%**	**62,65%**	**6,49%**	**21**
WAREHOUSE DEPARTMENTS	FP(TH)	59,68%	47,56%	12,13%	5	24	68,3%	75,56%	-7,22%	9
	21th/GARDEN/AMBIENTE	66,00%	68,00%	-2,00%	5	13	58,3%	69,17%	-10,83%	3
	RM	82,50%	83,33%	-0,83%	6	27	85,83%	97,50%	-11,67%	3
	AVERAGE	**69,39%**	**66,30%**	**3,10%**	**5**	**21**	**70,83%**	**80,74%**	**-9,91%**	**5**
	GLOBAL AVERAGE KPI	**58,83%**	**52,28%**	**6,55%**			**69,7%**	**68,7%**	**1,0%**	

Figure 20: overall Skill Matrix of ELBI S.P.A. regarding Hard and Soft skills (Workers + department Head).

4.3.2. Comments and results

The analysis in the various departments shows a clear discrepancy between the results obtained through interviews with the workers and the specific ones with the department heads. In most cases, there is a negative average difference, in relation to the experience and the point of view of the head. Hence, we noticed an average KPI that is lower than that suggested by the workers. For this reason, the most significant differences (those of the A and M departments) were highlighted in red. We have considered "not relevant" those less than or equal to 10%. However, in few departments (ie department C) there are some macro-processing areas with a higher polyvalence KPI than initially observed, thus getting a positive difference. As we can see in the final summary table (Figure 20), the several departments have been divided into two categories, those relating to production and those dedicated to warehouse management. This choice was made considering the activities carried out within the warehouses very similar to each other and consolidated at the procedural level, despite these departments perform different tasks being one devoted to the management of incoming material and the other two of the outgoing (including the shipping office). In fact, we note that, on average, among warehousing departments there is a higher Index of polyvalence, in terms of Hard skills, equal to 70%. On the contrary, for the production departments we have an average Index of polyvalence just over 50%. Therefore, there is a strong reason to believe that the activities carried out in the production departments are much more specific, thus having a slower and less automatic degree of learning. The comparison with the heads is certainly more considerable within the production departments. Relatively to Soft skills, these have a more homogeneous distribution between the various departments and there is a small difference between the two categories, in fact we have a final KPI of 69.14% in production departments and one equal to 70.83% in the others. In this case, the KPI provided by the interviews with the heads of departments is more in line with that obtained through the individual ones. Precisely, putting together all the data on Soft skills, we detected the following two rankings of polyvalence (see Figure 21):

RANKING	SOFT SKILL	WORKERS
1	Having clear the role	90,00%
2	Collaboration	77,36%
3	Serenity	71,36%
4	Sense of belonging	68,05%
5	Motivation	67,56%
6	Ability to work in a team	65,45%
7	Problem solving capacity	61,91%
8	Ability to make a decision	55,97%

RANKING	SOFT SKILL	DEPARTMENT HEAD
1	Having clear the role	76,8%
2	Collaboration	76,3%
3	Serenity	75,6%
4	Sense of belonging	69,6%
5	Ability to work in a team	69,6%
6	Motivation	67,8%
7	Ability to make a decision	58,2%
8	Problem solving capacity	55,5%

Figure 21: ranking of the soft skills according to the two interviews carried out.

The first four positions remain unchanged in both rankings, pointing out a very high KPI in reference to *Having clear the role*, which is going to be a cornerstone for what will be then the improvement process. Conversely, in the last four positions there is a change in the sequence of Soft skills detected, confirming however the need to intervene in terms of *Problem solving capacity* and *Ability to make a decision*, which are closely related to each other. Coming back again to the Hard skills, among the different production departments the degree of polyvalence varies in a minimal way, with an average level around 53%. This is a proof of an intrinsic rigidity that is common to the departments and it is independent of the "*number of employees*" rather than the "*number of activities within it*". Presumably, this rigidity is due to an inflexible management, still linked to the previous ownership.

The consequence is a non-diversification between the many departments, even if we consider the most performing ones in terms of "quantity produced or revenue", having a KPI of polyvalence that does not exceed 55%. In addition, the following three indexes were calculated at global level, necessary to complete the analysis:

1) *Average age of the workers* equal to 47,4 years.
2) *Average level of remuneration* equals to 4,1 out of 5, in accordance with National Labor Contract.
3) *Average work seniority* equal to 16,3 years.

Finally, we did a *Muda check* concerning the wastes that have emerged from this analysis, which are the following:

- In some KPIs there is a marked difference between the two assessments, workers and department head (*unclearness*).
- The average age of workers is high in all operating areas (*risk on generational change*).
- The salary framework is above average compared to the activities carried out and the responsibilities of each individual worker (*high and inappropriate labor cost*).
- Complete absence in human resources management within the Gemba (*most of the workers still refer to the previous governance*).
- The department heads are little supervised and aligned with business goals, as they do not have a *specific operational standard* and each of them has its *own way of management*.
- The departments are very rigid, with a very low degree of polyvalence that does not signal differences between the various operating areas, although these are very different from each other in terms of technical skills (*the company needs an increase in the degree of polyvalence inside and among the departments*).
- The department heads work little on people's growth, in fact among the workers there is a very low level of technical competence and personal training.

We are facing with an organizational business reality that needs an intervention in terms of reorganization and structural consolidation. From this analysis are emerged some *To-Do* that can be realized to have a solid base on which we can work towards Lean transformation process, pursuing Continuous Improvement.

The following corrective actions have been suggested:

- A clear and evident lack of human resources management implies the need to hire an *HR manager, who is a leader that can support and train workers through a specific development program*, according to the needs of the company.
- The mismatch between what was observed in the first analysis with the workers and then with the department heads suggests *the need to set a period of support to the latter, so as to justify the most far parameters, creating standards (procedures, job descriptions)*, by acting to create a certain linearity of information. The goal is to focus on value-added activities, considered critical, which have a strong difference, to make sure to increase the polyvalence index on these areas. It may be that the department head does not fully exploit his human resources because he is not aware of their knowledge.
- Create a team that can rotate between departments, which can begin to carry out a period of *Job Rotation*, especially trying to increase as much as possible the polyvalence of the departments that work together (i.e. departments B, C and M), as these they are very similar in terms of production process.
- Define the minimum operational structure, *identifying the exact needs of staff* (how many people are needed in that department to manage production? How many of these must be 100% polyvalent and how many, instead, must be specific? There is a seasonality within the department? If yes, how should it be managed? With temporary resources or with the same people but with a higher degree of training?).
- *Combine more departments in the same* (levelling the activities that are similar to each other, specifically when we talk about warehouses management, which are three separate entities that do not communicate with each other).
- *Actively intervene with new recruitment of operating staff* in such a way as to prevent the risk of generational turnover, which is actually very high (about 70% of the staff will retire within the next 10 years).
- *The corporate cultural level should be analysed more deeply,* by observing those who have obtained academic qualifications (licenses, diplomas, etc.) and, in relation to this, recommend a training course in line with the role-played, redefining new remuneration and career levels more aligned with each other.
- *Creation of a Visual Board* in the various departments, where in each of them will be highlighted the level of polyvalence of the department itself, pointing out the degree of each worker. Then, depending on the several improvement actions, based on a new HR

management together with an internal training development, we will observe if there has been or not an increase in these reported KPIs.

- The fact that there is a clear lack of supervision by the department heads on their employees indicates that the top management, in turn, does not supervise them enough, since they are considered as "simple controllers who monitor the work of their subordinates". In fact, the department heads are not doing their part and they are completely uninformed about how to work on people without having any kind of cultural background. *Training courses in leadership, coaching and personnel management* would be considered appropriate in order to create a more dynamic and transversal working environment.

4.4. Second project: Improvement of the Corporate Logistics Flows

The second project addressed by KaizenKey srl concerned the definition of a new *Internal Logistics* that would guarantee a more efficient management of the flows of materials and information within and between the various departments. It includes all material handling activities, from the acceptance and quality control activity, to the storage, picking up and feeding of the several production departments and, finally, the shipment to third parties or customers. Accordingly, the logistics aims in optimizing the connection of the various phases of a production process.

Internal Logistics are the core of the company's business, having to connect inputs to outputs in terms of optimization, minimizing losses and avoiding the generation of stocks that could negatively affect the company's financial statements. Having an integrated Internal Logistics that works smoothly allows you to work more efficiently once you have decided to intervene with improvement projects in the production departments, having around an already-working logistics context.

There was an evident lack regarding the Internal Logistics service, in fact there were many problems in terms of missing component and, for this reason, we could not meet two fundamental needs:

1) The first refers to the fact of providing a quality logistics service to production departments (considered as "surgeons").
2) The second concerns the introduction of the "nurse" figure, i.e. the management of procurement materials to the production centers (assembly lines, mechanical workings, etc.).

At the same time, it is essential to intervene on the warehouse management optimization by ensuring the right level of stocks, through a precise control on the transitions, rearranging the resources and immediately sorting out those necessary for production.

The work carried out by KaizenKey srl lasted two workshops on problem solving analysis.

4.4.1. Analysis

The *First* workshop allowed us to study what can be a functional Internal Logistics, avoiding to commit a whole series of wastes that slow down the handling materials process. In order to do that, we developed a *Muda chech*, by discussing the problems concerning the current service level of logistic, which is as follows:

- *Too many places for unloading goods*: there are many areas where the incoming material is unloaded because of a small Raw Material Warehouse.
- *Raw materials are located throughout Elbi*: a high level of material handling and an obvious danger related to the use of trucks and dollies that are always around the company by often doing different paths.
- *Unsuitable unloading places*: the unloading place of material is not appropriate if we consider its subsequent use. In fact, most of the times, it undergoes further movements.
- *There is no scheduling of incoming material arrivals*: if all the materials are scattered in the company without a very precise logic, it is more difficult to have them under control and report any lack them. If the notification starts late, there will also be a delay by the purchasing department in restoring the missing goods. There is little collaboration between the various actors along the supply chain (production departments, production planning, purchasing department).
- *Lack of goods acceptance and management of arrivals*: with regard to the inbound logistics, many materials are not checked carefully but sent directly into production departments.
- *There is no point of welcoming drivers:* this is not positive in terms of security and privacy.
- *There are three loading points for shipping documents* (raw materials warehouse, purchasing and shipping offices)*:* the activities of waybills loading are administered in three different areas.
- *The management of shipping documents is low added value*: it can cause difficulties in the management of both the document itself and of any missing material or wasting time in search because the expected quantity is not clear. Moreover, the materials upon acceptance do not have the right identification tag (this may involve problems in terms of quality, given that each product must meet certain standards and specification). If the material is not properly identified, this requires the intervention of the department head

to understand what product it is. This procedure slows down the start of the production process and it may happen that the production department is supplied in an inappropriate manner, with poor quality products, risking the shipping of a product that does not meets the requirements.

- *Lack of information on new incoming materials*: it is not always clear which material has actually been stored because it is often placed in a wrong location. There is a poor communication between the planning of production department and the raw materials warehouse.
- *Low level of information on urgent material:* if there are urgent goods to be produced, these are not readily performed, ending in not satisfying the final consumer.
- *There is no specific location of the material*: this occurs on average in all the warehouses, without any concept of standardization. The picking process is slowed down by the lack of specific procedures, as well as not being sufficiently supported at the IT level.
- *There is no standardization of containers for incoming material:* there are several containers that contain the same components taking up space when it would not be needed. There is no clear positioning of the materials and a fix location. It is not known exactly where the material will be placed, since the location is not clear. It has not even been agreed about who has to monitor the material and identify it correctly.
- *Logistics is not measurable*: the splitting of these activities into many departments and a global management of the materials, which is not defined, do not allow us to have an idea on what is the actual "logistics cost". Be aware of the impact that internal logistics has on the company it is an imperative, in order to be able to manage it in the right way.

Subsequently, all the unloading areas of the incoming material were identified (see figure 22), with a specific legend (see Figure 23), according to the various product families (see figure 24).

PRODUCT FAMILIES
1) Cardboard packaging
2) Membranes
3) Screw
4) Anodes
5) Resistors
6) Consumables
7) Labels
8) Coils and sheets
9) Accessories for plastic and mechanical processing
10) Seals
11) Powder for painting
12) Polyethylene
13) Purification accessories
14) Material for the assembly of the Dab
15) Insulation material
16) Enamel

Figure 24: product families of ELBI S.P.A.

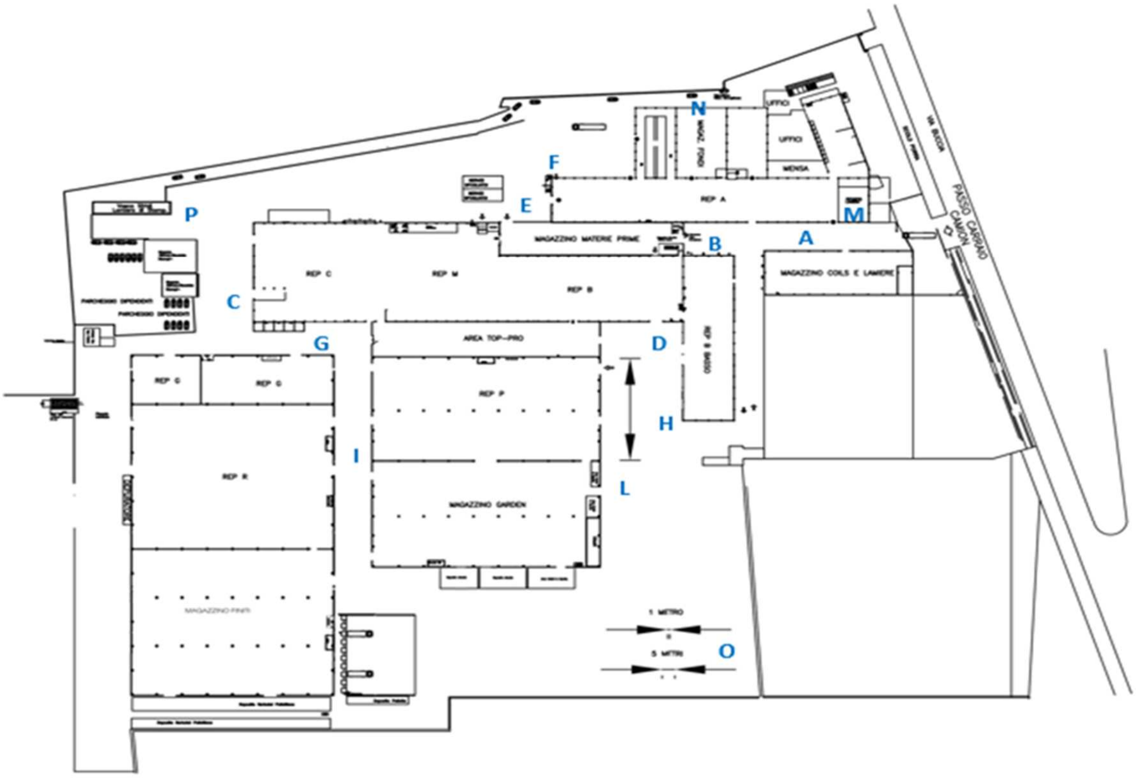
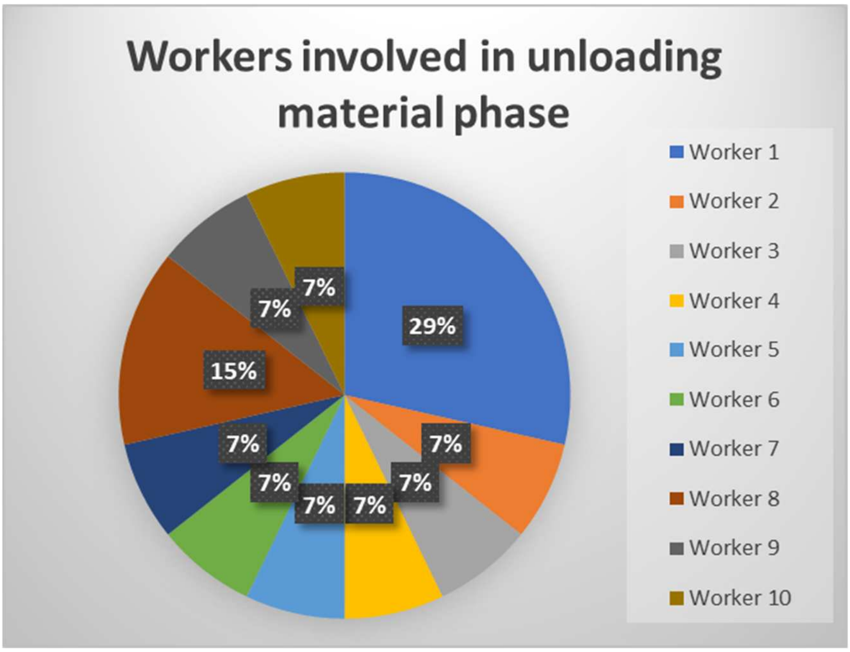


Figure 22: current Layout of Elbi regarding unloading areas.

LEGEND		
Worker 1	**A**	Coils + sheets + accessories
Worker 2	**B**	Consumables + raw materials
Worker 1	**C**	Coils per department C
Worker 1	**D**	Coils per department B
Worker 3	**E**	Membranes
Worker 4	**F**	Galvanizing material (in and out)
Worker 5	**G**	Flanges and empty baskets
Worker 8	**H**	Polyethylene, molds and pallet for Plasto (Modugno)
Worker 9	**I**	Enamel + consumables
Worker 10	**L**	Material for injection and lacquered
Worker 6	**M**	Raw material for department A (pipes and large sheets)
Worker 7	**N**	Bottom surface rounded
Worker 8	**O**	Recycled material (out)
Worker 1	**P**	Scrap (out)

Figure 24: legend of the 14 different unloading areas and workers involved.

As we can see in the Layout of Figure 22, 10 workers manage all the unloading areas in Elbi, which in total are 14 (see Figure 25). Thus, there are not only the workers of the Raw Materials warehouse that deal with the management of incoming materials, but there are 10 people who operatively lend themselves to perform the aforementioned activities, even before the material is handled into the production departments for subsequent processing.



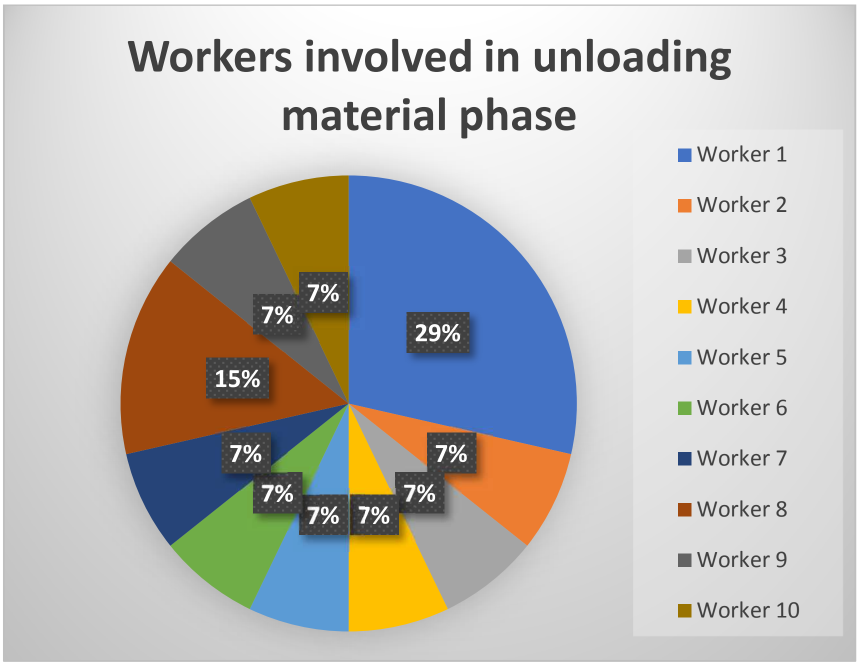


Figure 25: percentage of material unloading activities for each worker involved.

Regarding the three loading points for shipping documents, according to the Muda check, those activities are carried out by 4 workers (1 within the Shipping office, 2 within the Purchasing department and 1 within the Raw Materials warehouse).

Then, we analyzed how many arrivals, in purchase and by subcontracting arrangements, there have been in the different unloading areas highlighted in the layout (respectively, see figure 26 and 27).

LOCATION IN	ARRIVALS	%
A	304	14%
B	1598	71%
H	33	1%
I	144	6%
L	58	3%
M	30	1%
N	72	3%
TOTAL	2239	100%

Figure 26: arrivals by purchases.

LOCATION IN	ARRIVALS	%
A	2	1%
B	33	22%
F	74	49%
I	18	12%
L	15	10%
M	9	6%
TOTAL	151	100%

Figure 27: arrivals by sub-contracting arrangements.

In relation to figures 26 and 27, all the waybills collected in the last year were counted, from 01/07/2016 to 31/06/2017. Each of these have been associated with a single outgoing movement (unloading/management of the material). Although this estimate is high, it is understated because a waybill could also provide, for example, 10 pallets that would involve 10 movements. Thus, the resulting number of this analysis is the minimum achievable or better, this describes the best-case scenario. Summing up, we can consider that every shipping document requires at least one outgoing movement.

In the considered year, Elbi received 2239 waybills in total, of which 1598 in area B (consumables and raw materials) and 304 in area A (coils and sheets). We can state that the 85% of arrivals by purchases are concentrated in two areas (B and A). While, for those by sub-contracting arrangements, we have 151 arrivals in total and a greater incidence in the F area (through galvanizing material), equal to almost half of the total amount. Subsequently, we focused on the arrivals in major areas (location B and A). We noticed that shipping documents arrived in those two locations, marked in the layout, and then further moved to other areas (see Figures 28 and 29).

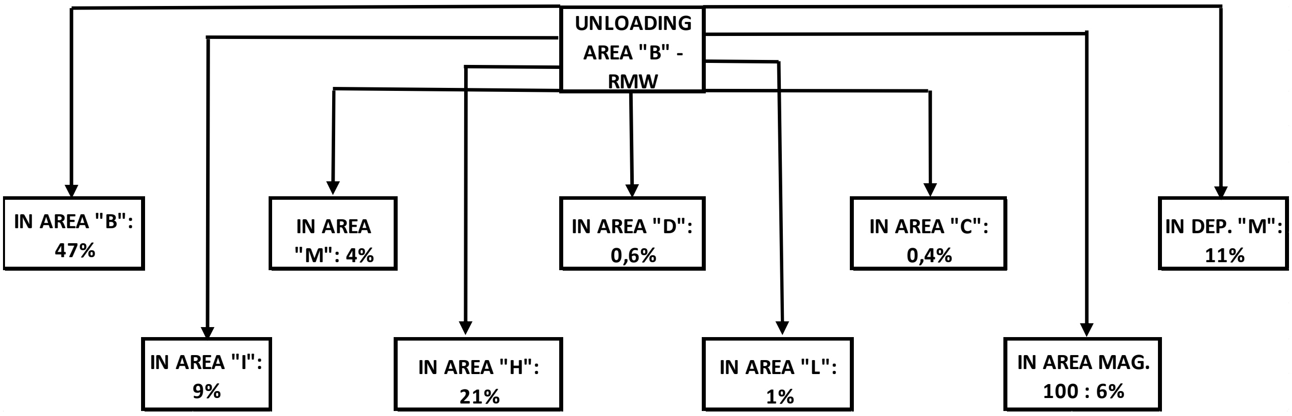


Figure 28: analysis of the 1598 waybills in area B.

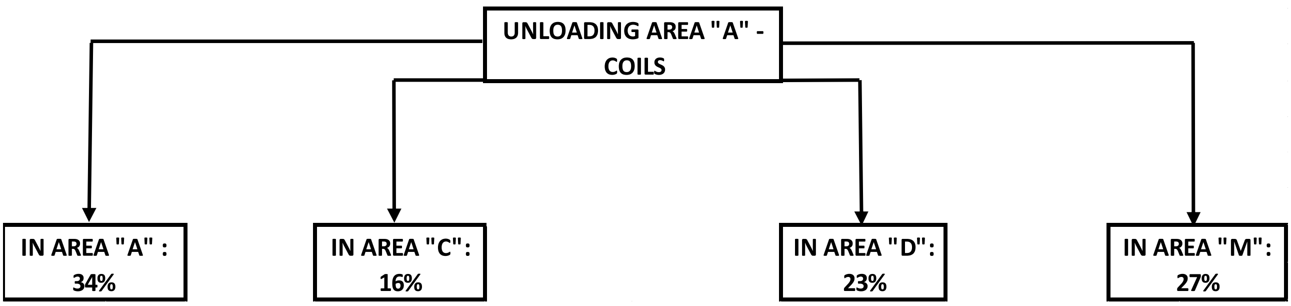


Figure 29: analysis of the 304 waybills in area A.

According to figure 28, only 47% (751 waybills) remain in the area B, as the others moved, in different percentages, to the areas highlighted in the graph. In the case of coils and sheets (figure 29), only 34% (119 waybills) remain within the area A, while the 66% goes into administration in the areas C, D and M.

This analysis confirmed what was highlighted in the *Muda check*: apparently, it seemed that most of the incoming materials were concentrated in some specific areas but, unfortunately, this is not what actually happens. More precisely, the arrivals are concentrated in some areas and then further sorted across the company.

Referring back to all those "letters", from A to P, marked in the layout, which have a very strong impact on handling material. Such high handling, not managed and organized appropriately, implies that many people are involved in the transport of goods. The goal is to understand how this handling takes place, in order to manage it better in the future, avoiding 10 workers to deal with Internal Logistics. Rearranging the layout of the plant and introducing new flows of material and information, we can achieve an improvement in terms of quality and costs.

Furthermore, we calculated the various flows concerning the movement of the material from one department to another in terms of annual kilometers traveled (see Figures 30 and 31).

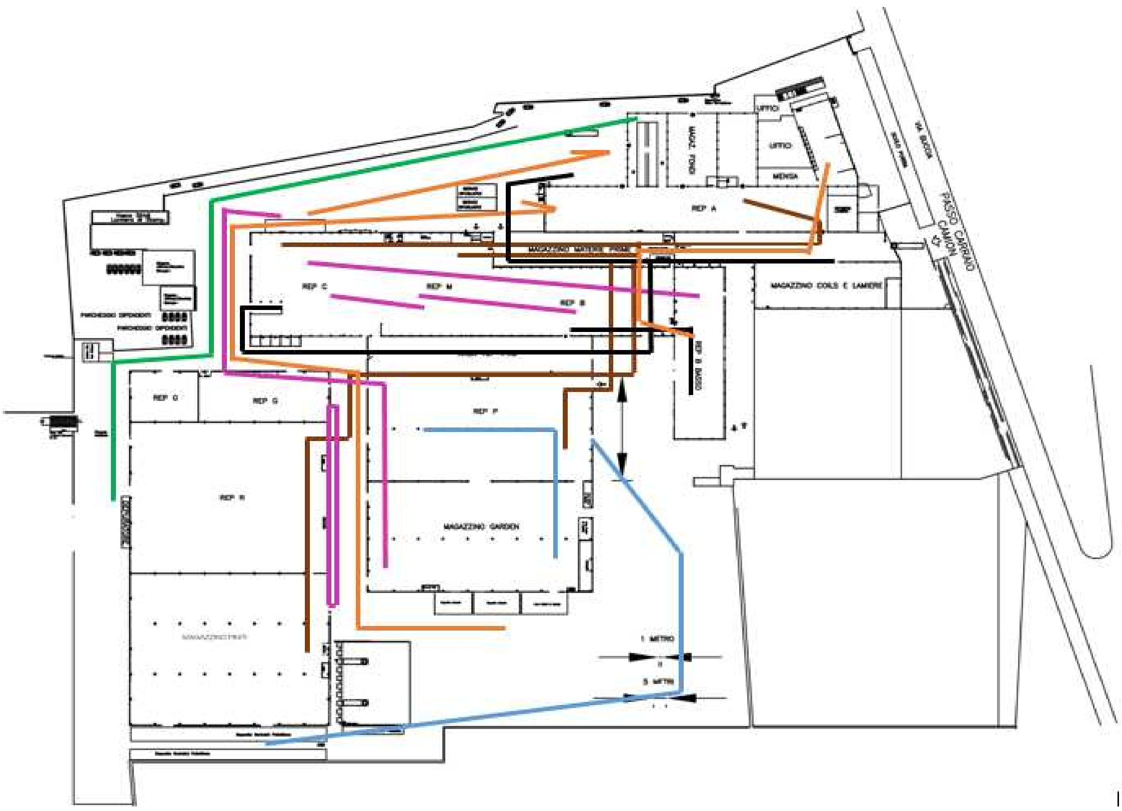


Figure 30: analysis of the main Internal Logistic flows.

LEGEND		
5349	→	POLYHETHYLENE RAW MATERIALS (H)
985	→	ENAMELLING RAW MATERIALS (I)
207	→	COILS (A=C+D)
1110	→	GALVANIZING (F+N)
258	→	RAW MATERIALS AND CONSUMABLES (B)
9258	→	INTERNAL HANDLING (B+C+M)
17167	←	TOTAL

Figure 31: legend of the analysis of current logistic flows in km.

The total annual kilometers traveled are equal to 17167, up until the current situation. According to figure 31, the internal management of the material between the production departments B, C and M gives the large movement (9258 km). In addition, that concerning the management of department P, through polyethylene and molds, is still considerable (5349 km). They account for almost 85% of the total logistic flows (14607 km). Even in this case, we counted a single outgoing movement (in kilometers) for each incoming arrival, when actually it is evident that there are many more. We were able to realize the intertwining of Internal Logistic flows within the company, understanding how the various departments are dealing with it. The logistic flow that emerges from the Spaghetti Diagram (figure 30) describes a dangerous situation in terms of safety, since a high and uncontrolled handling of the material may cause a greater risk of damage to the goods.

Once this analysis was completed, we figured out how to improve this condition without proposing actions that included big investments. Kaizen suggests “improvement in small steps with the minimum investment possible”. If we had reasoned by questioning all the production departments, this would have led to a result that was certainly different but it implied a considerable investment. Therefore, we decided to use what was available without undertaking huge organizational maneuvers. During the brainstorming phase, several improvement proposals emerged, on which we discussed analytically in order to decide which was more suitable. Eventually, we developed a new plant layout (see figure 32 and 33), which requires an Internal Logistics that would work as follows:

- the current Raw Materials warehouse will be moved to the 21st/Garden/Ambiente warehouse. In the new configuration, there will be the coils of the entire company in the current raw materials warehouse (those for the departments A, B and C) and the raw materials (pipes and large sheets) necessary for the processing of department A. The capacity of the warehouse will not be fully exploited, as there will be an area dedicated to other activities such as the maintenance related to carpentry. Therefore, the coils and sheets will be managed separately from the raw material, as it has been decided to concentrate in a specific area all the material that has similarity in terms of "type and use". Approximately 70% of the mechanical processing in Elbi uses sheet metal as process input, so this represents a large percentage of the total amount used. In the new layout (Figure 32), the letters ACDM indicate what has just been said.

- The new Raw Materials warehouse, indicated in the layout by the letters OBLHIFGE (see figure 32), will include all consumables, raw materials from the thermo-hydraulic, plastics and enameling departments and the commercial materials of the entire company. A quality control area will also be created regarding acceptance of incoming material, in order to make sure that such material, once it has arrived in production, it has been appropriately checked.
- Moreover, there will be an only one warehouse of the Finished Product, including all the divisions of Elbi, from the thermo-hydraulic to the Garden. This will help to manage the shipment of the finished product that will be more controlled.

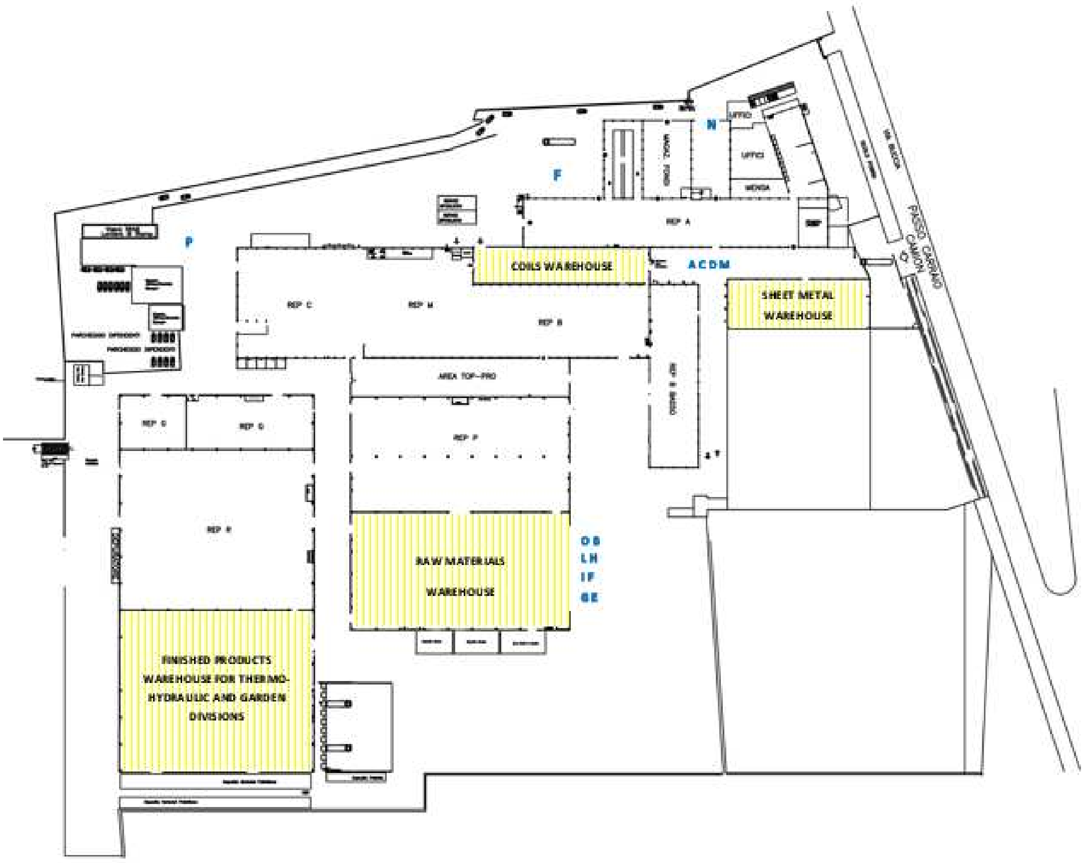


Figure 32: new plant layout of Internal Logistic.

LEGEND	
A-C-D-M	Coils + sheets + accessories
	Coils per department C
	Coils per department B
	Raw material for department A (pipes and large sheets)
B-O-L-H-I-G-E-F(in)	Consumables + raw materials
	Recycled material (out)
	Material for injection and lacquered
	Polyethylene, molds and pallet for Plasto (Modugno)
	Enamel + consumables
	Flanges and empty baskets
	Membranes
	Galvanizing material (in)
P	Scrap (out)
N	Bottom surface rounded
F(out)	Galvanizing material (out)

Figure 33: legend of the 5 unloading areas of the new layout.

In developing this new layout concept, we carefully analyzed, in terms of “Pro” and “Cons”, the two main displacements, which are as follows:

1) Transfer of the Raw Materials warehouse in the current 21st/Garden/Ambiente warehouse.

- Pro:

➢ *There is an increase in storage capacity, compared to the previous warehouse, equal to almost 150% more:* the fact of being forced to storage the raw materials and components in all production departments (14 different unloading areas) is even due to a too small Raw Materials warehouse. With this new arrangement, it will also advance some space that can be used as "quality control area" and "goods acceptance", which are not currently present in Elbi.

➢ *Materials management will be more under control*: with this kind of configuration, having a centralized Raw Materials warehouse increases the possibility to better manage the materials by reducing the percentage of "missing" and, consequently, it will be much easier to signal a problem of this type and a possible recovery, through an efficient stock management.

➢ *There will be mostly only 2 main unloading areas*: 95% of all arrivals will be absorbed in only two areas (ACDM and OBLMIFGE, according to the layout). In this way, some space within the company will be available and can be adopted for daily operational activities.

➢ *Creation of a customer-supplier logistic service*: having established goods storage areas (the suppliers) and knowing what the actual use of each material within the manufacturing process is (the consumer), it will be possible to institute a relationship of this type: associate to each items a precise processing, helping the traceability along the production process.

- *Creation of a centralized office for the reception of all drivers within the new Raw Materials warehouse*: the drivers, both suppliers and customers, are not supervised in any way.
- *There will be a reduction in the time of research and codification of the material:* the material will be properly managed in a centralized area. The workers of such area will take care of maintaining a direct relationship with all incoming suppliers.
- *The unloading of materials will take place in a covered area:* this takes place in many areas, most of which are not covered (thus facilitating workers and preserving the quality of products).
- Shorten the distances to the P, R departments and the Finished Product warehouse.
- *By freeing up the current Raw Materials warehouse, such space will be necessary to manage the coils and the sheet metal with a single storage area*: therefore, the safety and management in handling these specific materials will be increased.

