POLITECNICO DI TORINO

Master Degree course in Engineering and Management

Innovation and Entrepreneurship

Master Degree Thesis

Optimization of Production Processes through the Application of Lean Manufacturing Principles

An Analysis of the Case of an Italian Manufacturer of Stainless Steel Carpentry

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Academic Year 2023-2024

SUMMARY

INTRODUCTION

In the context of today's industrial landscape, the optimization of production processes is a strategic imperative for companies that want to maintain competitiveness on the global market. In this context, the Lean Manufacturing paradigm emerges as a fundamental management philosophy, aimed at eliminating waste and maximizing customer value.

This paper aims to examine the application of the principles of Lean Manufacturing within an Italian manufacturer of stainless-steel carpentry, located in Northern Italy. The analysis was enriched by the direct experience of the author: the pages contained in this document are the result of a project carried out between March and September 2023 at the industrial plant of Canelli, province of Asti, leader in the production of stainless-steel machinery for the bottling and packaging sector.

In the first chapter, the fundamental concepts of Lean Manufacturing will be outlined, with particular attention to its pillars and key tools, to provide an essential theoretical framework for the understanding of the subsequent analysis.

In the second chapter, the focus will be on the company being studied. Through a detailed analysis of the production plant, the layout, the products and the steel processing phase, a Current Value Stream Map will be elaborated in order to provide an overview of business flows and identify areas for improvement and potential optimization.

The third chapter will be the focus of the research, focusing on the analysis of identified business waste. Through an in-depth evaluation of the costs associated with the identified waste, practical and targeted solutions will be proposed to reduce the incidence and maximize the overall efficiency of the production process.

Through this in-depth analysis, we aim not only to identify and quantify the waste present within the company, but also to propose concrete and applicable solutions, to make a significant contribution to the continuous improvement and competitiveness of the company in the current industrial context.

NOTES ON CONFIDENTIALITY

The main result was the analysis of company waste, from the cause to the association of a cost and possible solutions to reduce them. To avoid violating the rules in force regarding confidentiality and industrial secrecy, it was therefore necessary to omit, modify or alter certain data, numbers and information about processes, production codes, volumes, and names.

Chapter 1

Lean Manufacturing

Lean Manufacturing is an organizational philosophy that indicates the set of tools and techniques aimed at eliminating waste within a system, to achieve maximum production efficiency (improvement of quality, production times and costs). The system guides the company towards a lean and flexible production management, eliminating what does not create value for the customer and responding quickly to market demand.

1.1 American Fordism and Japanese Toyotism: Two Models Compared

The 20th century presented the world with two types of organizational production models: Fordism from the United States and Toyotism from Japan, representing diametrically opposite cultures, not only in popular culture but also in the workplace. The foundations for these two business philosophies stem from different historical moments and needs. Between 1860 and 1920, America experienced a drastic population increase, both through births and mass migrations from Europe; people had an increasing need for a low-cost vehicle that they could afford. Henry Ford, founder of the future Ford Motor Company, met this need by creating the Ford Model T in 1908, a robust and economical car accessible to all. To meet the high demand for Ford cars, and thus increase production, Ford envisioned not only a larger factory but also an innovation in the assembly method: the assembly line was born, inspired by the work methods of watchmakers and bicycle manufacturers. This innovation, along with the introduction of interchangeable parts and the study of methods and timing, led to a significant increase in productivity: the cost of the Ford Model T dropped from $850 in 1908 to $290 in 1925, with 15 million units sold.

A few years earlier, in 1890, Sakichi Toyoda founded the Toyota Automatic Loom, a Japanese company that manufactured textile looms and, in 1933, opened a division aimed at producing cars, later managed by his son Kiichiro Toyoda. Under pressure from the Japanese government, this division specialized in producing trucks for the Japanese Imperial Army, necessary for the Second World War; thus, in 1937, the Toyota Motor Company was established as an independent company. The company's name changed from Toyoda to Toyota for superstitious reasons, as the latter could be written, in Japanese, with eight brush strokes (eight is considered a lucky number in Japanese culture).

The post-war socio-economic context makes the Western Fordist production model in Toyota inapplicable. The lack of capital that characterizes the Japanese economy and the high costs of production, of raw materials, do not allow to create, as happens in the West, economies of scale that would lead to a reduction in unit costs. In this phase of difficulty in finding an organizational model applicable to the Japanese context, comes into play the intuition of Tahiichi Ohno, initially employed by Toyota Automatic Loom and later transferred to the automotive division, in which he becomes a member of the Company’s Executive Board. The intuition is born and develops in the travels in America and in the visits to the companies that apply the Fordist model, like the Ford Motor Company, and decrees that the model of the assembly line, in his opinion full of wastes (MUDA), is not efficient and effective for the industries, indeed, the method adopted brought Toyota to the brink of bankruptcy. They note, instead, that the chain of American stores Piggly Wiggy adopts a model characterized by a particular way of setting up a route along which the products placed on the shelves could be picked up and then paid at the exit.

Once back in Japan, the TPS (Toyota Production System or Toyotismo) was born, based on the model of Piggly Wiggy, which regulates the production rate according to the trend of demand (as opposed to Fordism), characterized by quality production, low cost and with short lead time. Between 1962 and 1972, TPS was adopted by Toyota’s main suppliers and Lean Manufacturing became an extended and integrated system. In the seventies, the first manuals containing the key points of the TPS approach that reached the USA only in the early eighties were published.

The adaptation of flexible and streamlined systems, also referred to as the Reconfigurable Manufacturing System (RMS), are now indispensable in a world where customization is a requirement increasingly demanded by consumers. Figure 1.1 shows a representation of this trend, as suggested by Yoram Korena in his book "Design of reconfigurable manufacturing systems".

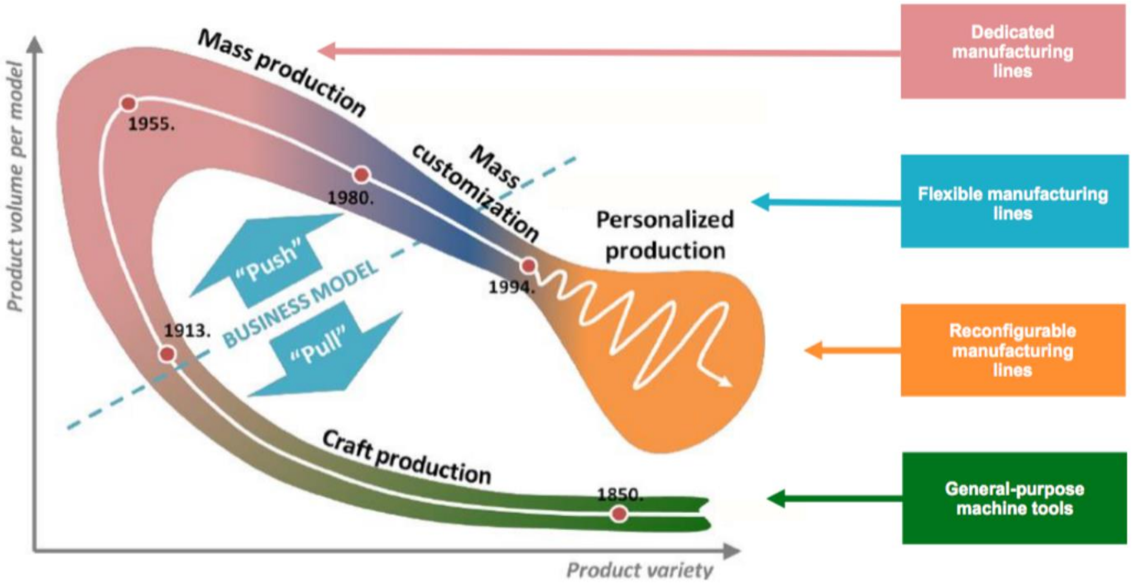

Figure 1.1 - From mass production to Reconfigurable Manufacturing System

1.2 Lean Manufacturing principles

Lean Manufacturing is “a management philosophy aimed at generating the maximum amount of value for the customer with the minimum amount of waste”.

1.2.1 MUDA: the 7 wastes of Lean Production

Waste is anything that does not add value to the product or service in the eyes of the customer or that does not add value to the company, as a whole. The first step to implementing a Lean strategy is, therefore, identifying the seven types of waste and their sources, called MUDA:

1. *Inventory* - Stocks can be in the form of raw materials, WIP (processing material), or finished products and represent capital that has not yet brought any added value to both the producer and the customer. The material waiting to be processed is considered a waste and can, in the long run, also become obsolete and no longer usable.

2. *Defects* - Defects are non-conforming materials due to design and/or production errors. This waste involves, for the company, great burdens, is financial that of image; moreover, they slow down the production and increase the lead time.
3. *Transportation* - Refers to the physical handling and management of the product or operators between processes, which does not add any value to the final product. Whenever a product is transferred from one area of the plant to another or outside the company, it risks being lost, delayed, or damaged; the transport does not introduce any processing to the product that the customer is willing to pay for.
4. *Overprocessing* - This waste is due to the need to handle parts, tools, and information more than is necessary in order to meet customer requirements.
5. *Motion* - Such waste is like Transport but refers to machinery and operators; whenever machinery or physical persons need to move to carry out an activity that does not add any value to the product, a waste occurs. To solve the problem, it is necessary to better design workstations and to program production and internal logistics effectively.
6. *Overproduction* - Overproduction is the main and most harmful waste according to the principles of Lean Manufacturing: production or acquisition of goods before they are requested by the customer can generate unsold products or waste linked to long stocks in stock. Such waste happens to obviate lacks in terms of quality and to prefer the overproduction.
7. *Waiting or delays* - It refers both to the time spent by operators waiting for the resource to be available, and to the capital fixed in goods and services that have not yet been delivered to the customer. The main cause can be traced back to the poor balance between the lines, lack of maintenance of the machinery and/or inefficiency of the warehouse system.

In recent years, the philosophy inserts an eighth waste (8 MUDA in total): waste of mis qualification or underemployment of operators. The eighth waste includes, for example, unbalanced workloads, absence of delegation, little accountability, education beyond the real needs required by employment, underused hard skills and everything that includes inadequate human resource management.

The Toyota Production System is based on two main pillars, aimed at reducing production costs by eliminating all forms of waste: the Just in Time and Jidoka (autonomy).

1.2.2. The Jidoka pillar

Traditionally translated as "*autonomation*", the Japanese term Jidoka indicates "a particular type of intelligent automation equipped with a "human touch", aimed at minimizing the faults of the production cycle thanks to man-machine collaboration". The operator, through a series of technical and cultural measures, perceives something abnormal in production, thanks to the input given by the machine, and stops production; after that, proceeds to analyze the situation, researching the causes that may have generated that defect, and resolves the non-compliance, restarting the production cycle. The tools that the Jidoka pillar uses are:

- *Poka-yoke*: term that identifies "a set of techniques and design choices of prevention and control aimed at avoiding waste and errors, increasing production efficiency and ensuring maximum value for the customer (higher quality)".
- *Adons*: indicates "the use of lights, displays, acoustic signals to indicate the state of a machine or a process, highlighting any anomalies".
- *5 why*: technique consisting in repeating the question "Why?" for at least 5 times to identify the root cause of a problem or a waste.

1.3 The Pull Logic

"Pull logic" is a key concept in Lean Production and represents an approach to manage production and workflows. In a pull production system, the goal is to produce only what is actually needed in response to customer demand, avoiding the overcrowding of inventories and waste of resources. Logic has the following principles:

- *Customer demand*: pull production starts with a clear understanding of customer demand. Instead of producing in anticipation of future demand (push approach), it reacts directly to customer demand.

- *Pull instead of push*: in a pull system, work is "pulled" through the production process only when there is an actual demand. This is based on the "pull" principle in which each stage of the process produces only when required by the next stage.
- *Visual signals*: often, pull systems use visual signals or kanban to indicate when it is necessary to start production or supply certain materials. The Kanban system is an "inventory and workflow management methodology" originally developed in Japan that is based on cards (called "*kanban*") which are used to manage the movement of materials and production activities in a way that is synchronized with actual demand. For example, when a container is empty or close to exhaustion, this is a signal to start the production of another batch of that product.
- *Eliminate waste*: the pull approach aims to eliminate waste associated with excess production, such as inventory overcrowding, transportation, and excess production. This leads to increased efficiency and cost reduction.
- *Flexibility*: pull systems are often more flexible, as they can adapt quickly to changes in customer demand. If demand increases, more is produced; if it decreases, production is reduced.

A common example of pull production is the *Just-in-time* (JIT) system, where materials or products are produced exactly when and how much they are needed. This approach aims to minimize storage costs and improve overall production efficiency by adapting production to customer demand. Thus, Just in Time simply involves the acquisition and procurement of the necessary resources at the right time, in the right place, and with the aim of maximizing efficiency without unnecessary waste. This practice allows the company to minimize the amount of inventory, thus avoiding one of the seven types of waste, and at the same time reduce the risk of working on components that will not be readily requested by customers or suppliers. In essence, the main objective of JIT is "to maintain a constant production ensuring that the flow of materials is optimally synchronized with the production process in terms of quantity and timing" (see the differences between the two types of production in Figure 2.1).

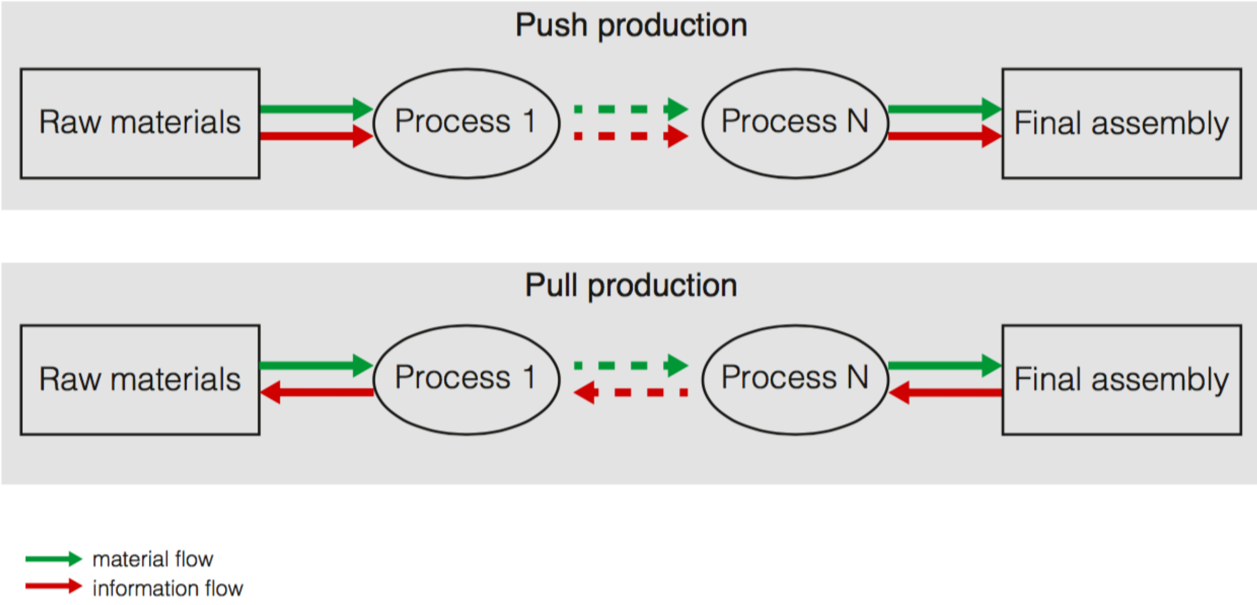

Figure 2.1 - Differences between push and pull production

In summary, the pull logic in Lean Production focuses on production based on actual demand, reducing waste, and improving efficiency through flexible and responsive workflow management.