- Cons:
- There is an increase in mileage to departments B, C, M and A, regarding the supply of these departments.
- *Some transportation of materials will be done outside (the passage is not covered and it is longer than before*): this can complicate the transport of the finished product or of the material in the production departments for subsequent processing.
- *There will be a need to buy a crane*: in such a way that the Ex Raw Materials warehouse is in a better position to manage the storage of coils (economic investment around 50000 Euro).

2) Transfer of the Finished Products warehouse 21st/Garden/Ambiente into the Finished Products warehouse of the Thermo-hydraulic division.

- Pro:
- *Unique warehouse of Finished Products for all the product divisions:* having only one Finished Product warehouse implies moving from 2 loading areas of outgoing goods to a single 1, with a consequent optimization of the transportations.
- *Optimization in human resources management*: we can take advantage of the interchangeability between the staff of the Thermo-hydraulics warehouse and that of the 21th/ Garden/Ambiente, because they will work together in storage and shipping of the finished products of Elbi. In addition, the current finished product warehouse of the Thermo-hydraulic is working on two shifts, guaranteeing a continuous working time of 10 hours during the day. This is definitely a

service to be exploited also at the commercial level, being able to load the trucks more consistently and having in just one area all the finished product of the company.

- *Today, the finished product warehouse of the Thermo-hydraulic division deals partially with the shipment of the finished product 21st/Garden/Ambiente*: with this new layout, there would be a reduction in terms of distance, as the management of the finished product would pass completely to the Thermo-hydraulic warehouse.
- *There would be an opportunity to adapt the 21st/Garden/Ambiente division to the IT system of order fulfillment already adopted in the Thermo-hydraulic warehouse*: expand the Kanban logic of the finished product even for the other divisions, taking advantage of what was previously developed through the workshop with the commercial Back Office. The integration can lead to a standardization of procedures and related processes through a more uniform logistic flow.

- Cons:

- *There is an increase in mileage for some logistic flows*: this is the case of finished products manufactured in department P that must be brought to the thermo-hydraulic warehouse, traveling a longer and partially external route before being stored in the warehouse.
- *The handling of some finished products of the 21st and Garden division would be a bit precarious*: transporting this type of product from one department to another by traveling outdoors requires the configuration of an *ad hoc* route to avoid the risk of falling and any damage to the product, considering remarkable the volume of such products.
- *Today, only one packing machine is available in the finished products warehouse of Thermo-hydraulic division*: another one will be needed for new products that must also be packed before being stored.
- *Today, in the finished product warehouse there is only one fork-lift truck:* probably, it will need at least one more, as there will be an increase in workload.
- *There are some objective difficulties regarding picking some Garden products from the second floor up*: the location of the goods, within the warehouse, will be strategically studied, in order to guarantee operators the fastest and easiest picking possible, even for those bulky products.

LEGEND		
5266	→	POLYHETHYLENE RAW MATERIALS (H)
985	→	ENAMELLING RAW MATERIALS (I)
129	→	COILS (A=C+D)
370	→	GALVANIZING (F+N)
290	→	RAW MATERIALS AND CONSUMABLES (B)
9258	→	INTERNAL HANDLING (B+C+M)
16298	←	TOTAL

Figure 34: analysis of future logistic flows in km.

In accordance with the new layout, there was also an overall reduction in the kilometers traveled, despite the increase in the distance for some specific materials. This was not the primary goal, rather than creating the conditions for guaranteeing an Internal Logistic service that works efficiently, with less area for unloading goods and management of shipping documents. We also analyzed whether in the finished product warehouse of Thermo-hydraulic division there is enough space to storage the products of the 21st/Garden/Ambiente. We did such analysis at the end of July 2017, when the warehouse was almost saturated as it was getting ready for the management of winter stocks. We observed a negative difference of -57 pallets. This means that, in the 21st/Garden/Ambiente warehouse there were 57 pallets more than what is available in the Thermo-hydraulic.

There are two considerations to make about it. Within the 21st/Garden/Ambiente warehouse there has been no work done in terms of "cleaning of obsolete goods", thus the negative delta can be reduced. Some pallets can be reviewed in terms of quantity and type of product requiring. In this way, we will need less storage capacity in the Thermo-hydraulic warehouse. It must be taken into account that in the Thermo-hydraulic warehouse there are different shelving that presuppose a re-palletization of the goods. It may be difficult to manage a saturated warehouse, if there is a need to produce an extra order.

The workshop ended with this proposal, which is a vision that KaizenKey supported during these activities. From here on, there will be further workshop activities, conducted by several participants who will lend themselves to the realization of the aforementioned project, through a sharing and a commitment in achieving the set goal. The next workshops will be useful to understand and to wonder how we can afford it. Specifically, make this new layout proposal the starting point for a better Internal Logistics service.

The *Second* workshop aimed to the "Transfer of the finished products of the 21st/Garden/Ambiente warehouse into the finished products warehouse of the Thermo-hydraulic division*"*. The first activity concerning the realization of the new Internal Logistics is about emptying the 21th/Garden/Ambiente warehouse, in order to make space for the new Raw Materials warehouse.

In doing that, we analyzed the different activities that were performed within the warehouse, identifying all those that absorb resources (Waste), without creating additional value. We found the following *Muda*:

- *Excessive inventory of finished goods*: most of the warehouse included the stock of finished products based on a sales forecast and customer orders (through MRP system), which is not properly managed, in fact the amount of goods is continuously accumulating.
- *There was an inconsistency between the volume occupied and the loading unit*: most of the pallets consisted of a quantity of unsuitable goods, ending up occupying a larger volume and creating inventories.
- *Unnecessary or repetitive checks*: the checks on the products stored, during shipment, were carried out several times, first by the department head of the 21st/Garden/Ambiente warehouse and, subsequently, even by the one of the Thermo-hydraulic warehouse.
- *Moving goods not necessary*: there was a high pallet handling, both in the storage phase, as the locations were not defined, and in the picking one, failing to optimize the total duration of this activity (which is the most expensive within the warehouse management). The type of route to follow is not suitable.
- *Lack of Standardization of internal procedures, storage and picking processes*: a key principle of Lean warehouse is the concept of Standardization. Creating standard work does not mean transforming people into robots but means creating guidelines from which to improve.

The goal was to create a Lean Warehousing, transforming the traditional top-down leadership into bottom-up initiatives: each worker must be a supervisor of the overall warehouse system and everyone is required to help the company in achieving its goal of Continuous Improvement.

The first operational activity was the reorganization of the warehouse, in terms of new layout and mapping of the processes, through a correct ABC analysis, which allows identifying an effective product storage strategy in order to minimize movements and wastes.

The ABC technique is based on 80/20 rule (Pareto, 1897), which states that most of the effects depend on a limited number of causes (approximating, it turns out that 80% of the effects depend on 20% of the causes). This analysis clarifies which are the items that need more attention. It is extremely useful in order to define classes of articles, based on their criticality, and locations within the warehouse, giving them a fixed position. In this way, we can get a reduction in the time required to carry out the daily picking activities. *How should we proceed?*

All products are listed by sorting them in descending order based on sales turnover, in terms of quantity sold. For each product, present within the 21st/Garden/Ambiente warehouse, we calculated the average quantity sold in the last 3 years (2015, 2016 and 2017). Then, we calculated the “% incidence” of each single product: by dividing the respective total average over the past three years with the total sum of the average sales over the past three years. Then, the cumulative percentage of sales for each product is calculated, by summing up the previous ones, one by one. We proceed to the division of the products into the 3 classes (A, B, C), by grouping in the class A the products that in the cumulative give rise to an approximate value of 80% (according to the Pareto law). In class B, there are the products that fall in the cumulative next band, from 80% to 95%. In class C, on the other hand, there are the products that occupy the complementary band to get 100% (see figure 35).

ITEMS	Stock	2015	2016	2017	TOTAL	AVERAGE ON THE THREE YEARS	% INC	COMULATIVE	ABC
VASO CONICO FESTONATO ANTICATO CF 55	126	1510	1494	1230	4234	1.411	1,99%	1,99%	A
VASO CONICO FESTONATO ANTICATO CF 45	346	1398	1392	1330	4120	1.373	1,93%	3,92%	A
VASO CONICO FESTONATO ANTICATO CF 65	133	1381	1524	1155	4060	1.353	1,91%	5,83%	A
VASO CONICO FESTONATO ANTICATO CF 40	246	1069	1069	986	3124	1.041	1,47%	7,30%	A
CASSETTA MILLERIGHE ANTICATO MRC 100	54	1125	1135	786	3046	1.015	1,43%	8,73%	A
VASO LISCIO DOPPIO BORDO ANTICATO DBL 55	69	1055	1044	912	3011	1.004	1,41%	10,14%	A
VASO LISCIO DOPPIO BORDO ANTICATO DBL 45	202	1052	991	860	2903	968	1,36%	11,50%	A
CALICE CON FOGLIE BIANCO CAF 45	92	458	1418	980	2856	952	1,34%	12,85%	A
VASO CONICO FESTONATO ANTICATO CF 75	121	962	898	817	2677	892	1,26%	14,10%	A
VASO CONICO FESTONATO ANTICATO CF 35	235	933	888	734	2555	852	1,20%	15,30%	A
VASO LISCIO DOPPIO BORDO ANTICATO DBL 65	96	847	830	607	2284	761	1,07%	16,38%	A
VASO LISCIO DOPPIO BORDO ANTICATO DBL 35	136	794	755	570	2119	706	1,00%	17,37%	A
CASSETTA FESTONATA ANTICATO FR 80	88	667	867	469	2003	668	0,94%	18,31%	A
CASSETTA FESTONATA ANTICATO FR 100	103	581	1129	289	1999	666	0,94%	19,25%	A
CASSETTA MILLERIGHE ANTICATO MRC 80	116	663	617	694	1974	658	0,93%	20,18%	A
VASO LISCIO DOPPIO BORDO ANTICATO DBL 75	69	757	701	459	1917	639	0,90%	21,08%	A
VASO CONICO FESTONATO ANTICATO CF 30	167	654	643	604	1901	634	0,89%	21,97%	A
CASSETTA CON FOGLIE ANTICATO CR 50	144	756	513	502	1771	590	0,83%	22,80%	A
VASO LISCIO DOPPIO BORDO ANTICATO DBL 42	90	645	593	502	1740	580	0,82%	23,62%	A
VASO CONICO FESTONATO ANTICATO CF 85	31	614	594	475	1683	561	0,79%	24,41%	A
S/VASO CIRCOLARE ANTICATO STVC 31	49	636	599	416	1651	550	0,78%	25,19%	A
S/VASO CASSETTA ANTICATO S/MRC 100	39	537	521	545	1603	534	0,75%	25,94%	A
FENICE 100 CASSETTA LISCIA ANTRACITE	47	438	414	570	1422	474	0,67%	26,61%	A
S/VASO CIRCOLARE ANTICATO STVC 38	55	536	456	393	1385	462	0,65%	27,26%	A
FENICE 100 CASSETTA LISCIA BIANCO	53	532	489	338	1359	453	0,64%	27,89%	A
CASSETTA FESTONATA ANTICATO FR 60	99	403	402	514	1319	440	0,62%	28,51%	A

Figure 35: ABC analysis of the products within the 21st/Garden/Ambiente warehouse.

CLASSIFICATION OF THE ITEMS (ABC ANALYSIS)						
TOTAL STOCK ITEMS			AVERAGE ON SOLD OF THE THREE YEARS		CURRENT LEVEL OF INVENTORIES	
1215			88489		30609	
CLASS	N° OF ITEMS	QUANTITY OF PRODUCTS SOLD	% ON ITEMS	% ON SOLD	LEVEL STOCK ITEMS	% ON STOCK LEVEL
A	301	70758	25%	80%	13637	45%
B	313	13306	26%	15%	7394	24%
C	601	4425	49%	5%	9578	31%

Figure 36: ABC classification regarding 21st/Garden/Ambiente warehouse.

What emerged from the analysis? (See figure 36)

We have a total amount of 1215 items, which have generated sales in the last 3 years (88489 products sold). Only 301 items (25%) generated 80% of the outgoing movement. As many items (313), related to B-Class, generated 15% of the sold. C-Class highlights a significant figure, where 601 items (almost 50% of the total) generate only 5% of sales. In summary, 614 items (A-Class + B-Class), just over half, generate 95% of sales. The other half is composed by the C-Class. The total quantity in stock, at the date of this analysis, is equal to 30609 products. A-Class, with 13637 products, occupies 45% of the total current inventories. There are more C-Class products than B-Class stored within the warehouse, although B-Class affects sales more consistently. A-Class requires special attention as it is the class that generates the greatest outgoing movement, which implies a high turnover rate. Consequently, it is good practice to provide an adequate stock, in order to avoid potential stock-outs, which would be particularly serious, given that these are items with a high demand. B-Class shows a lower criticality, given the lower influence on the company's sales. C-Class, on the other hand, has a less impact on the inventory turnover, therefore we can give less attention during the operational phase.

The ABC method represents a valid solution to optimize inventory management. In its various forms, it allows:

- *Prevent stock-outs risk:* ensuring a storage level as right as possible, based on quantities sold and the cost of stock-out.
- *Reduce stocks of products sold less:* focusing on A-Class products.
- *Analyzing the life of products:* subdividing the products into Classes, considering even if these have a seasonality or not.
- *Set the best location:* locate high turnover products in an area that allows a more efficient management.
- *Reduce stocking and picking time:* standardizing procedures.

With the aim in reducing inventory management costs and increasing the company's profitability.

Within the 1215 items considered, there are 283 related to the Living division and Injection processing. According to company directives, the production of these two product categories has been temporarily suspended for commercial reasons.

Then, it will pass from 1215 items to 932, which will be finally transferred to the finished products warehouse of the Thermo-hydraulics. The new ABC analysis is as follows (see figure 37):

CLASSIFICATION OF THE ITEMS (ABC ANALYSIS) - WITHOUT LIVING DIVISION						
TOTAL STOCK ITEMS			AVERAGE ON SOLD OF THE THREE YEARS		CURRENT LEVEL OF INVENTORIES	
932			70979		27969	
CLASS	N° OF ITEMS	QUANTITY OF PRODUCTS SOLD	% ON ITEMS	% ON SOLD	LEVEL STOCK ITEMS	% ON STOCK LEVEL
A	241	56719	26%	80%	12673	45%
B	243	10713	26%	15%	6746	24%
C	448	3547	48%	5%	8550	31%

Figure 37: final ABC classification regarding 21st/Garden/Ambiente warehouse.

As we can see in Figure 37, we still have a high percentage of C-Class items, equal to almost 50% of the total, which generate only 5% of the sales. The 95% of the sold is given by 52% of the items in stock (A-Class and B-Class).
The above analysis did not consider the "not-sold", defined as D-Class. This is split into two categories:

1) *Ruined*: they will be rejected and not considered in the new layout.
2) *Out of list*: they should be sold, perhaps at a lower price or at the purchase cost.

D-Class is equal to 170 items, which include 194 pallets for a total amount of 5500 products and an industrial cost of 55,000 Euro.

Therefore, during this workshop, we had to deal with a large amount of ruined and obsolete products. If we consider the obsolete, together with the Living and the injection products, they represent almost 30% of the items in stock. As a result, the workshop faced an additional problem compared to what was emerged during the "future vision". Since, the first workshop did not go into the details of each single operational activity, otherwise it would be lasted much longer. In order to respect the Kaizen philosophy, which teaches us "*small steps and short execution times*", we decided to work at the macro level.

According to that, we focused on the management of “not moving”, having a total amount of 350 different items and 450 pallets to re-locate in another warehouse, different from the one object of the analysis. We chose the department G, which is not used except as a temporary storage area for some extra order. For these reasons, the workshop has scaled down its goal.

What’s next?

Contextually, since in any case the workshop activities would have carried on towards the set goal, before coming to an integration, we worked on a new layout of the 21st/Garden/Ambiente warehouse, which would be more functional to that of the Thermo-hydraulics division. We used the time we were supposed to spend in rearranging the Thermo-hydraulic warehouse, by managing all the “not moving”.

What has been done?

What emerged during the workshop activities was that the workers spent the most of the time in unloading the pallet from the top floor to the ground one, in order to get the necessary products to complete the picking list, re-package the pallet and store it again in the shelving. Despite this, the product locations within the warehouse were not defined. In this way, the workers were forced to turn around the warehouse several times before picking what they were looking for. All those movements without value added are synonymous of waste.

Hence, we moved to analyze where the items of A-Class, B-Class and C-Class were located within the warehouse (see figure 38)

CLASSIFICATION OF THE ITEMS (ABC ANALYSIS)					
EUROPALLET TOTAL CAPACITY AVAILABLE ON THE GROUND FLOOR				600	
CLASS A		CLASS B		CLASS C	
TOT. N° OF PALLET IN THE WAREHOUSE	364	TOT. N° OF PALLET IN THE WAREHOUSE	291	TOT. N° OF PALLET IN THE WAREHOUSE	421
TOT. N° OF PALLET ON THE GROUND FLOOR	183	TOT. N° OF PALLET ON THE GROUND FLOOR	140	TOT. N° OF PALLET ON THE GROUND FLOOR	170
% ON THE GROUND FLOOR	50%	% ON THE GROUND FLOOR	48%	% ON THE GROUND FLOOR	40%
% ON THE TOTAL CAPACITY AVAILABLE	31%	% ON THE TOTAL CAPACITY AVAILABLE	23%	% ON THE TOTAL CAPACITY AVAILABLE	28%

Figure 38: % distribution of A-B-C-Classes on the ground, within the 21st/Garden/Ambiente warehouse.

As we can see from figure 38, the ground capacity of the 21th/Garden/Ambiente warehouse counts 600 pallets, in fact there are 161 shelving available that can hold, on average, 3 or 4 pallets each. Regarding A-Class, 364 pallets are storage of which only 183 (50%) are located on the ground, occupying 1/3 of the overall capacity. Even for the B-Class, we have a 50% on the ground that occupies 23% of the available capacity. While, for the C-Class, this is present on the ground for 28% of the total capacity, more than the B-Class and very close to the A-

Class even though it has a lower turnover rate. Moreover, none of these items is located according to a precise logic. The ground floor together with the first floor can storage almost 1100 pallets; here, we have 1076 pallets in total (291+354+421), which could be stored only in the first two levels, thus having the whole second floor free.

We decided to redesign a new warehouse layout, according to ABC picking rate frequency, in order to facilitate the picking activity. We introduce a new concept of optimization of stock location, giving a fixed place to the high-rotation product and its stock over, on the last floor, with the subsequent lowering. Logically, we consider fixed the location on the ground, where A-Class will be placed. The products of B and C Classes will occupy the second floor. The third floor will not have a fixed location, as there will be the stock of A-Class.

The implementation of what has been said and its consolidation (both at the practical and at the information system level) would have allowed the next step, the re-arrangement of the finished product warehouse of the Thermo-hydraulic division, much simpler and automatic, because we have already acquired a method. What we should do, will be moving the rest of the products, having already set a solid procedure. If we had proceeded differently, probably the change would be too traumatic.

We thought to manage the lowering activity in a standardized manner, which consists of the following activities:

- During the daily activity, presumably from the morning until 4 pm, only picking operations are carried out.
- From 4 pm to 5 pm, two specific workers are in charge and, thus, accountable for restoring the goods through lowering activity.

Today, the operator could do both picking and lowering activities, without any division of tasks. In most cases, to comply with the picking list, the lowering was rarely performed, if not those times that became necessary. However, most of the times the workers took the nearest matching pallet in order to reduce the picking time. With this new standardized procedure, if the worker has an order on the ground floor and the shelf is empty, since the lowering operation was not done previously, the latter is forced to do so. In this case, the daily picking productivity will be reduced. For this reason, it is important that the transfer from the last floor to the ground one be always executed; otherwise, the computer system records the picking order engaged (not available). Fixed stock locations and a standardized procedure absolutely improve the efficiency of the warehouse in terms of lead time and costs, having greater control over the products.

Therefore, according to the new location and ABC analysis previously made, we began to restoring all items, starting with the A-Class, introducing Kanban logic. In calculating the exact number of Kanban to be managed in the warehouse, for each item, the following parameters were taken into consideration:

- *Production Lead Time* → needed to restore the product in the warehouse (LT).
- *Minimum production lot* → in reference to some constraints that characterize the manufacture of some products (color, setups of molds, necessary human resources).
- *Maximum daily consumption during the Lead Time* → by dividing the respective total average over the past three years with the number of annual working days (C).
- *Current quantity on the pallet* → how many products of that specific item can be on the pallet. This is an independent variable (Q).
- *Other constraints* → the type of container (it could be a pallet, with different measures, or a cage depending on the type of item), the volume of the products and the storage capacity of the various shelving within the warehouse.
- We consider, in our calculation, for some critical products the related to SS (Safety stock).

The Formula is the following: $Kanban\ Number = \left(\left((C \times LT) + SS\right) \div Q\right) + 1$

This methodology has been applied to approximately 80% A-Class in stock (190 items out of 241). Of these 190 items, 60 are already working: the 21st/Garden/Warehouse for those items is working according to the *Pull* logic. In other words, excessive stocks will no longer be produced, but the company will work to restore what actually consumed. Obviously, the whole system of creation of the Kanban is computerized, supported by a specific software that works in parallel to the company one. The management of the tag will still be physical and will take place in the following way: the consumption of a Kanban product will generate a signal to the Production Planning department that will have to plan its restoration. How? Printing a new specific Kanban of that product and delivering it to the head of department P, which is the supplier of the 21th/Garden/Ambiente warehouse, who will know what should be produced. Given the high seasonality of the products, we decided to calculate the average consumption, not on 220 working days, but on 110. Therefore, the Kanban stock stored is much higher than what is a real average consumption. If this is not enough to guarantee a certain service to the customer, it will be possible, for some critical products, to produce an extra lot that will be stored and managed separately.

During the workshop, it emerged that the shipment management, both from an administrative and transport organization point of view, is not defined at all. It often happens that the head of the 21st/Garden/Ambiente warehouse is not aware of when exactly shipments occur, as the management of some types of finished products is carried out in a discretionary manner. In fact, there are products fully managed in this warehouse, while others are administered by the Thermo-hydraulic warehouse for reasons related to storage capacity or shelving dimensions. Sometimes, a product is stored in the shelving on the second floor, when shortly after, it must be picked up and brought to the Thermo-hydraulic warehouse for the final transport to the customer.

The goal was to reorganize the areas inside the warehouse, providing a new layout that would approach a concept of integration, both in terms of procedures for order fulfilment and management of the finished product. With the aim to achieve this objective, we analyzed the main product flows within the warehouse and then, we calculated the respective kilometres traveled (see Figures 39 and 40).

TYPE OF ITEMS (PLASTIC)	N° OF PRODUCTS	METRES TRAVELLED	METERS ON PALLET	N° OF PRODUCTS ON PALLET	TOTAL KM TRAVELLED FOR PRODUCT (PLASTIC)
EASY TANK	1486	100	148600	2	74
FEKABOX 200/280	1836	230	422280	4	106
LOWARA	2062	206	424772	4	106

Figure 39: analysis of the kilometers traveled by the products of Plastic division.

<table>
<tr><th colspan="4">ITALY</th><th colspan="2">ABROAD</th></tr>
<tr><td colspan="2">MOVEMENTS FROM WAREHOUSE 099 TO WAREHOUSE 100 (GARDEN)</td><td colspan="2">MOVEMENTS IN WAREHOUSE 099 (GARDEN)</td><td colspan="2">MOVEMENTS IN WAREHOUSE 099 (GARDEN)</td></tr>
<tr><td>N° OF PALLET</td><td>1736</td><td>N° OF PALLET</td><td>1436</td><td>N° OF PALLET</td><td>195</td></tr>
<tr><td>KM TRAVELLED</td><td>478</td><td>KM TRAVELLED</td><td>96</td><td>KM TRAVELLED</td><td>13</td></tr>
<tr><td colspan="4">TOTAL N° OF PALLET</td><td colspan="2" rowspan="2">TOTAL KM TRAVELLED GARDEN + PLASTIC (ITALY)</td></tr>
<tr><td colspan="4">3172</td></tr>
<tr><td colspan="4">TOTAL KM TRAVELLED (GARDEN)</td><td colspan="2" rowspan="2">860</td></tr>
<tr><td colspan="4">574</td></tr>
</table>

Figure 40: analysis of the kilometers traveled by the products of Garden division.

As we can see from figure 39, the products of the Plastic division are subdivided into three categories: Easy Tank, Fekabox 200/280 and Lowara. We analyzed the annual internal mileage that are made for the management of these products, from packaging, to storage and the following shipment.

For example, once a pallet of Easy Tank has been produced, it takes 100 meters before arriving in shipments. Considering that in the year were sold 1486 Easy Tanks and each pallet contains 2 of them, we would have a total of 743 pallets shipped or better, 74 kilometres annually traveled. The same reasoning has even been applied to the products of the Garden division (see figure 40). The management of such products is not defined according to specific criteria: sometimes it is only the 099 warehouse (21st/Garden/Ambiente) to deal with them while other times, instead, there is a transfer from the 099 warehouse to the 100 (Thermo-hydraulic) one.

In this case, the total travelling about the Garden division is equal to 574 kilometres per year. The transfers and the shipments abroad count13 kilometres per year and do not significantly affect the analysis, as they are carried out occasionally and never taken into account by the warehouse 100. Both divisions (Plastic + Garden) generate a total of 860 kilometres per year (almost 4 km per day).

The graphic representation of the outbound logistics flows is highlighted in Figure 41 and 42.

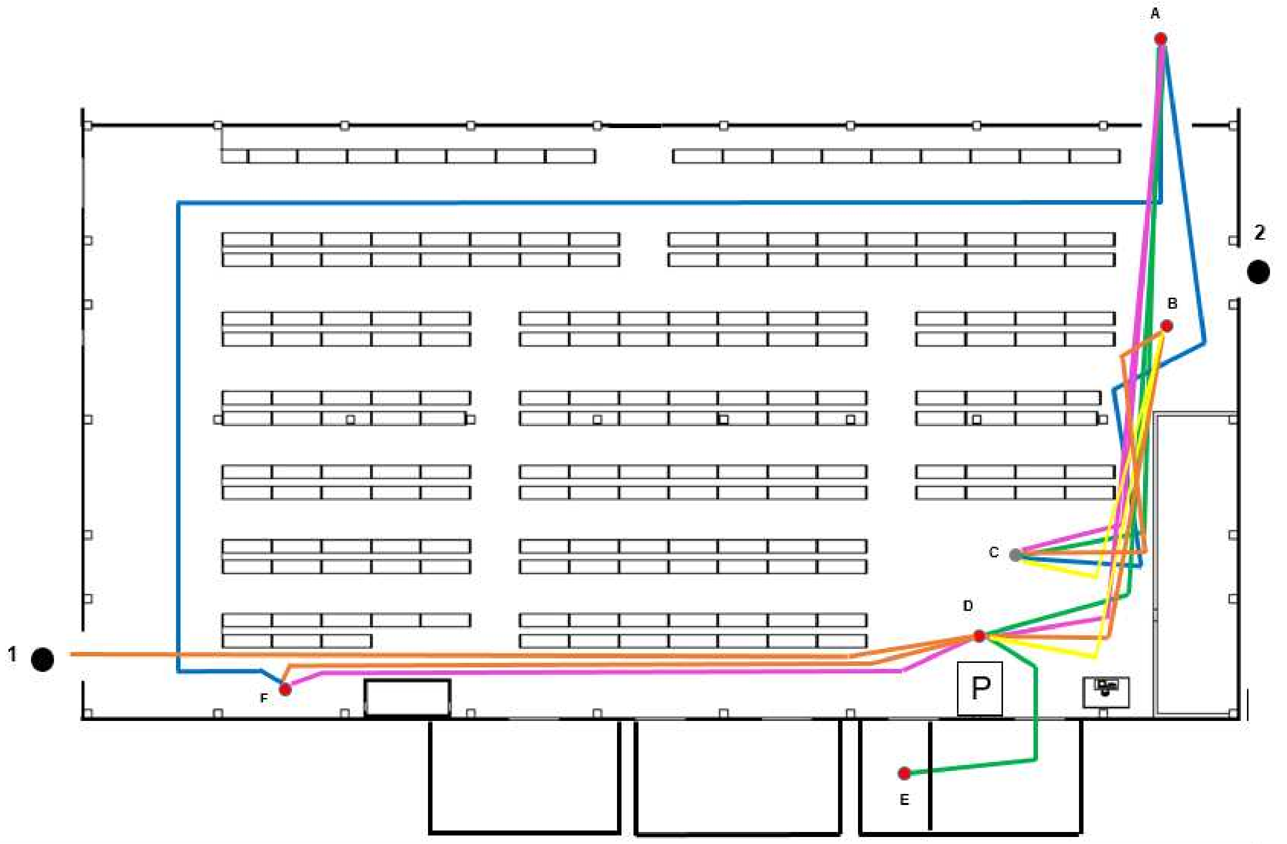


Figure 41: analysis of the logistic flows of the Plastic and Garden product divisions within the warehouse 099.

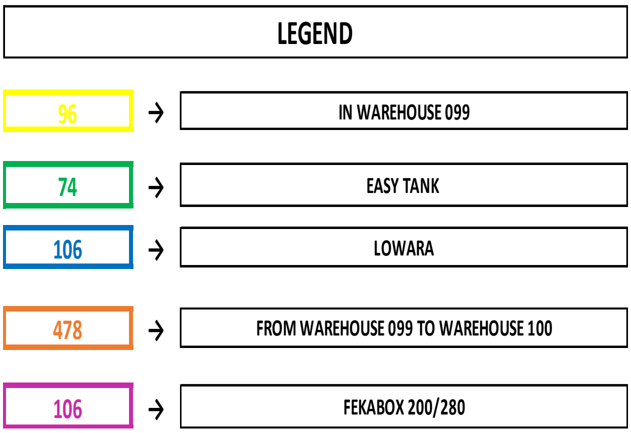


Figure 42: legend of the analysis of current logistic flows regarding Plastic and Garden products.

With reference to figure 41, the symbol (●), from A to F, points out four points that have been identified as collection areas or processing of products within the warehouse. Specifically:

- A ●: this point is located inside the department P and is reached by the workers of the 099 warehouse when they have to collect the finished product and bring it into their warehouse.
- B ●: consists of a small area inside the 099 warehouse, where the workers of the department P store some finished products.
- D ●: coincides with the packaging (P) activity of the finished product.
- E ●: In this delimited area, the Easy Tanks are stored.
- F ●: consists of a small area inside the 099 warehouse, where the workers of this warehouse store some finished products. Then, the workers of the 100 warehouse, before shipping, subsequently collect them.

The symbol (●) shows two areas (1 and 2) where the truck is loaded and the finished product is shipped. Today, the 099 warehouse has two loading areas, one (1) shared with the warehouse 100 and the second (2) managed independently by the head of the warehouse 099. There is no particular logic in the use of one rather than the other, if not for the Easy Tanks, which are loaded only in area 2.

The symbol C ● identifies a central area in the warehouse, considered the fulcrum of the activities. Around this area, there is the largest influx of workload.

As we can see from the logistic flows of figure 41, the movements that take place between the two warehouses, 099 and 100, are those that have the highest impact on the total (more than 50%). Starting from area C, the worker reaches up to B, where these products are stored, then go to D (where the packaging is made) and, finally, transport the product to the warehouse 100 or leave it stored in the F area.

A very similar route is carried out by the Fekabox 200/280, which is collected in the department P, in area A, and subsequently stored in F, after being packed, waiting to be picked again by the workers of warehouse 100. The only product that does not undergo any type of processing inside the warehouse is the Lowara, which is collected in point A and stored directly in point F, by the workers of the 099 warehouse. The products that are managed exclusively by the 099 warehouse, with a total annual distance of 96 km, are packed and stored directly. The shipment of these products is mainly executed in area 2. This analysis is shows the following waste:

- *Ship management activities are not defined*: the choice to load the trucks in area 1 rather than in area 2 is based on the discretion of the department head or it could be influenced by other reasons, due to the optimization of the transportations. In any case, there is no linearity in the execution.
- *The 100 warehouse uses an order fulfilment system different from the one of 099:* going towards a concept of integration also means working with similar procedures.
- *Logistic flows occupy a very large area within the 099 warehouse:* there are objective difficulties in creating a continuous flow from beginning to end. Non-standardization of flows can become a problem, obstructing the passage of the necessary resources for daily activities and slowing down the packaging and storage processes.
- *Presence of various areas of goods storage inside the warehouse:* areas A, B and F are not adequately managed and they can create situations of inventories build-up. An adequate supervision cannot be guaranteed, since the tasks are not shared among the different workers.
- *The management of some products is not optimized:* different departments (plastic department, warehouse 099 and 100) process some products several times. The same departments do not always do the same activities.

This current layout and the way of working hinder the achievement of an optimized logistic flow, which is marked by different wastes, being also far from a concept of integration.
We designed a new layout (see figure 43).

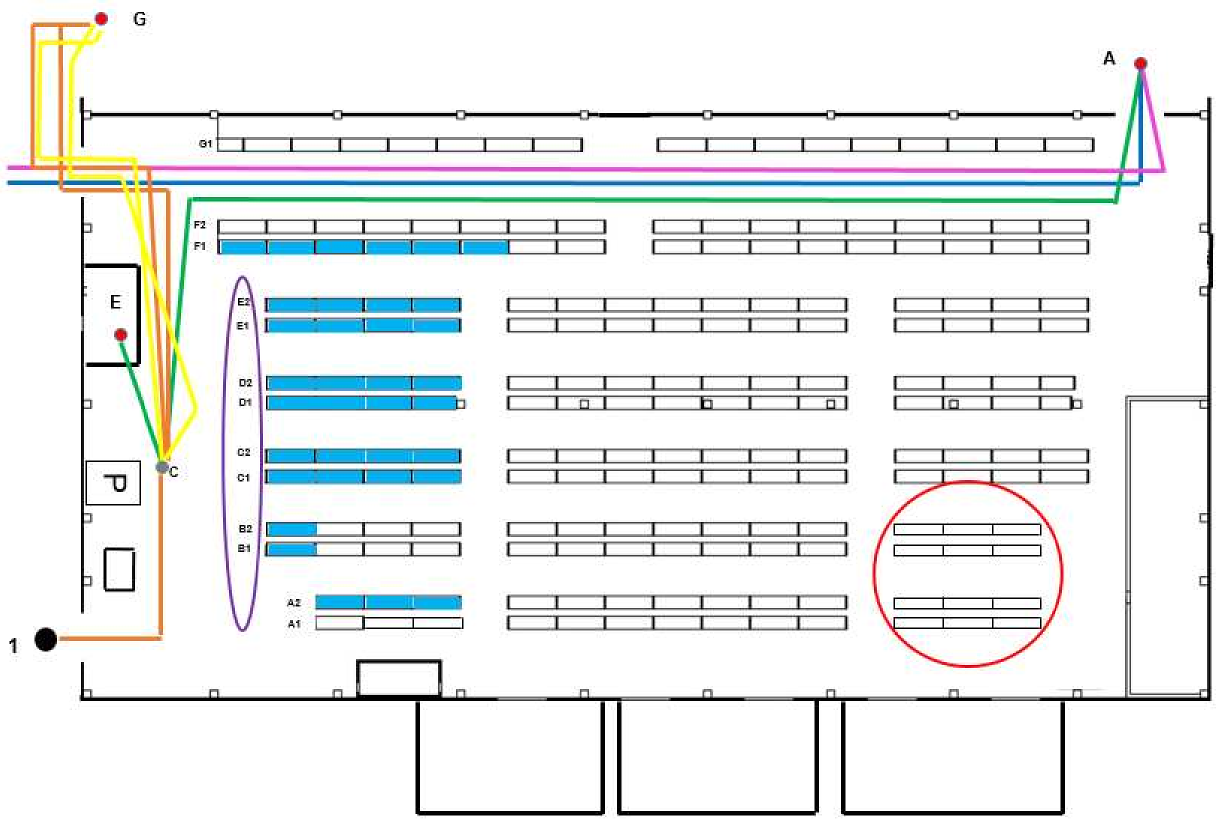


Figure 43: analysis of the logistic flows of the new layout of the Plastic and Garden product divisions within the warehouse 099.

The rearrangement of the layout consisted of the following corrective actions:

- *12 shelving units were moved (those circled in purple in the figure above)*: we positioned these shelving where previously there were the packing machine and the area C ● (in the layout they are circled in red). In this way the storage capacity remained unchanged.
- *The packing machine and the office have been moved close to the area 1*: it was decided to no longer use the area 2 (truck loading), so as to use a single area common to both warehouses, moving towards a concept of integration even from the point of view of shipments.
- *As a result, the focus of the activities, the area C ●, now is on the opposite side than before*: it coincides with the packaging and it is closer to area 1.
- *The management of the Lowara and Fekabox 200/280 passes completely to warehouse 100*: the workers of warehouse 100 are supposed to go to area A in order to collect the finished product and then, transport it in their warehouse for the packaging. In this way, the warehouse 099 is completely outside from the management of such products.

- *The Easy tanks will continue to be managed within this warehouse*: the deposit area was created near the packaging. For reasons of space and shelving capacity, this type of product cannot be stored in the warehouse 100. They will be loaded into trucks in area 1.
- *The concentration of logistics flows occurs between lanes F2 and G1:* the shelves of lanes F2 and G1 are used as a storage area of the molds of the department P. For this reason, there is not a high flow of movement within these two lanes. In this way, there is no longer the risk that the handling of these finished products (incoming and outgoing) could cause delays in picking and internal management, as the routes are defined and far from the heart of the warehouse.
- *The management of the products that is completely devoted to the warehouse 099 (highlighted in yellow in figure 43) remains unchanged*: the only thing that changes is the supply area. We move from the area A to the area G, which is closer in terms of distance. Area G coincides with a new "finishing" solution of the department P that will be discussed later (see figure 44).
- *The same reasoning is applied for the movements between warehouse 099 and warehouse 100 (highlighted in orange in figure 43):* if the product will be packed in the warehouse 099 then, it will be this one in charge of its shipment. Vice versa, if it is the warehouse 100 accountant of its management then, it will take care of the packing activity (division of tasks).
- *In the figure 40, there are some shelves, colored in blue, which will be used to store A-class goods:* these are the ones closest to the packaging, which is the previous activity before stocking, and the area 1, which is where they will be shipped. These 35 shelves, between the ground and the second floor, can accommodate about 250 pallets or better, the 70% of the A-Class (250 out of 364). This will be the starting point for the storage of goods. Then, we will expand towards the end of the warehouse (on the right), stocking the C-Class.

Before coming to this conclusion, we analyzed the "Pros" and "Cons" of this possible new layout, compared to the previous one:

- *Actual layout* (see figure 41)
- Pros:
- Picking optimization through storage of goods according to Kanban logic and ABC inventory turnover rate. The introduction of these improvements could be the same without moving the shelves, packaging etc.
- Proximity to the supplier (department P). The distance between area A and C is minimized.
- No implementation costs.

- Cons:
  - Any kind of integration with the warehouse 100.

➢ New layout (see figure 43)

- Pros:
  - Picking optimization through storage of goods according to Kanban logic and ABC inventory turnover rate.
  - Integration between the staff of the warehouse 099 and 100 that would work closer together and with only one shipment loading area.
  - Proximity to the customer (warehouse 100). Moreover, the management of some products (Lowara and Fakeboc 200/280) will pass completely to the warehouse 100. The warehouse 099 will have more autonomy, thanks to the standardization of tasks and procedures.

- Cons:
  - Physical displacement of the packaging, office and shelving areas.
  - Investment cost: three new sliding doors should be purchased, in order to facilitate workers' operations. All the electrical and air system must be linked with the new layout.
  - There is a move away from the supplier (the department P through the area A).

One of the negative aspects of the new layout coincides with the distance from the area A, which is located inside the department P. Therefore, we decided to review the layout of the finishing process, which is the last activity performed, before the product moves into the warehouse 099. Currently, the finishing takes place in two separate areas and five people are needed, in order to guarantee the expected performance. Talking with the head of department P, the fact that the finishing process is not managed as it should came up. As a result, there are high product rejects and there is a constant accumulation of WIP, as the process is not continuous. The first activity of this processing concerns the labelling of the product, which is performed on the line near the oven. Why? Because in this way the worker, through a purely visual quality control, realizes if the product, which has just finished the cooking process, is actually that expected or if there are any anomalies. If the product, once it undergoes the cooking phase, goes to finishing process without stopping in temporary transit areas, then the labeling could be carried out directly during the finishing phase. But since we are not aware of when the product will actually come in finishing, due to lack of staff and organization of the activities carried out, the labelling is executed immediately, in order to have the time necessary to report any defect and re-launch the production. Today, the finishing is performed where the product is labelled and the specific area, where such product is labelled, depends on who is doing that. To make sure that all the activities are carried out during the finishing processing, it is necessary to implement a new layout that includes all the processes, which is able to provide a constant rhythm of processing, with a single storage area of the finished product. The proposed solution is highlighted in figure 44.

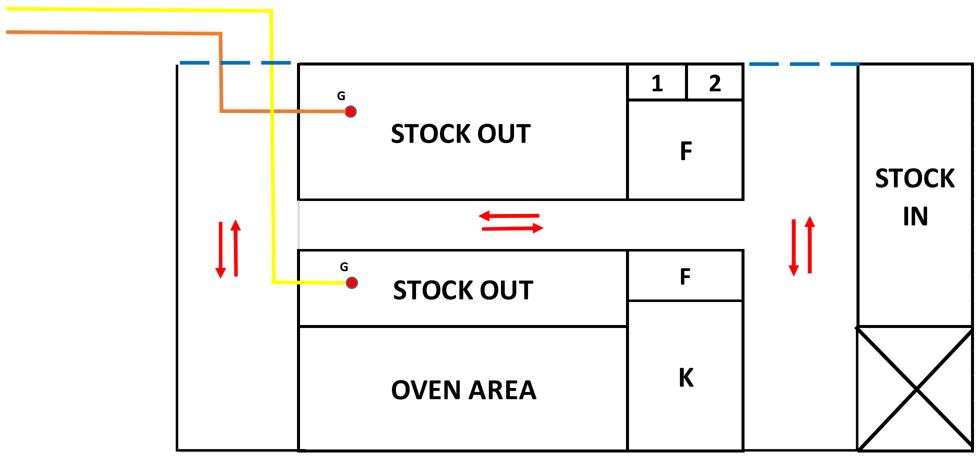


Figure 44: new layout of the finishing process within the department P.

In accordance with figure 44, there are three main areas, which are as follows:

1) Stock-in area → where the pallets will be stocked waiting to be collected by the workers of the warehouse 099.
2) Stock-in area → only one area where all the products will be stored.
3) Area F → where the finishing process is carried out.

The areas 1 and 2 contain all the materials (equipment, labels and nylon) necessary to perform the finishing process. The area K is dedicated to the management of the Kennels.

With this last activity, this workshop can be considered concluded. There are some *To-Do*, emerged during this workshop, that will be carried out later by who has been in charge (see figure 45).

TO - DO	WHO?
Displacement of the office and the packaging machine	Plant director
Standarization of the procedures regarding the management of the Lowara and the Ferabox 200/280	Plant director and warehouse 100
Ultimate the layout of the finishing process, within the department P	Plant director and department P
Introduction of lowering management at the information system level	IT office and Warehouse 099
Keep working on the creation of Kanban for A-Class and B-Class	Warehouse 099 and Production Planning department
Installation of sliding doors	Plant director

Figure 45: To-do list (what should be done and by whom)

4.5. Third project: Improvement of Assembly lines by studying Cycle Times

The third project carried out by KaizenKey srl concerned the analysis of the cycle time of the assembly lines within the department M. This analysis aimed to define a new balancing solution based on a redistribution of workloads. In doing that, we developed a Time and Methods framework, which is particular useful in order to calculate the standard cycle time within the production cycle.

The need to do this type of analysis, relative to the department M, is due to the fact that such department produces several pieces a day and it is the only one that is connected to the previous workshop activities, in terms of process and logistic service. As we know, all the products that come out from the department B and C are assembled in the department M. The analysis was performed only for the lines from D to G, where all the products (expansion tanks and autoclaves) from 35 to 500 liters are assembled. The coding of the expansion tanks is of two types: these can be ERCE or DV, depending on the type of product. While the autoclaves are coded with the acronym AFV.

Before starting talking about how to improve the productivity of an assembly line, it is relevant to understand: "how *Assembly Line* works" and in "what consists the function of the *Time and Methods* analysis". Those are the starting point for implementing a new balancing solution.

The production process, which is most often characterized by a strong presence of manpower, is the assembly one that typically constitutes the final phase of production, mainly in manufacturing. Generally, the assembly activity is carried out by means of a series of operations of composition of parts by insertion, union, screwing, etc., which in most cases enjoy the property of being reversible. In the course of industrial development, the concept of assembly has certainly undergone significant changes; from the organization oriented to the production of a single product (at the time of H. Ford with the T-model), to the need to diversify as much as possible the product to meet the needs of the customer. As a result, even production times have undergone significant changes: from the rigid design of production times to the flexibility required today. The assembly lines can classified, by type of working and manufacturing process, into three distinct categories (see figure 46):

1) *Single-model*: this kind of assembly line is used within the production of a single product and all the pieces assembled are identical to each other. The line runs continuously without having to perform set-up.
2) *Multi-model*: this kind of assembly line is used for the production of batches, each of them composed by only one model of product. This assembly line allows the short-term lot sizing issues related to set-up operations between the different lots. This type of production takes place in order to minimize the cost associated with setups, for each lot.
3) *Mixed-model:* in this kind of assembly line, the setup time between the different models is less relevant then before and it is enough to be ignored. Within this configuration, the workers assemble smaller lots or unit of different models in a mixed sequence, one after the other. In this way, the company can easily adapt to the fluctuations in demand without excessive stocks of finished products.

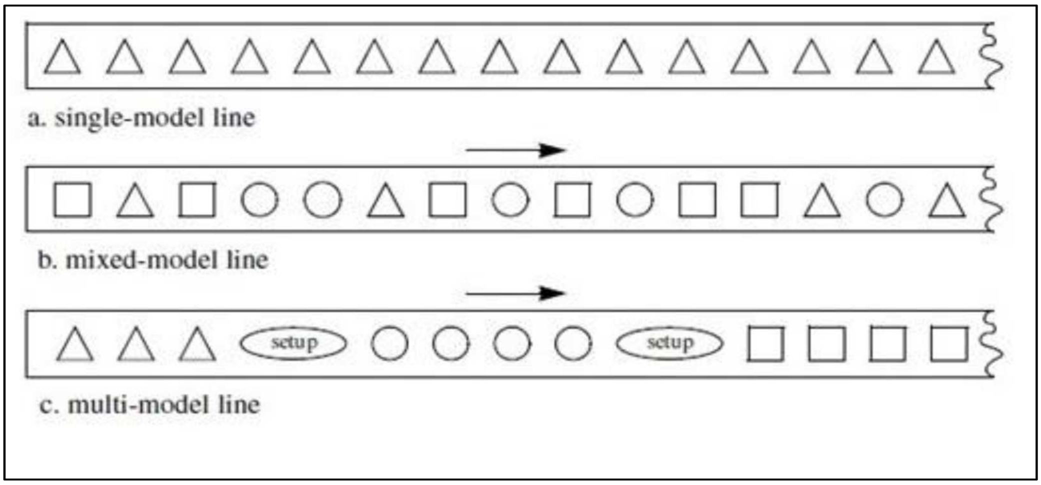


Figure 46: types of assembly lines.

For greater clarity, it is considered appropriate to introduce immediately the main terminology that will be used throughout the text, which is necessary for an effective description of the assembly lines.

- *Task*: this is a fraction of the total work content necessary to obtain the finished product. The time required to perform such task is called Task time. All the tasks are considered indivisible, in the sense that they cannot be divided into operations that are more elementary.
- *Station*: it coincides with a portion of the assembly line in which a certain number of tasks are performed. The elements that make it possible to identify the different stations along the assembly line are the equipment and machinery, as well as the type of work assigned. Either the stations can be automated, where there are machinery that works automatically, or manual, where, instead, operators use specific tools or semi-automatic machines do perform their work.

A station will be treated as a previous to another if it is, compared to the latter, closer to the beginning of the assembly line.

- *Cycle time*: it represents the time needed to manufacture one single product (Mattson, 2004) or better, referring to the specific operator, it coincides with the time he or she needs to perform his or her tasks (Rother and Shook,2002).
- *Work content*: it is given by the sum of the task times assigned to a specific station.
- *Throughput time*: it is the time taken by the product to transit through the process (in this case the assembly line). It also includes the time spent in the queue between one station and another of the assembly process.
- *Balancing line*: it consists in the decision to which tasks should be allocated to each of the stations in the assembly line. It aims in maximizing the production rate by minimizing the number of workstations.
- *Standard time*: is the time that the company assigns to the resources involved in a specific operation in order to perform it, according to a specific established method.

The assembly lines are typical flow systems in the industrial production of large quantities of standardized products. Their manufacturing process is defined as "continuous", with very high volume, low variety and the work can be very repetitive. They are part of those production techniques called "mass" or "flow", characterized by a sequential arrangement of machinery, such as to reflect the technological sequence of operations necessary upon completion of the product. The typical configuration layout is that of “product” or “line”, where the transformed resources flow along a line of process through a prearranged route consisting of a number of stations connected to each other, in which the sequence of activities have been located.

One of the first points for solving assembly problems is determining the times of each individual tasks. From a practical point of view, this data is difficult to obtain, besides being the input for the subsequent analysis (balancing line), essentially for two reasons:

1) The costs related in obtaining the data are high. Time recording activity does not create added value in the product and therefore it has seen as a cost by companies. The Time and Method offices are interested in this data more as cost analysis for the final reporting of production operations than for reasons related to design and optimization.
2) In the case in which there are different models, the number of data to be obtained would be too high. Furthermore, for new products there is not even a historical to be based on.

The function of the Times and Methods deals with the following activities:

- Collect data related to methods, times and conditions of the production environment through labor measurement techniques.
- Describe the processing cycle and the related methods used.
- Calculate the Normal Time.
- Increase Normal Time based on working conditions.
- Get the Standard time, keeping its reliability updated over time with reference to technological improvements.
- Elaborate the data collected according to the logic as objective and clear as possible, sharing them with the rest of the corporate functions.

Therefore, it is important to define the two fundamental concepts underlying this study: the *Method* and *Time*. The *Method* is a rational way of proceeding to achieve certain results. The different methodologies carried out by the operators are analyzed and, after an accurate evaluation, a better method, for performing such activities, is identified. *Time* is the dimension in which the passing of events is conceived and measured.
There are several techniques for measuring Standard Cycle Times. This process varies depending on how the working time is observed. Two main methodologies can be included:

1) Time-and-motion-study technique (Bedaux, 1900).

This technique involves using the stopwatch as a tool for time measuring. This method aims in detecting several times the time necessary to execute a task. The first activity, performed by the analyst, consists in the "description of operations performed by the operators". In this case, there is the decomposition of the working method, indicating the sequence of the operations to be measured. Furthermore, the activities are separated from human resources and machine, which will be observed separately. The tasks are further divided into cyclical and acyclical. The execution of the time study (Bedaux) technique consists in the contemporary and repetitive collection of two fundamental information: the working time related to the measured operation and the so-called "*efficiency Bedaux*" of the operator who perform the task. The efficiency Bedaux refers to a subjective judgment of the analyst on the speed and precision that the operator has in performed the assigned task. During the analysis of the production cycle, the analyst must therefore simultaneously measure the time of each activity and identify the operator's efficiency in that specific activity for each measure of the processing cycle.

Consequently, the Normal time will be calculated in proportion between the time taken for each activity and the corresponding level of efficiency established. These Normal times require some additions related to physiological needs (going to the bathroom, coffee break, psychological recovery, etc.), unforeseen events (micro-stops, lack of material, anomalies, controls etc.) and fatigue (physical effort, nervous tension, monotony of work, danger, etc.). The final result obtained coincides with the Standard time.

2) Methods-time-measurement (H.B. Maynard et al., 1940) and its derivatives (MTM2 and MTM3).

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The basic principle of this technique is the following: "Every elementary movement requires, if performed by a sufficiently skilled performer, always the same time, under equal conditions". This technique is based on the analysis of the working method decomposed into micro tabular movements. The micro-movements are very detailed and their composition, in the correct sequence, represents the method in its entirety. In fact, the object of this technique is the method and not the movement (the operator specifically). No stopwatch is required; just a table in which the basic movements are provided. Times are expressed in particular units, called Time Measurement Units (where 1 TMU is equal to 0.036 seconds). Each basic movement has an accurate description within the reference table. The preparation of the detection takes place in the same way as for the Bedaux technique: decomposition of the working method into identifiable and measurable phases, with separation of cyclic and acyclic operations. In performing the MTM recorded, the analyst will instead ask the operator to execute the method clearly and slowly, in fact it will not be necessary to ascertain the speed and precision with which the operator has completed the activities, but it will be important to correctly determine the method and movements within the processing cycle. Once the sum of the values has been calculated for each of the detected movements then, the Normal time will be determined. This Normal time requires some addition that will lead to the definition of the Standard one.
The obvious laboriousness in using the MTM has suggested the development of more simplified versions called MTM2 and MTM3. Both are two tabular systems, more concise, which contain a limited series of movements, but having a greater error in terms of clarification, although a faster application.

In addition to these two methods, there is another one based on statistical analysis, which is called *Work Sampling*. It provides that the analyst observes how a specific operation is performed at random times, in order to obtain useful information for the success of the analysis. The logic of this system is based on the statistical observation of a sample of events and therefore the production time is estimated because of a series of information collected in the field. This method evaluates the percentages of time that a worker spends carrying out different tasks: the timing proportions observed during the performance of the sample work are the same proportions of time spent in the activity in general.

In recent years, we have witnessed a significant increase in automation within production systems. This derives from a series of advantages that these systems offer: from the increased in production capacity (machines that can work 24 hours continuously) to a high quality standard, to the opportunity in monitoring easily production data. However, there are many companies with manual assembly production systems. This is the case of Elbi spa, where the assembly activities, taken into consideration in this analysis, are completely performed manually.

4.5.1. Analysis

Before starting talking about the analysis, we observed the current situation of the department M, concerning the assembly lines D, E, F and G, which will be the object of the subsequent study. We identified the following waste:

- *The maximum capacity of the department is not fully exploited*: the department M is organized, as regards the assembly from 35 litres to 500 litres, on four assembly lines of which only two are working (line E and F) and perform the same activities. The other two lines, D and G, are used occasionally, in order to provide quality control or maintenance work, but for 90% of the time they are idle.
- *There is a high degree of discretion in carrying out the activities*: in each of the two lines, there are three operators who work according to a method that is not defined. Moreover, the activities are not standardized and often unclear.
- *No interchangeability by operators 1*: there is a low degree of polyvalence and rotation within the assembly line and from one to another. Especially regarding the operators 1, while operators 2 and 3 sometimes rotate in the two lines.
- *The assembly process is highly disorganized*: there is no kind of daily productivity and it is not possible to measure the performance of any operator.
- *Poor supervision by management*: there is no control of responsibility on what should or should not be assembled by the operators.
- *The flexibility of the lines is not exploited*: the production model adopted is the batches one and, specifically, the assembly lines fall into the Multi-model category. This type of configuration is desirable when set-up times and costs are high. In this case, working on autoclaves and expansion tanks, the flexibility of the line is an advantage, because the transition from one to the other (from an autoclave and an expansion tank or within the same type of product) involves very low setup times.
- *Complete absence of daily goal through a Visual Board*: operators are not part of what goes beyond their mere daily assembly activities.

Secondly, we defined the Method to be used in order to develop an appropriate analysis. According to the several methods listed and described above, with regard to the detection and calculation of the Standard Cycle Time, we pointed out the following limits:

- Time-study (Bedaux):

  - Subjectivity in the definition of the analyst's judgment of efficiency on the activities carried out by the operators.
  - The analyst is forced to time and, at the same time, evaluate the production process, so he or she may have difficulty in questioning the working method used by the operators as he or she is very busy during the detection phase.
  - Need for a sample of n° observations, so there is the impossibility of application to long and not very repetitive cycles.

- MTM and its derivatives.

  - The initial investment for the first MTM observation of a process is more expensive than that based on the stopwatch (Bedaux). In fact, there is an objective difficulty in learning the tables and applying them.
  - The parameters chosen for determining the times may not be adapted to any work situation (there are countless factors that could introduce variability in execution times and not all are taken into consideration in the tables).
  - The analyst does not calculate any working time. It is put together with the help of the tabular movements, going over again the entire working cycle performed by the operator. If the cycle were not always the same, there would be difficulties in analyzing and improving the assembly line.

- Work sampling:

  - This method does not use time detection systems, but only the activities performed by the operator, since the cycle time is calculated as a function of how the operator distributes his time available between the different tasks he has to perform.
  - Incorrect planning of observations (i.e. at the same time) may influence it.
  - It is less accurate compared to Time-study, in fact the several work activities are not divided as much as in the other techniques.

- It is not properly suitable for the calculation of all repetitive activity time.

The application of the aforementioned Methods can certainly guarantee a better result compared to what is currently present in Elbi: there is no standard productivity for every single product. Moreover, none of such Methods, despite the various limitations and disadvantages listed, is linked to Kaizen philosophy, since it is based on the analysis of Value Added activities and those of Waste.

For this reason, we set up the analysis through the adoption of a *New Method*, which consists of the following activities:

1) *Breaking down of the work performed by the operators*: in this phase, the analyst identifies all the macro tasks for each operator within the assembly line (see figure 47). Furthermore, the materials and tools necessary for carrying out the above activities are listed (see figure 48). The precedence diagram is also designed, where the constraints and sequences of the working cycle operations are defined (see Figure 49).
2) *Progressive chronometric detection performed on each operator several times* (see figure 50): by using the stopwatch, all the activities carried out by the operators are observed in a sequential manner. The task time of each activity is given by the difference between the time measured in correspondence with it and the previously one, corresponding to the prior activity. During the data collection, only one operator was analysed at a time, recording all the activities performed, trying to break them down in the smallest possible interval (up to a maximum of 3 seconds). At the same time, it was also pointed out, in correspondence to the critical activities, the reason why the operator performed them differently or slowed down the execution. At the end of the observation, the analyst talked with the operator, in order to know the reason for this slowdown or alleged problem.
3) *Analysis of each task*: once the task time of each of them has been determined then, every single task will be analyzed according to the Lean Production principles, highlighting which are the Value Added ones and those, instead, linked to a concept of Waste (see Figure 51).
4) *Analysis of the results obtained*: we analyzed, for each operator, the different percentages of time used in carrying out Value added activities rather than Waste on the total time taken. Afterwards, we compared the results in terms of any similarities or differences, knowing that the operators perform various activities and the products observed are not always the same (see figure 52).
5) *Computation of the Standard Cycle Time*: as a result of the sum between the average Value Added tasks, necessary for the assembly of a single product (considering all the three operators),

and a percentage of Waste due to the realization of the same. Then, it requires some additions related to physiological needs, unforeseen events and fatigue.

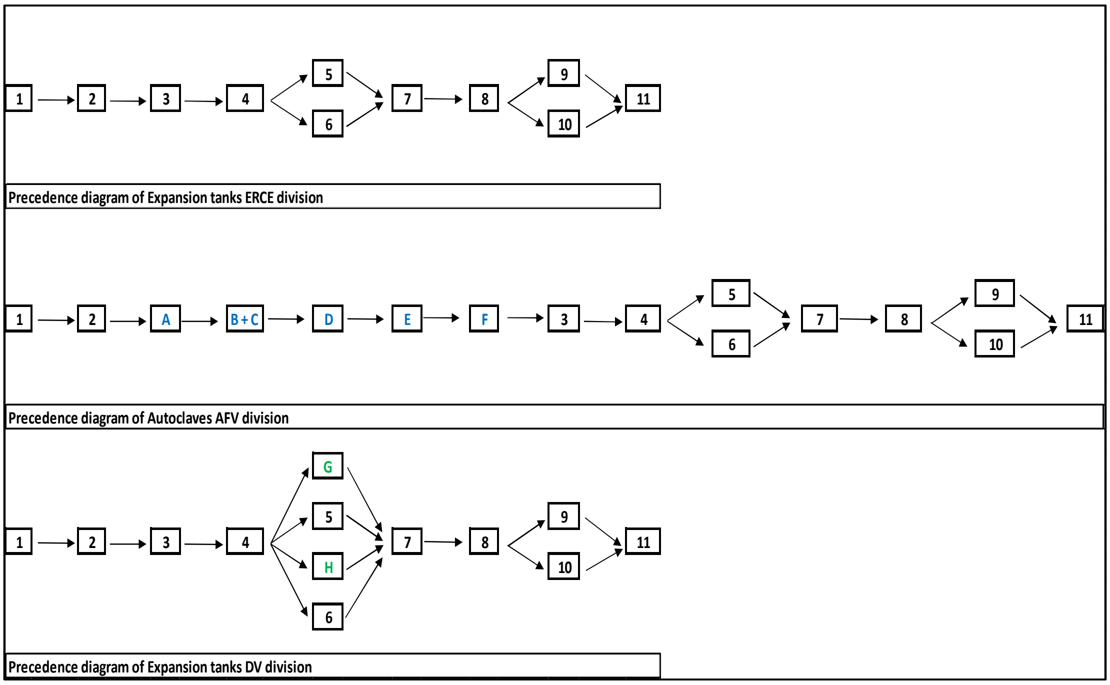


Figure 49: precedence diagrams of the products covered by this analysis.

TYPE OF PRODUCT	MATERIALS AND TOOLS USED
Expansion tank - ERCE division	valve, labels, nylon, compliance sheet, color spray, sandpaper, drill, allen key, pre charge, carton, taping machine, pallet, cutter, pen, paper, adhesive tape, pallet truck, tub, elevator, glue, mechanism.
Autoclave - AFV division	valve, labels, nylon, compliance sheet, color spray, sandpaper, drill, allen key, pre charge, carton, taping machine, pallet, cutter, pen, paper, adhesive tape, pallet truck, tub, elevator, flange, screwdriver, washer, screw, membrane, plastic, pole, hammer and nut.
Expansion tank - DV division	valve, labels, nylon, compliance sheet, color spray, sandpaper, drill, allen key, pre charge, carton, taping machine, pallet, cutter, pen, paper, adhesive tape, pallet truck, tub, elevator, glue, mechanism.

Figure 48: list of tools and materials used by the operators during the assembly process.

Operators	N° of task	Type of task
Operator 1	1	Insert of the valve
	2	Fixing the valve
	3	Insert the pre-charge
	4	Testing in the water
Operator 2	5	Put the label
	6	Put the conformity and instruction sheet
	7	Put the nylon
	8	Prepare an empty box
Operator 3	9	Put the label on the empy box
	10	Put the expansion tank inside the box
	11	Close the box with the expansion tank inside
List of the tasks performed by the operators (Expansion tanks ERCE division)		

Operators	N° of task	Type of task
Operator 1	1	Insert of the valve
	2	Fixing the valve
Operator 2	A	Insert the pole inside the membrane
Operator 1 + Operator 2	B	Insert the pole with the membrane inside the autoclave
	C	Removal of the pole from autoclave, during the insertion of the membrane
Operator 2	D	Screwing the nut
Operator 1	E	Fixing the plastic on the flange
	F	Fixing the flange
	3	Insert the pre-charge
	4	Testing in the water
Operator 2	5	Put the label
	6	Put the conformity and instruction sheet
	7	Put the nylon
Operator 3	8	Prepare an empty box
	9	Put the label on the empy box
	10	Put the expansion tank inside the box
	11	Close the box with the expansion tank inside
List of the tasks performed by the operators (Autoclaves AFV division)		

Operators	N° of task	Type of task
Operator 1	1	Insert of the valve
	2	Fixing the valve
	3	Insert the pre-charge
	4	Testing in the water
Operator 2	5	Put the label
	G	Put the second label
	H	Put the third label
	6	Put the conformity and instruction sheet
	7	Put the nylon
Operator 3	8	Prepare an empty box
	9	Put the label on the empy box
	10	Put the expansion tank inside the box
	11	Close the box with the expansion tank inside
List of the tasks performed by the operators (Expansion tanks DV division)		

Figure 47: main tasks carried out by the operators.

PRODUCT MODEL	Expansion tank - ERCE division		
ITEM CODE	A102L34		
VOLUME CAPACITY	50 liters		
ASSEMBLY LINE	Line F		
OPERATOR	Operator 2		
PRODUCTION LOT	30		
Notes	**Description of the task**	**Progressive Time**	**Effective Time of the Task**
	The expansion tank has finished the testing and it is ready for packaging	00:00:00	00:00:00
	Put the conformity and instruction sheet on the first expansion tank	00:00:04	00:00:04
	Put the conformity and instruction sheet on the second expansion tank	00:00:08	00:00:04
	Put the nylon on the first expansion tank	00:00:18	00:00:10
	Put the first expansion tank in the box	00:00:22	00:00:04
	Put the nylon on the second expansion tank	00:00:33	00:00:11
	Put the second expansion tank in the box	00:00:37	00:00:04
	He brings close to him the third and fourth expansion tank	00:00:43	00:00:06
	Put the conformity and instruction sheet on the third expansion tank	00:00:46	00:00:03
	Put the conformity and instruction sheet on the fourth expansion tank	00:00:50	00:00:04
	Put the nylon on the third expansion tank	00:00:57	00:00:07
	Put the third expansion tank in the box	00:01:01	00:00:04
	Put the nylon on the fourth expansion tank	00:01:11	00:00:10
	Put the fourth expansion tank in the box	00:01:17	00:00:06
	He brings close to him the fifth and sixth expansion tank	00:01:25	00:00:08
	Put the conformity and instruction sheet on the fifth expansion tank	00:01:29	00:00:04
	Put the conformity and instruction sheet on the sixth expansion tank	00:01:34	00:00:05
	Put the nylon on the fifth expansion tank	00:01:41	00:00:07
	Put the fifth expansion tank in the box	00:01:44	00:00:03
	Put the nylon on the sixth expansion tank	00:01:55	00:00:11
	Put the sixth expansion tank in the box	00:01:59	00:00:04
	He brings close to him the seventh and eighth expansion tank	00:02:06	00:00:07
	Put the conformity and instruction sheet on the seventh expansion tank	00:02:15	00:00:09
	Put the conformity and instruction sheet on the eighth expansion tank	00:02:20	00:00:05
	Put the nylon on the seventh expansion tank	00:02:29	00:00:09
	Put the seventh expansion tank in the box	00:02:33	00:00:04
	Put the nylon on the eighth expansion tank	00:02:43	00:00:10
	Put the eighth expansion tank in the box	00:02:47	00:00:04
	Close the box with the expansion tank inside	00:02:54	00:00:07
	Move the boxes	00:03:05	00:00:11
	Open a new pack of boxes	00:03:15	00:00:10
	Prepare an empty box	00:03:24	00:00:09
	Prepare an empty box	00:03:35	00:00:11
	Prepare an empty box	00:03:48	00:00:13
	Prepare an empty box	00:03:58	00:00:10
	Prepare an empty box	00:04:09	00:00:11
	Prepare an empty box	00:04:20	00:00:11
	Prepare an empty box	00:04:29	00:00:09
	Write on the paper	00:05:10	00:00:41
	Put the closed box with the expansion tank inside on the pallet	00:05:17	00:00:07
	Put the closed box with the expansion tank inside on the pallet	00:05:26	00:00:09
	Move five empy boxes close to the label container	00:05:44	00:00:18
	Put the conformity and instruction sheet on the first expansion tank	00:05:51	00:00:07
	Put the conformity and instruction sheet on the second expansion tank	00:05:55	00:00:04
	Put the nylon on the first expansion tank	00:06:07	00:00:12
	Put the first expansion tank in the box	00:06:10	00:00:03
	Put the nylon on the second expansion tank	00:06:20	00:00:10
	Put the second expansion tank in the box	00:06:24	00:00:04
	He brings close to him the third and fourth expansion tank	00:06:31	00:00:07

Figure 50: example of a progressive chronometric detection regarding operator 2.

Description of the task	Progressive Time	Effective Time of the Task	Type of task	Type of waste
The expansion tank has finished the testing and it is ready for packaging	00:00:00	00:00:00		
Put the conformity and instruction sheet on the first expansion tank	00:00:04	00:00:04	Value Added	
Put the conformity and instruction sheet on the second expansion tank	00:00:08	00:00:04	Value Added	
Put the nylon on the first expansion tank	00:00:18	00:00:10	Value Added	
Put the first expansion tank in the box	00:00:22	00:00:04	Value Added	
Put the nylon on the second expansion tank	00:00:33	00:00:11	Value Added	
Put the second expansion tank in the box	00:00:37	00:00:04	Value Added	
He brings close to him the third and fourth expansion tank	00:00:43	00:00:06	Evident Waste	1
Put the conformity and instruction sheet on the third expansion tank	00:00:46	00:00:03	Value Added	
Put the conformity and instruction sheet on the fourth expansion tank	00:00:50	00:00:04	Value Added	
Put the nylon on the third expansion tank	00:00:57	00:00:07	Value Added	
Put the third expansion tank in the box	00:01:01	00:00:04	Value Added	
Put the nylon on the fourth expansion tank	00:01:11	00:00:10	Value Added	
Put the fourth expansion tank in the box	00:01:17	00:00:06	Value Added	
He brings close to him the fifth and sixth expansion tank	00:01:25	00:00:08	Evident Waste	1
Put the conformity and instruction sheet on the fifth expansion tank	00:01:29	00:00:04	Value Added	
Put the conformity and instruction sheet on the sixth expansion tank	00:01:34	00:00:05	Value Added	
Put the nylon on the fifth expansion tank	00:01:41	00:00:07	Value Added	
Put the fifth expansion tank in the box	00:01:44	00:00:03	Value Added	
Put the nylon on the sixth expansion tank	00:01:55	00:00:11	Value Added	
Put the sixth expansion tank in the box	00:01:59	00:00:04	Value Added	
He brings close to him the seventh and eighth expansion tank	00:02:06	00:00:07	Evident Waste	1
Put the conformity and instruction sheet on the seventh expansion tank	00:02:15	00:00:09	Value Added	
Put the conformity and instruction sheet on the eighth expansion tank	00:02:20	00:00:05	Value Added	
Put the nylon on the seventh expansion tank	00:02:29	00:00:09	Value Added	
Put the seventh expansion tank in the box	00:02:33	00:00:04	Value Added	
Put the nylon on the eighth expansion tank	00:02:43	00:00:10	Value Added	
Put the eighth expansion tank in the box	00:02:47	00:00:04	Value Added	
Close the box with the expansion tank inside	00:02:54	00:00:07	Value Added	
Move the boxes	00:03:05	00:00:11	Evident Waste	1
Open a new pack of boxes	00:03:15	00:00:10	Hidden Waste	F
Prepare an empty box	00:03:24	00:00:09	Value Added	
Prepare an empty box	00:03:35	00:00:11	Value Added	
Prepare an empty box	00:03:48	00:00:13	Value Added	
Prepare an empty box	00:03:58	00:00:10	Value Added	
Prepare an empty box	00:04:09	00:00:11	Value Added	
Prepare an empty box	00:04:20	00:00:11	Value Added	
Prepare an empty box	00:04:29	00:00:09	Value Added	
Write on the paper	00:05:10	00:00:41	Evident Waste	2
Put the closed box with the expansion tank inside on the pallet	00:05:17	00:00:07	Hidden Waste	D
Put the closed box with the expansion tank inside on the pallet	00:05:26	00:00:09	Hidden Waste	D
Move five empy boxes close to the label container	00:05:44	00:00:18	Evident Waste	1
Put the conformity and instruction sheet on the first expansion tank	00:05:51	00:00:07	Value Added	
Put the conformity and instruction sheet on the second expansion tank	00:05:55	00:00:04	Value Added	
Put the nylon on the first expansion tank	00:06:07	00:00:12	Value Added	
Put the first expansion tank in the box	00:06:10	00:00:03	Value Added	
Put the nylon on the second expansion tank	00:06:20	00:00:10	Value Added	
Put the second expansion tank in the box	00:06:24	00:00:04	Value Added	
He brings close to him the third and fourth expansion tank	00:06:31	00:00:07	Evident Waste	1

Figure 51: analysis of each task, determining the type (value added or not and which kind of waste).

Total time observed	00:06:31	% of Time performed
Value Added Time	00:04:27	68%
Evident Waste Time	00:01:38	25%
Hidden Waste Time	00:00:26	7%

Evident Waste Time	00:01:38	% of Time performed
1	00:00:57	58%
2	00:00:41	42%

Hidden Waste Time	00:00:26	% of Time performed
D	00:00:00	0%
F	00:00:16	62%

Figure 52: Analysis of the results obtained, concerning figure 51.