1.4 Value Stream Map

The *Value Stream Map* (VSM) is a visual representation technique used for continuous progress, born from the Japanese lean management philosophy. This graph analyzes the entire production process from start to finish, including the raw material flow and delivery of the final product to the customer or customer's plant. The Value Chain Map is a visual tool that follows the entire life cycle of a product or a range of products, including all the operations and movements that they cross, from supplier to customer (example in figure 4.1). This allows to highlight the phases that do not add value to the product, allowing the company to take corrective measures in this regard. The Value Stream Map consists of three main blocks:

- *Information flow*: this block represents the path of information needed to manage demand and planning. This includes details of planning, forecasting, customer requests and production scheduling.
- *Flow of materials*: this is the path of materials, semi-finished products or finished products within the plant. It is important to distinguish between materials handling and moving (generally value-added) and processing activities that add value to the product.
- *Crossing time scale*: this detail allows to highlight the crossing time (LT) and the value added time (VAT)

Figure 3.1 shows the differences between the times involved in the process.

This methodology allows you to take corrective actions to highlight and reduce waste and make decisions based on clear and visual information. In addition to this, it allows you to:

- Show processes and their cycle times (cycle times) and view the entire life cycle of a product or family
- Showing the link between the information flow and the production process
- Create order in terms of time and methods, improving handling activities, limiting overproduction and indirect material waste.

The next chapter shows the creation of the Current Value Stream Map for the production process of the company’s industrial cap elevators, to show the production flow from supplier orders to customer delivery.

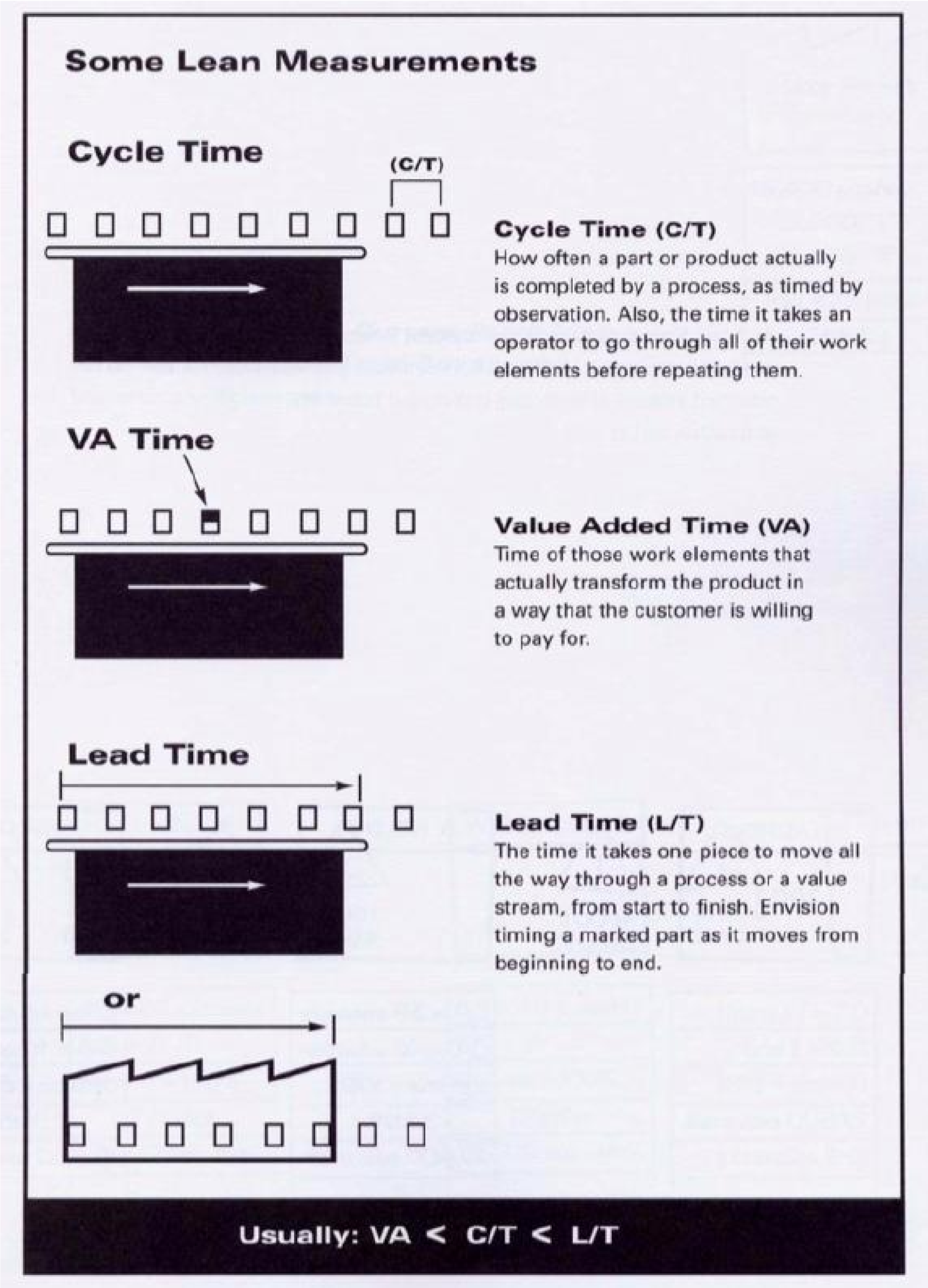

Figure 3.1 - Difference between Cycle Time, Value Added Time and Lead Time in a VSM

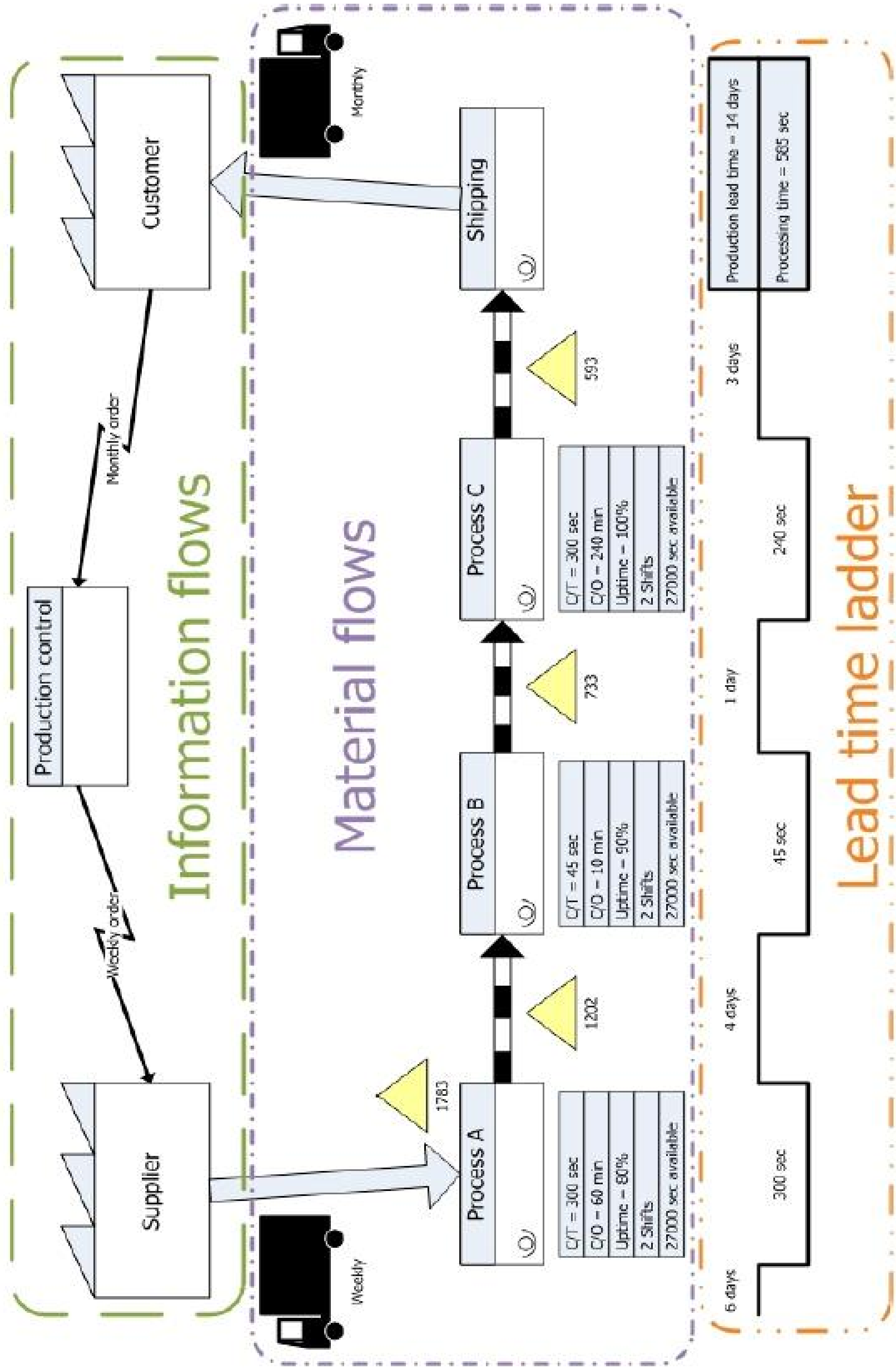

Figure 4.1 - Example of Value Stream Map

1.5 Human Resource Management in a Lean World

The philosophy of Lean Management has effects on production processes, but also on the culture of business management and human resources: for this reason, the philosophy must be introduced in the corporate context in an effective way, because it radically changes the way people work (and live) and the staff must be guided in the direction of this cultural change. Lean finds a channel of development and implementation that identifies itself in constant training, commitment to the exploitation of talents and definition of career paths; other successful actions are:

- *Celebration of success*: the company recognizes the successes and merits (not only monetary but also in the form of corporate benefits) of the staff in order to guide them towards an awareness of their position.
- *Autonomy of the working group*: the promotion of highly autonomous groups, characterized by a diverse and transversal composition within the organization, is a valuable support for the implementation of the Lean principles in projects.
- *Problem solving*: in order to improve processes, optimize flows and reduce waste, the lean approach aims to involve all levels of operators and employees in the resolution of operational and production issues. This practice is a crucial element to establish a strong commitment within the productive environment.
- *Multiskilled workers*: Ohno often stresses the importance of having workers with multiple skills within production facilities in order to ensure production stability and promote improvements in production processes. For example, in the logic of cellular production, where a small group of workers operates a series of machines, without multipurpose workers it would be impossible to implement such an approach successfully.

Chapter 2

The company object of the thesis study is a small-medium company producing stainless steel carpentry, for the packaging and bottling industry. In recent years, the company enters the food and textile market to create customized solutions to customer needs; the products, in fact, are not standard, but the designs are made ad hoc, at the request of the customer, by internal or external technical designers (customer drawings).

2.1 Analysis of the Facility

2.1.1 Definition of products and processes

The main products are:

- *Cap Elevators*: these machines automatically feed caps to the capping machine in the bottling line. The caps are placed haphazardly in a large ground container (hopper) made entirely of stainless steel and are lifted by a rubber elevator belt. The system can vary depending on the type of cap handled (pneumatic or magnetic).

Figure 5.2 - Example of Cap elevator

- *Industrial Protection*: perimeter structures to protect workers from risks and accidental incidents, creating a safe and efficient industrial environment (see figure 6.2).

Figure 6.2 - Example of industrial protection

- *Stainless Steel Structures*: stairs, statues, or custom products made to client specifications (see figure 7.2).

Figure 7.2 - Example of a statue in stainless steel in the center of Canelli

- *Safety Devices*: totems, portals, and tunnels that ensure automatic management of secure entries to workplaces, public places, and commercial activities. These products were developed during the COVID-19 pandemic.
- *Containment Basins*: these basins contain food products that require special processing, such as mixing or rinsing.

The company, which has been in the market for 60 years, is located in the so-called eno-mechanical Silicon Valley, an area between the Langhe and Monferrato regions rich in companies and realities dedicated to wine culture. In addition to this last sector, the company in question operates in other markets, such as pharmaceutical, food, and textile, thanks to which it has the opportunity to expand its market abroad (especially in France). In addition to finished products, the company offers mechanical processing services only. The most requested are.

- *Laser cutting:* a process which uses a high-power laser to cut industrial sheet metal, according to the shape set by the operator to the system.
- *Bending*: a process which permanently deforms the steel part by bending using a bending machine.
- *Welding:* irreversible joining method, achieving the continuity of the parts that are joined.

Figure 8.2 - Welding workshop

2.1.2 Facility Layout

The corporate layout is a hybrid between *Line* and *Department* layouts:

Table 1.1 - Facility Layout

Department Layout Aspects	Line Layout Aspects
The machines are grouped in specialized departments (laser, satin, bending and welding machines are placed in their own reference areas) and sometimes work independently of other departments (This is the case where customers require only individual machining service, using their own material or that from third parties)	Machining parts are transferred from one machine to another
The processing times of each department are monitored	Production planning aims to obtain and maintain a certain production flow in a given unit of time
Products travel by lot within the company	Close interdependence between the various operations that make up the process (inefficiency pours on the internal production system)

The type of layout depends on the type of product or service that the customer requires. In the case of the product "Elevator", the layout is inline as the details go through the process in all its stages, from laser cutting to internal assembly.