As we can see, we determined the type of each task, recorder during the detection analysis (see figure 51). We subdivided the Waste into two types: *Evident Waste* and *Hidden Waste*. The first concerns all the activities that do not create added value to the product and therefore, they do not give value to the customer. For this reason, the Evident Waste activities are not necessary and should be removed (see figure 53). The second, instead, refers to all the activities that do not create added value to the product but their execution is necessary for some reasons (regulatory requirements or technological constraints). For this reason, the Hidden Waste activities must be minimized must be minimized. Then, we have all the *Valued Added* activities, which create value to the product and the consumer is willing to pay for them (see Figure 54). For this reason, the goal is to improve them. According to Lean philosophy, the Evident Waste activities are divided into seven types of waste (see figure 55). Regarding Hidden Waste activities, they consist in those, which were recorded during the detection phase, considered as necessary steps for the completion of the assembly process (see figure 56).

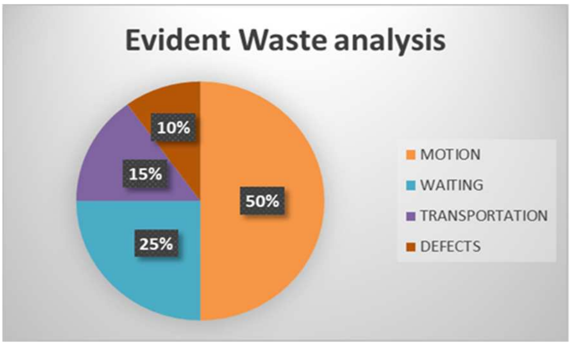


Figure 53: example of evident waste analysis.

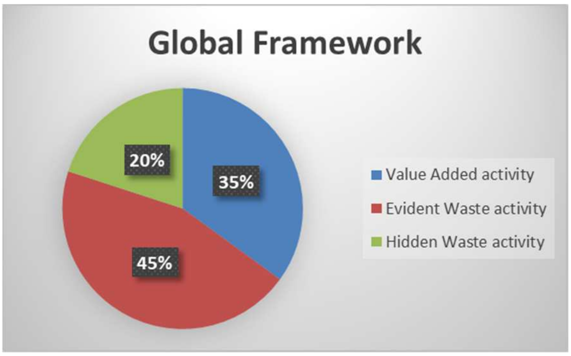


Figure 54: example of global Framework of the analysis.

TYPE	EVIDENT WASTE ACTIVITY
1	Motion
2	Waiting
3	Trasportation
4	Defects
5	Inventory
6	Overprocessing
7	Overproduction

Figure 55: list of the seven types of Evident Waste.

TYPE	HIDDEN WASTE ACTIVITY
A	Pressure control and removal of the pre-charge
B	Removal of the cap on the expansion tank
C	Put the adhesive tape around the closed boxes on the pallet
D	Put the closed box, with the expansion tank, inside on the pallet
E	Change the tape to the slider
F	Open a new pack of boxes
G	Preparation of the conformity and instruction sheet
H	Preparation of the screws with the respecitve washers

Figure 56: list of Hidden Waste activities observed during the analysis.

In accordance with the example of figure 51, the total time measured is equal to 6 minutes and 31 seconds, in which all the recorded activities are carried out. The analysis is highlighted in figure 52, where the 68% of the time is used to perform Value Added activities, while the remaining 32% is due to Waste. The Evident counts for the 25% whereas the Hidden for the 7%. Subsequently, we analyzed how is distributed the time used to carry out Evident and Hidden Waste activities. Concerning Evident Waste, we have the first and second type of waste, respectively equal to 58% and 42%. While referring to Hidden Waste, the 38% of the time is spent in "*Putting the adhesive tape around the closed boxes on the pallet*" and the 62% in "*Opening a new pack of boxes*". In relation to figure 53, some examples of what we considered as Motion, Waiting, Transportation and Defects wastes, which include all types of wastes identified within the analysis, are listed below:

- *Motion waste*:
- place an autoclave or expansion tank on the workbench;
- place a pallet in station;
- take the drill or the valves;
- move an empty box near the label container;
- bring a box, with the finished product inside, close to the pallet;
- move an autoclave or expansion tank along the work bench.

- *Waiting waste*:
- waits for the operator 1 to complete the test of the product;
- operates the elevator (this can lower or elevate);
- waits for the operator 2 or 3 (in order to do together a specific activity);
- write on the paper;
- he does not do anything.

- *Transportation waste*:
  - the operator move, with the trans pallet, the lot near the office of the department M;
  - he goes in after the department M office to pick up two pallets and take them to the station;
  - picking up the trans pallet;
  - picking up an expansion tank or autoclave in the other assembly line.

- *Defects waste*:
  - scratch the expansion vessel or autoclave with sandpaper;
  - color the expansion tank in red;
  - color the autoclave in blue;
  - threading the autoclave or the expansion tank.

Once the Method for detecting Standard Cycle Times has been defined, the KaizenKey team began to perform the analysis concerning the department M's assembly lines. *What has emerged?*

The times recording and the related analysis lasted almost 5 months, of which the first month used as a trial period so that the analyst could learn the New Method, acquiring the skills necessary to obtain reliable data. total amount of 19,000 activities were detected, over a total of 75 hours (the average time of detection was 14 seconds, considering all the activities observed), distributed on twenty different products. The analysis was carried out on the six operators of the two assembly lines.

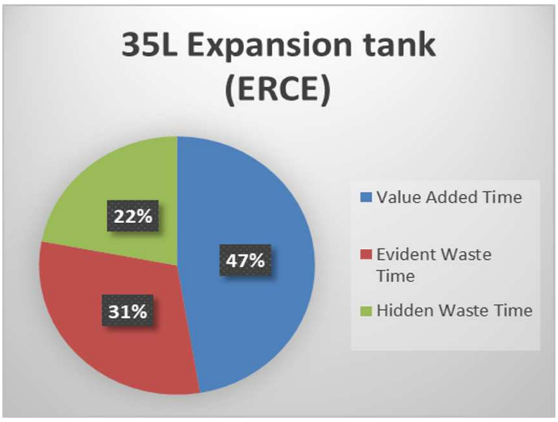
The goal was to of this improvement project was:

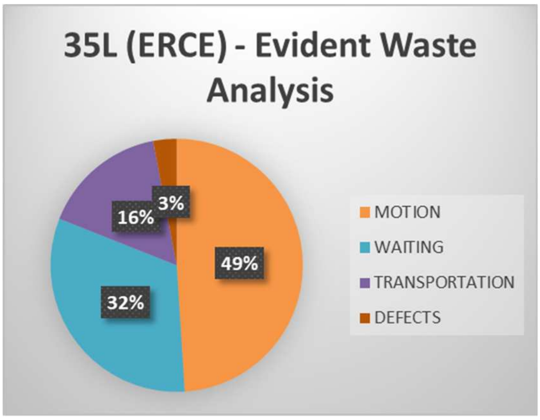
- application of the Lean Production principles in the reduction of Waste related to the Non-Value Added activities;
- definition of a daily average standard productivity for each product, taking advantage of the flexibility of the line;
- definition of a new layout, based on the distribution of workloads with the new standard cycle times and the standardization of the activities carried out.

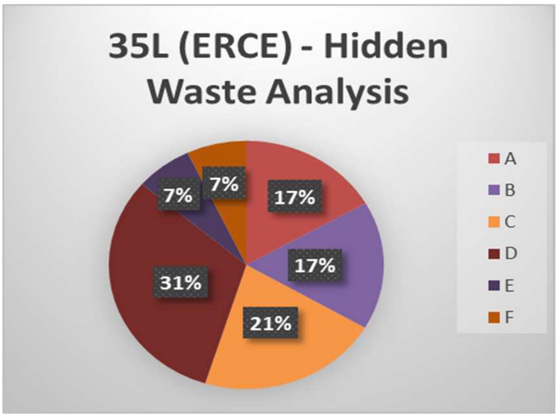
The Value Added time analysis (Vat) aims in having a global picture of the 20 products and it gave the following results:

❖ <u>Expansion tank (ERCE division) analysis</u>

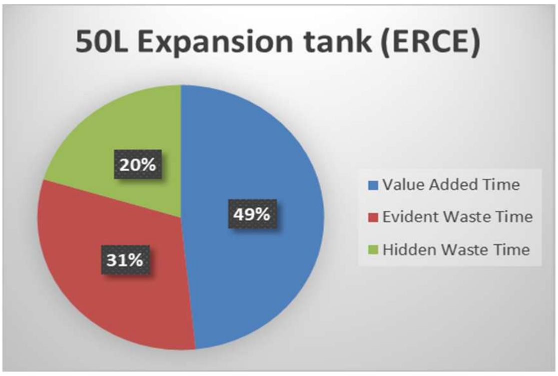
- *35L Expansion tank*

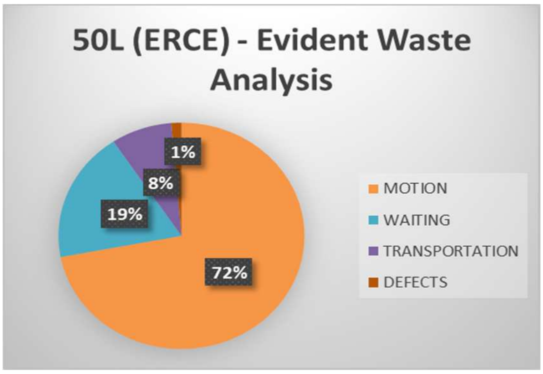


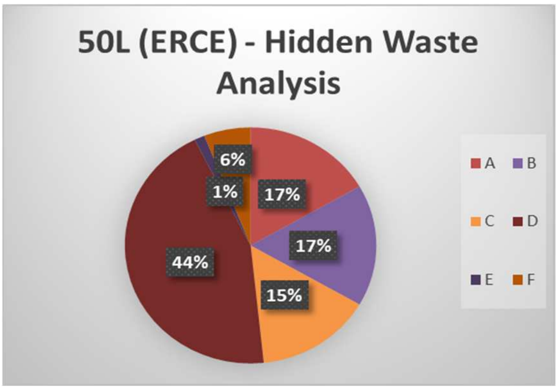




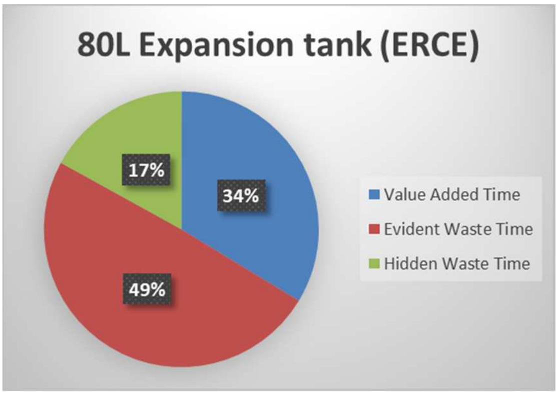
- *50L Expansion tank*

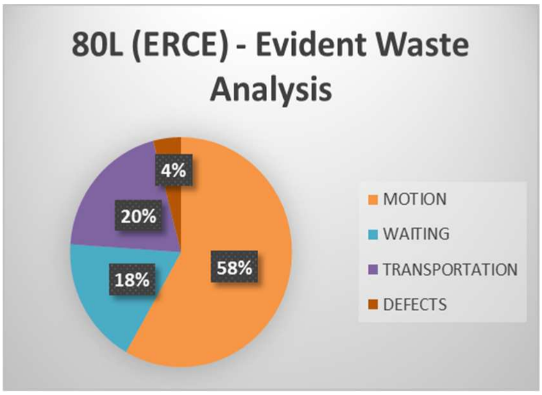


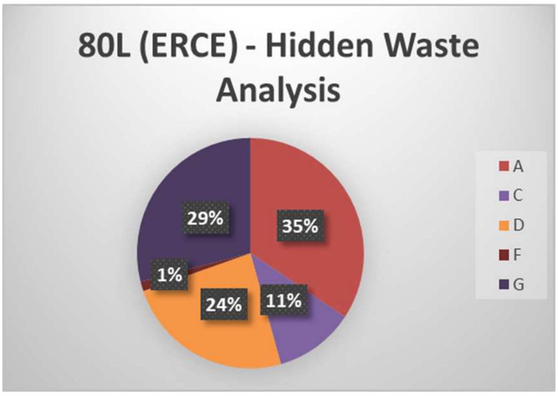




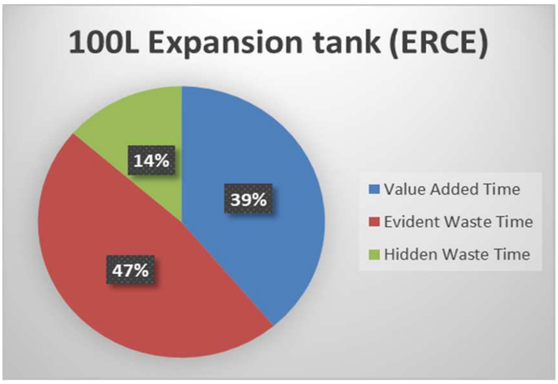
- *80L Expansion tank*

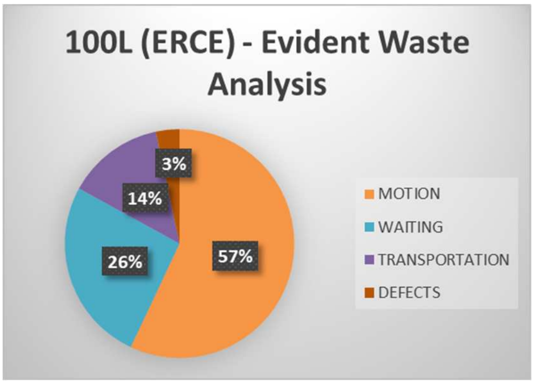


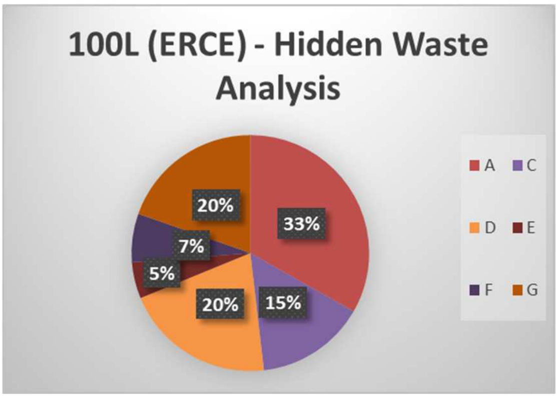




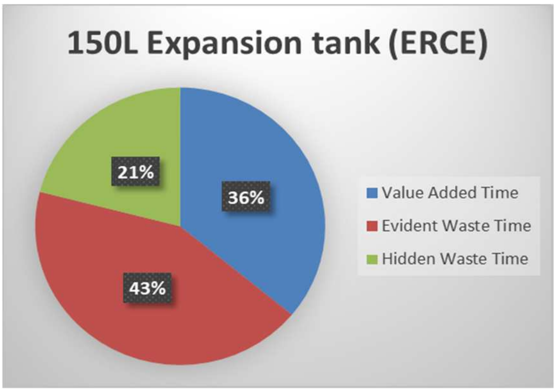
- *100L Expansion tank*

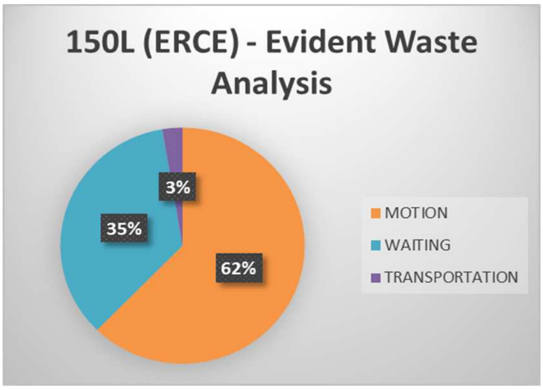


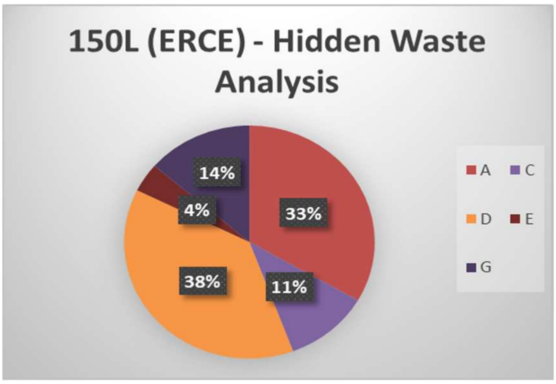




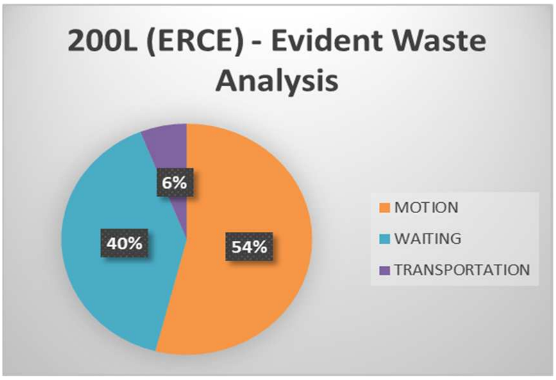
- 150 Expansion tank

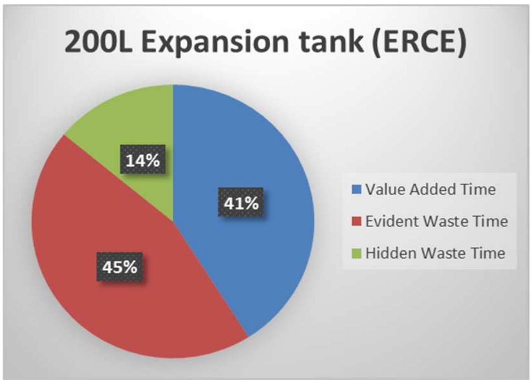


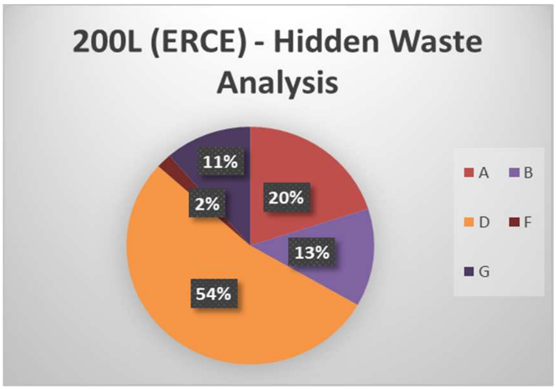




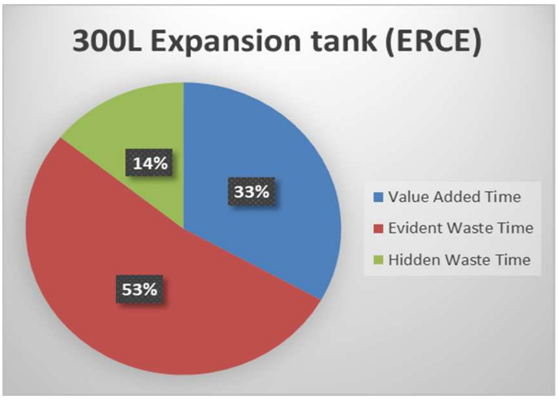
- 200L Expansion tank

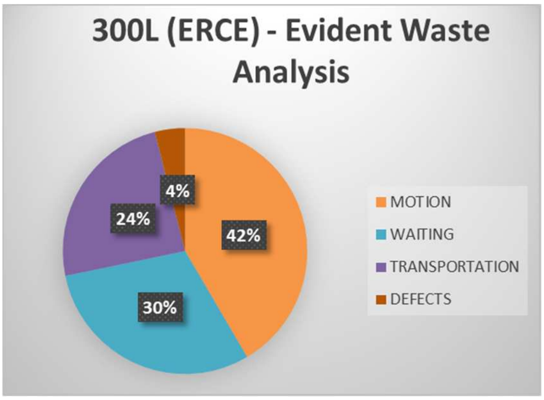


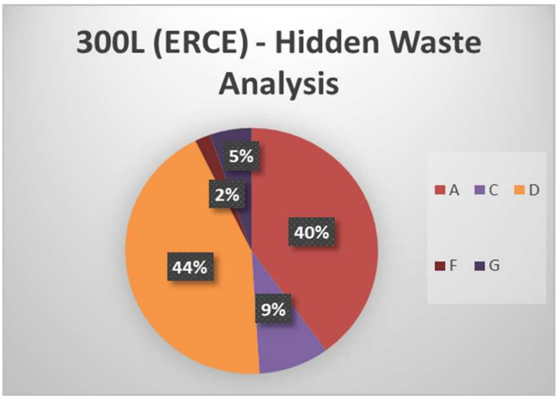




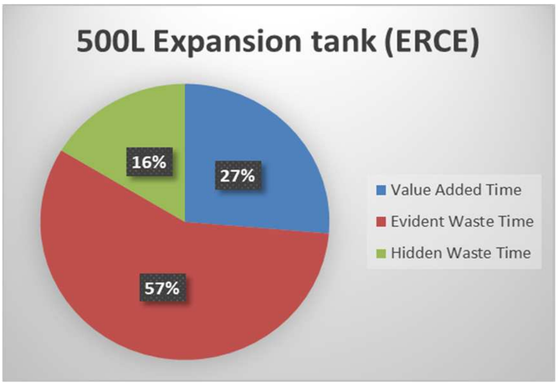
- 300L Expansion tank

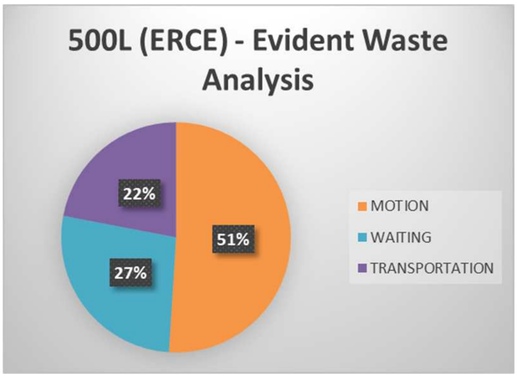


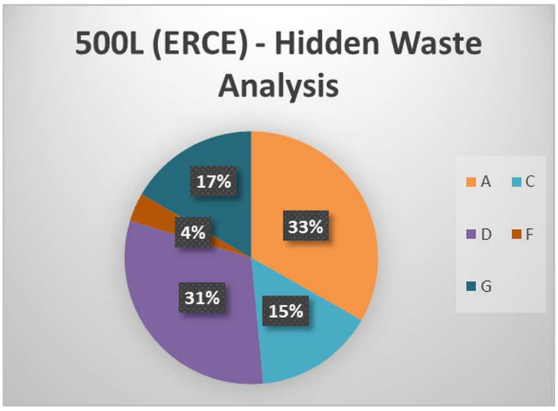




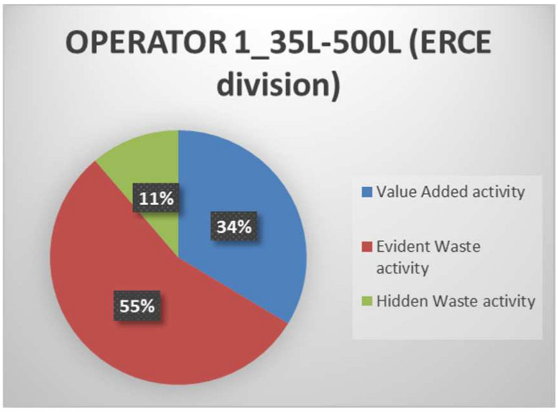
- 500L Expansion tank

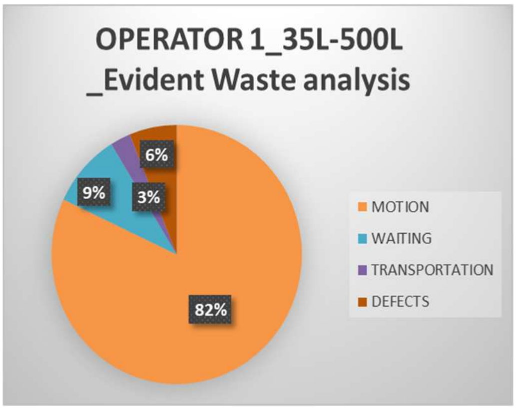


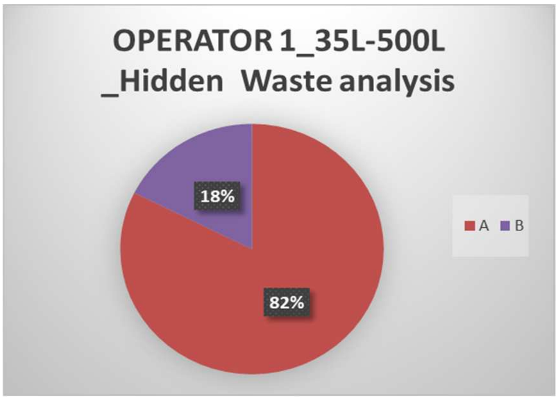




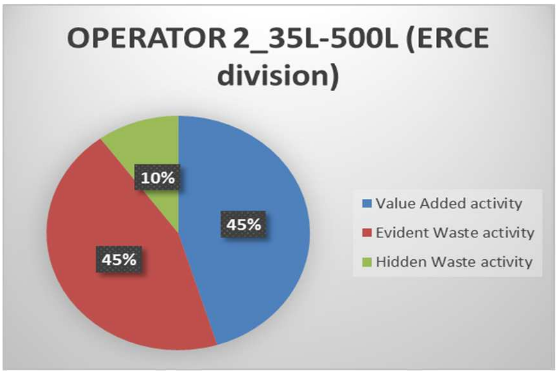
- Operator 1 analysis - ERCE division

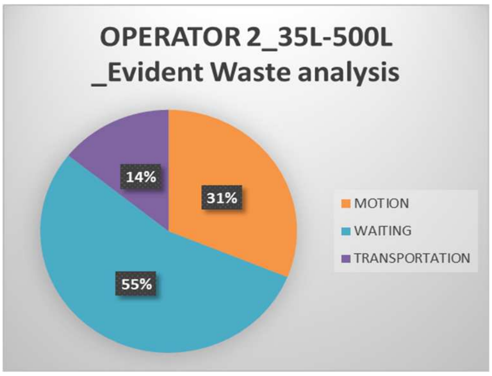


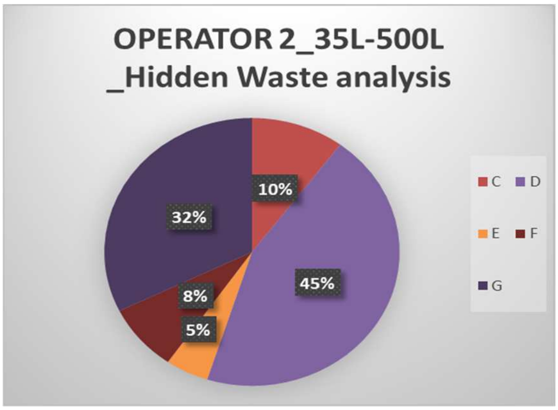




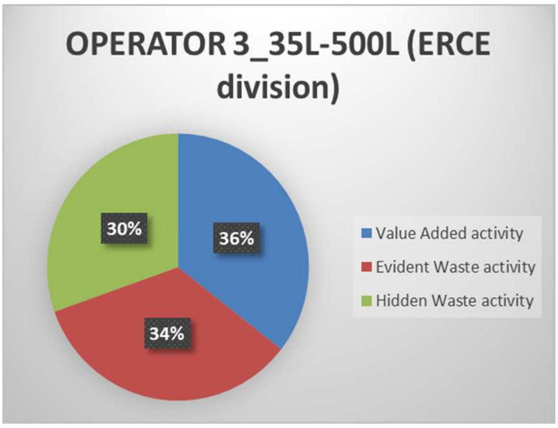
- Operator 2 analysis - ERCE division

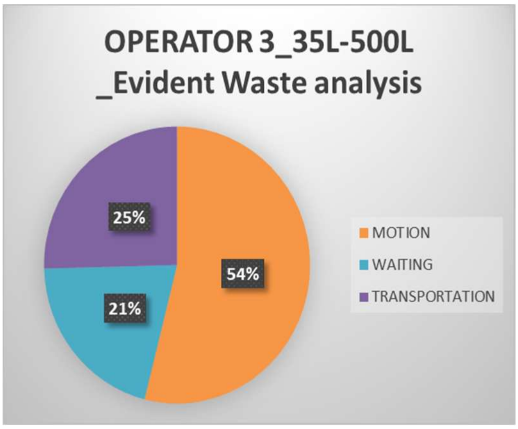


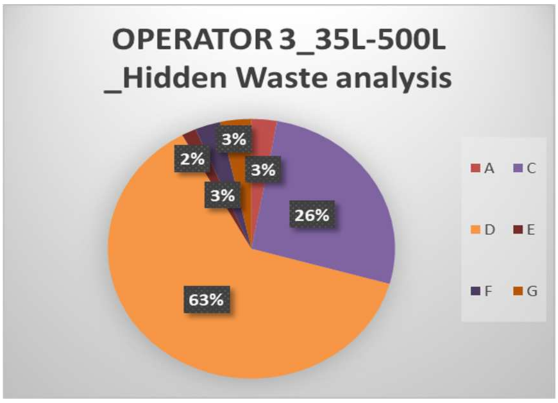




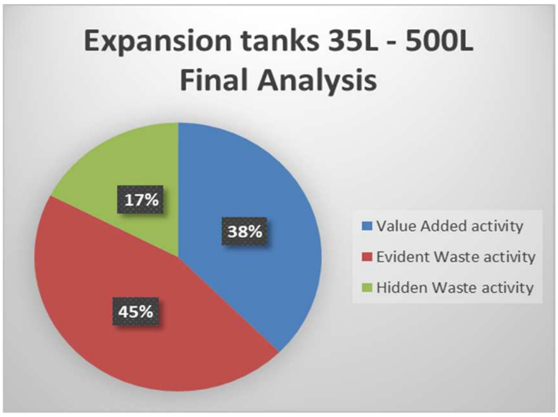
- Operator 3 analysis - ERCE division

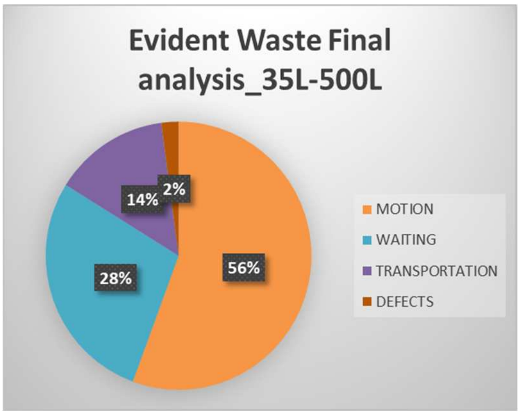


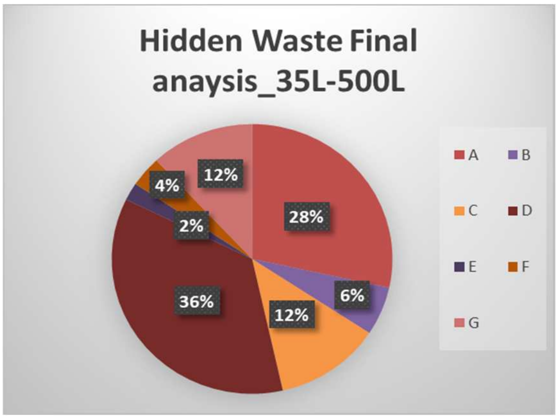




- Final results - ERCE division

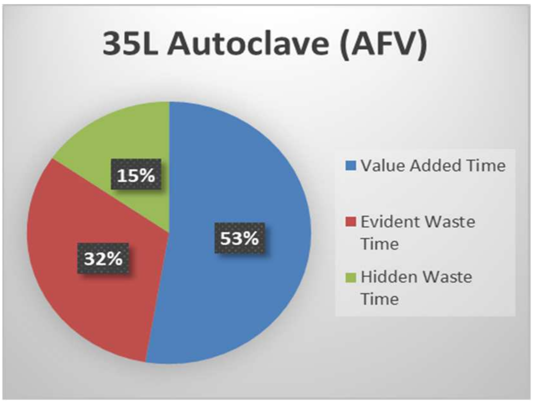


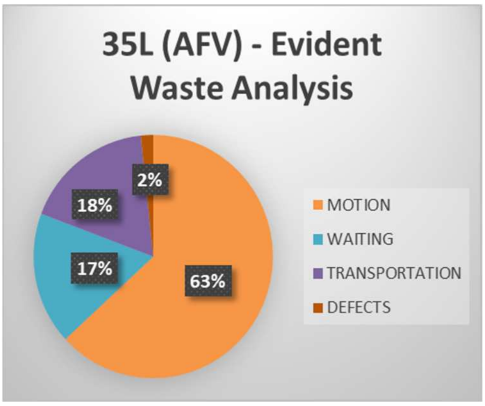


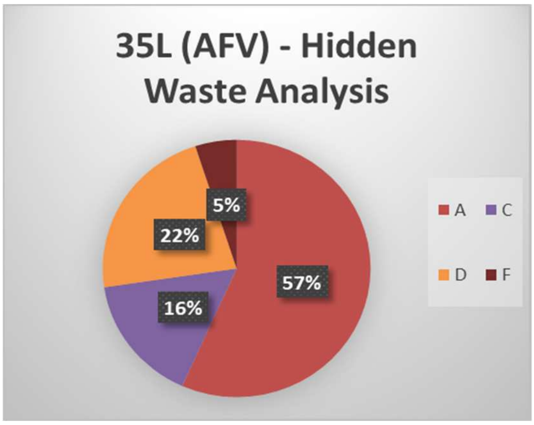


- Autoclaves (AFV division) analysis

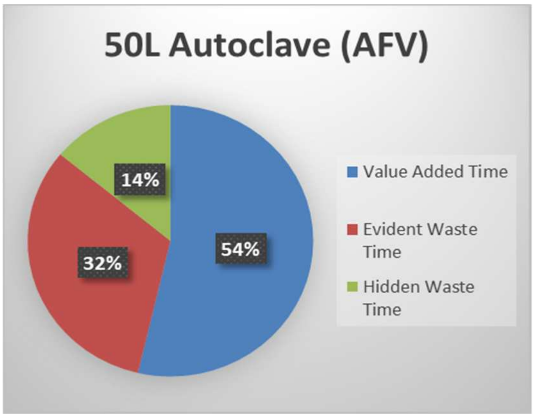
-35L Autoclave

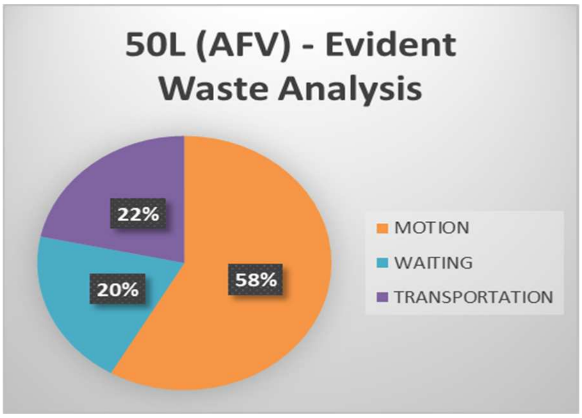


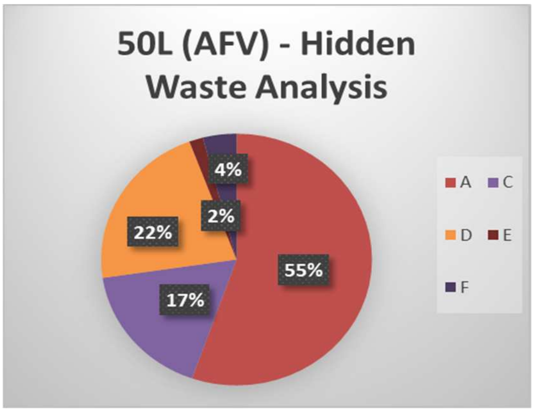




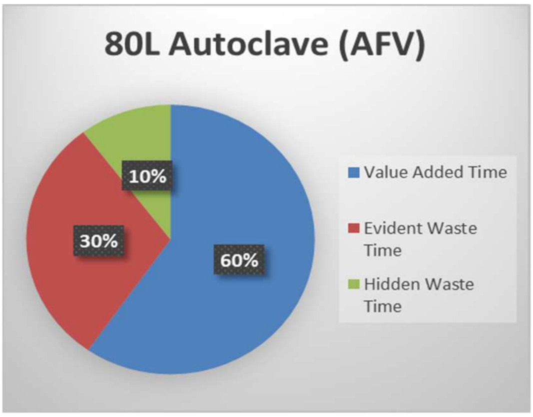
-50L Autoclave

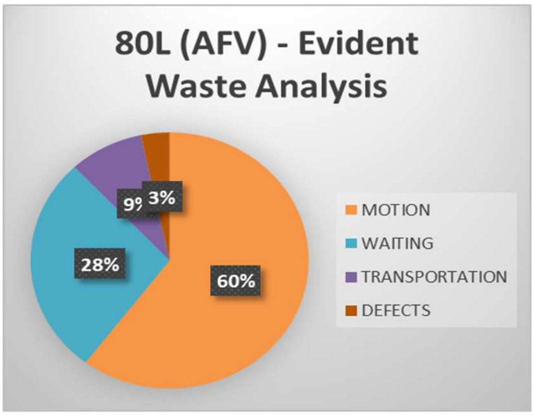


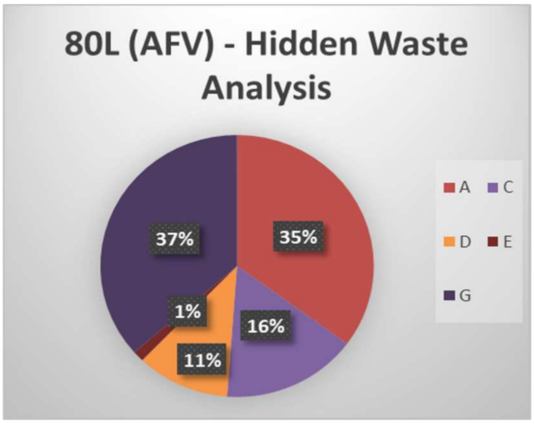




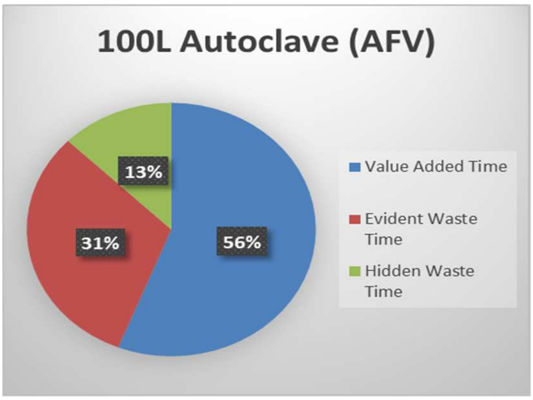
-80L Autoclave

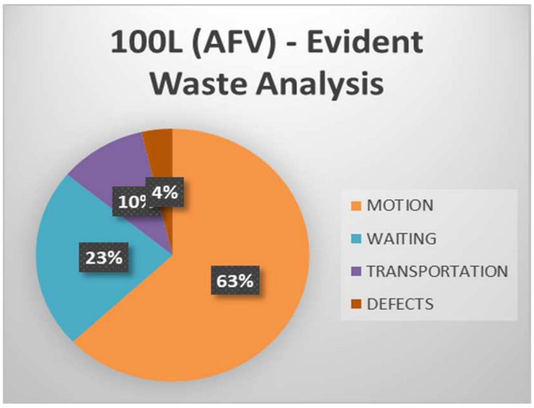


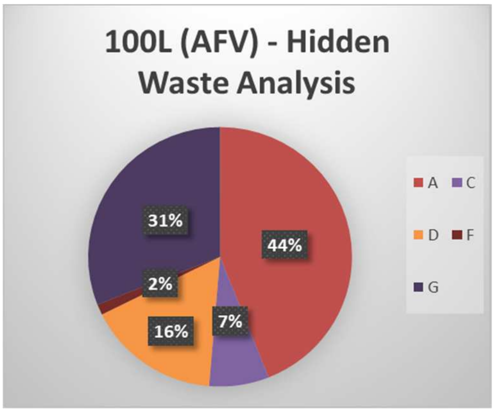




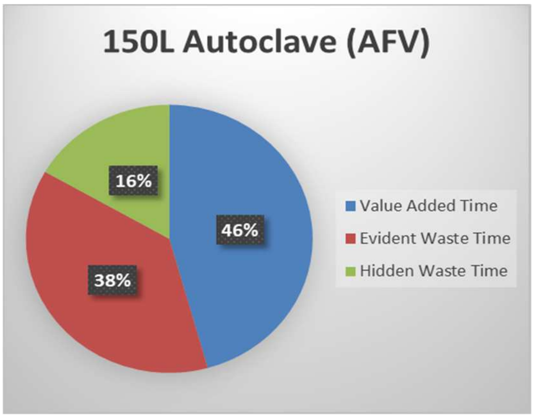
-100L autoclave

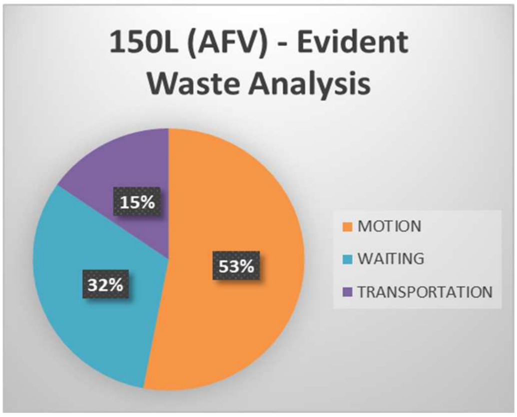


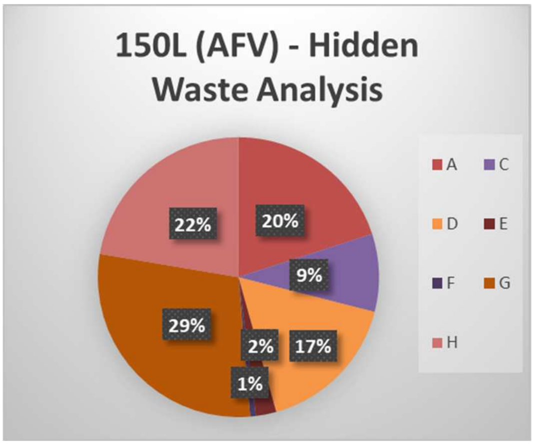




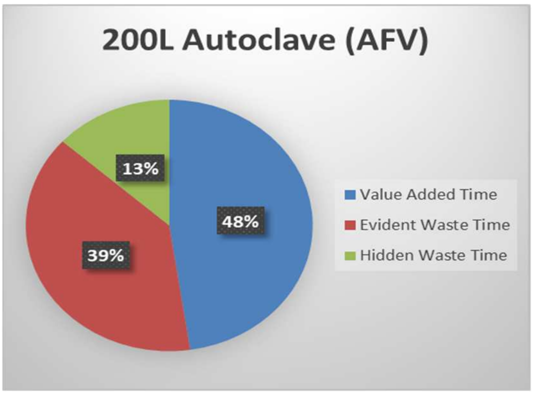
-150L Autocave

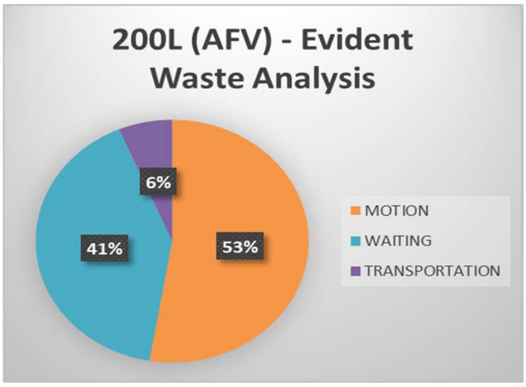


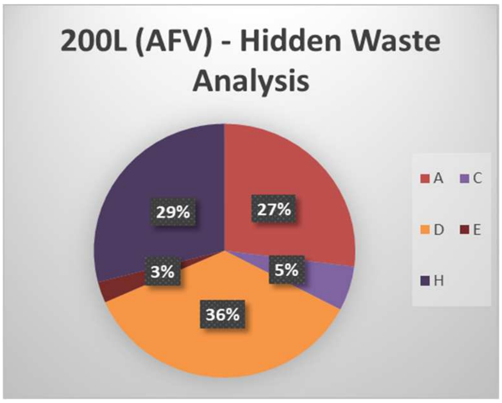




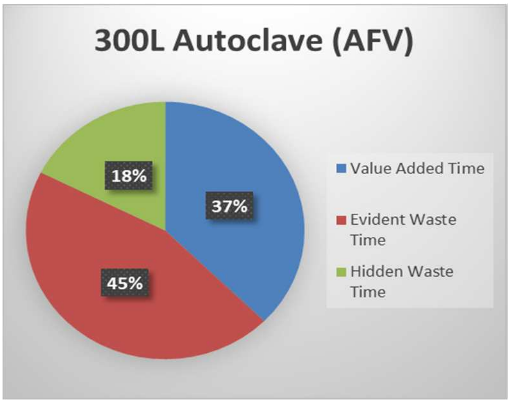
-200L Autoclave

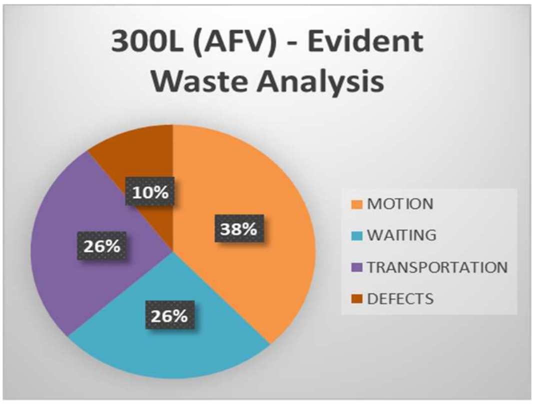


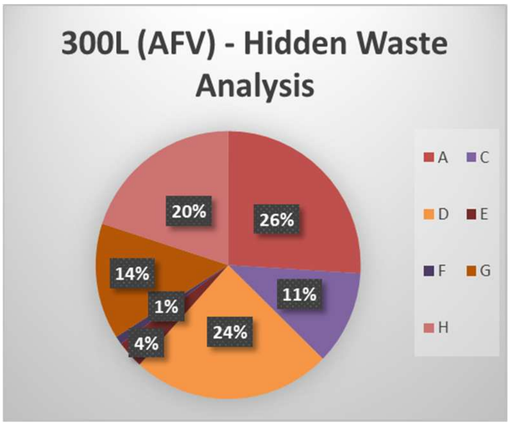




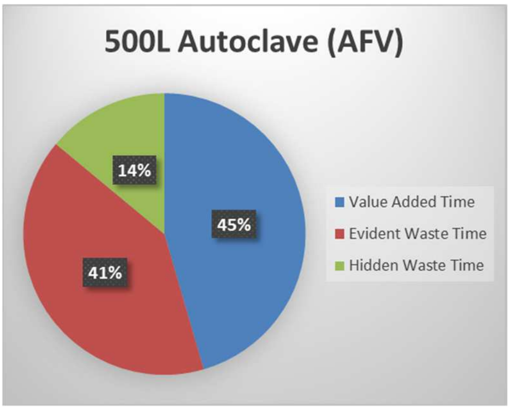
-300L Autoclave

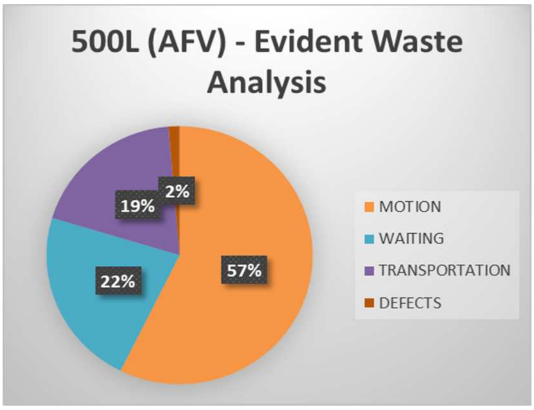


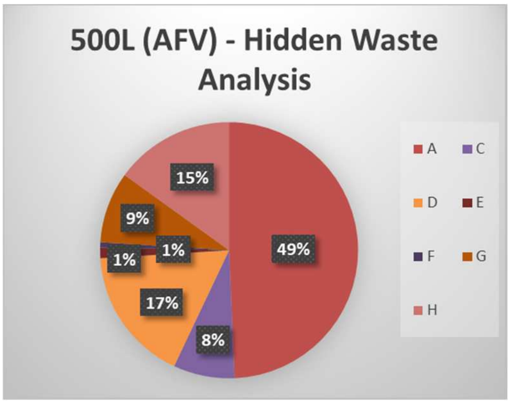




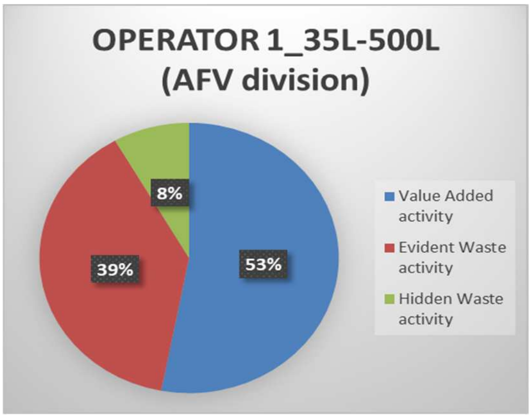
-500L Autoclave

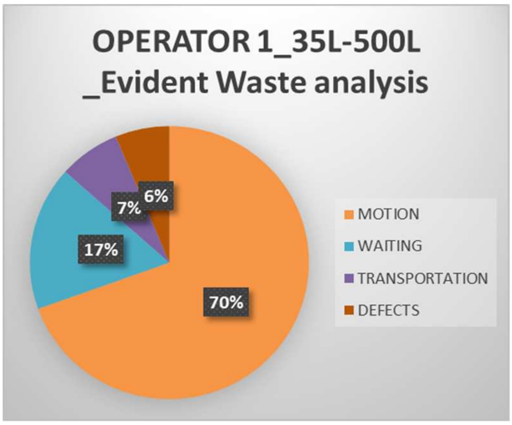


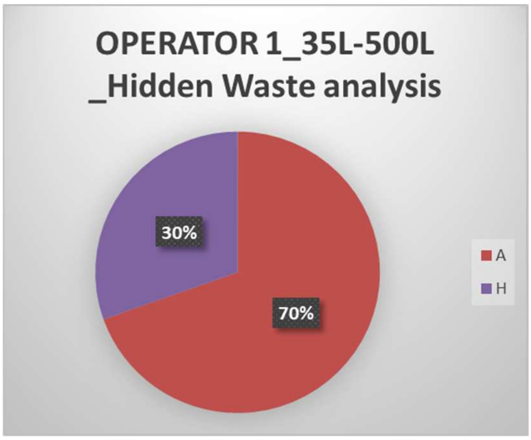




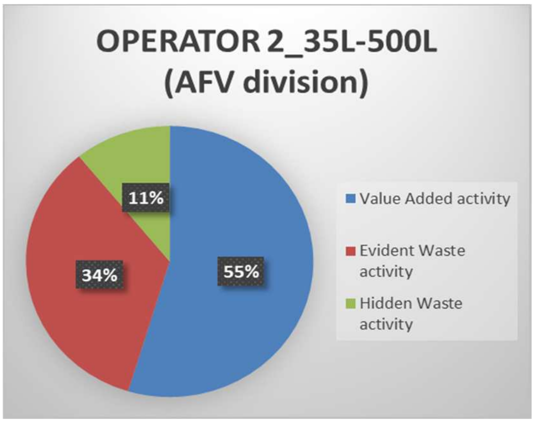
-Operator 1 analysis - AFV division

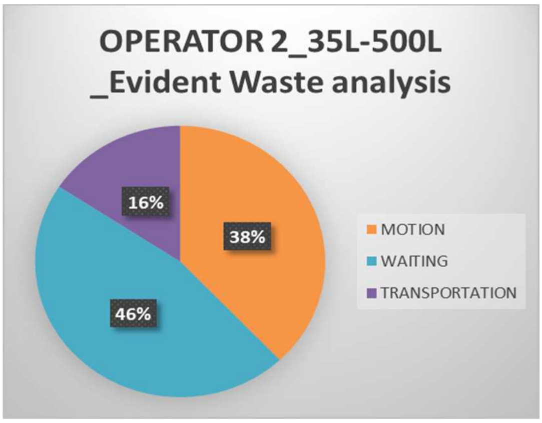


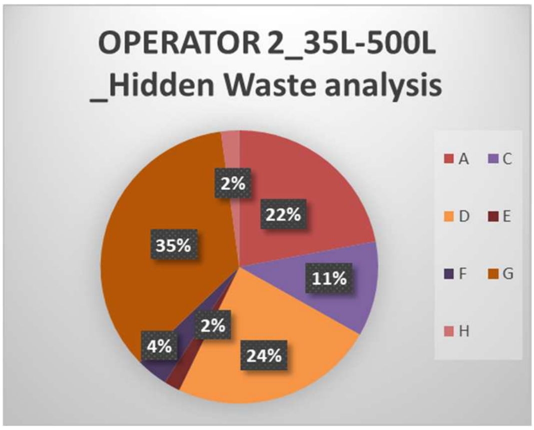




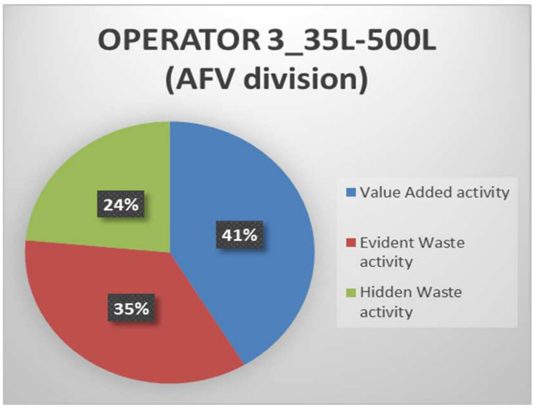
-Operator 2 analysis - AFV division

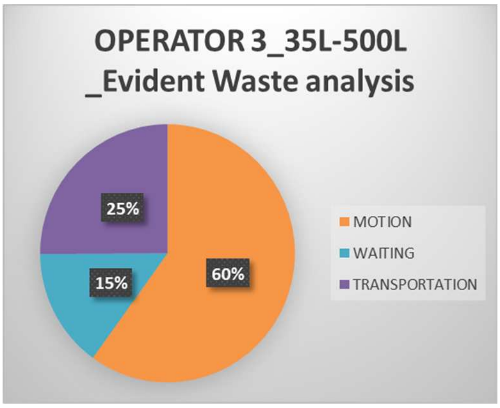


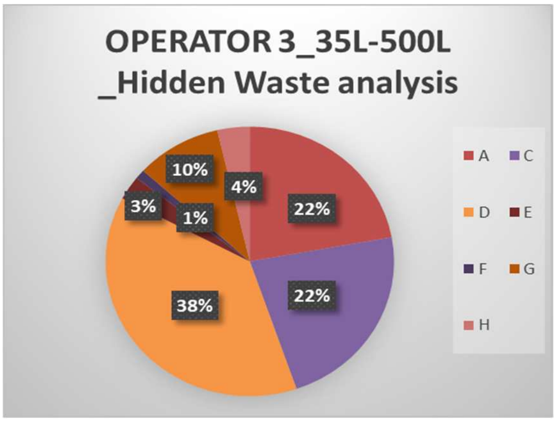




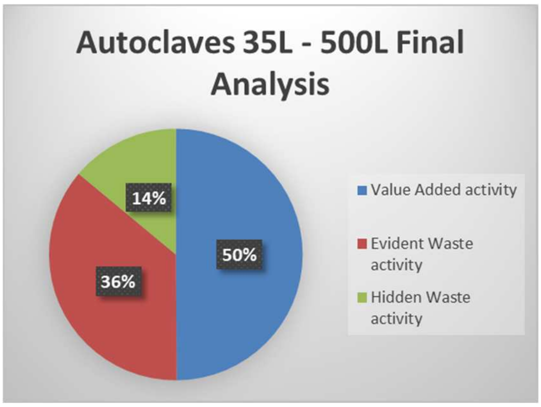
- Operator 3 analysis - AFV division

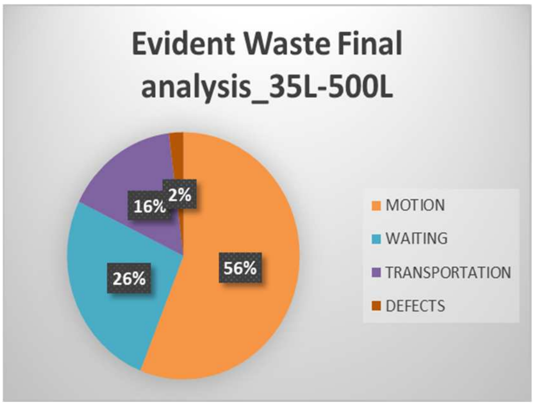


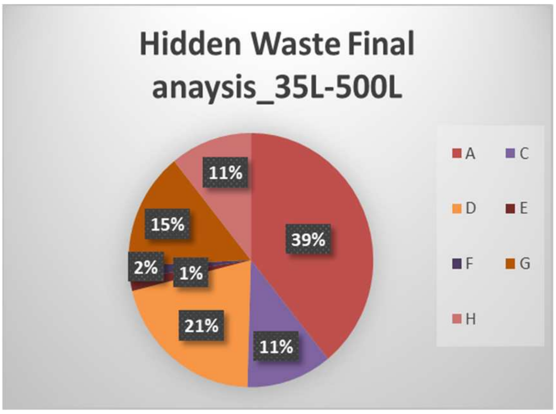




-Final results - AFV division

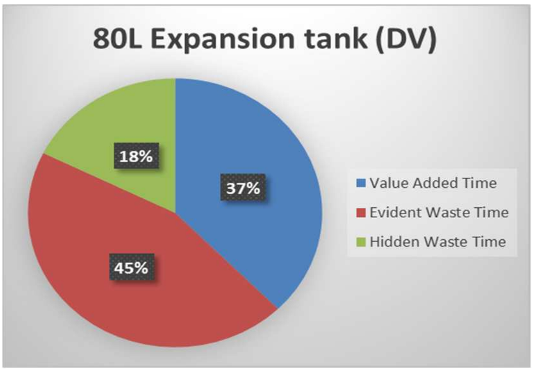


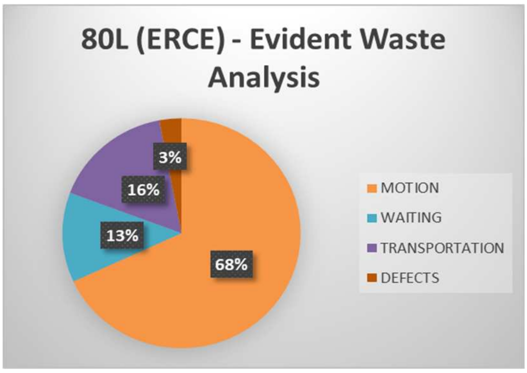


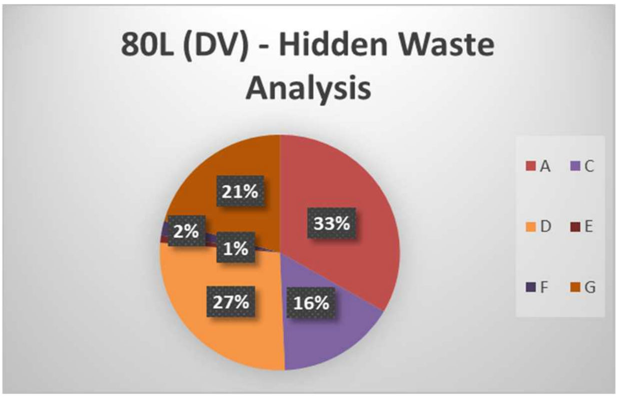


- Expansion tank (DV division) analysis

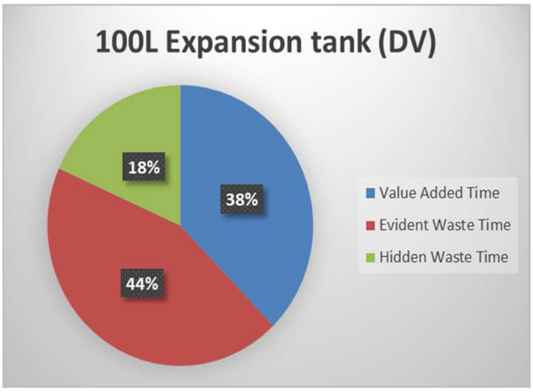
  -80L Expansion tank

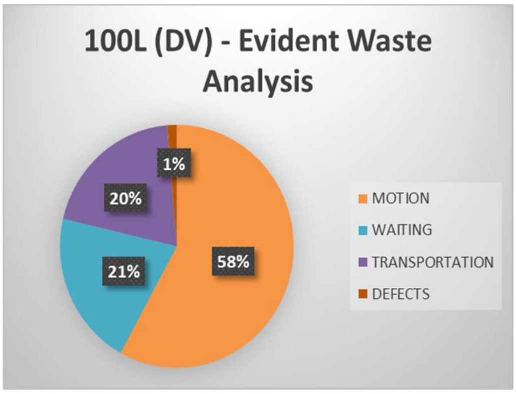


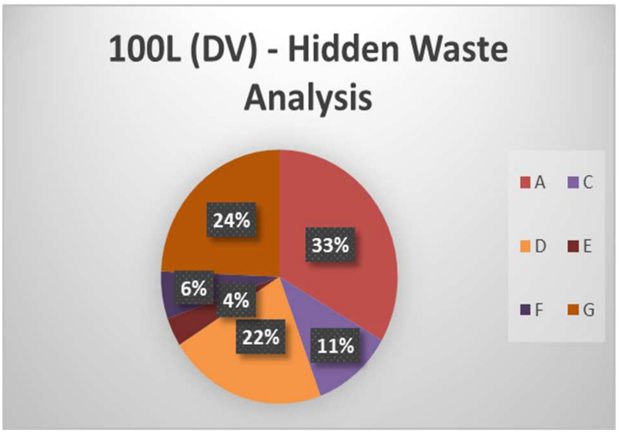




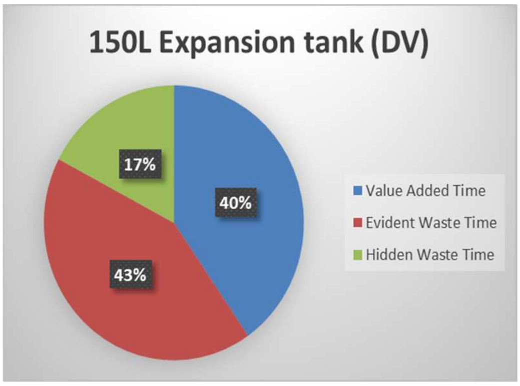
-100L Expansion tank

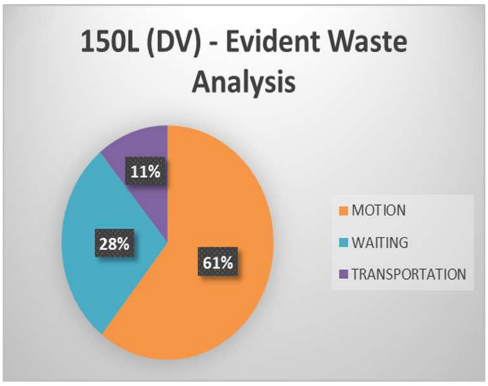


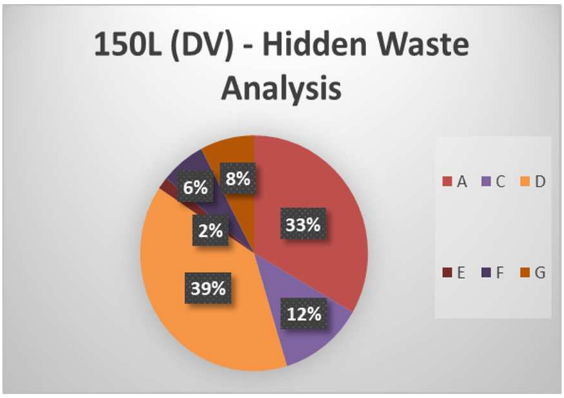




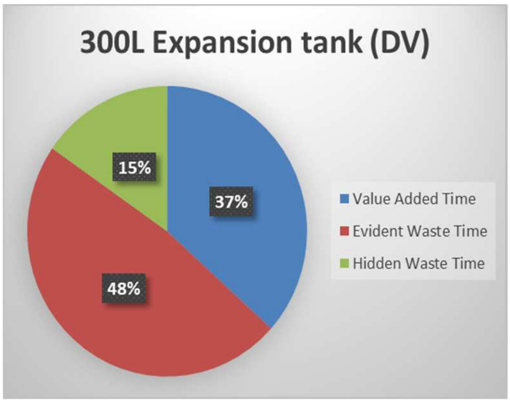
-150L Expansion tank

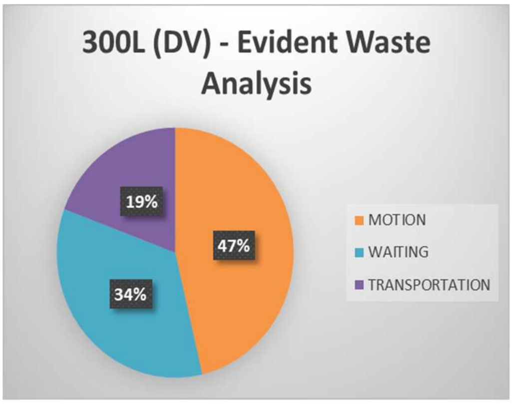


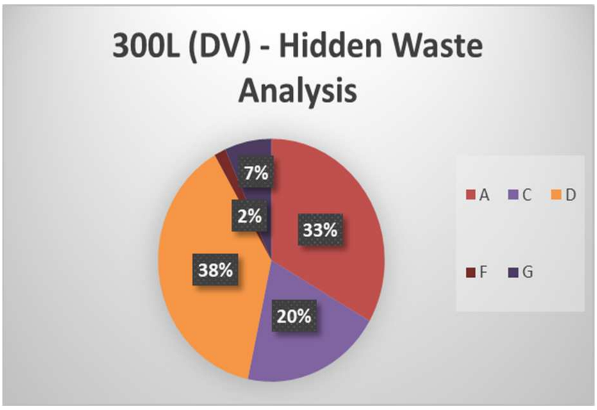




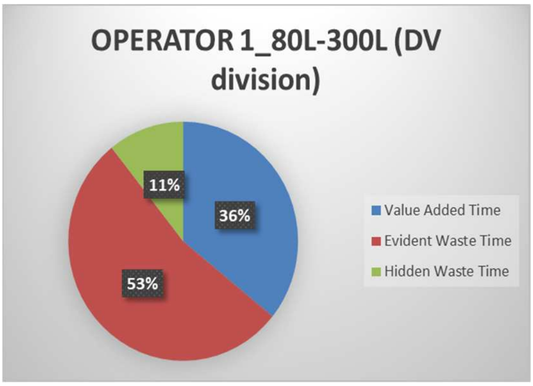
-300L Expansion tank

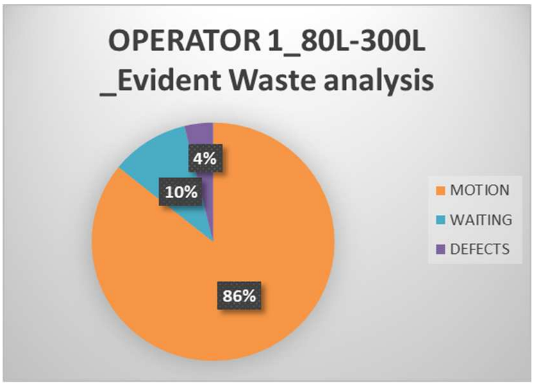


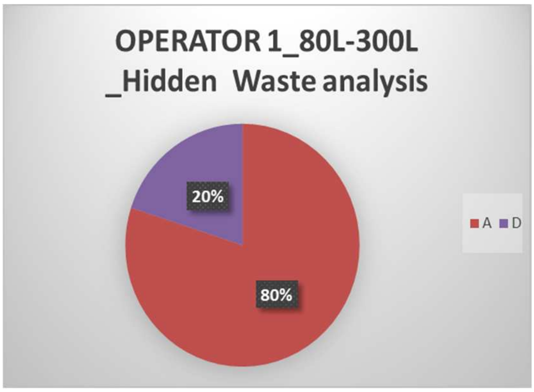




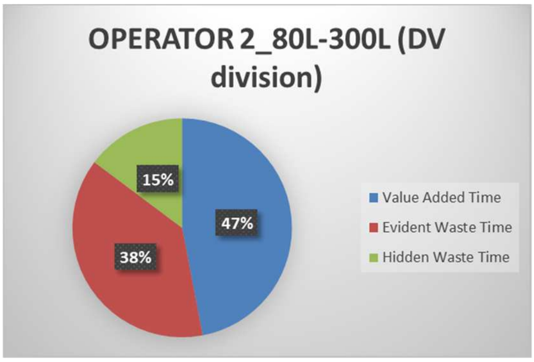
-Operator 1 analysis - DV division

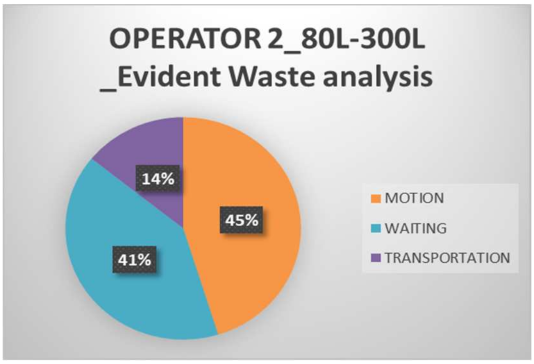


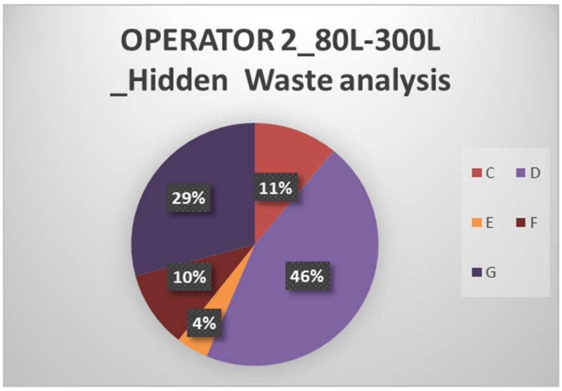




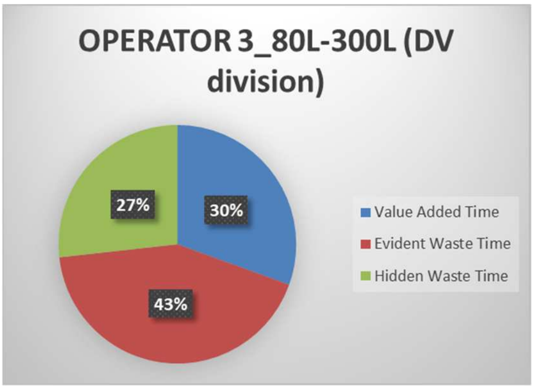
-Operator 2 analysis - DV division

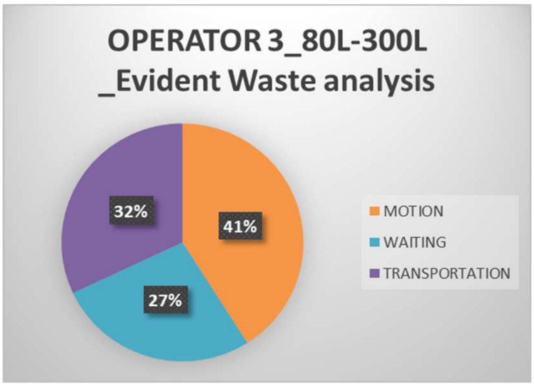


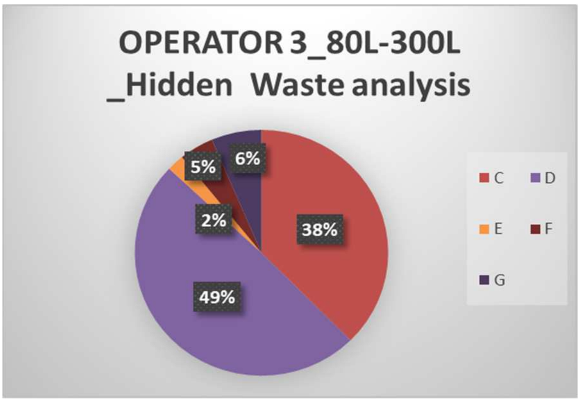




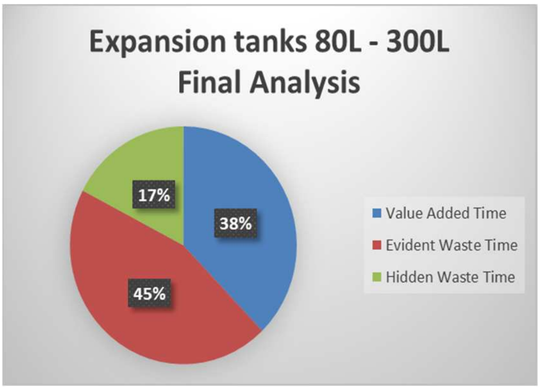
-Operator 3 analysis - DV division

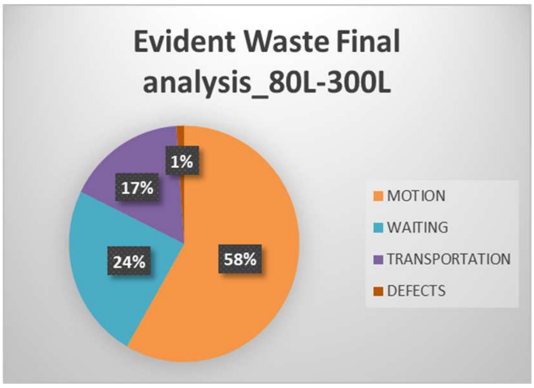


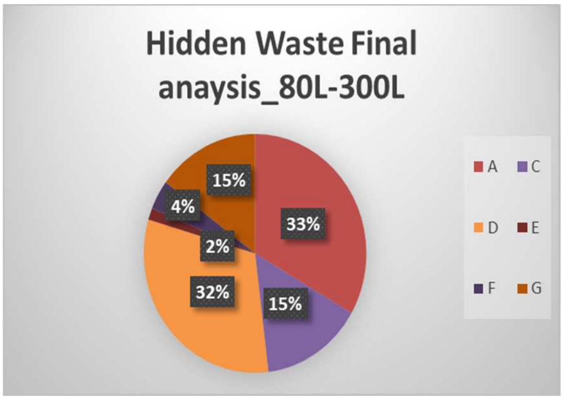




-Final results - DV division







4.5.2 Comments and results

The results obtained from the analysis carried out are the following:

- ERCE division
  - Considering the product range from 35 to 500 liters, the average time taken to carry out Value Added activities is equal to 38% of the total time. This means that, out of a total of 31 hours detected, the operators used only 12 hours in order to perform VA activities. The Evident Waste activity that affects most, in percentage terms, is that linked to the movement of the material and products along the line (56%). Similarly, the operators used almost 8 hours out of 31 in performing activities related to this type of waste. Another noticeable Evident Waste refers to "Waiting" activities and it is equal to 4 hours (28%). Regarding Hidden Waste, more than 60% (2 hours) of the total time detected is given by the performance the following activities: "Pressure control and removal of the pre-charge" that counts for a 28% and "Putting the closed box, with the expansion tank inside, on the pallet" that counts for a 36%.