2.1.3 Production methodology

The "Make to Order logic" (MTO), translatable as "Produce to Order," is "a production approach that focuses on the realization of products or services only after receiving a specific order from a customer". The company adopts this methodology for its own production: the products are highly customized, designed internally or by the customer's technical team and, once the order is confirmed, production begins. The laser cutting department creates a forecast of the demand for steel sheets, based on previous orders, and reorders a certain amount of raw material to keep in stock in the primary warehouse: only once the order is confirmed and the order generated, will start the actual production of the product.

2.1.4 Organisational chart

The company has 6057 employees, below the organizational chart:

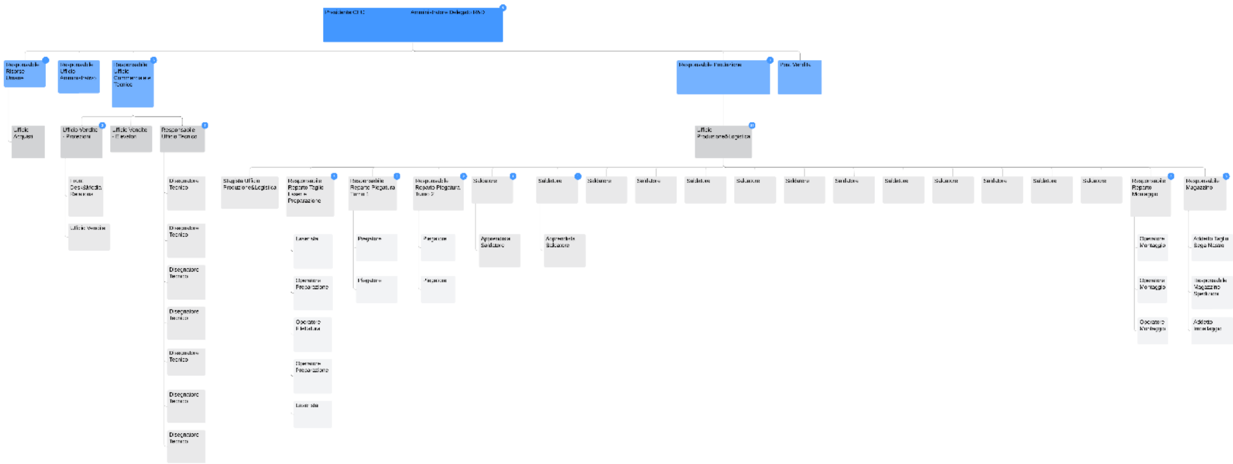

Figure 9.2 - Organisational chart

1. The CEO President is the executive figure who has the greatest responsibility for the activities and guides the strategies of the company; the director of Research and Development department reports to him, the one who studies new technologies and cutting-edge methods to be applied to the pro-production. The CEO and the director of R&D, however, share many of the company's strategic decisions and they are linked by a parental relationship; the company has been active in the market for 60 years and sees the management of two family generations, in the first years the father and subsequently, the two sons.
2. The Administration Department and the After Sales Department are composed of one single resource each, the person responsible.
3. The Commercial and Technical department, in addition to the productive one, is the most populated one; as previously said, the products are very customized and the

department must be well organized to define all the details of the customer's requests, Design in 3D the layout of the machinery and then upload to the company management all the data related to the job.

4. The Production department is the heart of the company and is the real site where products are born and processed. A manager manages all the production, has decision-making power over the departments and monitors the production progress; a junior manager, under him, of the production office coordinates the daily work and checks the production data. Welding requires more labor because it is the most delicate processing, being the one that combines all the details received from the previous department; depending on the type of welding, the operator takes more or less time, but still has high production times. Assembly is the production department with fewer operators because it has to work, for most of the time, only one type of product: the cap elevator. Four resources are sufficient to meet the monthly demand for the product and, if for a period the demand for elevators drops, operators are sorted to work in other departments. The warehouse manager has control over both the receiving warehouse and the shipping warehouse; under him, an operator devotes time to the processing of cutting-saw (tube and box cutting), an employee processes the packaging of the machines.

The company expects a 20% increase in staff by the end of 2024.

2.2 Analysis of the life cycle and production process of the product "Industrial cap elevator"

The months of training underline the importance for the company to have a greater awareness of the production process as a whole, from the moment when the sheet metal enters the primary warehouse, to the moment when the finished product leaves the industrial plant. If the staff (in the office and in the workshop) knows in detail how all the process phases work, they have an overview that goes to improve and make the single department work more effective and efficient. For this reason, the thesis covers the history of the company and its analysis, to provide a clear and complete business description of its structure and how it works.

For the reasons described below, the thesis presents the analysis of the Value Stream Map of the product Cap elevator subject to thesis (see Figure 9.2); the following paragraphs analyze, in detail, the areas of the Value Stream Map and their flows between them. The thesis provides a detailed explanation of the various departments of the company, how they work and how they interact with other areas of the company; the treatment identifies in the first place, the waste related to the department and describes its nature.

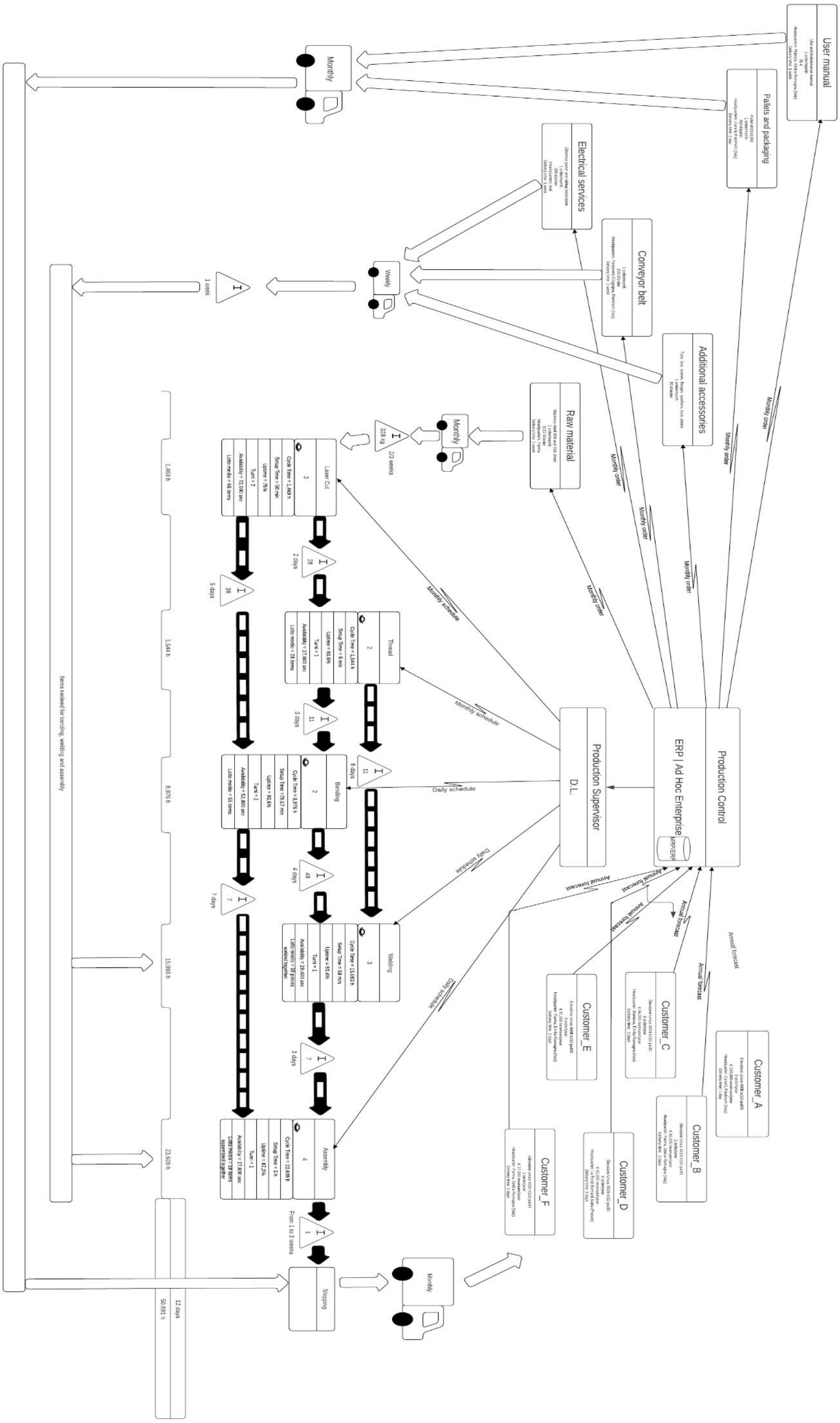

Figure 10.2 - Value Sream Map of the company

2.2.1 Commercial phase and generation of the order

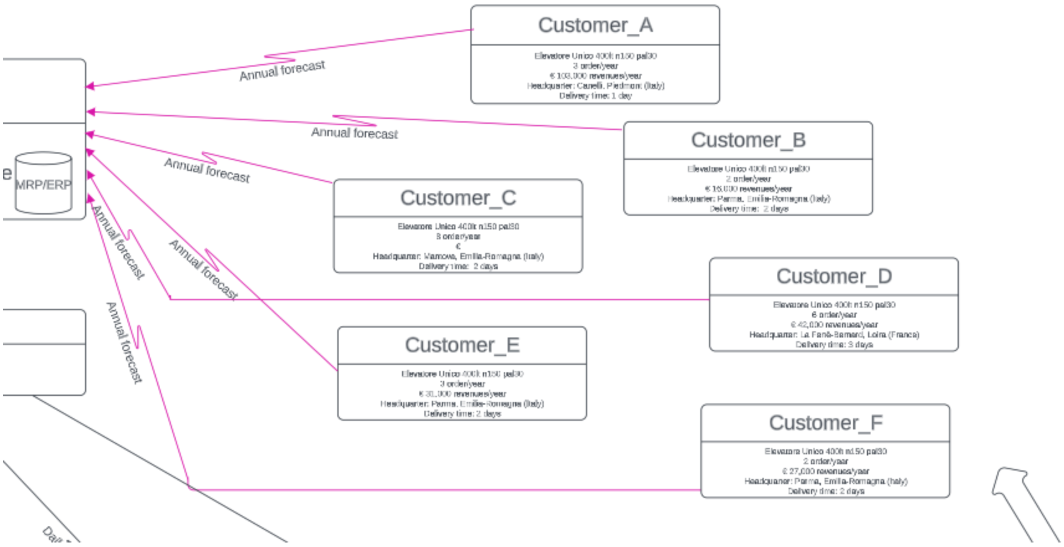

Figure 11.2 - VSM Customers

The production process of industrial elevators is born from the commercial phase: in this first step, the commercial department looks for potential customers and sends a preventive offer of the product and, once the agreements are defined, a delivery date is agreed, which must be confirmed in the following weeks. Before concluding the final contract, the company's technical department designs the product (in 2D and 3D using SolidWorks software) according to customer specifications; in fact, the *Industrial Elevator* is a highly customized product and rarely a previously created project is required. After eventual changes and revisions, if the drawing is confirmed and the contract stipulated, it is proceeded with the generation of the store clerk, an activity of loading of the order to managerial and of the creation of the requirement of store (taken particular from the central warehouse), LISAP (Supply List, that is the necessary purchases for that determined store clerk) and requirements of account labor (productive workings of third party on the business details since not realizable internally).

Most of the product details are not coded to systems, because, as previously described, the product is very customized; the operator needs to create new codes associated with the relevant article, entering the type of material (304 stainless steel, 316 stainless steel or iron) and the type of finish (SB, 2B), information that extrapolates from the data on the drawing. The order generation phase is a very important and delicate step of the production process because it is the basis on which the next step will begin production planning. For this reason, to the production office, the order must be delivered complete, with the budget of production times for each department entered and the needs and purchases managed.

At this stage we find the *first type of waste*: if there are many orders and therefore many orders to be generated, the operator of the technical office creates first all the codes of all orders, then manages all the requirements per order of all orders, then all the LISAP, all the accounts work and finally delivers the orders paper generated all together in block. By adopting this method, in each period of time, no orders are sent into production, but they will be delivered all together, resulting in delays and difficulties in planning. Instead, by managing one job at a time (codifying and generating the needs in a single step), the production office, in a short time, will already have a job to manage. The proposed solution can be easily adopted within the company by informing the technical office and changing the working methodology.

This waste of time does not have a high impact on business costs and therefore will not be analyzed in detail in the following thesis.

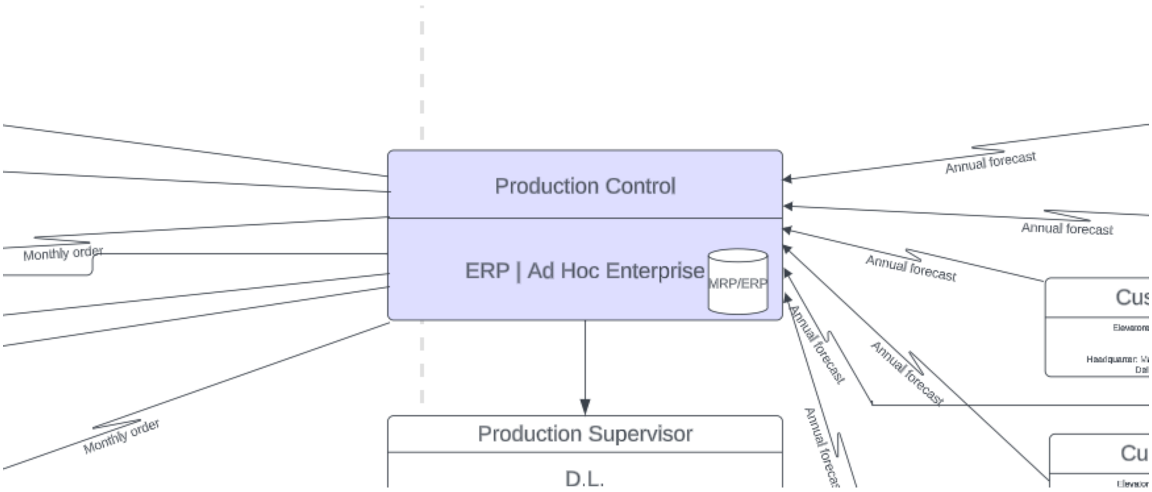

Figure 12.2 - VSM Production Control

Once the order is generated, the operator of the technical office prints the label of the order (example in figure 12.2), the list of the works to be carried out (internal and external) and the codes to be worked (example in figure 13.2) and deposit the paper in a carp outside the office.

Stampa ODL per Centro di Lavoro MARMOINOX SRL

Centro di Lavoro : SALDATURA

Commessa :

Prevista Evasione :
Intestatario :

Riferimento Ordine	N.Riga	Articolo da Lavorare			Materiale da Utilizzare			Q.tà	Data	Codice di	Fasi di Lavorazione			
ODL	Ord.Cli.	Tipo	Codice Articolo	Descrizione	Materiale	Finitura	Spess.	da prod.	lavorazione	destinazione	Padre	Prec.	da Eseg.	Succ.
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009990300841292		PF	03630526U0200-A	SUPPORTO SCATOLA DI DERIVAZIONE	INOX 304	SB	1,200	1,000		03630526U0200	SA	IN	CB	
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009990300840891		SE	0363052900703	GRUPPO FLUSSO SINGOLO MOD. MTF 4824				1,000	10/07/2023	03630529UE003	SA		SA	
009990300841073		SE	0363052901000	COMPL. GUIDA				2,000	10/07/2023	03630529UE003	SA		SA	
009990300841272		SE	0363052901000-A	STAFFA SOSTEGNO FILTRO	INOX 304	SB	1,500	2,000	10/07/2023	0363052901000	SA	PI	SA	

Figure 13.2 - Order example

Stampa Etichetta per Produzione MARMOINOX SRL

Data Evasione Prevista:

Commessa : **23.00528OC**
Intestatario : **Note di commessa :** **UT___** **NOTE:**

Figure 14.2 - Order Label example

The label of the order is necessary to apply it on the trolleys or pallets on which there are the processed details, while the list of codes is indicative of the amount of work and the type of article. The latter printing, for production purposes, is not totally necessary because it is visible directly to management and this operation involves an unnecessary waste of paper. Aware of the waste, the company is currently working on a system to eliminate printing and make it possible to manage the job without using paper.

Subsequently, the operator of the production office takes the printed orders from the carp and from the screen of Planning of the managerial defines a date of forecast of the workings in the various departments, taking into account the dates of arrival of the supplies, the time needed to perform external processing and a time buffer to buffer any urgencies or non-conformities. After that, the data automatically passes to the laser department that can start the concrete production process.

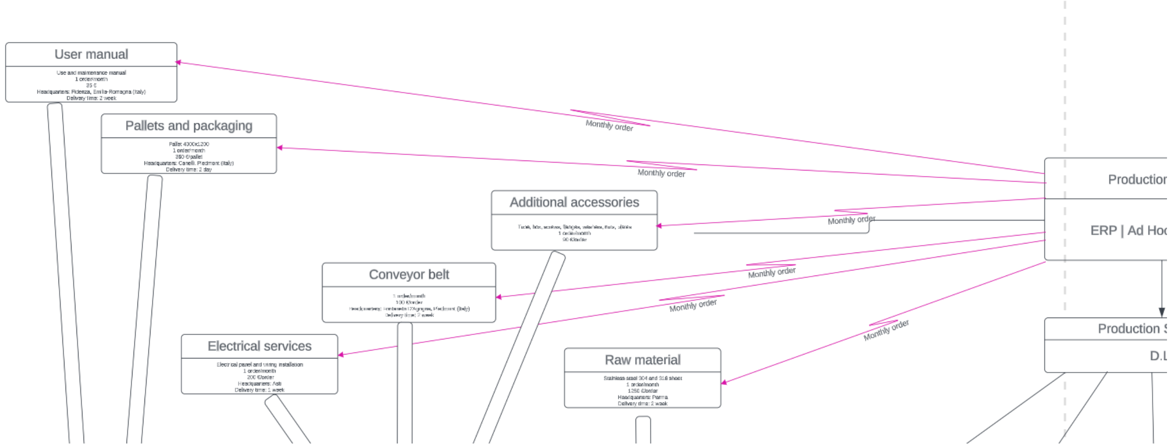


Figure 15.2 - VSM Suppliers

2.2.2 Phase of the purchases

At the same time as production planning, the purchasing department manages the material to be purchased and the work accounts to be programmed. The *industrial elevator* needs the following supplies:

- *Manual of use and maintenance*: to be associated with the product packed before shipment or sent to the customer after installation.

- *Pallets and packaging material*: since the elevator is a customized product, each order will have a different pallet size and you need to order them with customized sizes.

The previous supplies will be integrated to the product during the phase of preparation of the cargo in the warehouse unit shipments. The user manual is delivered by Fidenza to the company in a maximum of one week and is estimated 1 order per month. The pallet and packaging material have a much shorter delivery time when the supplier is based in the same country as the company being studied. It is estimated at most a delivery time of two days for the time of material reorganization.

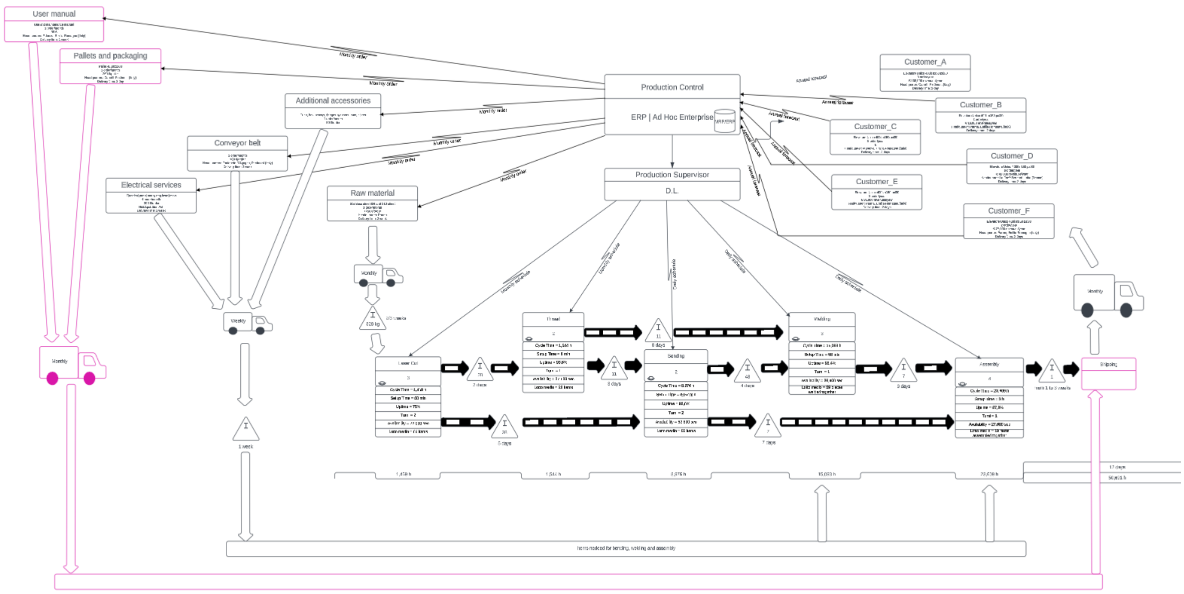


Figure 16.2 - VSM Purchases

- *Raw material*: stainless steel is purchased in 3000x1500 mm sheet metal sheets (maximum dimensions accepted by laser machinery). The cost of sheet metal is quoted on the stock exchange and is sold at €/kg. The main suppliers of sheet metal are based in Parma, Emilia-Romagna, Italy, which although distant 200km from Canelli (AT), is convenient in terms of cost and quality.

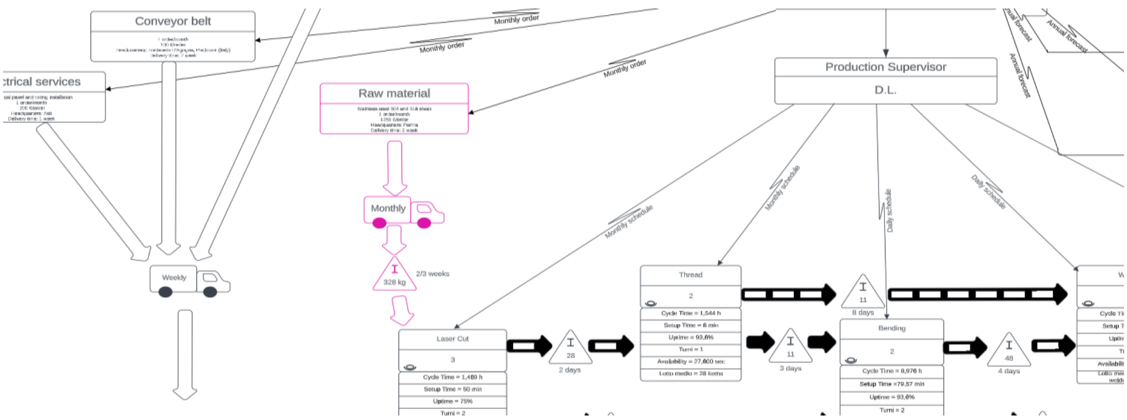


Figure 17.2 - VSM Raw Materials 1

- *Tape:* usually plastic, needed to transport industrial caps and convo them to the next area of the production line. The width, height and material vary depending on the size of the cap, the type and the weight.
- *Electrical services:* need for insertion and wiring of the electrical panel on the elevator, to make possible its ignition and function.
- *Additional accessories:* tube, box, screws, flanges, washers, nuts, plates to be installed on the product.

The previous supplies are added to the welding and assembly process.

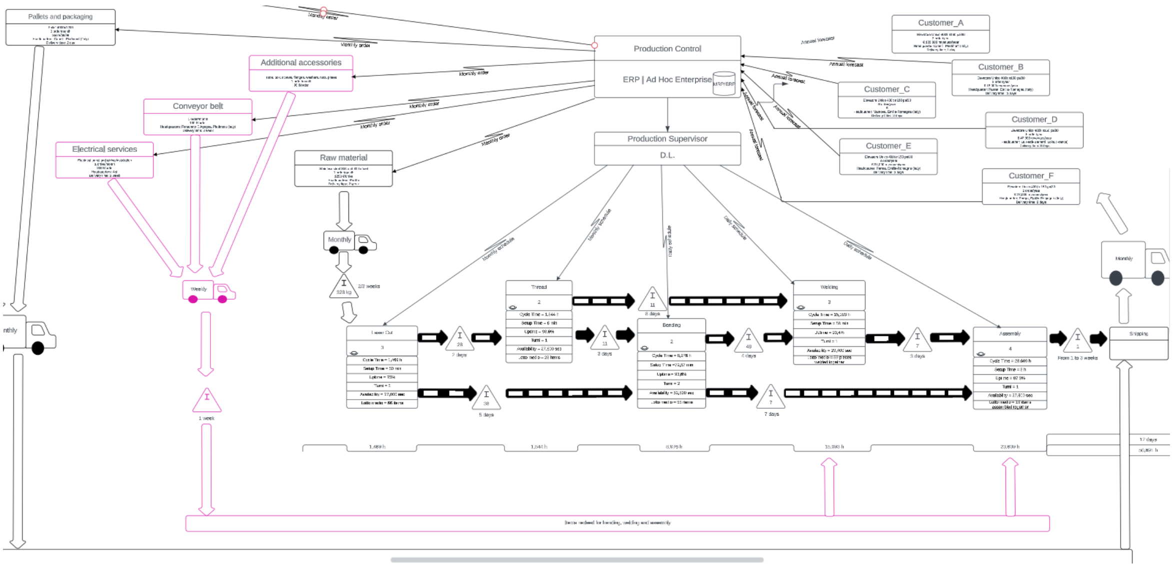


Figure 18.2 - VSM Raw Materials 2

2.2.3 Phase 1 – Laser Cut

With the arrival of the raw material, the elevator production process is officially started. The average weight of a stainless-steel supply for the construction of an elevator is about 330kg (depending on the customization of the product). Here are the characteristics of the most used sheets:

Material: Inox 304

Finishing: SB

Thickness: 15/10, 30/10, 20/10

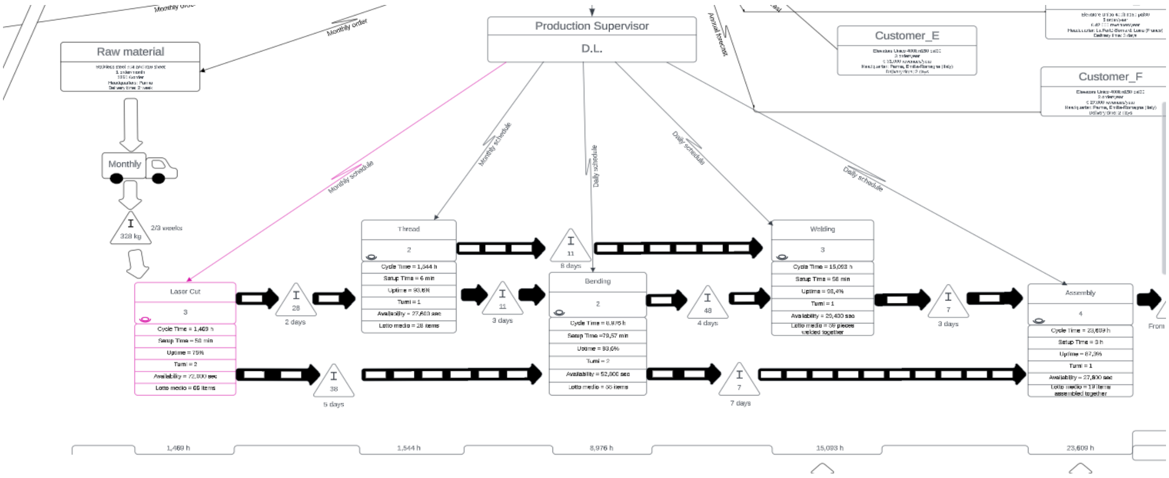


Figure 19.2 - VSM Laser Cut

The raw material warehouse is automatic: the operator manages the software that controls the warehouse trolleys, which deposit the sheet metal directly inside the laser machinery. The laser machinery used in the company is the manufacturer Mazak and works via fiber optics, with a maximum power of 8.0 Kw. The cutting dimensions are 1490x2975 mm (1450x3000 mm but it is not possible to obtain material from the frame of the sheet). Once the laser has been cut, the mechanism of the automatic magazine proceeds with the sheet metal coming out of the machine and depositing it on a trolley. The sheets accumulate on the trolley as the cutting phase is faster than the unloading phase of the sheets; if there is an urgent need to take sheets of sheet metal deposited under other material, a mechanical arm equipped with suction cups removes the sheets from the surface and deposit them on an additional trolley, so as to make possible the removal of the required material. Usually, the operator sends to the cut consecutive sheets having as much as possible details of the same order; a sheet houses details of different orders to optimize the use of the raw material.