    Specifically, the types of Evident Waste that distinguish each operator are as follows:

    - Operator 1: *Motion* (82%) and *Waiting* (9%).
    - Operator 2: *Waiting* (55%) and *Motion* (31%).
    - Operator 3: *Motion* (54%) and *Transportation* (25%).

    The main Hidden Waste activities for each operator are as follows:

    - Operator 1: "*Pressure control and removal of the pre-charge*" that counts for an 82%. He is the only one that perform such activity.
    - Operator 2: "*Putting the closed box, with the expansion tank inside, on the pallet*" that counts for a 45% and the "*Preparation of the conformity and instruction sheet*" that counts for a 32%.
    - Operator 3: "*Putting the closed box, with the expansion tank inside, on the pallet*" that counts for a 63%.

    The trend, in percentages terms, of time used to carry out Value Added, Evident and Hidden Waste activities, for each operator on all the range products, is depicted in the figures 57, 58 and 59).

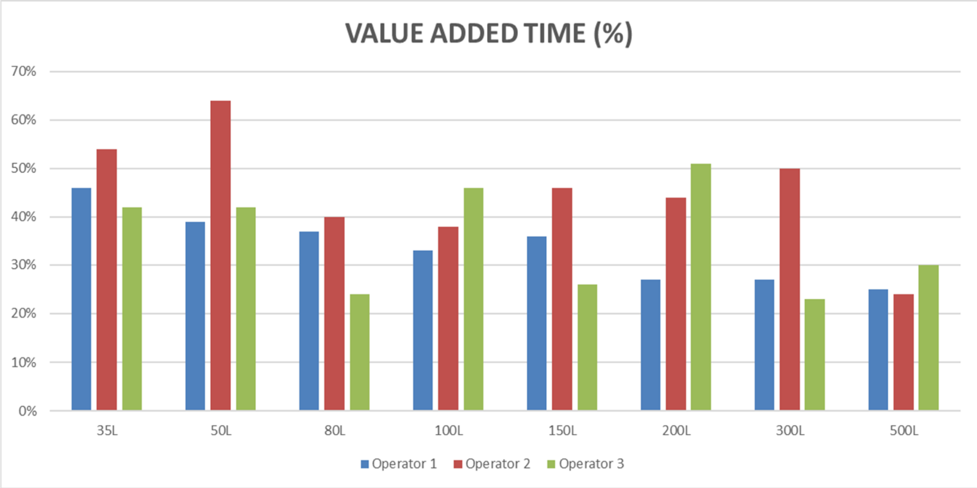


Figure 57: comparison among the three operators on Valued Added Time for each product.

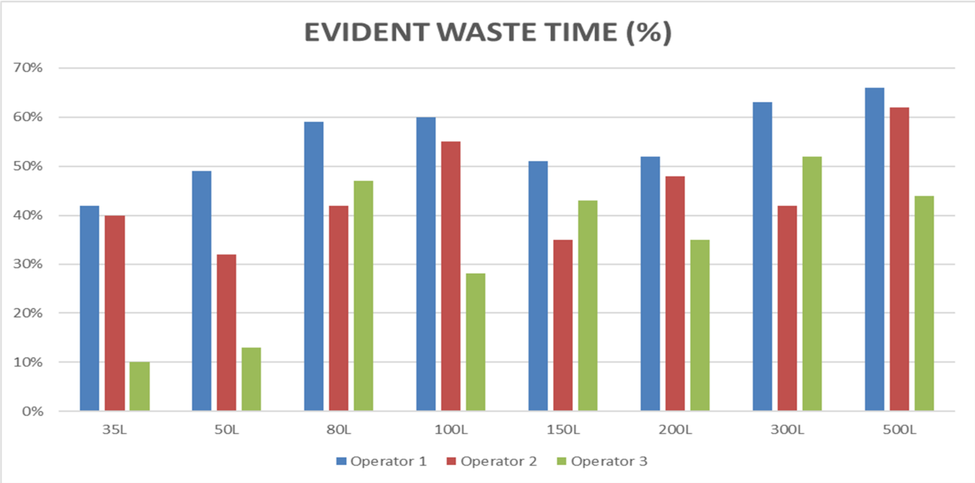


Figure 58: comparison among the three operators on Evident Waste Time for each product.

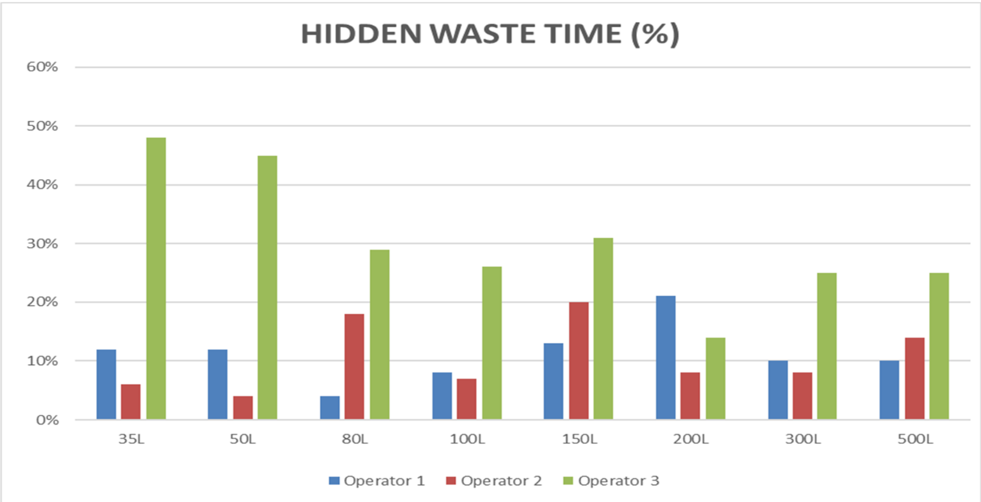


Figure 59: comparison among the three operators on Hidden Waste Time for each product.

- AFV division
  - Considering the product range from 35 to 500 liters, the average time taken to carry out Value Added activities is equal to 50% of the total time. We can observe that, compared to the ERCE product division, there is an increase in the time spent in performing Value Added activities. This is because the assembly of autoclaves provides a greater number of Value Added activities and, therefore, it is correct that, at the same time, we witness to an increase of this kind. However, the operators used only 17 hours, out of 34 total detected, in order to perform VA activities. The Evident Waste activity that affects most, in percentage terms, is that linked to the movement of the material and products along the line (56%). Similarly, the operators used almost 7 hours, out of 34, in performing activities related to this type of waste. Another noticeable Evident Waste refers to "Waiting" activities and it is equal to 3 hours (26%). Regarding Hidden Waste, the 60% (2 hours and a half) of the total time detected is given by the performance the following activities: "Pressure control and removal of the pre-charge" that counts for a 39% and "Putting the closed box, with the expansion tank inside, on the pallet" that counts for a 21%.

Specifically, the types of Evident Waste that distinguish each operator are as follows:

- Operator 1: *Motion* (70%) and *Waiting* (17%).
- Operator 2: *Waiting* (48%) and *Motion* (38%).
- Operator 3: *Motion* (60%) and *Transportation* (25%).

The main Hidden Waste activities for each operator are as follows:

- Operator 1: "*Pressure control and removal of the pre-charge*" that counts for a 70% and "*Preparation of the screws with the respective washers, for fixing the flange*" that counts for a 30%.
- Operator 2: "*Putting the closed box, with the expansion tank inside, on the pallet*" that counts for a 24%, "*Preparation of the conformity and instruction sheet*" that counts for a 35% and "*Pressure control and removal of the pre-charge*" that counts for a 22%.
- Operator 3: "*Putting the closed box, with the expansion tank inside, on the pallet*" that counts for a 38%, "*Pressure control and removal of the pre-charge*" that counts for a 22% and "*Put the adhesive tape around the closed box on the pallet*" that counts for a 22%.

The trend, in percentages terms, of time used to carry out Value Added, Evident and Hidden Waste activities, for each operator on all the range products, is depicted in the figures 60, 61 and 62).

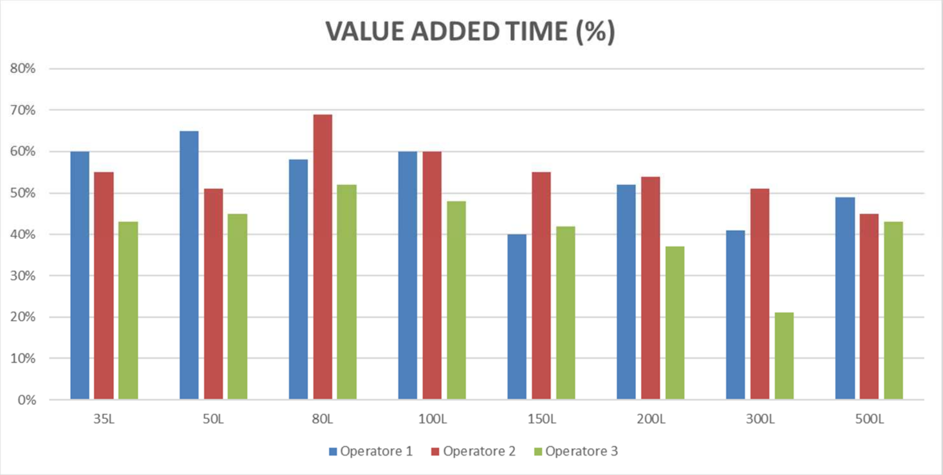


Figure 60: comparison among the three operators on Value Added Time for each product.

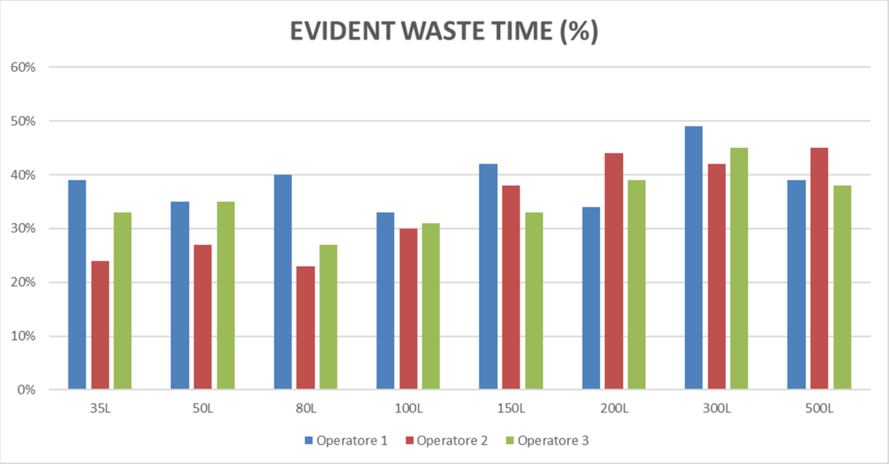


Figure 61: comparison among the three operators on Evident Waste Time for each product.

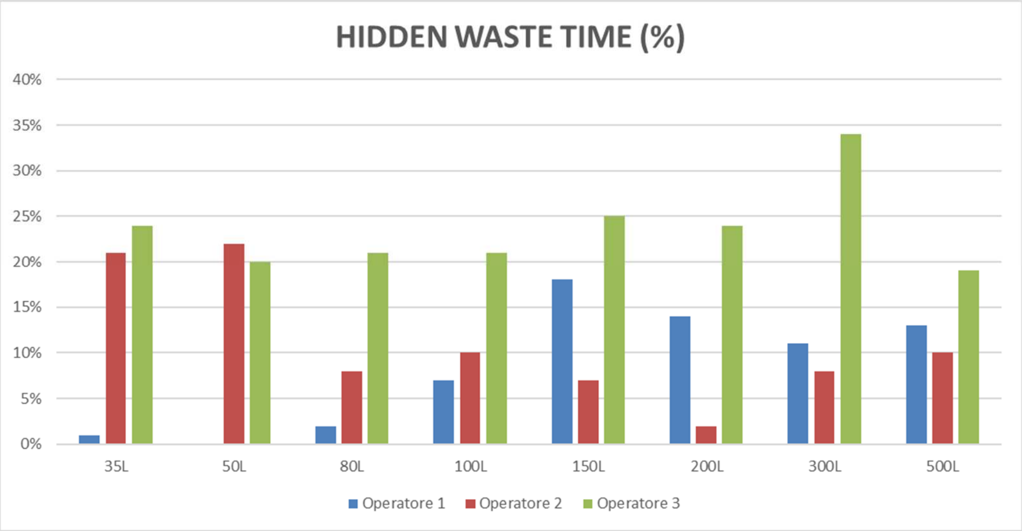


Figure 62: comparison among the three operators on Hidden Waste Time for each product.

- DV division
  - Considering the product range from 80L to 300L, the average time taken to carry out Value Added activities is equal to 38% of the total time. Compared to assembling of ERCEs products, those includes two more Value Added activities (put the second and third labels). Moreover, the DV expansion tanks require 3 bars of pressure before starting the testing, while ERCEs just 1.5. Recapitulating: on the one hand, we have an increase in Value Added activities, which should lead to an increase in the corresponding Value Added Time detected, while, on the other hand, if the pre-testing activity (going in pressure of the expansion tank) is not properly managed, it can experience long periods of waiting within the process. That is because the Average is very similar to that of ERCEs.

    However, the operators used only 4 hours, out of 10 total detected, in order to perform VA activities. The Evident Waste activity that affects most, in percentage terms, is that linked to the movement of the material and products along the line (58%). Similarly, the operators used almost 2 hours and a half, out of 10, in performing activities related to this type of waste. Another noticeable Evident Waste refers to "Waiting" activities and it is equal to 1 hour (24%). Regarding Hidden Waste, the 66% (1 hour) of the total time detected is given by the performance the following activities: "Pressure control and removal of the pre-charge" that counts for a 33% and "Putting the closed box, with the expansion tank inside, on the pallet" that counts for a 32%.

    Specifically, the types of Evident Waste that distinguish each operator are as follows:

    - Operator 1: *Motion* (86%) and *Waiting* (10%).
    - Operator 2: *Waiting* (45%) and *Motion* (41%).
    - Operator 3: *Motion* (41%) and *Transportation* (32%).

The main Hidden Waste activities for each operator are as follows:

- Operator 1: "*Pressure control and removal of the pre-charge*" that counts for an 80%.
- Operator 2: "*Putting the closed box, with the expansion tank inside, on the pallet*" that counts for a 46% and the "*Preparation of the conformity and instruction sheet*" that counts for *a* 29%.
- Operator 3: "*Putting the closed box, with the expansion tank inside, on the pallet*" that counts for a 49% and "*Put the adhesive tape around the closed box on the pallet*" that counts for a 38%.

The trend, in percentages terms, of time used to carry out Value Added, Evident and Hidden Waste activities, for each operator on the range products, is depicted in the figures 63, 64 and 65).

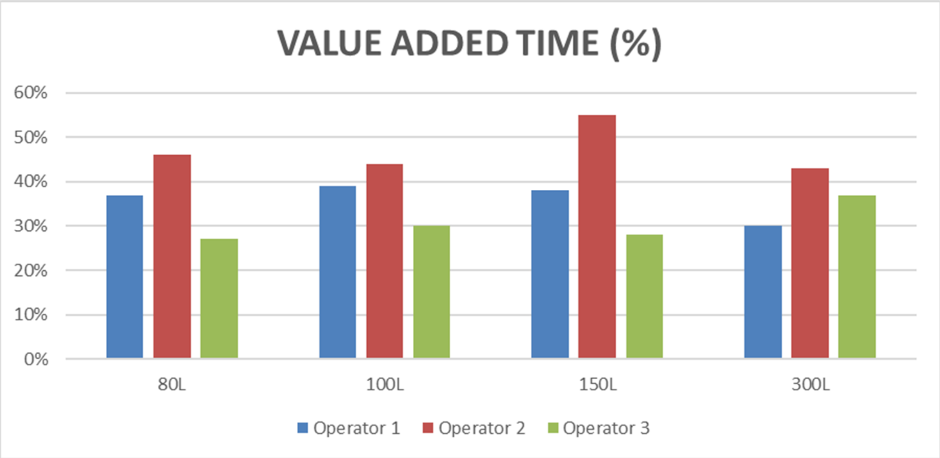


Figure 63: comparison among the three operators on Value Added Time for each product.

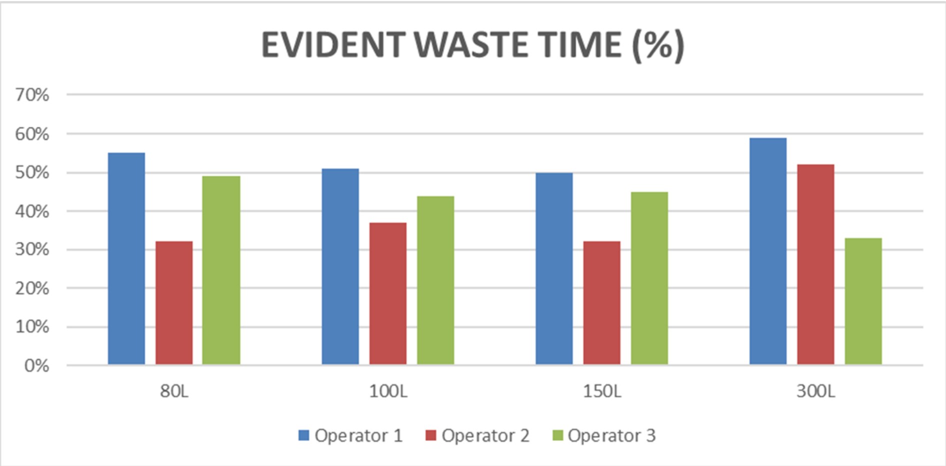


Figure 64: comparison among the three operators on Evident Waste Time for each product.

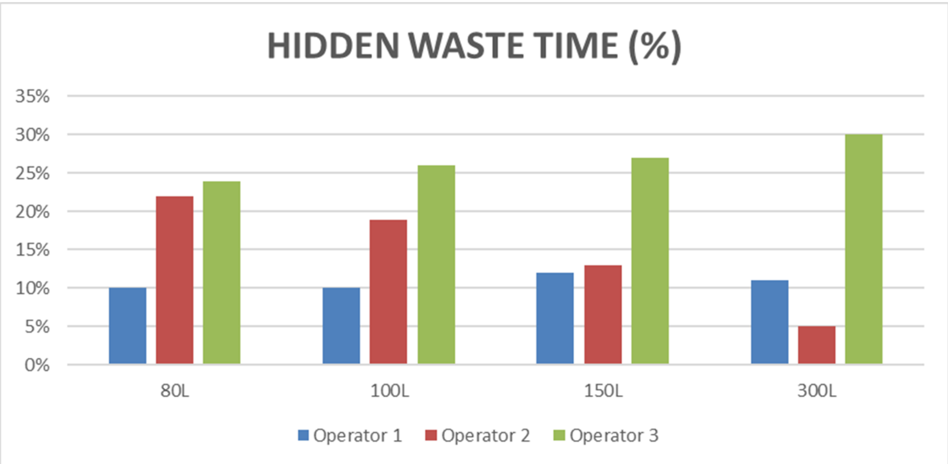


Figure 65: comparison among the three operators on Hidden Waste Time for each product.

As previously mentioned, the analysis was performed on a total amount of 75 hours, which are distributed among the six operators of the assembly line E (AL E) and assembly line F (AL F). In addition to this, we decided to made a comparison of the two lines concerning the assembly of three specific products of ERCE division and three of AFV one. We collected a total amount of 14 hours and we started taking in consideration that the same product assembled requires the same activities to be performed. Nevertheless, during the analysis, it was noticed that the operator 1 of the line E carried out some activities in a different manner with respect to the operator 1 of the line F. For example, the operator 1 of the line F has never performed the activity of "*Putting the closed box, with the expansion tank or autoclave inside, on the pallet*", while the operator 1 of the line E performed it several times. As also the activities of "*Put the adhesive tape around the closed box on the pallet*" and that of the "*Preparation of the conformity and instruction sheet*" were carried out several times by the operator 1 of the line E. Working in this way, the operator 2 of the line E, in order to complete the assembly process, is forced to perform activities such as "*Pressure control and removal of the pre-charge*" or the "*Insertion of the valve in the expansion tank or autoclave* ", which were almost never carried out by the operator 2 the line F. The following tables describe the results of this comparison (see Figures 66 and 67).

	150LT ERCE								
	AL F	AL E	AL F	AL E	AL F	AL E	AVERAGE		
	OP 1	OP 1	OP 2	OP 2	OP 3	OP 3	AL F	AL E	DIFFERENCE
Value Added Time	33%	38%	46%	46%	27%	25%	**35%**	**36%**	**-1%**
Evident Waste Time	53%	50%	36%	33%	44%	42%	**44%**	**42%**	**3%**
Hidden Waste Time	14%	12%	18%	21%	29%	33%	**20%**	**22%**	**-2%**
	200LT ERCE								
	AL F	AL E	AL F	AL E	AL F	AL E	AVERAGE		
	OP 1	OP 1	OP 2	OP 2	OP 3	OP 3	AL F	AL E	DIFFERENCE
Value Added Time	26%	27%	38%	49%	51%	52%	**38%**	**43%**	**-4%**
Evident Waste Time	53%	51%	53%	44%	34%	35%	**47%**	**43%**	**3%**
Hidden Waste Time	21%	21%	9%	7%	15%	13%	**15%**	**14%**	**1%**
	300LT ERCE								
	AL F	AL E	AL F	AL E	AL F	AL E	AVERAGE		
	OP 1	OP 1	OP 2	OP 2	OP 3	OP 3	AL F	AL E	DIFFERENCE
Value Added Time	20%	33%	43%	58%	32%	14%	**32%**	**35%**	**-3%**
Evident Waste Time	66%	60%	51%	32%	44%	60%	**54%**	**51%**	**3%**
Hidden Waste Time	14%	7%	6%	10%	24%	27%	**15%**	**15%**	**0%**

Figure 66: comparison of operators 1, 2 and 3 regarding ERCE products (150L 200L and 300L).

	100LT AFV								
	AL F	AL E	AL F	AL E	AL F	AL E	AVERAGE		
	OP 1	OP 1	OP 2	OP 2	OP 3	OP 3	AL F	AL E	DIFFERENCE
Value Added Time	65%	55%	58%	61%	48%	48%	**57%**	**55%**	**2%**
Evident Waste Time	34%	31%	33%	29%	32%	30%	**33%**	**30%**	**3%**
Hidden Waste Time	1%	14%	9%	11%	20%	22%	**10%**	**15%**	**-5%**
	200LT AFV								
	AL F	AL E	AL F	AL E	AL F	AL E	AVERAGE		
	OP 1	OP 1	OP 2	OP 2	OP 3	OP 3	AL F	AL E	DIFFERENCE
Value Added Time	52%	50%	54%	55%	37%	36%	**48%**	**47%**	**1%**
Evident Waste Time	34%	34%	44%	43%	39%	42%	**39%**	**40%**	**-1%**
Hidden Waste Time	14%	16%	2%	2%	24%	22%	**13%**	**13%**	**0%**
	500LT AFV								
	AL F	AL E	AL F	AL E	AL F	AL E	AVERAGE		
	OP 1	OP 1	OP 2	OP 2	OP 3	OP 3	AL F	AL E	DIFFERENCE
Value Added Time	49%	48%	45%	51%	43%	39%	**45%**	**46%**	**-1%**
Evident Waste Time	38%	41%	45%	42%	38%	38%	**41%**	**40%**	**1%**
Hidden Waste Time	13%	11%	10%	7%	19%	23%	**14%**	**14%**	**0%**

Figure 67: comparison of operators 1, 2 and 3 regarding AFV products (100L, 200L and 500L).

The results obtained show levels of minimal differences between the various comparisons. Despite the different way of operating, above all by the operators 1, the overall percentages of Added Value, Evident Wastes and Occult are very similar to each other. On the one hand, we allocate some Value Added activities to the Operator 3 of the line F while in the line E is the operator 1 who performs the same. Conversely, we obtained the same result because the performance of the activities is at the completely discretion of the operators who do what they want regardless if they are in line F rather than in line E. The operators 1 never alternate between the two lines, so we can say that they are the ones who affect the way the other two operators work. The analysis carried out contributed to the creation of the std cycle times. Each activity reported in the worksheet has its standard reference cycle time. This is given by the arithmetic average of the various cycle times obtained on the multiple observations carried out on the same activity within the working cycle. All values too high or too low compared to the average and for which, during the data collection phase, was pointed out the reason why the operator performed them differently or slowed down the execution, were not considered for the calculation of the average cycle time as they would have affected the average significantly. The data observation sample for each activity is at least 30 observations, in order to obtain a statistically reliable standard cycle time. Initially, we calculated the std cycle times corresponding to the Value Added activities for each operator on the different product divisions being analyzed (see figure 68, 69 and 70).

	Valued Added (VA) activity	Value Added Time of each activity 35L	50L	80L	100L	150L	200L	300L	500L
Operator 1	Insert of the valve	00:00:04	00:00:04	00:00:04	00:00:05	00:00:04	00:00:04	00:00:04	00:00:04
	Fixing the valve					00:00:03	00:00:04	00:00:04	00:00:04
	Put the label	00:00:05	00:00:05	00:00:05	00:00:05				
	Insert the pre-charge	00:00:03	00:00:03	00:00:03	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04
	Testing in the water	00:00:07	00:00:09	00:00:13	00:00:14	00:00:18	00:00:22	00:00:22	00:00:25
Std VA Cycle Time of OP1		00:00:19	00:00:21	00:00:25	00:00:28	00:00:29	00:00:34	00:00:34	00:00:37
Operator 2	Put the label					00:00:07	00:00:06	00:00:07	00:00:06
	Put the conformity and instruction sheet	00:00:05	00:00:05	00:00:07	00:00:06	00:00:08	00:00:07	00:00:07	00:00:10
	Put the nylon	00:00:09	00:00:08	00:00:08	00:00:10	00:00:12	00:00:12	00:00:18	00:00:18
	Put the expansion tank inside the box	00:00:05	00:00:04	00:00:03	00:00:04	00:00:05	00:00:06	00:00:06	00:00:09
	Prepare an empty box	00:00:09	00:00:09	00:00:10			00:00:20	00:00:23	
Std VA Cycle Time of OP2		00:00:28	00:00:26	00:00:28	00:00:20	00:00:32	00:00:51	00:01:01	00:00:43
Operator 3	Close the box with the expansion tank inside	00:00:10	00:00:10	00:00:11	00:00:09	00:00:08	00:00:16	00:00:21	00:00:19
	Put the label on the empy box	00:00:06	00:00:08	00:00:08	00:00:07	00:00:06	00:00:09	00:00:09	00:00:07
	Prepare an empty box				00:00:11	00:00:13			00:00:25
Std VA Cycle Time of OP3		00:00:16	00:00:18	00:00:19	00:00:27	00:00:27	00:00:25	00:00:30	00:00:51
VA WORK CONTENT		00:01:03	00:01:05	00:01:12	00:01:15	00:01:28	00:01:50	00:02:05	00:02:11

Figure 68: Standard cycle time of the Valued Added activity for each Operator of the ERCE division.

	Valued Added (VA) activity	Value Added Time of each activity 80L	100L	150L	300L
Operator 1	Insert of the valve	00:00:04	00:00:04	00:00:05	00:00:06
	Fixing the valve			00:00:04	00:00:05
	Put the second label	00:00:10	00:00:08	00:00:10	00:00:08
	Insert the pre-charge	00:00:04	00:00:04	00:00:04	00:00:05
	Testing in the water	00:00:13	00:00:12	00:00:17	00:00:22
Std VA Cycle Time of OP1		00:00:27	00:00:24	00:00:31	00:00:35
Operator 2	Put the label	00:00:06	00:00:07	00:00:07	00:00:07
	Put the third label	00:00:10	00:00:09	00:00:11	00:00:09
	Put the conformity and instruction sheet	00:00:09	00:00:10	00:00:07	00:00:07
	Put the nylon	00:00:07	00:00:07	00:00:10	00:00:15
	Put the expansion tank inside the box	00:00:04	00:00:03	00:00:04	00:00:05
	Prepare an empty box	00:00:09			00:00:22
Std VA Cycle Time of OP2		00:00:45	00:00:36	00:00:39	00:01:05
Operator 3	Close the box with the expansion tank inside	00:00:12	00:00:09	00:00:10	00:00:20
	Put the label on the empy box	00:00:06	00:00:07	00:00:06	00:00:08
	Prepare an empty box		00:00:11	00:00:15	
Std VA Cycle Time of OP3		00:00:18	00:00:27	00:00:31	00:00:28
VA WORK CONTENT		00:01:30	00:01:27	00:01:41	00:02:08

Figure 69: Standard cycle time of the Valued Added activity for each Operator of the DV division.

	Valued Added (VA) activity	35L	50L	80L	100L	150L	200L	300L	500L
		Value Added Time of each activity							
Operator 1	Insert of the valve	00:00:06	00:00:05	00:00:05	00:00:04	00:00:04	00:00:04	00:00:05	00:00:05
	Fixing the valve				00:00:03	00:00:03	00:00:05	00:00:04	00:00:05
	Put the label	00:00:06	00:00:06	00:00:04	00:00:05	00:00:04	00:00:04	00:00:05	00:00:07
	Insert the pole with the membrane inside the autoclave			00:00:23	00:00:22	00:00:25	00:00:17	00:00:20	00:00:21
	Fixing the flange	00:00:25	00:00:26	00:00:24	00:00:22	00:00:26	00:01:02	00:00:58	00:00:59
	Insert the pre-charge	00:00:03	00:00:03	00:00:04	00:00:03	00:00:03	00:00:04	00:00:04	00:00:05
	Testing in the water			00:00:13	00:00:12	00:00:16	00:00:19	00:00:22	00:00:24
Std VA Cycle Time of OP1		**00:00:40**	**00:00:40**	**00:01:13**	**00:01:11**	**00:01:21**	**00:01:55**	**00:01:58**	**00:02:06**
Operator 2	Fixing the plastic on the flange			00:00:03	00:00:03	00:00:04	00:00:04	00:00:04	00:00:04
	Insert the pole inside the membrane			00:00:26	00:00:24	00:00:25	00:00:24	00:00:25	00:00:28
	Removal of the pole from autoclave, during the insertion of the membrane			00:00:18	00:00:21	00:00:22	00:00:21	00:00:24	00:00:24
	Screwing the nut	00:00:07	00:00:07	00:00:08	00:00:08	00:00:09	00:00:07	00:00:25	00:00:17
	Put the conformity and instruction sheet	00:00:05	00:00:06	00:00:08		00:00:07		00:00:06	00:00:06
	Put the nylon	00:00:05	00:00:05	00:00:09		00:00:10		00:00:15	00:00:16
	Put the expansion tank inside the box	00:00:05	00:00:05	00:00:03		00:00:04		00:00:07	00:00:10
	Put the label on the empy box	00:00:07	00:00:07						
	Prepare an empty box	00:00:09	00:00:09				00:00:11		
Std VA Cycle Time of OP2		**00:00:38**	**00:00:39**	**00:01:15**	**00:00:56**	**00:01:21**	**00:01:07**	**00:01:46**	**00:01:45**
Operator 3	Close the box with the expansion tank inside	00:00:09	00:00:10	00:00:14	00:00:13	00:00:13	00:00:13	00:00:23	00:00:30
	Put the label on the empy box			00:00:09	00:00:08	00:00:08	00:00:09	00:00:07	00:00:09
	Prepare an empty box			00:00:11	00:00:12	00:00:13		00:00:23	00:00:25
	Testing in the water	00:00:07	00:00:08						
	Insert the membrane into the autoclave	00:00:10	00:00:11						
	Put the conformity and instruction sheet				00:00:05		00:00:05		
	Put the nylon				00:00:10		00:00:11		
	Put the expansion tank inside the box				00:00:05		00:00:05		
	Fixing the plastic on the flange	00:00:03	00:00:03						
Std VA Cycle Time of OP3		**00:00:29**	**00:00:32**	**00:00:34**	**00:00:53**	**00:00:34**	**00:00:43**	**00:00:53**	**00:01:04**
VA WORK CONTENT		**00:01:47**	**00:01:51**	**00:03:02**	**00:03:00**	**00:03:16**	**00:03:45**	**00:04:37**	**00:04:55**

Figure 70: Standard cycle time of the Valued Added activity for each Operator of the AFV division.

Figure 68 describes the Value Added cycle times for each activity carried out by the operators regarding the ERCE expansion tanks. More than one operator has been assigned the same activities

(I.e. example "*Put the label*") because, during time detection, we noticed that this specific task was carried out both by the Operator 1 and Operator 2, as there was no *Standardization* in the allocation of tasks. We decided to assign the reference cycle time to the operator who performed the aforementioned activity many times within the same observed time. Specifically, the Value Added cycle time calculated for the Operator 1 is increasing, moving from 35 to 500 liters.

Testing activity is the one that influences more this increase in cycle time. This activity occurs by immersing the expansion tank in the water, visually checking for leaks at the valve and circumferential welding level. It averages from 7 seconds to 25 (almost four times), without considering the time required for the expansion tank to reach the required pressure (1.5 bar), which is obviously higher for a 500L compared to a 35L (having the same initial pressure incoming). The "*Testing in the water*" activity is only proper to the time that the expansion tank stays in the water because this is the actual testing and, therefore, the actual Added Value. Obviously, there is a waste, in terms of *Motion* of the expansion tank (carried out by the

Operator 1) and *Waiting*, once the test has been completed (carried out by the Operator 2) in getting the expansion tank and continuing the working cycle with the subsequent packaging.
Regarding Operator 2 and 3, we noticed that there is, in general, an increase moving from 35 to 500 liters. This increase does not occur only if the operator 3, instead of the operator 2, has performed the activity of "*Prepare an empty box*". We highlighted in blue the activities that are constantly increasing and then, they have a greater impact on cycle times.
For each data sample, in addition to calculating the arithmetic mean, we decided to calculate the respective standard deviation, which expresses the variability of the data around the mean. Only in reference to some activities for certain products (300L and 500L), such as "*Put the Nylon*", "*Closed the box with the expansion tank inside*" and "*Prepare an empty box*", we got a standard deviation of more than 20%, compared to the sample average. As for other Value Added activities, the standard deviation is between 1% and 10% if compared to the respective mean.
Whereas, we are talking about of manual activities that are performed without the definition of any standard where the operator decides how to carry out them. Thus, we can assume that if in some cases there is a level of variability of this type however, this is statistically acceptable.