The routine maintenance of the laser machinery is essential to allow the correct operation of the same; in particular, the well-made cleaning of the extruder allows to avoid possible malfunctions and deviations of the laser beam. The Mazak laser is the most powerful and fastest laser within the company; an additional laser machine is present in the workshop, the same parent company of the one described above, with the difference that it works with CO gas and not fiber optic. This allows to reach a maximum power of 4.0 KW: it is usually used for extra work, emergencies, or overproduction. Again, the cutting dimensions are 1475x2990 mm.

Both laser machines can cut the following materials: 304 stainless steel, 316 stainless steel, iron, zinc, aluminum, brass, titanium with a minimum thickness of 0.5 mm to a maximum of 20 mm for iron (the thickness varies depending on the type of machinery).

In this first step of the process, you can notice the *second waste* of productive time due to the unused laser, turned on, during working hours. This waste will be analyzed in the next chapter.

The head of the laser department is the one who creates the nesting to fill the sheet metal with the geometries of the various parts to be cut: Initially, the operator proceeds to import the specifications of the part from the management to a program called Lantek Expert, CAD/CAM nesting software, able to view the geometries of the items and be able to insert them into the sheet of metal (see figure 19.2). The larger pieces will be the first to be inserted in the laminar rectangle, then the operator fills as much as possible the available spaces with the details having the same specifications. One rule of laser cutting is that it is not possible to cut the geometries and wire with each other, but it is necessary to leave some space between the geometries and the others and the frame itself, to prevent them from getting damaged.

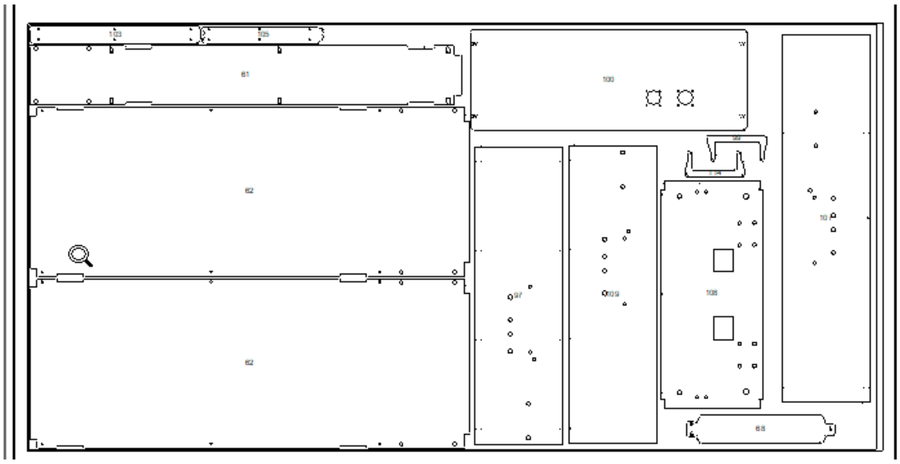


Figure 20.2 - Worksheet Lantek example

2.2.4 Phase 2 – Drain and Thread

After performing the laser cutting, an operator replaces the loading trolley of cut sheets with an empty trolley and takes care to detach the parts from the sheet, by hand or by means of tools: what is not an article of the order, is thrown into a caisson and becomes scrap or waste destined to return to the foundry.

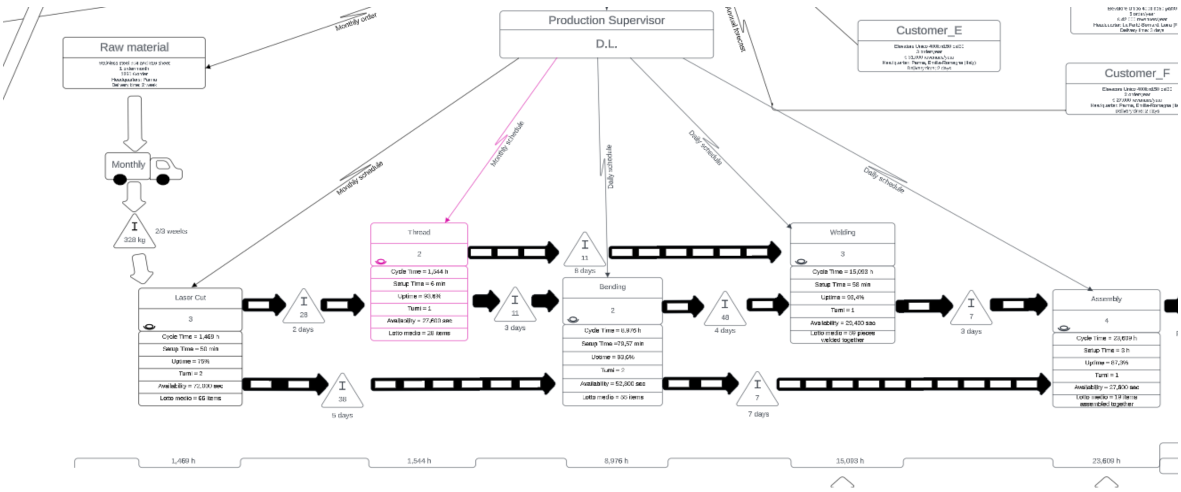


Figure 21.2 - VSM Drain and Thread

This action involves a waste (*third waste*) of expensive raw material and for this will be analyzed in detail in the next chapter. In addition to this procedure, the operator applies on the details a label that defines the code and characteristics of the article and deposits them on the trucks of the intermediate warehouse; this phase is defined labelling. The operator prints an adhesive label, through a special printer, that identifies the detail thanks to the following information (see figure 21.2):

- *Reference contract*
- *Code*
- *Barcode to open 2D drawing*
- *Identification image*
- *Working cycle*
- *Thickness*
- *Quantity*

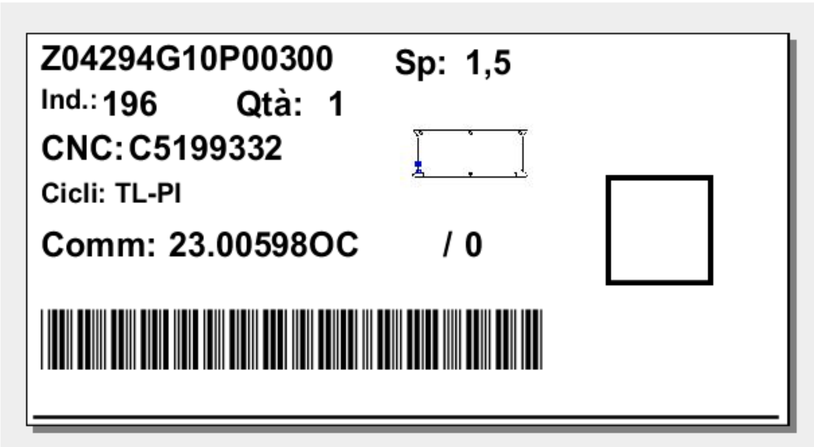


Figure 22.2 - Product Label example

The procedure takes time and material, and this involves a waste of the same, because the operator must search for the piece on which to apply the label and, Although the software supports the operator at this stage by showing the geometry of the piece and its code, it is not an immediate procedure.

The thesis proposes the application of an alternative method: investing in a laser marking machine to facilitate the part coding process and to waste less paper material. In many industrial sectors laser marking has become a standard; influencing information directly on the part to be identified ensures greater flexibility, quality, speed, and a low ecological impact. The initial investment is high, but the laser allows a considerable saving on the costs of processing and maintenance (changing cartridges, lack of ink, jamming of the machine, etc.).

As mentioned before, during the unloading phase the operator stores the parts on a trolley that will be taken from the next phase and machined; some parts of the industrial elevators need a threading process to prepare the piece for the insertion of the screw, others go directly to the bending phase. The time of permanence of the details on the trolleys is usually of maximum one week, in order not to accumulate material in the phases begins them of the process. The threading process consists in creating a thread inside the cylindrical hole through a manual machinery on which it is possible to change the size and type of the shape of the male. It is advisable to lubricate the instruments with cutting oil and fix the element to be threaded with a vice. Subsequently, the operator places the threaded parts on the trolley of the reference job: some will be processed in the bending phase, others will be transported directly to the welding phase. In this process there is no waste.

2.2.5 Phase 3 - Bending

The bending phase consists in deforming the particular by means of a force to make it assume a certain shape with characteristics specified in the drawings, considering the angle and the type of quarry.

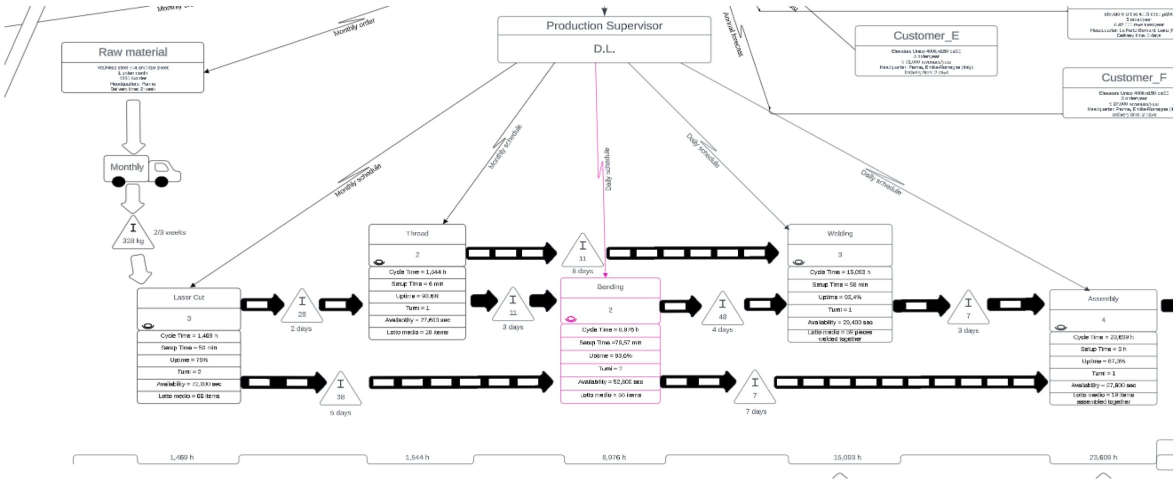


Figure 23.2 - VSM Bending

The operator first opens the folding drawing by means of the barcode on the label that appears directly on the computer of the workstation and then sets the folding machine according to the indicated parameters:

- *angle of bend*
- *type of quarry*
- *bend line position*

The company has 3 bending machines with a maximum bending length of 4000 mm and height 350 mm, a smaller bending machine used for small parts, a paneling machine of maximum length 3123 mm and a calender of maximum length 1600 mm.

Setting the settings of the bending machine takes a few minutes and for this reason the operator tends to bend together similar parts to optimize the time. Large parts require the work of two operators together. The bending phase shows a waste (*fourth waste*) of time common to the welding department: operators ask the production office for clarifications regarding the processing method to be carried out because no indication is marked on the drawings or the request is not clear, resulting in a waste of time by both parties. The thesis will analyze this type of waste in the next chapter.

After bending, the operator places the machined parts on a trolley and an internal transport operator delivers them to the next department. Inland transport has two problems:

1. The material is not transported or wrongly transported to the next department (on an incorrect welding island).

2. Loss or loss of the processed parts needed by the next department.

The first case is manifested because the operator is not able to view the subsequent processing of the article anywhere, not being reported on the sheet of the order and not having the management software; the operator is obliged to request the support of the production office to direct it to the place of delivery. Currently, the operator knows the machining cycle either because it is manually entered by the production office on the printed label of the order or because he is confronted in person with a manager or by experience. The process does not follow a Lean logic, but the company intends to invest in the Japanese philosophy and the solutions proposed later will be a taste.

With regard to the second case, the details of the order travel inside the workshop on the same trolley or pallet (or on several trolleys or pallets) to optimize the transport and search for the parts, but often operators do not find the necessary material to work and waste time looking for it for the workshop; in doing so, it can happen that you forget the timer on (processing time calculator) and that the order has, in the end, more time than is actually needed.

The following cases occur for which the detail:

- is placed on another trolley.
- is in another department.
- has not yet been processed by the previous department or directly laser cut.
- not coded by technical office.
- not delivered by a supplier.

The cause of the previous errors reported is inattention or cluttered environment and little intuitive. The Lean philosophy, which provides for order and cleanliness in its principles, will improve the current condition.

The waste of time described (*fifth and sixth waste*) are not to be ignored because they affect, even if probably little, the company’s economy, but above all the well-being of operators who may suffer from stress due to the continuous loss of time.

Costs and solutions of the problem of internal transport will be analyzed later.

2.2.6 Phase 4 - Welding

After bending, the details of the elevators pass to the next department: welding.

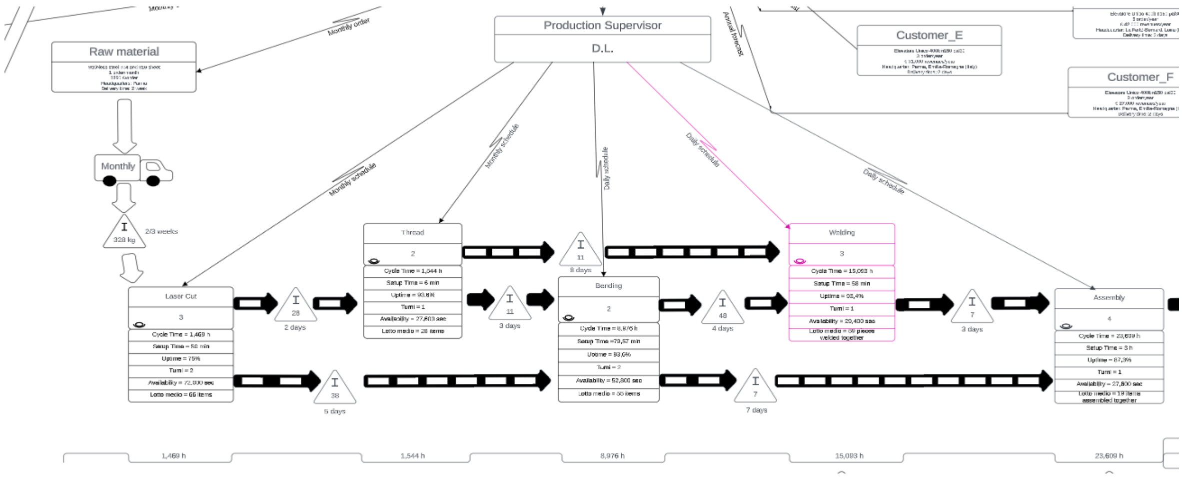


Figure 24.2 - VSM Welding

The workshop has 16 welding stations, each with its own shadow board, workbench, tool trolley, welding machine, computer, cleaning tools and various equipment.

Most of the locations are concentrated in the central hall, while the other five are divided between the first and the third. The types of welding are:

- *TIG - Tungsten Inert Gag*
- *TIG to rest*
- *With continuous wire*

The company also owns a semi-automatic welding machine, mainly used for circular section welding.

The materials used in the processing are 304 and 316 steel, iron and aluminum, with the possibility of applying a coating to the particular of 316 stainless steel or iron. The thickness of the material available for processing is minimum 0.8 mm to maximum 30 mm (steel case). The ISO 9606-01:2013 certification, in possession of the company under analysis, specifies the requirements for the qualification test of welders for melting steel welding. Welding uses some finishing accessories to improve the quality of the part, including the following tools:

- *Lamellar discs,*
- *Platorelli,*
- *Brushes,*
- *Polinox rollers,*
- *Abrasive discs,*
- *Abrasive cloth belts and*
- *Abrasive rubber.*

The order and cleanliness of the accessories is among the principles of Lean that the company aims to put into practice; in the personal experience of internship, I and my trainee manager have applied small improvements to the welding stations to facilitate work and get closer to the Japanese philosophy. Here are some examples:

- Creation of a door-plate structure on the wall.
- Creation of a female door to the wall.
- Removal of unnecessary instruments at workstations (old tubes, excess trolleys, boxes, ...).
- Completion and coloring of the Shadow Board staff.
- Cleaning or ordering of drawers.
- Adding a hook to the wall for cleaning accessories (broom and dustpan).

The described process improved the working condition of the operators and made the search for the necessary tools intuitive.

Usually, always the same two or maximum three operators work the elevators for a matter of product knowledge; experience leads to a decrease in errors, and recognition of the errors themselves and a quick repair time. The welding time of a lift depends on the customization of the same; some in 8 hours are welded, others also need 4 days. The elevators lead to a good part of the turnover and for this the production office tends to give priority to their working, anticipating the planning even a month before the delivery date (considering any non-conformities and urgencies). As the operator welds the parts, assembly workers can pick up the first welded parts and proceed with the machining. As previously mentioned, welders may find it difficult to interpret the welding drawings due to the lack of indications, on the 2D drawing, the type of welding and additional and accessory machining to be carried out on the piece, such as grinding, deburring or acidification. This involves the assessment of the problem by the welding operator and the production office, leading to a waste of time on both sides. A waste analysis will follow in the next chapter.

The welding department also takes care of the following ancillary processes that improve the quality of the workpiece:

- grinding, which makes the edge of the detail shiny, manageable and no longer sharp.
- deburring, which, like grinding, refines the surface of the workpiece and removes hidden burrs, irregularities or contaminants.
- acidification, the process of removing the passive oxide film after welding; it is carried out by soaking the part in acid solutions. The company owns three acidifying machines located in an area outside the shed.

2.2.7 Phase 5 - Assembly

If the welding is completed and additional work is carried out, the assembly department proceeds with the progress of the order; the department is divided into four workstations, but often several operators work on the same product at the same time and the work area is enlarged.

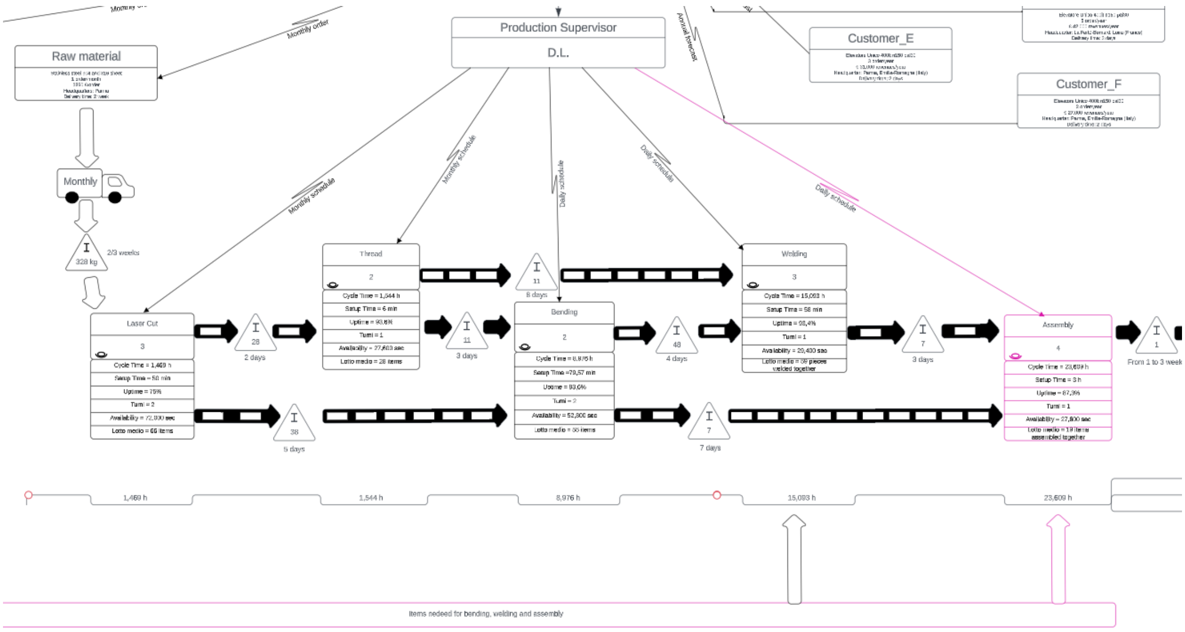


Figure 25.2 - VSM Assembly

The *industrial elevator* is the main product that requires assembly; without enough elevators to assemble, the department would not be saturated and would have a waste of human resources. In case there is no work, the manager will sort the workers in the departments where there is need. On average, an elevator stays in the department for 5 to 8 days, but production often lags due to a lack of details or a previous mishandling that requires the specific part to be put back into production. Urgencies, errors, shortcomings, and losses are part of the big picture of non-compliance. The company faces a non-compliance every time a requirement is not met or when you have adapted to it only partially; this happens when a particular is not managed and/or worked in the proper way. Below are some examples of non-compliance:

- *Dimensional error* - The dimensions of the part are wrong and happens both in the design phase and in the machining phase.
- *Non-specific execution* - The operator performs the machining not according to the specifications required by the project and/or the customer.
- *Poor quality execution* - The operator does not perform the required processing and/or management to the best of his abilities and does not pay attention to the quality of the product.

- *Quality control error* - The part requested by the customer has a processing error due to the lack of a final control on the material sent.
- *Quantity Control Error* - The company delivers to the customer an amount of material from the planned or the quantity of the parts is not well controlled within the production chain (part loss, wrong calculation, etc.) .

A non-conformity is associated with a management time of the same and the time is either entered in the final balance on the contract subject to non-compliance or inserted in non-productive times; in any case, the business costs increase in many items of the income statement (personnel, electricity, equipment depreciation, etc.) and decreases both total and individual profit. Non-conformities arise either from an error within the company, or from an error of customers or suppliers; in the last two cases, most of the cost is often associated with one of the two figures and the company pays only the time of the operators who manage the solution.

Whenever this scenario occurs, a production office operator has the task of entering the non-conformity related to the contract on the management, specifying the following parameters:

- *Number of orders*
- *Client*
- *Supplier (if necessary)*
- *Issuing institution*
- *Receiving agency*
- *Type of non-conformity (one of the five described above)*
- *Priority (high, medium or low)*
- *Status (Open, closed, in-process, in-process, pending or reopened)*
- *Reporting description*
- *Possible solution*
- *Place of intervention*

By saving the document, the report is linked to the order and can be viewed at any time, even in the final balance, to make the various considerations of the case and ensure that the error is not repeated.

In the assembly department, the Elevators' non-conformities reflect unused and discarded steel material that is affected by an error (among those listed above); operators, where possible, reuse the parts, but most of the time, they break them. As described above, the Elevator product is highly customized and every detail of the machine has different dimensions, therefore difficult to reintegrate into the production chain in subsequent orders.

The cause of the error arises both from previous processing (design and/or mechanical machining), from the testing phase of the assembly, which analyzes the operation of the machine, and from the packaging phase, which sometimes causes damage to the product. Operators shall report the non-conformities described to the production office, which shall ensure that they are included in the system.

The company begins to analyze in detail the non-conformities from the year 2018 (first insertion in the system), when it understands the need for and importance of their control. The thesis analyzes the waste of time, material and resources (*seventh waste*) related to the non-conformity of elevators for each department of the production process, from the design phase to the shipping phase, from 2018 to 2023. The next chapter defines a total cost per year, which departments are most responsible for managing non-compliance and possible solutions. Abstract: the year 2023 has the most data because the company has manually uploaded more reports, while the loading of previous years is weaker; it is not always easy to separate the non-compliance in its causes and associate a wasted time (linked to a cost), so the reporting to management was not made.

Non-conformities can generate so-called red and green orders. The first ones are urgent orders that have the production priority; they are orders to work from scratch or integrations of details to the store clerk already in the process. The latter are less urgent than the former, but still have priority over the orders already in production. These urgencies put in difficulty the process in how much they demand time and material that not always the company has to disposition (for example, steel sheets need at least a week of shipping and may happen that the raw material warehouse is lacking the supply necessary to deal with the urgency) and involve the temporary stop of some details already in production. In this context, the company should define an undershoot, that is the minimum quantity of the product that must always be in stock. Underselling considers the frequency of use of that specific sheet in a period of time (dictated by demand) and lead time; if the number of sheets, having certain characteristics, falls below a certain value, the head of the laser cutting department must place a new order to the suppliers. The choice of the automatic reordering of the plate faces some obstacles as the company would go to store in warehouse a certain amount of capital that for a period would remain immobilized. The thesis emphasizes the necessity to carry out such investment in order to avoid to remain without material in the house and not to be able to face urgencies or advances from customers; this does not mean to enrich the warehouse with all the typologies of materials used, but at least define an undershoot of some standard sheets, such as 304 SB 15/10 and 12/10 stainless steel, mostly processed sheets in the production process.

Red and green orders are also born from commercial agreements; the urgency arises, but this does not include non-compliance. This is the case of deliveries or early installations, details promised urgently to the customer, addition or replacement of items or changes required by the customer during production. The production department analyses and checks, monthly, the origin of the red and green orders and creates a report that will be shared with the management, to find optimal solutions to the reduction of the presence of urgent orders.

The end of the assembly phase consists in the testing of the elevator: the operator sets the machinery in motion, inserts the test caps (or sent directly by the customer or bought from suppliers) and evaluates the correct operation, reporting all the parameters of the case and the problems that may arise. Sometimes, the operator takes a video of the operation and sends the material to the customer (this mainly occurs with new customers). If the test is successful, the operator closes the order, the elevator passes to the preparation and packaging phase.

2.2.8 Phase 6 – Packaging and Shipping

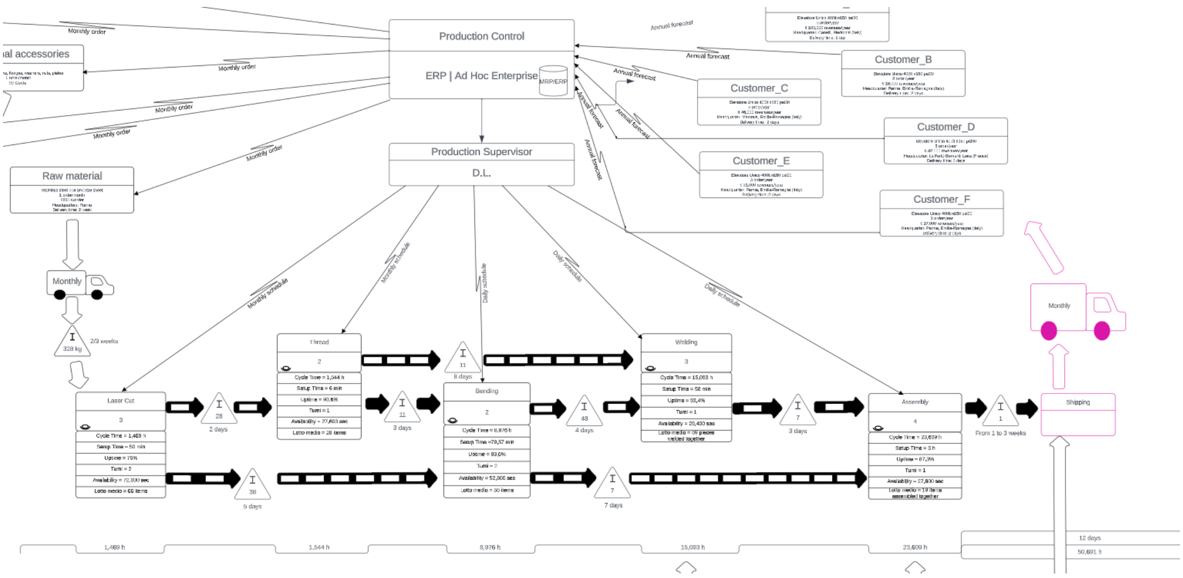


Figure 26.2 - Packaging and Shipping

When the elevator successfully completes the testing phase, an operator packs the machinery and deposits it in the final warehouse. The elevator remains in the warehouse area even many days before the actual delivery date because production tends to give priority to the production of elevators rather than to other product families. The reason is that the *Elevator* product has a very high selling price and involves a high margin. The poduct is ready for pick-up and shipment by an external transport company. Delivery is fast (less than a week, depending on customer location). After the shipment, the operator of the production office proceeds with the analysis of the budgets/results of the order associated with the elevator: the analysis studies the course of the production of the store clerk and the times reported from the operators and marks eventual deviations from the estimate budgets. The subsequent correction of the budget is essential to define the production time and, above all, the selling price: the control must understand the reason for the origin of the deviation and find solutions to correctly align the budget/ final balance.

Once the process phases have been defined, the thesis proceeds with the analysis of the company waste found during the internship period.

Chapter 3

The previous chapter analyzes the production process of the product "*Industrial Elevator*" and defines the waste of time and material that involve a certain company cost. This chapter considers the waste previously reported, defines a degree of economic impact to each and analyzes in detail causes, costs, and solutions of waste with greater impact.