Figure 69 describes the Value Added cycle times for each activity carried out by the operators regarding the DV expansion tanks. In addition, within the DV products division, the same considerations made regarding the ERCEs are valid as well. We noticed that there is an increase in the cycle time that is due to an increase in Value Added activities, which are necessary so that the product is properly assembled ("*Put the second label*" and "*Put the third label"*, which are highlighted in green in the table).
Figure 70 describes the Value Added cycle times for each activity carried out by the operators regarding the AFV autoclaves. As we can notice, there are more Valued Added activities, which are highlighted in blue in the table, that lead to an increase of cycle times. The time spent in performing those activities (such as the "*Fixing of the flange*", "*The insertion of the membrane*" etc.) increases the final cycle time of each operator compared to ERCEs and DVs. In addition, within the AFV products division, the same considerations made regarding ERCEs and DVs are valid as well. There are two Valued Added activities that are "*Screwing the nut*" and "*Insert the pole inside the membrane"*, both performed by the Operator 2, which present a standard deviation higher than 20% if compared with the respective mean.
For each products of each division, we calculated the respective Value Added Work Content, by summing up the Value Added cycle times of the three operators.

Valued Added cycle times are useful, because they are the starting point in order to calculate the Actual Cycle Times, which also include Evident and Hidden Waste activities.

How it was calculated?

After finishing the progressive chronometric detection of the operator, we took note of the actual output, for example regarding the Operator 1 “the number of tested products”, within the time taken. Then we also considered all the Waste activities, which are necessary in order to complete the assembly process. We did it for each operator and product observed.

Then, we calculated the following KPIs:

- balancing loss;
- hourly production rate;
- Percentage of Value Added and Waste cycle time on the Actual cycle time.

The results are described in the Figure 71, 72 and 73.

	35L ERCE			IDLE TIME	TOTAL WORKING TIME	BALANCING LOSS	THROUGHPUT RATE	HOURLY PRODUCTION RATE	% OF VALUE ADDED CYCLE TIME	% OF WASTE CYCLE TIME
	Valued Added CT	Waste CT	ACTUAL CT							
Operator 1	00:00:19	00:00:22	00:00:41						46%	54%
Operator 2	00:00:28	00:00:22	00:00:50	00:00:21	00:02:30	**14%**	0,020	**72**	56%	44%
Operator 3	00:00:16	00:00:22	00:00:38						42%	58%

	50L ERCE			IDLE TIME	TOTAL WORKING TIME	BALANCING LOSS	THROUGHPUT RATE	HOURLY PRODUCTION RATE	% OF VALUE ADDED CYCLE TIME	% OF WASTE CYCLE TIME
	Valued Added CT	Waste CT	ACTUAL CT							
Operator 1	00:00:21	00:00:29	00:00:50						42%	58%
Operator 2	00:00:26	00:00:15	00:00:41	00:00:13	00:02:30	**9%**	0,020	**72**	63%	37%
Operator 3	00:00:18	00:00:28	00:00:46						39%	61%

	80L ERCE			IDLE TIME	TOTAL WORKING TIME	BALANCING LOSS	THROUGHPUT RATE	HOURLY PRODUCTION RATE	% OF VALUE ADDED CYCLE TIME	% OF WASTE CYCLE TIME
	Valued Added CT	Waste CT	ACTUAL CT							
Operator 1	00:00:25	00:00:36	00:01:01						41%	59%
Operator 2	00:00:28	00:00:39	00:01:07	00:00:09	00:03:21	**4%**	0,015	**54**	42%	58%
Operator 3	00:00:19	00:00:45	00:01:04						30%	70%

	100L ERCE			IDLE TIME	TOTAL WORKING TIME	BALANCING LOSS	THROUGHPUT RATE	HOURLY PRODUCTION RATE	% OF VALUE ADDED CYCLE TIME	% OF WASTE CYCLE TIME
	Valued Added CT	Waste CT	ACTUAL CT							
Operator 1	00:00:28	00:00:39	00:01:07						42%	58%
Operator 2	00:00:20	00:00:47	00:01:07	00:00:02	00:03:24	**1%**	0,015	**53**	30%	70%
Operator 3	00:00:27	00:00:41	00:01:08						40%	60%

	150L ERCE			IDLE TIME	TOTAL WORKING TIME	BALANCING LOSS	THROUGHPUT RATE	HOURLY PRODUCTION RATE	% OF VALUE ADDED CYCLE TIME	% OF WASTE CYCLE TIME
	Valued Added CT	Waste CT	ACTUAL CT							
Operator 1	00:00:29	00:00:46	00:01:15						39%	61%
Operator 2	00:00:32	00:00:54	00:01:26	00:00:22	00:04:18	**9%**	0,012	**42**	37%	63%
Operator 3	00:00:27	00:00:48	00:01:15						36%	64%

	200L ERCE			IDLE TIME	TOTAL WORKING TIME	BALANCING LOSS	THROUGHPUT RATE	HOURLY PRODUCTION RATE	% OF VALUE ADDED CYCLE TIME	% OF WASTE CYCLE TIME
	Valued Added CT	Waste CT	ACTUAL CT							
Operator 1	00:00:34	00:01:06	00:01:40						34%	66%
Operator 2	00:00:51	00:00:55	00:01:46	00:00:12	00:05:18	**4%**	0,009	**34**	48%	52%
Operator 3	00:00:25	00:01:15	00:01:40						25%	75%

	300L ERCE			IDLE TIME	TOTAL WORKING TIME	BALANCING LOSS	THROUGHPUT RATE	HOURLY PRODUCTION RATE	% OF VALUE ADDED CYCLE TIME	% OF WASTE CYCLE TIME
	Valued Added CT	Waste CT	ACTUAL CT							
Operator 1	00:00:34	00:01:50	00:02:24						24%	76%
Operator 2	00:01:01	00:01:17	00:02:18	00:00:18	00:07:30	**4%**	0,007	**24**	44%	56%
Operator 3	00:00:30	00:02:00	00:02:30						20%	80%

	500L ERCE			IDLE TIME	TOTAL WORKING TIME	BALANCING LOSS	THROUGHPUT RATE	HOURLY PRODUCTION RATE	% OF VALUE ADDED CYCLE TIME	% OF WASTE CYCLE TIME
	Valued Added CT	Waste CT	ACTUAL CT							
Operator 1	00:00:37	00:01:53	00:02:30						25%	75%
Operator 2	00:00:43	00:02:37	00:03:20	00:01:10	00:10:00	**12%**	0,005	**18**	22%	79%
Operator 3	00:00:51	00:02:09	00:03:00						28%	72%

Figure 71: cycle times analysis of each product of the ERCE division.

	80L DV			IDLE TIME	TOTAL WORKING TIME	BALANCING LOSS	THROUGHPUT RATE	HOURLY PRODUCTION RATE	% OF VALUE ADDED CYCLE TIME	% OF WASTE CYCLE TIME
	Valued Added CT	Waste CT	CT							
Operator 1	00:00:27	00:00:42	00:01:09	00:00:08	00:03:36	**4%**	0,014	**50**	39%	61%
Operator 2	00:00:45	00:00:22	00:01:07						67%	33%
Operator 3	00:00:18	00:00:54	00:01:12						25%	75%
	100L DV			**IDLE TIME**	**TOTAL WORKING TIME**	**BALANCING LOSS**	**THROUGHPUT RATE**	**HOURLY PRODUCTION RATE**	**% OF VALUE ADDED CYCLE TIME**	**% OF WASTE CYCLE TIME**
	Valued Added CT	**Waste CT**	**CT**							
Operator 1	00:00:24	00:00:45	00:01:09	00:00:09	00:03:45	**4%**	0,013	**48**	35%	65%
Operator 2	00:00:36	00:00:39	00:01:15						48%	52%
Operator 3	00:00:27	00:00:45	00:01:12						38%	63%
	150L DV			**IDLE TIME**	**TOTAL WORKING TIME**	**BALANCING LOSS**	**THROUGHPUT RATE**	**HOURLY PRODUCTION RATE**	**% OF VALUE ADDED CYCLE TIME**	**% OF WASTE CYCLE TIME**
	Valued Added CT	**Waste CT**	**CT**							
Operator 1	00:00:31	00:00:47	00:01:18	00:00:26	00:04:45	**9%**	0,011	**38**	40%	60%
Operator 2	00:00:39	00:00:56	00:01:35						41%	59%
Operator 3	00:00:31	00:00:55	00:01:26						36%	64%
	300LT DV			**IDLE TIME**	**TOTAL WORKING TIME**	**BALANCING LOSS**	**THROUGHPUT RATE**	**HOURLY PRODUCTION RATE**	**% OF VALUE ADDED CYCLE TIME**	**% OF WASTE CYCLE TIME**
	Valued Added CT	**Waste CT**	**CT**							
Operator 1	00:00:35	00:02:25	00:03:00	00:00:32	00:09:00	**6%**	0,006	**20**	19%	81%
Operator 2	00:01:05	00:01:39	00:02:44						40%	60%
Operator 3	00:00:28	00:02:16	00:02:44						17%	83%

Figure 72: cycle times analysis of each product of the DV division.

	35L AFV			IDLE TIME	TOTAL WORKING TIME	BALANCING LOSS	THROUGHPUT RATE	HOURLY PRODUCTION RATE	% OF VALUE ADDED CYCLE TIME	% OF WASTE CYCLE TIME
	Valued Added CT	Waste CT	CT							
Operator 1	00:00:40	00:00:32	00:01:12						56%	44%
Operator 2	00:00:38	00:00:48	00:01:26	00:00:25	00:04:18	**10%**	0,012	**42**	44%	56%
Operator 3	00:00:29	00:00:46	00:01:15						39%	61%
	50L AFV			**IDLE TIME**	**TOTAL WORKING TIME**	**BALANCING LOSS**	**THROUGHPUT RATE**	**HOURLY PRODUCTION RATE**	**% OF VALUE ADDED CYCLE TIME**	**% OF WASTE CYCLE TIME**
	Valued Added CT	**Waste CT**	**CT**							
Operator 1	00:00:40	00:00:25	00:01:05						62%	38%
Operator 2	00:00:39	00:00:48	00:01:27	00:00:34	00:04:21	**13%**	**0,011**	**41**	45%	55%
Operator 3	00:00:32	00:00:43	00:01:15						43%	57%
	80L AFV			**IDLE TIME**	**TOTAL WORKING TIME**	**BALANCING LOSS**	**THROUGHPUT RATE**	**HOURLY PRODUCTION RATE**	**% OF VALUE ADDED CYCLE TIME**	**% OF WASTE CYCLE TIME**
	Valued Added CT	**Waste CT**	**CT**							
Operator 1	00:01:13	00:00:47	00:02:00						61%	39%
Operator 2	00:01:15	00:00:34	00:01:49	00:00:31	00:06:00	**9%**	0,008	**30**	69%	31%
Operator 3	00:00:34	00:01:06	00:01:40						34%	66%
	100L AFV			**IDLE TIME**	**TOTAL WORKING TIME**	**BALANCING LOSS**	**THROUGHPUT RATE**	**HOURLY PRODUCTION RATE**	**% OF VALUE ADDED CYCLE TIME**	**% OF WASTE CYCLE TIME**
	Valued Added CT	**Waste CT**	**CT**							
Operator 1	00:01:11	00:00:45	00:01:56						61%	39%
Operator 2	00:00:56	00:01:04	00:02:00	00:00:22	00:06:27	**6%**	0,008	**28**	47%	53%
Operator 3	00:00:53	00:01:16	00:02:09						41%	59%
	150L AFV			**IDLE TIME**	**TOTAL WORKING TIME**	**BALANCING LOSS**	**THROUGHPUT RATE**	**HOURLY PRODUCTION RATE**	**% OF VALUE ADDED CYCLE TIME**	**% OF WASTE CYCLE TIME**
	Valued Added CT	**Waste CT**	**CT**							
Operator 1	00:01:21	00:01:59	00:03:20						41%	**60%**
Operator 2	00:01:21	00:02:11	00:03:32	00:00:35	00:10:36	**6%**	0,005	**17**	38%	62%
Operator 3	00:00:34	00:02:35	00:03:09						18%	82%
	200L AFV			**IDLE TIME**	**TOTAL WORKING TIME**	**BALANCING LOSS**	**THROUGHPUT RATE**	**HOURLY PRODUCTION RATE**	**% OF VALUE ADDED CYCLE TIME**	**% OF WASTE CYCLE TIME**
	Valued Added CT	**Waste CT**	**CT**							
Operator 1	00:01:55	00:01:14	00:03:09						61%	39%
Operator 2	00:01:07	00:02:13	00:03:20	00:01:01	00:11:15	**9%**	0,004	**16**	34%	67%
Operator 3	00:00:43	00:03:02	00:03:45						19%	81%
	300L AFV			**IDLE TIME**	**TOTAL WORKING TIME**	**BALANCING LOSS**	**THROUGHPUT RATE**	**HOURLY PRODUCTION RATE**	**% OF VALUE ADDED CYCLE TIME**	**% OF WASTE CYCLE TIME**
	Valued Added CT	**Waste CT**	**CT**							
Operator 1	00:01:58	00:03:02	00:05:00						39%	61%
Operator 2	00:01:46	00:02:31	00:04:17	00:01:58	00:15:00	**13%**	0,003	**12**	41%	59%
Operator 3	00:00:53	00:02:52	00:03:45						24%	76%
	500L AFV			**IDLE TIME**	**TOTAL WORKING TIME**	**BALANCING LOSS**	**THROUGHPUT RATE**	**HOURLY PRODUCTION RATE**	**% OF VALUE ADDED CYCLE TIME**	**% OF WASTE CYCLE TIME**
	Valued Added CT	**Waste CT**	**CT**							
Operator 1	00:02:06	00:02:11	00:04:17						49%	51%
Operator 2	00:01:45	00:03:15	00:05:00	00:01:26	00:15:00	**10%**	0,003	**12**	35%	65%
Operator 3	00:01:04	00:03:13	00:04:17						25%	75%

Figure 73: cycle times analysis of each product of the AFV division.

First, in order to compute the *Balancing Los,* we calculated the Idle time of each product, which is a non-productive time and it is based on the "referring" cycle time. As referring cycle time, we used those highlighted in red, which are the bottlenecks of each assembly process. In fact, the station/operator with the higher cycle time gives the production rate to the entire line. Then, we calculated the Total Working time by multiplying the bottleneck cycle time by the number of stations/operators within the assembly line, which are three in total. The balancing loss is given by the division between the Idle time and the Total Working time. It indicates how much are, in percentage, the losses due to an incorrect balance within the line among the three operators. What has emerged is a situation in which the cycle time of each operator is, on average, quite in line with that of the others. In fact, the average value of Balancing Loss is equal to 8%, considering all the product divisions. This situation is possible because the operators settle between them, working in such a way as to absorb the waste of the other, through *Waiting* activities or unnecessary *Motion* or processing of materials. The balancing efficiency thus obtained is given by a high percentage of Waste, which would have been difficult to identify without having carried out an analysis of this kind, by studying the marginality of each activity (Value Added or not) on the total of the Actual cycle time. Then, we calculated the Hourly Production rate of each product, by multiplying the Throughput rate (equal to 1/ referring cycle time) with the total amount of seconds that constitute one hour of work (3600 seconds). *What is next?* This method allowed us to precisely identify and analyze the Cycle Time of each activity for each operator, obtaining a final Cycle Time for each product. The analysis carried out confirmed all the assessments made at the beginning, concerning the current situation of the company and it highlighted a potential that is not exploited, in fact, there is a high incidence of wasteful activities within the assembly process. Starting from the results obtained that describes the As-Is state, the next steps are as follows:

- distribution of workloads according to Value Added cycle times and a percentage of Waste necessary for the execution of the assembly process;
- design of a new layout, depending on the specific cycle times and the number of required work stations needed in order to respond to the customer demand;
- standardization of the activities, which will lead to a lower throughput time, being capable to respond faster to the market.

The work done by KaizenKey s.r.l., concerning this project, is concluded. The next step will be to work in workshops with all the people involved in the project, in order to achieve the aforementioned goals.

4.5.3. New Vision of the Assembly Department

In an ideal company, organized according to Kaizen methods, I should have for each type of product assembled the respective daily average demand, the number of products that must be assembled per day and based the production as a function of this and defining a Takt Time, also based on number of people current available in the department. Takt Time represents the time needed to produce a single component or an entire product in such a way as to satisfy the customer's demand, i.e. it represents the speed that the production process should have to meet the demand (Nguyen Thi Lam, 2016). In order to calculate it there are you required quantities:

1) D = that is the average daily customer demand for the products to be assembled
2) W = that is the total available working time per day (it is express in minutes).

Therefore, we have the following formula: $Takt\ Time = \frac{W}{D}\ in\ seconds\ per\ each\ product$

Then, I calculated the Takt Time goal of the assembly department based on the following information (see figure 74 and 75).

TYPE OF PRODUCT	LITERS CAPACITY	ACTUAL CYCLE TIME	AVERAGE DEMAND 2017
ERCE	35L	00:00:50	14517
	50L	00:00:50	10475
	80L	00:01:07	5100
	100L	00:01:08	5687
	150L	00:01:26	3973
	200L	00:01:46	3611
	300L	00:02:30	2430
	500L	00:03:20	1795
AFV	35L	00:01:26	1268
	50L	00:01:27	6803
	80L	00:02:00	912
	100L	00:02:09	6519
	150L	00:03:32	932
	200L	00:03:45	2645
	300L	00:05:00	1836
	500L	00:05:00	1678
DV	35L	00:01:00	3622
	50L	00:01:00	4126
	80L	00:01:12	501
	100L	00:01:15	681
	150L	00:01:35	297
	200L	00:02:00	828
	300L	00:03:00	650
	500L	00:04:00	496

Figure 74: average demand (2017) of each product assembled by ELBI S.P.A and the respective Actual Cycle Time

TOTAL DEMAND 2017	81382
N OF WORKING DAYS	250
DEMAND PER DAY (D)	326
N OF HOURS PER DAY	07:30:00
N OF MINUTES PER DAY (W)	450
TAKT TIME	**00:01:23**

TOTAL DEMAND 2018	86000
N OF WORKING DAYS	250
DEMAND PER DAY (D)	344
N OF HOURS PER DAY	07:30:00
N OF MINUTES PER DAY (W)	450
TAKT TIME	**00:01:18**

Figure 75: computation of the *Takt Time* of the products assembled in 2017 and in 2018.

Figure 74 describes the average demand of each product assembled, from ERCE division to DV one. The total demand of 2017 is equal to 81382 products, which is composed by the mix of all the products assembled within the same department (line E and line F). The respective Takt Time, according to the formula mentioned above, is equal to 00:01:23 minutes.
Based on the sales forecasts, I assumed that ELBI S.P.A. would increase sales by 6% in 2018. Then, the total demand for the year 2018 will be 86000 products, regarding the assembly department. The respective Takt Time, with the same hours worked, will be 00:01:18 minutes.

Working according to Takt Time is the basis for a standardized and cyclical assembly process. The process assigned to each workstation must be completed in accordance with the Takt Time. In this way, throughput time and wastes are reduced and, at the same time, there is an increase in the productivity rate. Then, we have to deal concerning the definition of the number of stations/operators required to carry out all the activities.
Finally, we arrive at the One-Piece-Flow assembly line, in which the products flow on the line one at a time, without studying a fixed production sequences, depending on what is really required by the market (Takt Time). This kind of assembly line is far more flexible than those mentioned at the beginning (single, multi and mixed models) and it is applicable when the set-ups moving from products to another are close to zero time and in the absence of technical and logistic constraints that prevent the change of production type immediately.

The supplier of the assembly lines is the painting process, which produces on two ovens that can work with one color each (of three available). During the analysis, I noticed that, between the different lines, there were storage areas where the paint output was placed before being used in the next phase (assembly process). This concept is expressed as *Buffering* and it allows the phases to take place independently. If there is no buffer between the two phases, it is assumed that these are directly connected. The bottleneck concerning all the production process, starting from the Processing of sheet metal in department B or C up to the final Assembly, is the painting that has a production rate (total of pieces of hour) defined. The bottleneck limits the capacity or the maximum output of a process.
The goal will be to optimize the painting mix and, depending on this and on what it will be produced, defining the assembly department with the right number of operators/station, materials, etc. needed.
In a process designed like that, problems, in terms of *Blocking* and *Starving*, may arise with reference to assembly lines.
The first occurs when the activities of a phase must stop because there is no place to deposit the product just completed (I.e. when the operator 1 has completed the testing and he does not know where to place the expansion tank or autoclave because the operator 2 is still finishing packing the previous one). The second occurs, when the activities of one phase have to stop because there is no work to do (I.e. when the operator 2 stopped working, because he was waiting for the operator 1 to finish the test or when the operator 3 is waiting for the logistics staff to take the pallet with the lot on it, in order to place a new pallet in the workstation).
For these reasons, I thought that the testing phase should be automated, so that the time needed to test an expansion tank or an autoclave is defined for each type of product. In this way, the variability observed within the data collection, through the standard deviation, could be eliminated.
If we consider that in addition to the Value Added testing, there is also the *Motion* of handling the product before and after, with a consequent *Waiting* by the operator 2, since the two phases are not correctly balanced, with an automated testing we can achieve efficiency within the process.
Figure 76 describes the testing times for each product.

	ERCE	AFV	DV
35L	00:00:15	00:00:18	00:00:20
50L	00:00:17	00:00:20	00:00:23
80L	00:00:21	00:00:27	00:00:31
100L	00:00:23	00:00:32	00:00:36
150L	00:00:30	00:00:43	00:00:49
200L	00:00:36	00:00:53	00:01:02
300L	00:00:49	00:01:15	00:01:28
500L	00:01:15	00:02:00	00:02:20

Figure 76: testing time for each product.

As we can see in Figure 76, DV division gives the highest automated testing time, in fact, before being tested, they must reach three bar of internal pressure. The ERCE division must reach 1.5 bar, while the AFV division 2.5 bar.

How will the testing work?

The test will be completely automated. The testing will work with a Programmable Logic Controller where the operator will set a pressure value related to the specific product assembled and, subsequently, he inserts the pre-charge, connecting the air-line to the expansion tank or autoclave.
Starting from an initial pressure of eight bar, the expansion tank or autoclave will reach the established bar (1.5, 2.5 or 3 bar). At the end, once the pressure has been reached, the inflow of incoming air will be blocked and the product tested, through a high precision pressure sensor, checking for any pressure losses. The effective time of testing on average is close to 10 seconds.
In this way, the operator will no longer be forced to check the pressure several times and to perform activities that are not required to mask this *Waiting time*. From the analysis carried out previously, the average time spent to perform the activity of "*Pressure control and removal of the pre-charge*" affected the total amount of Hidden Waste with a 40%, on average.
The Human Machine Interface (HMI), with which the operator 1 interfaces, is shown in Figure 77.

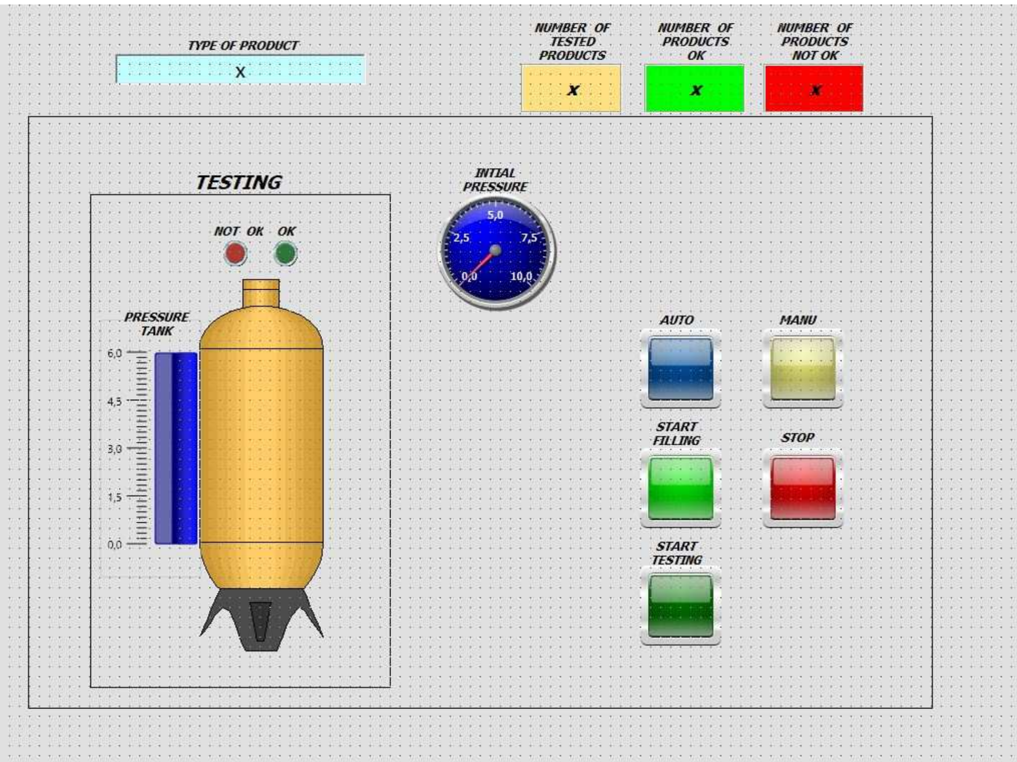


Figure 77: HMI of the automated testing.

Figure 77 describes the real-time view of the product being tested. As we can see, it indicates the level of starting pressure, the setting of the pre-charge pressure for each product and the possibility to carry out the test in an automatic or manual way, in case we want to test the expansion tank or autoclave at a different pressure. Moreover, the number of tested products and how many of them have been a negative or positive test is also shown.

With the introduction of an automatic test, the respective times will become the new Takt time goal. In cases where the testing time will be less than the referring Takt time (equal to 00:01:18 minutes), there will be no problems because we are below the Takt time, when, instead, the time required for the test will be greater than the Takt time then, this one will become the new target time. There are three cases where it happens: 300L DV and 500L DV and AFV (according to figure 76).
From what emerged from the analysis, shown in figures 71, 72 and 73, the percentage of cycle time with Valued Added on the total Actual cycle time (equal to Value Added cycle time + Waste cycle time) is approximately 40%, on average.
The goal, after improving the line, is in achieving a Future assembly state in which the percentage of cycle time with Valued Added on the total Actual cycle time is approximately between 50 and 55%, on average. Consequently, the percentage of Waste cycle time on the total Actual cycle will be approximately around time 50% and 45%, when, today, it has an average impact of 60%.

How can we achieve these results?

- *Workspace optimization:* optimizing the workplace of each workstation, standardization of the tools and materials and removing what is not necessary. 5S practices can be implemented.
- *Standardization of operators' tasks and giving a method of execution*:
    - standardized work: the tasks, especially those critical, are broken down into small activities and then examined in order to provide a define Method to carry out them. This Method has to be the best and safest, it is based on the cycle times detected and on all the technical constraints that are inside the working cycle. Then, those standards must be established, taught and sustained by the operators.
- *Reduction of wastes* such as:
    - unnecessary motions (of the expansion tank along the workbench, going to take the product in undefined areas once the painting process is over, etc.).
    - transportation (of the lot complete on the pallet by Operator 3, because the logistics staff is often inefficient in collecting the goods).

- waiting activities (doing something that is not properly required implies waiting time by other operators who have to move the product to the next work station).

- *Internal logistic design*: based on the new layout definition, it is important to guarantee the right material in the right quantity to the lines, mostly if we want to exploit the flexibility of the products, working on different products once at time within the same division. Moving from a concept of batch-model line to a one-piece-flow line. The results is that operators perform primarily Value Added activity and the logistics activity will be separated between assembly ones.
- *Layout design:* in order to get a better assembly process, a new assembly layout must be created, which is more suitable for the new workplace optimization and logistics service, it is space saving and more convenience by supporting one-piece flow concept.

The current layout assembly line of the department M is as follows (see figure 78):

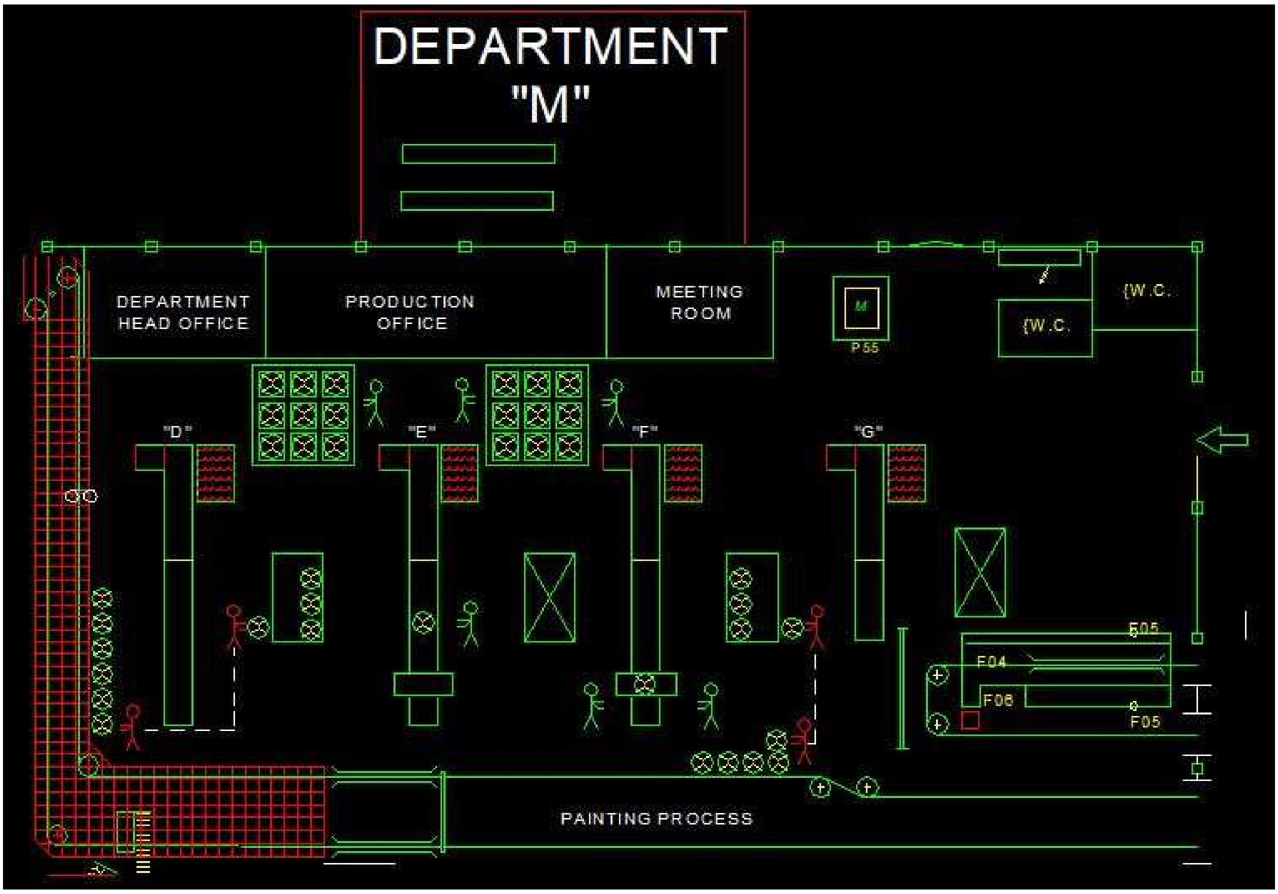


Figure 78: current layout of the assembly lines within the Department M.

As we can see in figure 78, only two lines out of four are working, so the capacity of the assembly department is not fully exploited. The two lines that are working are Line F and Line E, where we can see three workers for each of them, highlighted in green in the figure. Between the different lines there are the storage areas where the workers, highlighted in red, bring the product from the painting process to the assembly one. There are more than one storage area and none of these is defined.

Thus, first the logistics staff bring the product to the storage area and then, the operator 1 takes the product from there and brings it into the assembly line. The workplace is not optimized because the operators are currently working on a long line; in fact, the space between the tub for testing and the offices is narrow and sometimes for the logistics staff it can be difficult to go through, since packaging has been carried out, being the packaging right there.

For these reason, I developed a new layout for the assembly process (see figure 79).

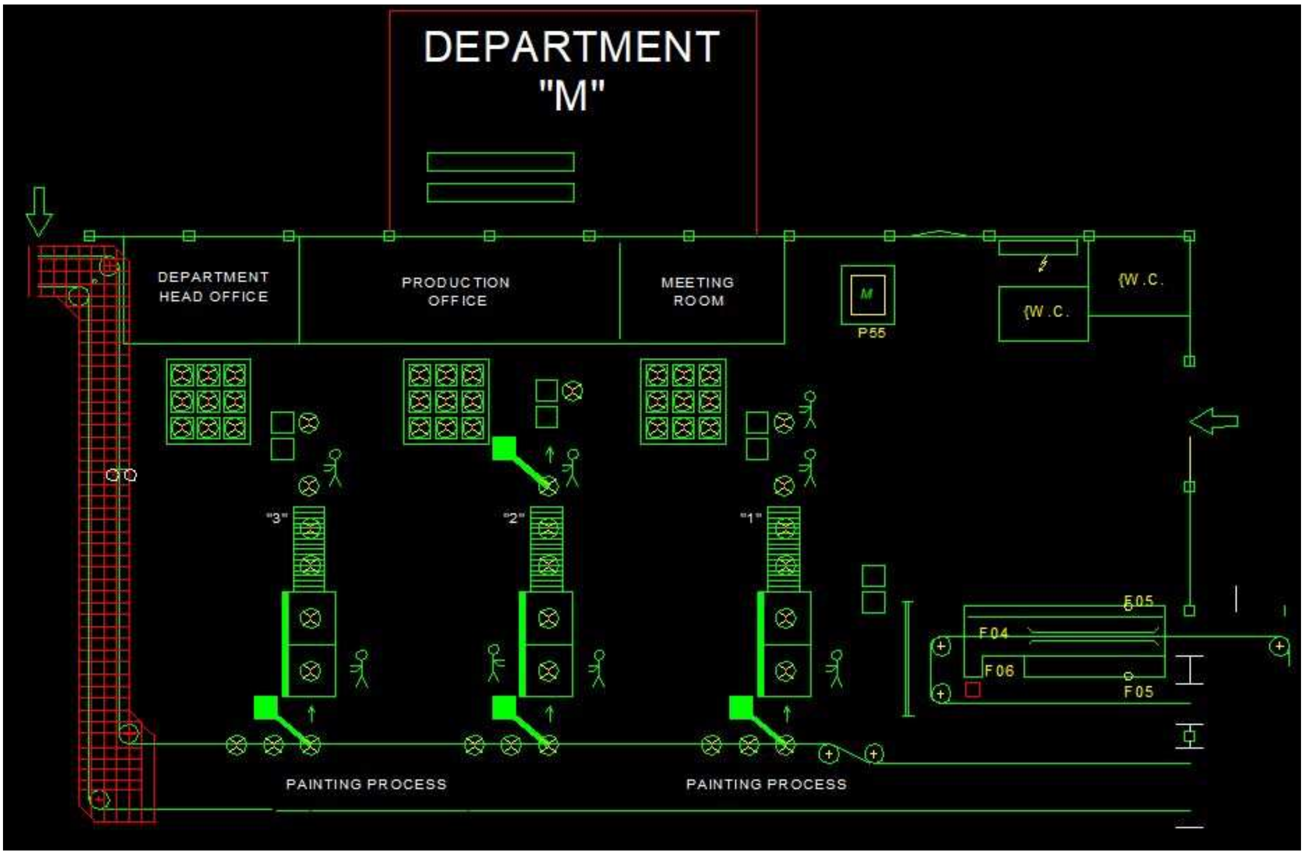


Figure 79: future layout of the assembly lines within the Department M.

Figure 79 describes a new concept of potential layout concerning the assembly process.
There will no longer be four assembly lines, but three stations based on the product family (ERCE, AFV and DV). In each station will be assembled only the products that are part the same family.
The goal is no longer to work in batches, but to take advantage of the flexibility, working on one-piece-flow, moving also from a 100L ERCE to a 500L ERCE. Each station will be designed specifically with all the equipment and materials necessary for the completion of the assembly process. The number of operators required for each station will be given by the actual requirement and will be established according to the previously planned painting mix. All activities prior to testing will be carried out in the first station. Regarding ERCE and DV expansion tanks, only one operator will be needed in the first station. Concerning AFV division, if we decide to automate the insertion of the membrane and the fixing of the flange (by reducing the cycle time) then, a single operator, in the first station, will be needed as well, instead of two. The automatic test will be done in a station adjacent to the first one in the way described above and it is independently from the process. Once the test is finished, the product will run on a conveyor belt, arriving at the next stage, labeling and packaging. Thus, there will be only two separate workstations connected by a conveyor belt. In this way, the operator can independently perform all the work in the same station, from the beginning to the end, without having to travel miles that are not necessary and are not Value Added.
As we see in Figure 79, the space between the end of the conveyor belt and the offices is greater than before, so a defined area of passage for Internal Logistics can be designed. The workers of the logistics staff (the ones in red in the previously layout), who brought the painted products to the storage areas, will no longer be needed. With this new configuration, the product will be moved directly by the Operator 1 who, using a hoist, will position the product in the station. The others will remain hanging on the painting line waiting to be assembled. The chain of the painting line will then be modified and brought close to the three "*assembly islands*". A hoist will also be necessary in station two, immediately after the conveyor belt, for the handling, during the packaging phase, of the autoclaves from 200 to 500 liters, given their size.
The investment was estimated around 30 thousand euros per station. The total amount is 90 thousand euros, concerning the automated testing, conveyor belt, hoists etc.

The future assembly state for each of the three stations and obviously, for each product division is highlighted in the following tables (see figure 80, 81, 82, 83, 84, 85 and 86)

ERCE	35L	50L	80L	100L	150L	200L	300L	500L
Insert of the valve	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04
Fixing the valve	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04
Put the label	00:00:06	00:00:06	00:00:06	00:00:06	00:00:06	00:00:06	00:00:06	00:00:06
Insert the pre-charge	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04
Prepare an empty box						00:00:20	00:00:23	00:00:25
VALUED ADDED WORK CONTENT	**00:00:18**	**00:00:18**	**00:00:18**	**00:00:18**	**00:00:18**	**00:00:38**	**00:00:41**	**00:00:43**
% OF WASTE	**45%**	**45%**	**45%**	**45%**	**45%**	**45%**	**45%**	**45%**
FUTURE WORK CONTENT	**00:00:33**	**00:00:33**	**00:00:33**	**00:00:33**	**00:00:33**	**00:01:09**	**00:01:15**	**00:01:18**
N° OF OPERATORS	1	1	1	1	1	1	1	1
CYCLE TIME OF EACH OPERATOR	**00:00:33**	**00:00:33**	**00:00:33**	**00:00:33**	**00:00:33**	**00:01:09**	**00:01:15**	**00:01:18**
AUTOMATIC TESTING	**00:00:15**	**00:00:17**	**00:00:21**	**00:00:23**	**00:00:30**	**00:00:36**	**00:00:49**	**00:01:15**
Put the conformity and instruction sheet	00:00:05	00:00:05	00:00:06	00:00:06	00:00:08	00:00:07	00:00:07	00:00:10
Put the nylon	00:00:08	00:00:08	00:00:08	00:00:10	00:00:12	00:00:12	00:00:18	00:00:18
Prepare an empty box	00:00:08	00:00:08	00:00:10	00:00:10	00:00:13			
Put the label on the empy box	00:00:06	00:00:06	00:00:06	00:00:06	00:00:06	00:00:06	00:00:06	00:00:06
Put the expansion tank inside the box	00:00:04	00:00:04	00:00:04	00:00:04	00:00:05	00:00:06	00:00:06	00:00:09
Close the box with the expansion tank inside	00:00:09	00:00:09	00:00:10	00:00:10	00:00:10	00:00:16	00:00:20	00:00:20
VALUED ADDED WORK CONTENT	**00:00:40**	**00:00:40**	**00:00:44**	**00:00:46**	**00:00:54**	**00:00:47**	**00:00:57**	**00:01:03**
% OF WASTE	**45%**	**45%**	**45%**	**45%**	**45%**	**45%**	**45%**	**45%**
FUTURE WORK CONTENT	**00:01:13**	**00:01:13**	**00:01:20**	**00:01:24**	**00:01:38**	**00:01:25**	**00:01:44**	**00:01:55**
N° OF OPERATORS	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**
CYCLE TIME OF EACH OPERATOR	**00:00:36**	**00:00:36**	**00:00:40**	**00:00:42**	**00:00:49**	**00:00:43**	**00:00:52**	**00:00:57**

Figure 80: future balancing state – Proposal 1 with Value added cycle time 55% and Waste cycle time 45% on the total Actual cycle time (ERCE division).

ERCE	35L	50L	80L	100L	150L	200L	300L	500L
Insert of the valve	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04
Fixing the valve	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04
Put the label	00:00:06	00:00:06	00:00:06	00:00:06	00:00:06	00:00:06	00:00:06	00:00:06
Insert the pre-charge	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04
Prepare an empty box						00:00:20	00:00:23	00:00:25
VALUED ADDED WORK CONTENT	**00:00:18**	**00:00:18**	**00:00:18**	**00:00:18**	**00:00:18**	**00:00:38**	**00:00:41**	**00:00:43**
% OF WASTE	**50%**	**50%**	**50%**	**50%**	**50%**	**50%**	**50%**	**50%**
FUTURE WORK CONTENT	**00:00:36**	**00:00:36**	**00:00:36**	**00:00:36**	**00:00:36**	**00:01:16**	**00:01:22**	**00:01:26**
N° OF OPERATORS	1	1	1	1	1	1	1	1
CYCLE TIME OF EACH OPERATOR	**00:00:36**	**00:00:36**	**00:00:36**	**00:00:36**	**00:00:36**	**00:01:16**	**00:01:22**	**00:01:26**
AUTOMATIC TESTING	**00:00:15**	**00:00:17**	**00:00:21**	**00:00:23**	**00:00:30**	**00:00:36**	**00:00:49**	**00:01:15**
Put the conformity and instruction sheet	00:00:05	00:00:05	00:00:06	00:00:06	00:00:08	00:00:07	00:00:07	00:00:10
Put the nylon	00:00:08	00:00:08	00:00:08	00:00:10	00:00:12	00:00:12	00:00:18	00:00:18
Prepare an empty box	00:00:08	00:00:08	00:00:10	00:00:10	00:00:13			
Put the label on the empy box	00:00:06	00:00:06	00:00:06	00:00:06	00:00:06	00:00:06	00:00:06	00:00:06
Put the expansion tank inside the box	00:00:04	00:00:04	00:00:04	00:00:04	00:00:05	00:00:06	00:00:06	00:00:09
Close the box with the expansion tank inside	00:00:09	00:00:09	00:00:10	00:00:10	00:00:10	00:00:16	00:00:20	00:00:20
VALUED ADDED WORK CONTENT	**00:00:40**	**00:00:40**	**00:00:44**	**00:00:46**	**00:00:54**	**00:00:47**	**00:00:57**	**00:01:03**
% OF WASTE	**50%**	**50%**	**50%**	**50%**	**50%**	**50%**	**50%**	**50%**
FUTURE WORK CONTENT	**00:01:20**	**00:01:20**	**00:01:28**	**00:01:32**	**00:01:48**	**00:01:34**	**00:01:54**	**00:02:06**
N° OF OPERATORS	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**
CYCLE TIME OF EACH OPERATOR	**00:00:40**	**00:00:40**	**00:00:44**	**00:00:46**	**00:00:54**	**00:00:47**	**00:00:57**	**00:01:03**

Figure 81: future balancing state – Proposal 2 with Value added cycle time 50% and Waste cycle time 50% on the total Actual cycle time (ERCE division).

AFV	35L	50L	80L	100L	150L	200L	300L	500L
Insert of the valve	00:00:06	00:00:05	00:00:05	00:00:04	00:00:04	00:00:04	00:00:05	00:00:05
Fixing the valve	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04
Put the label	00:00:06	00:00:06	00:00:04	00:00:05	00:00:04	00:00:04	00:00:05	00:00:07
Insert the pole inside the membrane			00:00:26	00:00:24	00:00:25	00:00:24	00:00:25	00:00:28
Insert the pole with the membrane inside the autoclave			00:00:23	00:00:22	00:00:25	00:00:17	00:00:20	00:00:21
Insert the membrane into the autoclave	00:00:10	00:00:10						
Removal of the pole from autoclave, during the insertion of the membrane			00:00:18	00:00:21	00:00:22	00:00:21	00:00:24	00:00:24
Screwing the nut	00:00:07	00:00:07	00:00:08	00:00:08	00:00:09	00:00:07	00:00:25	00:00:17
Fixing the plastic on the flange	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04
Fixing the flange	00:00:25	00:00:26	00:00:24	00:00:22	00:00:26	00:01:02	00:00:58	00:00:59
Insert the pre-charge	00:00:03	00:00:03	00:00:04	00:00:03	00:00:03	00:00:04	00:00:04	00:00:05
VALUED ADDED WORK CONTENT	**00:01:05**	**00:01:05**	**00:02:00**	**00:01:57**	**00:02:06**	**00:02:31**	**00:02:54**	**00:02:54**
% OF WASTE	**45%**	**45%**	**45%**	**45%**	**45%**	**45%**	**45%**	**45%**
FUTURE WORK CONTENT	**00:01:58**	**00:01:58**	**00:03:38**	**00:03:33**	**00:03:49**	**00:04:35**	**00:05:16**	**00:05:16**
N° OF OPERATORS	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**
CYCLE TIME OF EACH OPERATOR	**00:00:59**	**00:00:59**	**00:01:49**	**00:01:46**	**00:01:55**	**00:02:17**	**00:02:38**	**00:02:38**
AUTOMATIC TESTING	**00:00:18**	**00:00:20**	**00:00:27**	**00:00:32**	**00:00:43**	**00:00:53**	**00:01:15**	**00:02:00**
Put the conformity and instruction sheet	00:00:05	00:00:05	00:00:06	00:00:06	00:00:08	00:00:07	00:00:07	00:00:10
Put the nylon	00:00:08	00:00:08	00:00:08	00:00:10	00:00:12	00:00:12	00:00:18	00:00:18
Prepare an empty box	00:00:08	00:00:08	00:00:10	00:00:10	00:00:13	00:00:20	00:00:23	00:00:25
Put the label on the empy box	00:00:06	00:00:06	00:00:06	00:00:06	00:00:06	00:00:06	00:00:06	00:00:06
Put the expansion tank inside the box	00:00:04	00:00:04	00:00:04	00:00:04	00:00:05	00:00:06	00:00:06	00:00:09
Close the box with the expansion tank inside	00:00:09	00:00:09	00:00:10	00:00:10	00:00:10	00:00:16	00:00:20	00:00:20
VALUED ADDED WORK CONTENT	**00:00:40**	**00:00:40**	**00:00:44**	**00:00:46**	**00:00:54**	**00:01:07**	**00:01:20**	**00:01:28**
% OF WASTE	**45%**	**45%**	**45%**	**45%**	**45%**	**45%**	**45%**	**45%**
FUTURE WORK CONTENT	**00:01:13**	**00:01:13**	**00:01:20**	**00:01:24**	**00:01:38**	**00:02:02**	**00:02:25**	**00:02:40**
N° OF OPERATORS	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
CYCLE TIME OF EACH OPERATOR	**00:01:13**	**00:01:13**	**00:01:20**	**00:01:24**	**00:01:38**	**00:02:02**	**00:02:25**	**00:02:40**

Figure 82: future balancing state – Proposal 1 with Value added cycle time 55% and Waste cycle time 45% on the total Actual cycle time (AFV division).

AFV	35L	50L	80L	100L	150L	200L	300L	500L
Insert of the valve	00:00:06	00:00:05	00:00:05	00:00:04	00:00:04	00:00:04	00:00:05	00:00:05
Fixing the valve	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04
Put the label	00:00:06	00:00:06	00:00:04	00:00:05	00:00:04	00:00:04	00:00:05	00:00:07
Insert the pole inside the membrane			00:00:26	00:00:24	00:00:25	00:00:24	00:00:25	00:00:28
Insert the pole with the membrane inside the autoclave			00:00:23	00:00:22	00:00:25	00:00:17	00:00:20	00:00:21
Insert the membrane into the autoclave	00:00:10	00:00:10						
Removal of the pole from autoclave, during the insertion of the membrane			00:00:18	00:00:21	00:00:22	00:00:21	00:00:24	00:00:24
Screwing the nut	00:00:07	00:00:07	00:00:08	00:00:08	00:00:09	00:00:07	00:00:25	00:00:17
Fixing the plastic on the flange	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04
Fixing the flange	00:00:25	00:00:26	00:00:24	00:00:22	00:00:26	00:01:02	00:00:58	00:00:59
Insert the pre-charge	00:00:03	00:00:03	00:00:04	00:00:03	00:00:03	00:00:04	00:00:04	00:00:05
VALUED ADDED WORK CONTENT	**00:01:05**	**00:01:05**	**00:02:00**	**00:01:57**	**00:02:06**	**00:02:31**	**00:02:54**	**00:02:54**
% OF WASTE	**50%**	**50%**	**50%**	**50%**	**50%**	**50%**	**50%**	**50%**
FUTURE WORK CONTENT	**00:02:10**	**00:02:10**	**00:04:00**	**00:03:54**	**00:04:12**	**00:05:02**	**00:05:48**	**00:05:48**
N° OF OPERATORS	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**
CYCLE TIME OF EACH OPERATOR	**00:01:05**	**00:01:05**	**00:02:00**	**00:01:57**	**00:02:06**	**00:02:31**	**00:02:54**	**00:02:54**
AUTOMATIC TESTING	**00:00:18**	**00:00:20**	**00:00:27**	**00:00:32**	**00:00:43**	**00:00:53**	**00:01:15**	**00:02:00**
Put the conformity and instruction sheet	00:00:05	00:00:05	00:00:06	00:00:06	00:00:08	00:00:07	00:00:07	00:00:10
Put the nylon	00:00:08	00:00:08	00:00:08	00:00:10	00:00:12	00:00:12	00:00:18	00:00:18
Prepare an empty box	00:00:08	00:00:08	00:00:10	00:00:10	00:00:13	00:00:20	00:00:23	00:00:25
Put the label on the empy box	00:00:06	00:00:06	00:00:06	00:00:06	00:00:06	00:00:06	00:00:06	00:00:06
Put the expansion tank inside the box	00:00:04	00:00:04	00:00:04	00:00:04	00:00:05	00:00:06	00:00:06	00:00:09
Close the box with the expansion tank inside	00:00:09	00:00:09	00:00:10	00:00:10	00:00:10	00:00:16	00:00:20	00:00:20
VALUED ADDED WORK CONTENT	**00:00:40**	**00:00:40**	**00:00:44**	**00:00:46**	**00:00:54**	**00:01:07**	**00:01:20**	**00:01:28**
% OF WASTE	**50%**	**50%**	**50%**	**50%**	**50%**	**50%**	**50%**	**50%**
FUTURE WORK CONTENT	**00:01:20**	**00:01:20**	**00:01:28**	**00:01:32**	**00:01:48**	**00:02:14**	**00:02:40**	**00:02:56**
N° OF OPERATORS	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
CYCLE TIME OF EACH OPERATOR	**00:01:20**	**00:01:20**	**00:01:28**	**00:01:32**	**00:01:48**	**00:02:14**	**00:02:40**	**00:02:56**

Figure 83: future balancing state – Proposal 2 with Value added cycle time 50% and Waste cycle time 50% on the total Actual cycle time (AFV division).

DV	35L	50L	80L	100L	150L	200L	300L	500L
Insert of the valve	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04
Fixing the valve	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04
Put the label	00:00:06	00:00:06	00:00:06	00:00:06	00:00:06	00:00:06	00:00:06	00:00:06
Put the second label	00:00:09	00:00:09	00:00:09	00:00:09	00:00:09	00:00:09	00:00:09	00:00:09
Put the third label	00:00:10	00:00:10	00:00:10	00:00:10	00:00:10	00:00:10	00:00:10	00:00:10
Insert the pre-charge	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04
VALUED ADDED WORK CONTENT	**00:00:37**	**00:00:37**	**00:00:37**	**00:00:37**	**00:00:37**	**00:00:37**	**00:00:37**	**00:00:37**
% OF WASTE	**45%**	**45%**	**45%**	**45%**	**45%**	**45%**	**45%**	**45%**
FUTURE WORK CONTENT (BEFORE TESTING)	**00:01:07**	**00:01:07**	**00:01:07**	**00:01:07**	**00:01:07**	**00:01:07**	**00:01:07**	**00:01:07**
N° OF OPERATORS	1	1	1	1	1	1	1	1
CYCLE TIME OF EACH OPERATOR	**00:01:07**	**00:01:07**	**00:01:07**	**00:01:07**	**00:01:07**	**00:01:07**	**00:01:07**	**00:01:07**
AUTOMATIC TESTING	**00:00:20**	**00:00:23**	**00:00:31**	**00:00:36**	**00:00:49**	**00:01:02**	**00:01:28**	**00:02:20**
Put the conformity and instruction sheet	00:00:05	00:00:05	00:00:06	00:00:06	00:00:08	00:00:07	00:00:07	00:00:10
Put the nylon	00:00:08	00:00:08	00:00:08	00:00:10	00:00:12	00:00:12	00:00:18	00:00:18
Prepare an empty box	00:00:08	00:00:08	00:00:10	00:00:10	00:00:13	00:00:20	00:00:23	00:00:25
Put the label on the empy box	00:00:06	00:00:06	00:00:06	00:00:06	00:00:06	00:00:06	00:00:06	00:00:06
Put the expansion tank inside the box	00:00:04	00:00:04	00:00:04	00:00:04	00:00:05	00:00:06	00:00:06	00:00:09
Close the box with the expansion tank inside	00:00:09	00:00:09	00:00:10	00:00:10	00:00:10	00:00:16	00:00:20	00:00:20
VALUED ADDED WORK CONTENT	**00:00:40**	**00:00:40**	**00:00:44**	**00:00:46**	**00:00:54**	**00:01:07**	**00:01:20**	**00:01:28**
% OF WASTE	**45%**	**45%**	**45%**	**45%**	**45%**	**45%**	**45%**	**45%**
FUTURE WORK CONTENT (AFTER TESTING)	**00:01:13**	**00:01:13**	**00:01:20**	**00:01:24**	**00:01:38**	**00:02:02**	**00:02:25**	**00:02:40**
N° OF OPERATORS	1	1	1	1	1	2	2	2
CYCLE TIME OF EACH OPERATOR	**00:01:13**	**00:01:13**	**00:01:20**	**00:01:24**	**00:01:38**	**00:01:01**	**00:01:13**	**00:01:20**

Figure 84: future balancing state – Proposal 1 with Value added cycle time 55% and Waste cycle time 45% on the total Actual cycle time (DV division).

DV	35L	50L	80L	100L	150L	200L	300L	500L
Insert of the valve	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04
Fixing the valve	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04
Put the label	00:00:06	00:00:06	00:00:06	00:00:06	00:00:06	00:00:06	00:00:06	00:00:06
Put the second label	00:00:09	00:00:09	00:00:09	00:00:09	00:00:09	00:00:09	00:00:09	00:00:09
Put the third label	00:00:10	00:00:10	00:00:10	00:00:10	00:00:10	00:00:10	00:00:10	00:00:10
Insert the pre-charge	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04	00:00:04
VALUED ADDED WORK CONTENT	**00:00:37**	**00:00:37**	**00:00:37**	**00:00:37**	**00:00:37**	**00:00:37**	**00:00:37**	**00:00:37**
% OF WASTE	**50%**	**50%**	**50%**	**50%**	**50%**	**50%**	**50%**	**50%**
FUTURE WORK CONTENT (BEFORE TESTING)	**00:01:14**	**00:01:14**	**00:01:14**	**00:01:14**	**00:01:14**	**00:01:14**	**00:01:14**	**00:01:14**
N° OF OPERATORS	1	1	1	1	1	1	1	1
CYCLE TIME OF EACH OPERATOR	**00:01:14**	**00:01:14**	**00:01:14**	**00:01:14**	**00:01:14**	**00:01:14**	**00:01:14**	**00:01:14**
AUTOMATIC TESTING	**00:00:20**	**00:00:23**	**00:00:31**	**00:00:36**	**00:00:49**	**00:01:02**	**00:01:28**	**00:02:20**
Put the conformity and instruction sheet	00:00:05	00:00:05	00:00:06	00:00:06	00:00:08	00:00:07	00:00:07	00:00:10
Put the nylon	00:00:08	00:00:08	00:00:08	00:00:10	00:00:12	00:00:12	00:00:18	00:00:18
Prepare an empty box	00:00:08	00:00:08	00:00:10	00:00:10	00:00:13	00:00:20	00:00:23	00:00:25
Put the label on the empy box	00:00:06	00:00:06	00:00:06	00:00:06	00:00:06	00:00:06	00:00:06	00:00:06
Put the expansion tank inside the box	00:00:04	00:00:04	00:00:04	00:00:04	00:00:05	00:00:06	00:00:06	00:00:09
Close the box with the expansion tank inside	00:00:09	00:00:09	00:00:10	00:00:10	00:00:10	00:00:16	00:00:20	00:00:20
VALUED ADDED WORK CONTENT	**00:00:40**	**00:00:40**	**00:00:44**	**00:00:46**	**00:00:54**	**00:01:07**	**00:01:20**	**00:01:28**
% OF WASTE	**50%**	**50%**	**50%**	**50%**	**50%**	**50%**	**50%**	**50%**
FUTURE WORK CONTENT (AFTER TESTING)	**00:01:20**	**00:01:20**	**00:01:28**	**00:01:32**	**00:01:48**	**00:02:14**	**00:02:40**	**00:02:56**
N° OF OPERATORS	1	1	1	1	1	2	2	2
CYCLE TIME OF EACH OPERATOR	**00:01:20**	**00:01:20**	**00:01:28**	**00:01:32**	**00:01:48**	**00:01:07**	**00:01:20**	**00:01:28**

Figure 85: future balancing state – Proposal 2 with Value added cycle time 50% and Waste cycle time 50% on the total Actual cycle time (DV division).

		CURRENT SITUATION (VA 40% AND WASTE 60%)			PROPOSAL 1 (VA 55% and WASTE 45%)			PROPOSAL 2 (VA 50% AND WASTE 50%)		
		CYCLE TIME	HOURLY PRODUCTION RATE	N° OF OPERATORS	CYCLE TIME	HOURLY PRODUCTION RATE	N° OF OPERATORS	CYCLE TIME	HOURLY PRODUCTION RATE	N° OF OPERATORS
ERCE	35L	00:00:50	72	3	00:00:36	99	3	00:00:40	90	3
	50L	00:00:50	72	3	00:00:36	99	3	00:00:40	90	3
	80L	00:01:07	54	3	00:00:40	90	3	00:00:44	82	3
	100L	00:01:08	53	3	00:00:42	86	3	00:00:46	78	3
	150L	00:01:26	42	3	00:00:49	73	3	00:00:54	67	3
	200L	00:01:46	34	3	00:01:09	52	3	00:01:16	47	3
	300L	00:02:30	24	3	00:01:15	48	3	00:01:22	44	3
	500L	00:03:20	18	3	00:01:18	46	3	00:01:26	42	3
AFV	35L	00:01:26	42	3	00:01:13	49	3	00:01:20	45	3
	50L	00:01:27	41	3	00:01:13	49	3	00:01:20	45	3
	80L	00:02:00	30	3	00:01:49	33	3	00:02:00	30	3
	100L	00:02:09	28	3	00:01:46	34	3	00:01:57	31	3
	150L	00:03:32	17	3	00:01:55	31	3	00:02:06	29	3
	200L	00:03:45	16	3	00:02:17	26	3	00:02:31	24	3
	300L	00:05:00	12	3	00:02:38	23	3	00:02:54	21	3
	500L	00:05:00	12	3	00:02:40	23	3	00:02:56	20	3
DV	35L	00:01:00	60	3	00:01:13	50	2	00:01:20	45	2
	50L	00:01:00	60	3	00:01:13	50	2	00:01:20	45	2
	80L	00:01:12	50	3	00:01:20	45	2	00:01:28	41	2
	100L	00:01:15	48	3	00:01:24	43	2	00:01:32	39	2
	150L	00:01:35	38	3	00:01:38	37	2	00:01:48	33	2
	200L	00:02:00	30	3	00:01:07	54	3	00:01:14	49	3
	300L	00:03:00	20	3	00:01:28	41	3	00:01:28	41	3
	500L	00:04:00	15	3	00:02:20	26	3	00:02:20	26	3

Figure 86: comparison between the current situation of the assembly process and the two proposals (1 and 2) provided by the analysis carried out.

As we can see from figure 80 to 85, I started from considering all the Valued Added activities for each operator and I reported the time of each of them according to the analysis previously explained based on the detection of cycle time.

I divided the analysis in five steps:

1) In the first step, I considered all the activities performed before the Testing and I computed a Value Added Work Content given by the sum of all the times necessary to perform the activities. Some activities have a different time compared to the one detected during the observation analysis because I suppose that for several activities we can reach a fix predetermined time based on the standardization of the methods and improving the condition of the layout. Then, I considered a fix percentage about 45% or 50% of Waste cycle time on the total Future cycle time. The results of this optimization, in terms of having a higher percentage of Valued Added activity within the total Work content, is due the application of a whole series of improvement like: workspace optimization, reduction of Evident Waste, Internal Logistics design etc. By summing the Valued Added Work Content and the percentage of Waste, I computed the Future Work Content before Testing.
2) The second step is the Testing, according to the times provided by figure 76.
3) The third step concerns all the activities carried out after the Testing, which consist in labelling and packaging and they are the same moving from expansion tanks to autoclaves. As before, I computed the Future Work Content, by summing the Valued Added Work Content and the same percentage of Waste.
4) Then, I compared the final two Work Content (before and after the Testing) and calculated the number of operators required in order to maintain a certain productivity and a balancing of the line. In some cases, we have two operators before Testing while in others just one.
5) Finally, I compared the Cycle Time of each Operator before and after the Testing with the time required to perform the testing of the product and I chose the highest as Bottleneck of that specific product (they are highlighted in red in figure 86).

Regarding some products of ERCE division (200, 300 and 500 liters), it will be the Operator 1 to "*prepare an empty box*" and then to put it in the conveyor belt together with the product tested. This choice aims in having a more efficient line balance and a lower cycle time (see figure 81 and 82). Figure 86 describes the final comparison between the current situation and the Two Proposal presented. As we can see, there is an increase in terms of productivity and, in some cases (from 35L to 150L of the DV division), we have a slightly high cycle time but only two operators who work on them.

Conclusion

In these six months of internships carried out in collaboration with KaizenKey s.r.l., in ELBI S.P.A, we worked on the following three projects described above:

1) **Improvement of Human Resources Management**

We have performed a Skills Matrix for every departments and then, we have computed an analysis based on the results obtained. The aim of this project was to understand the real productive capacity of each individual worker, related to the different activities carried out in the department of belonging. Furthermore, it was important to comprehend the sensitivity of the department head in assessing and managing the human resources for which he is accountable. The achieved result is depicted in the following table (see Figure 87).

2) **Improvement of the Corporate Logistics Flows**

The work carried out by KaizenKey s.r.l. lasted two workshops on problem solving analysis. In the first workshop we developed a *Muda Check* regarding the current service level of Internal Logistics. Then, after studying the unloading areas of the incoming materials and the respective flows, we proposed a new Layout concept of the Internal Logistics flow. In the second workshop, we started working on the realization of the new layout. The aim was to provide an efficient logistics service within the company's operation and a new warehouse management. The project is under development. The new layout is depicted in the following table (see Figure 88).

3) **Improvement of Assembly lines by studying Cycle Times**

At the beginning, we studied the current situation of the assembly process, highlighting all the inefficiencies observed. Then, a new Cycle Time detection Method has been defined, based on the following procedure:

- *Breaking down of the work performed by the operators* (identifying the macro tasks of each operator, the materials and tools necessary for performing such tasks and design the precedence diagram).

- *Progressive chronometric detection performed on each operator several times* (observation, by using a stopwatch, of all the activities carried out by the operators in a sequential manner and, at the same time, pointing out if some of them were performed differently with the related reason).
- *Analysis of each task, which could be Valued Added, Evident and Hidden Waste* (each single task will be analyzed, by defining the type of each activity and how many times is carried out by the operator within the working cycle detected).
- *Analysis of the results obtained* (the percentages of time spent in performing Valued Added, Evident and Hidden Waste activities, on the total time taken, has been analyzed, in terms of the differences, for each operator).
- *Computation of the Standard Cycle Time* (it is given by the sum of the average Value Added tasks, which are necessary for the assembly of a single product and a percentage of Waste (Evident + Hidden) due to the realization of the same.

This method allowed us to precisely identify and analyze the Cycle Time of each activity for each operator, obtaining a final Cycle Time of each product. The analysis carried out confirmed all the assessments made at the beginning, concerning the current situation of the company and it highlighted a potential that is not exploited, in fact, there is a high incidence of wasteful activities within the assembly process. Starting from the results obtained that describes the *As-Is* state, the next steps are as follows:

- distribution of workloads according to the value of the assembly process;
- design of a new layout, depending on the specific cycle times and the number of required work stations required to respond to the customer demand;
- standardization of the activities, which will lead to a lower throughput, being capable of responding faster to the market.

Moreover, I developed a new configuration of balancing and layout of assembly lines (see figure 89) that guarantees an increase in Hourly Productivity, even with the same human resources involved, and an efficiency of the assembly process, in terms of cost and Lead time.

	DEPARTMENT	HARD SKILLS WORKERS	HARD SKILLS DEPARTMENT HEAD	HARD SKILLS DIFFERENCE	N° of macro - processing areas	N° of activities	SOFT SKILLS WORKERS	SOFT SKILLS DEPARTMENT HEAD	SOFT SKILLS DIFFERENCE	N° of workers
PRODUCTION DEPARTMENTS	A	52,57%	36,05%	16,51%	7	29	71,8%	57,38%	14,40%	21
	R	54,84%	46,19%	8,65%	6	34	69,3%	75,54%	-6,25%	14
	M	52,61%	33,54%	19,06%	7	17	65,6%	44,26%	21,37%	27
	C	55,36%	58,43%	-3,07%	3	22	70,3%	71,03%	-0,72%	16
	B	53,71%	52,67%	1,05%	2	14	68,8%	63,83%	5,00%	15
	P	52,16%	44,74%	7,42%	8	19	69,0%	63,88%	5,14%	29
	AVERAGE	**53,54%**	**45,27%**	**8,27%**	**6**	**23**	**69,14%**	**62,65%**	**6,49%**	**21**
WAREHOUSE DEPARTMENTS	FP(TH)	59,68%	47,56%	12,13%	5	24	68,3%	75,56%	-7,22%	9
	21th/GARDEN/AMBIENTE	66,00%	68,00%	-2,00%	5	13	58,3%	69,17%	-10,83%	3
	RM	82,50%	83,33%	-0,83%	6	27	85,83%	97,50%	-11,67%	3
	AVERAGE	**69,39%**	**66,30%**	**3,10%**	**5**	**21**	**70,83%**	**80,74%**	**-9,91%**	**5**
	GLOBAL AVERAGE KPI	**58,83%**	**52,28%**	**6,55%**			**69,7%**	**68,7%**	**1,0%**	

Figure 87: overall Skill Matrix of ELBI S.P.A. regarding Hard and Soft skills (Workers + department Head).

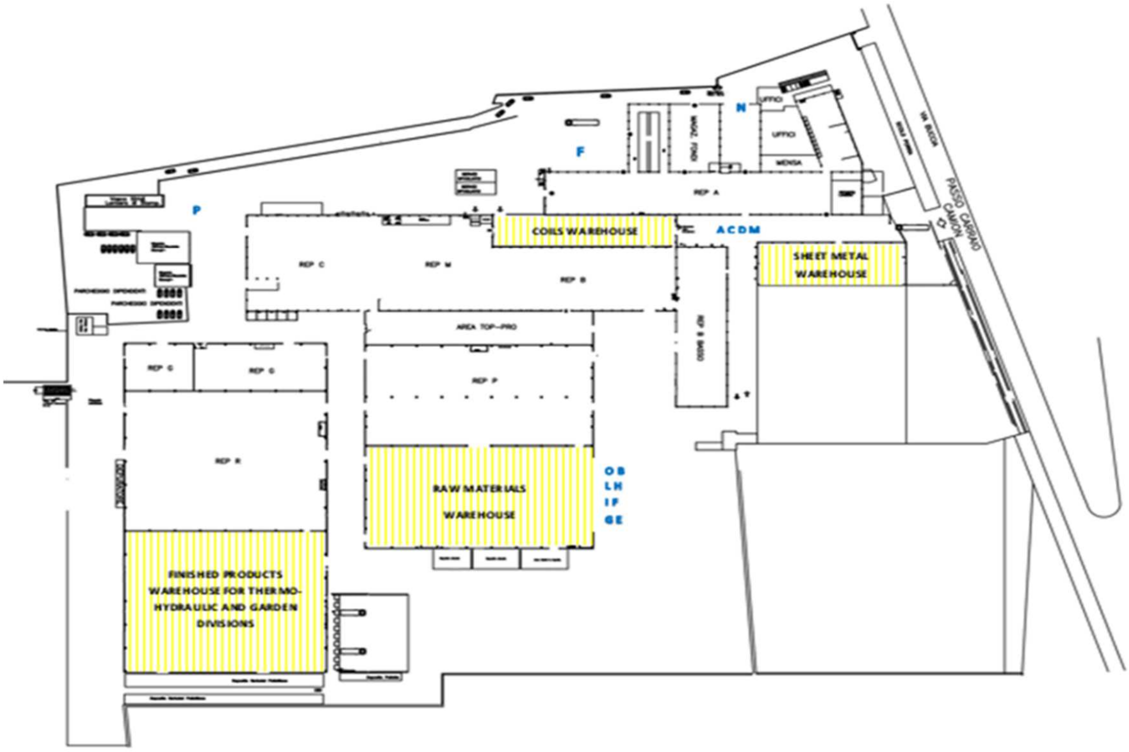


Figure 88: new plant layout of Internal Logistic.

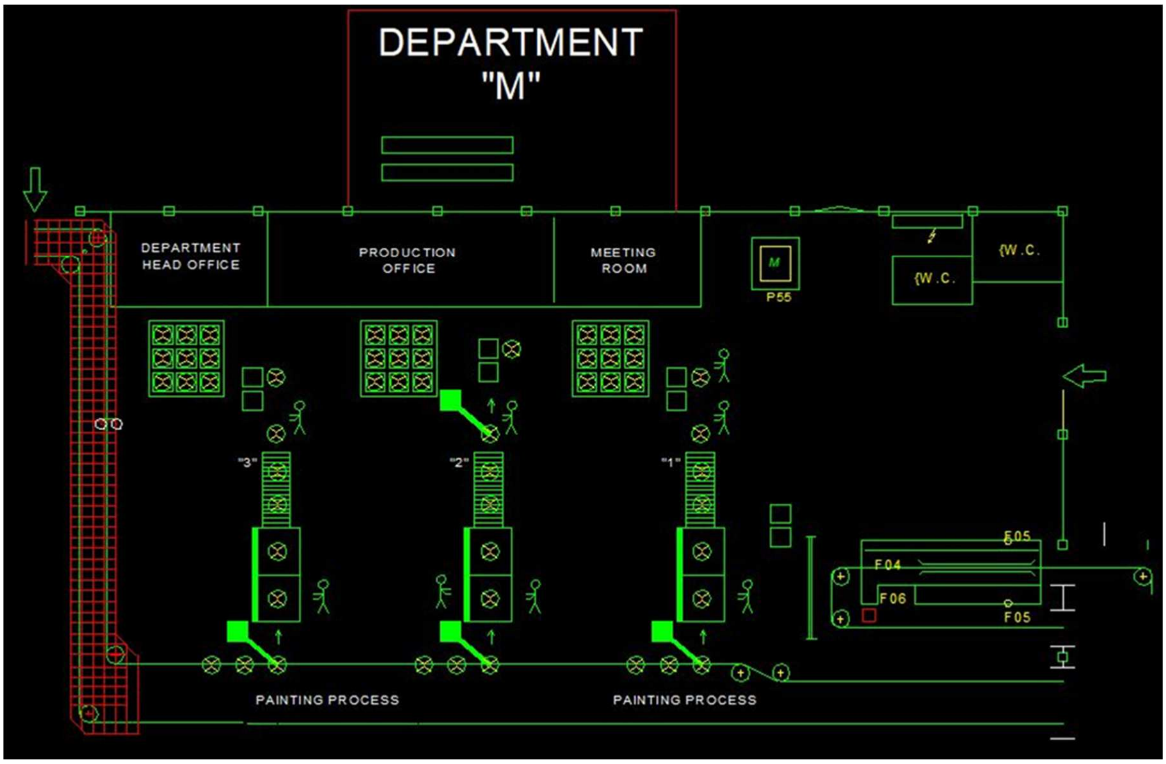


Figure 89: future layout of the assembly lines within the Department M.

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