Below the thesis associates every waste with an alphabetical index:

Tabella 1.3 - Waste List

ID	Waste
A	Inefficient order generation sequence
B	Laser disuse
C	Scrap metal
D	Paper labeling
E	Request for technical drawings
F	Errors due to internal transport
G	Non-conformities

The following matrix is a tool built with the level of economic impact, considering the recurrence of that waste and its potential criticality:

ECONOMIC IMPACT
NEGLIGIBLE
TO CONTROL
NOT INCONSIDERABLE

Tabella 2.3 - Waste Economic Impact

		Potential Criticality				
		NEGLIGIBLE	LOW	MEDIUM	HIGH	VERY HIGH
Recurrence	DAILY	D			B	C
	WEEKLY	A	F	E	G	
	MONTHLY					
	SEMI-ANNUAL					
	ANNUAL					

- Waste A (*Inefficient order generation sequence*) has recurrence weekly and foresees a potential negligible criticality; waste D (Labeling paper) happens daily, but also its potential criticality is negligible. For this reason, they will not be considered in the cost analysis as their economic impact is negligible.

- Also, the wastes E (*Demand indications drawings*) and F (*Errors due to the transport inside*) have recurrence weekly magazine, but they have a medium-low potential criticality; the thesis previews an economic impact on the company not excessively high, but to hold sot-to control. Waste E and F will be costified.

- The *unusability of the laser* (waste B), the *scrap of the sheet metal* (waste C) and the *non-conformities* (waste G) occur almost every day and their level of potential criticality is high sic-how they could impact the business economy; for this reason, an average cost of these wastes is estimated in order to show the company the potential economic loss and make possible the consideration of possible remedies.

3.1 Analysis of “not negligible” economic impact waste (B, C, G)

3.1.1 Waste B analysis – Laser disuse

The thesis analyzes the monthly use of each laser machinery to verify the actual hours of production and the hours of machine downtime, to determine a cost of un-using. The reference period is 5 years, from September 2018 to June 2023. In September 2018 the company replaces a 4kw power laser machinery with the current 8kw laser; analyzing this period, it is possible to have a more accurate and consistent study of data and information compared to years before the 8kw laser.

Laser 8000 W analysis

The data is derived from Lantek Expert software. Below are the data used:

Tabella 3.3 - Laser 8000W Data

DATA	Days in a month (average)	21
	Hours in a shift	8
	Daily shifts	2
	Available working hours	16
	Night time available	3
	Total daily hours available	19
	Available monthly hours	399

The first shift is from 06:00 to 14:00, the second from 14:00 to 22:00 where both operators and laser work. The potential of the laser offers the possibility of having 3 hours available per night (from 22:00 until 06:00 the next day) to be able to cut the sheet without the help of an operator; the system deposits one sheet on top of the other and the next day the operator unloads the material. The choice of 3 hours of night for the analysis of the use is an average value that is closer to reality: it is possible to cut all night, up to a maximum of 8 hours, but almost never this scenario occurs; thus, the average value is lower and considered as 3 hours per night. The monthly hours available for laser cutting are 399 h/month.

$$Monthly\ Hours\ Available = (\text{Daily Hours Available}) + (NightHourse\ Available) * Days\ in\ a\ month$$

$$399 = \big((16) + 3\big) * 21$$

Laser Department cost items:

Tabella 4.3 - Cost items of laser department

LASER DEPARTMENT	
Item	COST [€/h]
Personal	28.59
Amortization	23.72
MDO	14.79
Energy	18.12
Maintenance	15.10
Other	2.42
Various	22.64
TOT	125.38

The data in the above table vary over the life of the production process. The item *Various* includes consumables (in this case gas) and various equipment, while the item *Other* includes rental of tools and equipment (such as nitrogen cylinders) and other ancillary services.

Monthly usage is calculated:

$$Monthly\ Usage\ [\%] = \frac{Monthly\ Hours\ Productive}{Monthly\ Hours\ Available}$$

An Excel table shows the monthly values of the hours worked by the machine (derived from the nesting software) and the monthly usage and shows the trend of the percentage use of the laser in the reference period:

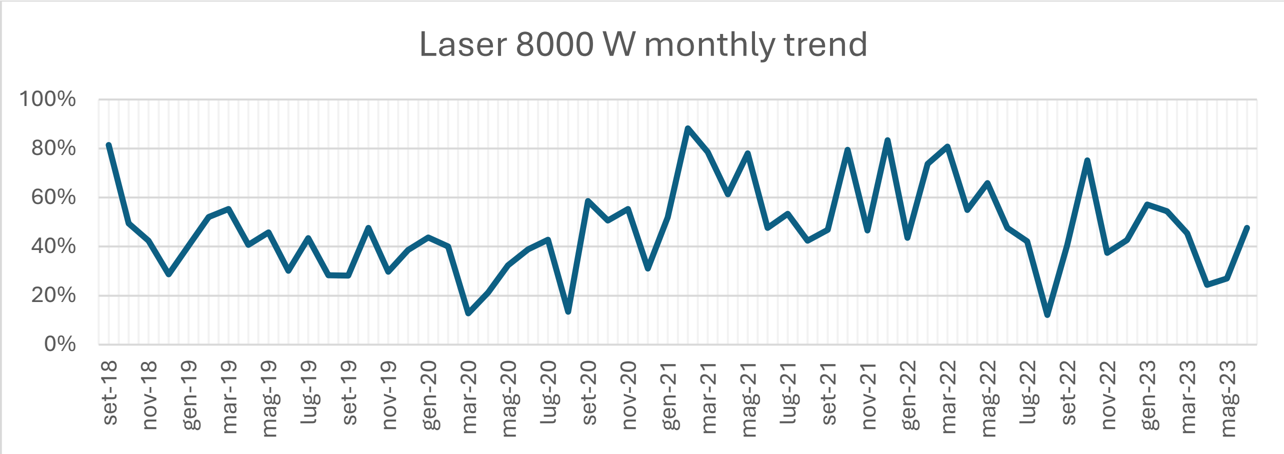


Figure 27.3 - Laser 8000W trend

August 2022 has the lowest usage, 12%, due to a breakdown of the machinery source modules. The intervention was carried out in the following month, the maintainer reconnected the repaired source, reinserted the cables, reassembled the casings and grafted the fiber into the cutting head.

Also, August 2020 shows a very low use, due to the decrease of shifts, from 2 to 1, to allow the holidays (only 2 operators specialized in laser cutting operated in that period). March 2020 sees a laser break and for 15 days the machinery could not work.

February 2021 is the month with the highest usage, 88%, as the company acquires many cutting and bending orders, and the machine works almost to its maximum.

The average monthly value is:

$$average(monthly\ values) = 189.40\ h/month$$

The average monthly usage is:

$$average(monthly\ usage) = 47.47\%$$

The monthly machine downtime hours are:

$$Monthly\ hours\ available - average\ monthly\ value$$

$$399 - 189.40 = 209.6\ h/month$$

The cost items used to calculate the cost of the machine are as follows:

- *Amortization*
- *Energy*
- *Maintenance*
- *Other*
- *Various*

The laser, when not in use, remains on to avoid high costs of switching on and off during working hours and to be ready in case of need. The costs amount to:

$$c.depreciation + c.energy + c.maintennace + c.other + c.various$$

$$23.72 + 18.12 + 15.10 + 2.42 + 22.64 = 82\ €/h$$

The average monthly cost of laser (unproductive cost):

$$209.6 \frac{h}{month} * 82 \frac{€}{h} = 17{,}187.89\ €/month$$

The latter is the cost that the company costs on average per month to pay the 8000 W power laser that does not work and is not productive, leading to a waste of resources.

Laser 4000 W analysis

The data are the same as for the previous analysis, both for the 16-hour day shifts and for the 3-hour night shifts:

Tabella 5.3 - Laser 4000W data

DATA	Days in a month (average)	21
	Hours in a shift	8
	Daily shifts	2
	Available working hours	16
	Night time available	3

	Total daily hours available	19
	Available monthly hours	399

It is necessary to make a premise: the company uses the 4000 K laser as auxiliary machinery, to cope with urgent problems of increased production load or machine failure laser 8000 K; therefore, it is already expected that its use will not be very high and, above all, lower than the other.

Also in this case, an Excel table shows the monthly values of the hours worked by the machine (obtained from the nesting software) and the monthly usage and shows the trend of the percentage usage of the laser in the reference period:

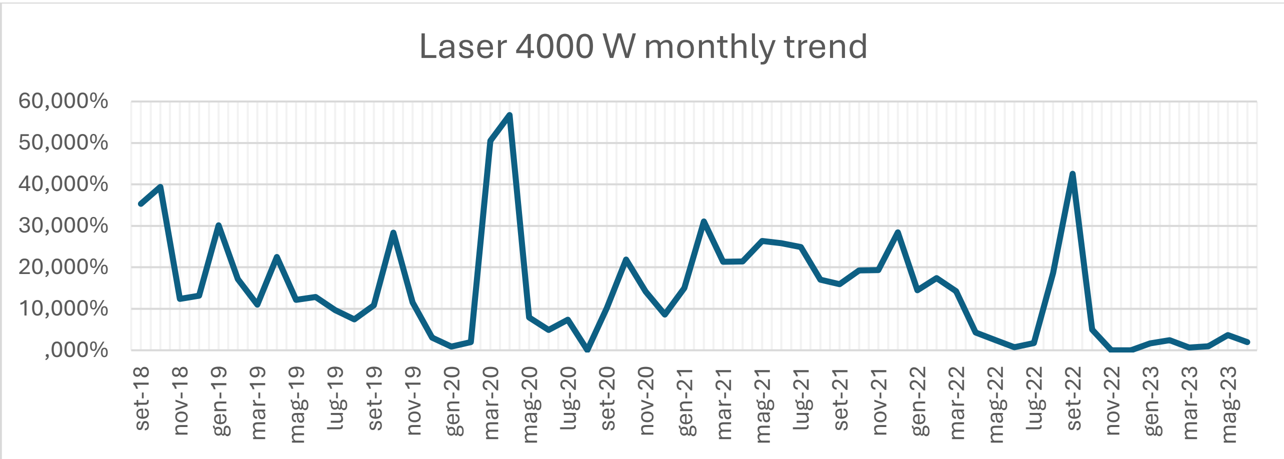


Figure 28.3 - Laser 4000 W monthly trend

The average monthly value is:

$$average\ (monthly\ value) = 59.26\ h/month$$

That is 31.3% of the value of 8000 W.

The average monthly usage is:

$$average\ (monthly\ usage) = 14.85\%$$

The monthly machine downtime hours are:

$$Monthly\ hours\ available - monthly\ average\ value$$

$$399 - 59.26 = 339.74\ h/month$$

The operator turns the laser on when it is required and turns it off when the work is finished; therefore, in the hours of inactivity the laser is turned off and the cost of energy is not considered. The depreciation is zero as the laser has completed this process (zero depreciation cost). As a result of much lower usage, maintenance costs are lower: we assume 31.3% of the maintenance costs described above:

$$0.313 * 15.10 = 4.72\ €/h$$

The same assumption applies to *Various* and *Other* cost items, respectively:

$$0.313 * 22.64 = 7.1\ €/h$$

$$0.313 * 2.42 = 0.76\ €/h$$

The costs amount to:

$$c.maintenance + c.other + c.various$$

$$4.72 + 7.1 + 0.76 = 12.58\ €/h$$

The average monthly cost of laser (unproductive cost) is:

$$339.74 \frac{h}{month} * 12.58 \frac{€}{h} = 4{,}273.93\ €/month$$

The total cost of the laser department's monthly unproductive hours is equal to the sum of the individual costs of the two machines:

$$17{,}187.89 \frac{€}{month} + 4{,}273.93 \frac{€}{month} = 21{,}461.82 \frac{€}{month}$$

Following the previous analysis, the thesis proposes the following solution to increase the use of the machine and thus reduce costs related to unproductive times:

1. Intensify research and acquisition of new customers that require a Laser Cutting product only. The company's fiber optic laser, the possibility of using a second laser machinery that, although less powerful, still works and the availability to handle the sheet through the night shift, allow you to have many hours to cope with increased demand for laser cutting work.

Interesting is the overlap of the two graphs of the trends of the monthly uses to be able to demonstrate and to confirm the greater use of the 8000 W regarding 4000 W:

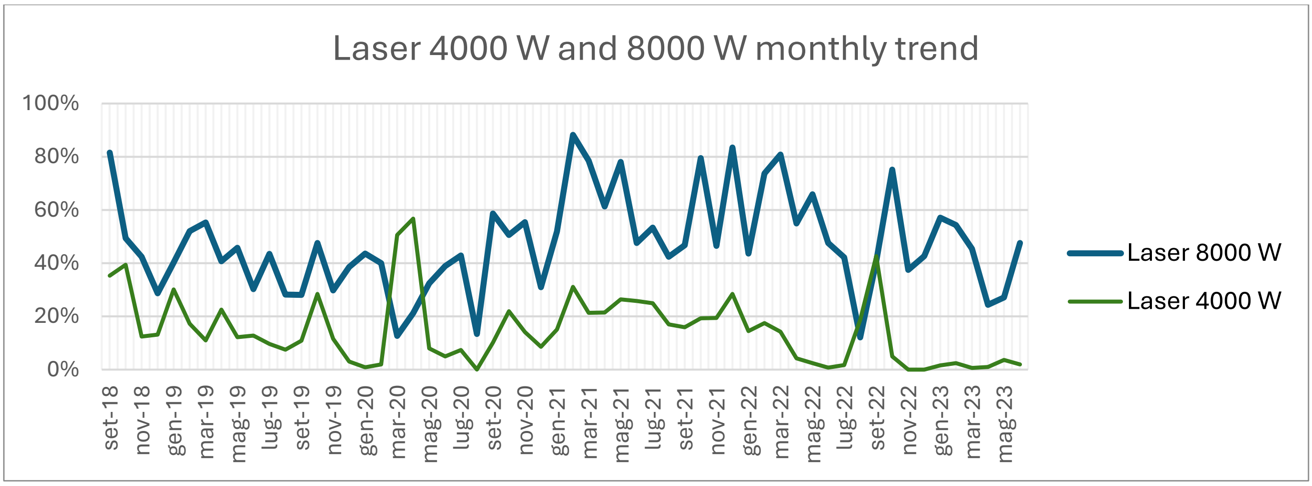


Figure 29.3 - Laser 4000 W and 8000 W monthly trend

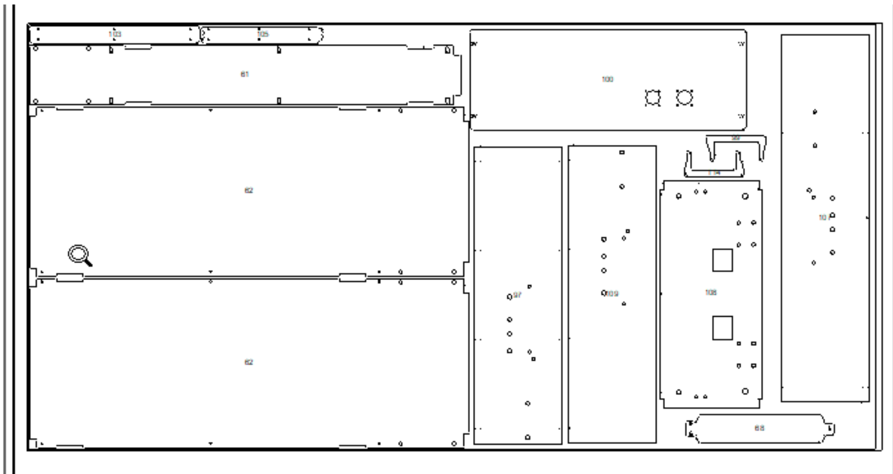
As expected, between the two lasers, the one with 8000 W power is preferred over the one at 4000 W because it implies a higher speed and a lower production cost (about 1/5 of the 4000W). The graph clearly shows this preference and shows how the 4000 W laser replaces the more powerful one when the latter is in maintenance or in a machine failure condition. The best example is that of March 2020 in which the use of the 4000 W is much greater than the 8000 W that had to cope with a major maintenance problem, so it remained out of use for 15 days.

The laser cutting phase is not what distinguishes the company in question, as it can be bending or welding, and for this reason the laser is a good offer that is not always exploited to its full potential. Despite this, the addition to the production chain of the 8000 W machinery makes it possible to acquire new and larger orders and speeds up the production process.

3.1.2 Waste C analysis – Scrap metal

The waste of material not used for the production determines a high cost for the company, as it pays the material it does not use. Considering the last 5 years, the cost of the sheet varies from a minimum of 2.15€/kilograms to a maximum of 5.95€/kilograms. The cost of the sheet varies according to the quotation on the stock exchange of the price of nickel (main component of stainless steel, which determines the price); the company bears the cost of 5.95 €/kilograms of the sheet in April 2022, period of the beginning of the war in Ukraine. As a result of the outbreak of conflict, speculation on raw material prices increases, as does demand, and there are not many reserves of nickel; this leads to a staggering increase in the price of steel. During the next four months, the price returned to an average of 3.40 €/kilograms and then decreased again reaching 2.20 €/kilograms. Instead, the price of 2.15 €/kilograms refers to the period of September 2020, period of economic stability.

Figure 30.3 - Example of Lantek production sheet



Macchina	Mazak OPTIPLEX 8K	Peso	70.65 kg
Materiale	INOX 304 SB	X	2957.341
Tempo totale	00:08:31.12	Y	1492.153
Lunghezza di taglio Mt.	37.757	Sfruttamento (%)	86.554
Trasportatore		Sfrido (%)	13.446

From the data contained in the memory of Lantek Expert (see xample of Lantek production sheet in figure 29.3), it is possible to derive the average weight of material cut per month, equal to 20,000 kilograms/month; of this material, it is estimated a variable difference between 8% and 15%, average data obtained from the nesting sheet that detects the percentage of exploitation and the percentage of scrap of the sheet. The scrap includes the frame of the sheet and the space between the details that, for reasons previously described, cannot be used to cut, and spaces that have not been used for any geometry. If the unused space is very large and is an easily reusable geometry, the operator places the sheet of a special area, to be reused in the future to manually store the piece of the sheet in the laser machinery. If it is not possible to reuse the material, the operator throws the scrap into a special bin that will be taken directly from the scrap, processed, and taken to the foundry. Also, the price of the scrap to be scrapped is quoted on the stock exchange and varies from a minimum of 0.80 €/kilograms to a maximum of 1.12 €/kilograms, much less than the cost of the new material (prices derived from the 5 years of reference for the analysis).

Analysis without quota resale steel

Below are the analyses carried out to derive the costs of the scraps of the sheet:

Tabella 5.3 - - Cost scrap sheet (no resale fee)

DATA	Min sheet metal cost [€/kilo]	2.15 €			
	Max sheet metal cost [€/kilo]	5.95 €			
	Average material cut [kg/month]	20000,00			
	Min deviation [%]	8.00%			
	Max deviation [%]	15.00%			
ANALISYS	Min discarded material [kg/month]	1,600.00	Min cost	3,440.00 €	**BEST SCENARIO**
			Max cost	9,520.00 €	
	Max discarded material [kg/month]	3,000.00	Min cost	6,450.00 €	
			Max cost	17,850.00 €	**WORST SCENARIO**

In the *best case*, the material discarded monthly is equal to:

$$20{,}000 * 8\% = 1{,}600\ kg/month$$

The price of the raw material varies from 2.40€/kg to 5.10€/kg.

- In the *best case*, the cost incurred by the company is equal to:

$$1{,}600 * 2.15 = 3{,}440.00\ €/month$$ → BEST SCENARIO

- In the *worst case*, the cost incurred by the company is equal to:

$$1{,}600 * 5.95 = 9{,}520.00\ €/month$$

In the *worst case*, the material discarded monthly is equal to:

$$20{,}000 * 15\% = 3{,}000\ kg/month$$

The price of the raw material varies from 2.40€/kg to 5.10€/kg.

- In the *best case*, the cost incurred by the company is equal to:

$$3{,}000 * 2.15 = 6{,}450.00\ €/month$$

- In the *worst case*, the cost incurred by the company is equal to:

$$3{,}000 * 5.95 = 17{,}850.00\ €/month$$ → WORST SCENARIO

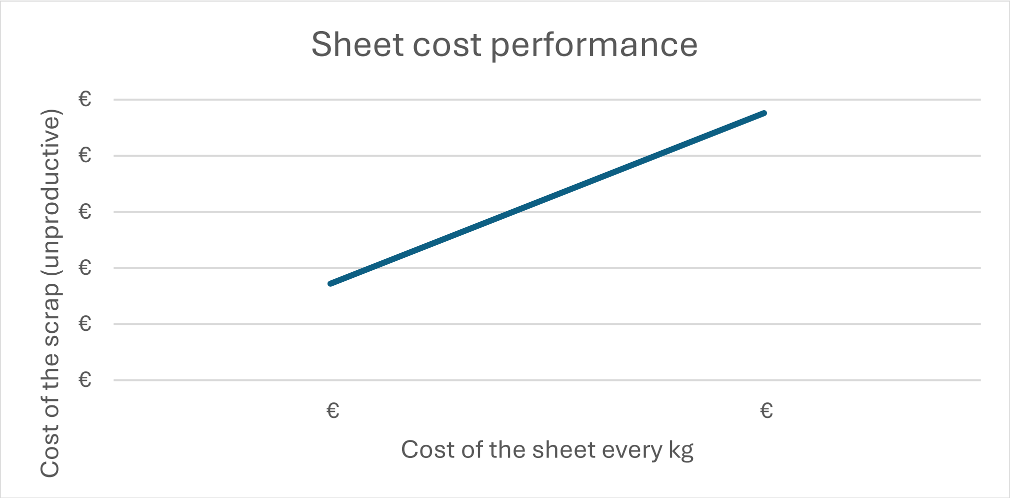


Figure 31.3 - Sheet cost performance

The above graph shows that, as the cost per kilo of the sheet increases, the cost of its scrap increases.

Analysis with quota resale steel

The following is an analysis of the proceeds from the sale of scrap:

Tabella 6.3 - Scrap sheet metal (with resale price)

DATA	Min scrap price	0.80 €		

	Max scrap price	1.12 €		
ANALYSIS	Min discarded material [kg/month]	1,600.00	Min revenue	1,280,00 €
			Max revenue	1,792.00 €
	Max discarded material [kg/month]	3,000.00	Min revenue	2,400.00 €
			Max revenue	3,360.00 €

From this analysis it is not yet possible to evaluate the best solution for the company as it is necessary to compare it to the actual cost of the waste calculated as follows:

$$effective\ scrap\ cost = scrap\ cost - revenues\ by\ discarded\ material$$

Below the calculations performed to get the true monthly cost borne by the company, at best and at worst:

Tabella 7.3 - Best Scenario and Worst Scenario Cost

		Actual Cost Scenario 1		Actual Cost Scenario 2	
Min discarded material [kg/month]	1,600.00	Min cost - min revenue	2,160.00 €/month	Min cost - max revenue	**1,648.00 €/month BEST SCENARIO**
		Max cost - max r revenue	7,728.00 €/month	Max cost - min revenue	8,240.00 €/month
Max discarded material [kg/month]	3,000.00	Min cost - min revenue	4,050.00 €/month	Min cost - max revenue	3,090.00 €/month
		Max cost - max revenue	14,490.00 €/month	Max revenues - min cost	**15,450.00 €/month WORST SCENARIO**

$$Best\ scenario: 3{,}440\frac{€}{month} - 2{,}160\frac{€}{month} = 1{,}648\ €/month$$
$$Worst\ scenario: 17{,}850\frac{€}{month} - 2{,}400\frac{€}{month} = 15{,}450\ €/month$$

Scenario 1 subtracts to the lower cost the minor revenues and to the greater cost the greater revenues. Scenario 2 subtracts to the lower cost the maximum revenues and to the maximum cost the minor revenues. This analysis creates a range of possible cost values in which the company could present itself to support based on the amount of the cost and the selling price: the lower cost incurred is obtained in scenario 2, paying less raw material and reselling waste at the highest possible selling price, claiming € 1,648.00 per month (average). The greatest cost that the company claims is obtained when it buys the raw material at the highest possible price, but resells it at a very low price, claiming a cost of 15,450.00 € per month (average).

The following table shows the percentage of cost incurred after subtracting the share of revenues and how much percentage of material cost is transformed into revenues:

$$\%\ effective\ cost\ on\ initial\ cost = \frac{effective\ cost}{initial\ cost}$$

$$\%\ cost\ transformed\ in\ revenue = 1 - \%effective\ cost\ on\ initial\ cost$$

Tabella 8.3 - Waste cost percentages on initial cost

	Effective cost	% effective cost respect to initial cost	% cost transformed in revenue
Scenario 1	Min cost - min revenues	63%	37%
	Max cost - max revenues	81%	19%

	Min cost - min revenues	63%	37%
	Max cost - max revenues	18%	19%
Scenario 2	Min cost - max revenues	47,91%	52.09%
	Max cost - min revenues	86.55%	13.45%
	Min cost - max revenues	47.91%	52.09%
	Max revenues - min cost	86.55%	13.45%

The best case shows a % of cost transformed in revenues very high, that is 52.09%: this is a good result as little more than half of the cost of the discards is recovered through the resale. There will never be a 100% recovery because the frames and the spaces between the details of the sheet are necessary for the correct operation of the laser machinery and for the realization of quality details. The worst case, however, shows a decrease in cost after resale very low and therefore a recovery of only 13.45%. In this case, the operator discards useful material for production.

Following the previous analysis, the thesis proposes some solutions that could optimize the waste described:

1. To intensify the research and the acquisition of new customers who need stainless steel products (material mainly processed by the company under analysis). This solution would easily fill the gaps that are generally very small and would create a new family of products within the company organization. Some interesting markets could be tags, prizes, pendants, and other small items of this kind.
2. Use an e-commerce site for scraps. If the piece had a well-defined and standard shape, the company could make use of a platform in which to sell the item, entering its characteristics (type, dimensions, finish, quantity) and deciding the selling price based on how much you want to make from that item. Thanks to this secondary market, the company can sell waste that for another company are good material and maybe with less processing required than a standard sheet. This solution is also environmentally sustainable as it recycles the material and prevents it from being transported and processed in the foundry.

3. Putting waste back into the production chain by creating internal company commissions to obtain useful tools or accessories for the office or workshop, such as tags, signals, warnings, supports, etc.
4. Search for an alternative scrap or consider the alternative of transporting the scrap directly to the foundry, at the expense of the company. In fact, the scrapper in contact with the company offers a good contract as the supplier takes directly in the company in analysis of the dump load of waste, using your own mechanical arm and your own truck and pay on the spot when collecting the material. This is very convenient for the company as it receives liquidity in no time and has no additional costs; the only duty of the company is to directly separate the types of material from the caisson, such as iron from steel. For this reason, the last solution proposed does not suit the company in analysis, but is exposed to analyze the options available at 360 º. Just as it is not convenient to transport the waste directly from the company to the foundry, located very far from the company headquarters, resulting in a too high cost and losing the facilities described above.

3.1.3 Waste G analysis – Non-conformity

The previous chapter defines the term "non-conformity" and its causes; the following analysis derives a total annual cost, using as reference period 5 years (from January 2018 to June 2023). From the management software it is possible to derive the data relating to non-conformities; the thesis analyzes the non-conformities only and exclusively of the product *Industrial Elevator* as it is possible to carry out a product-by-product analysis. The cost of waste is expected to be lower than that of the other cases analyzed (which consider all production). The year refers to the fiscal year (June to July of the following year). The treatment will shorten the word non- conformity in *n.c.*.

The following table shows, in the columns, the reference year, the reported non-conformity hours, the average hourly cost per department [€/h] over the 5 years and the associated total annual cost:

Tabella 9.3 - Cost department for non-conformity management

Year	Annual hours	Average hourly cost department [€/h]	Annual total cost
2018	33.1	32,14	1,063.80 €
2019	23	32,14	739.19 €
2020	16.25	32,14	522.26 €
2021	61.5	32,14	1,976.54 €
2022	4.6	32,14	147.84 €
2023	103.9	32,14	3,338.69 €
TOTAL			**7,788.32 €**

The average hourly cost of the department is calculated as the average of the hourly costs of each department excluding the maximum value associated with the laser department; the value is much higher than the others and would affect the analysis, for this reason it is not considered.

$$Annual\ total\ cost\ \left[\frac{€}{year}\right] = Annual\ hours\ \left[\frac{h}{year}\right] * Average\ hourly\ cost\ department\ \left[\frac{€}{h}\right]$$

$$Total\ cost\ 5\ years = \sum Annual\ costs$$

The total cost of non-conformities uploaded to the system (January 2018 to June 2023) is €7,788.32.

As mentioned in the previous chapter, the year 2023 presents an increase in the number of reports entered on the system and is the case with the highest annual total cost. This does not mean that previous years have presented fewer cases of non- conformity. For this reason, the current analysis is weaker, compared to other analyses of waste, due to lack of data entry. The thesis proceeds with the treatment to emphasize the importance and the potential drastic increase in the presence of non-conformities.

The following graph shows the trend of the hours of non-conformity of industrial elevators:

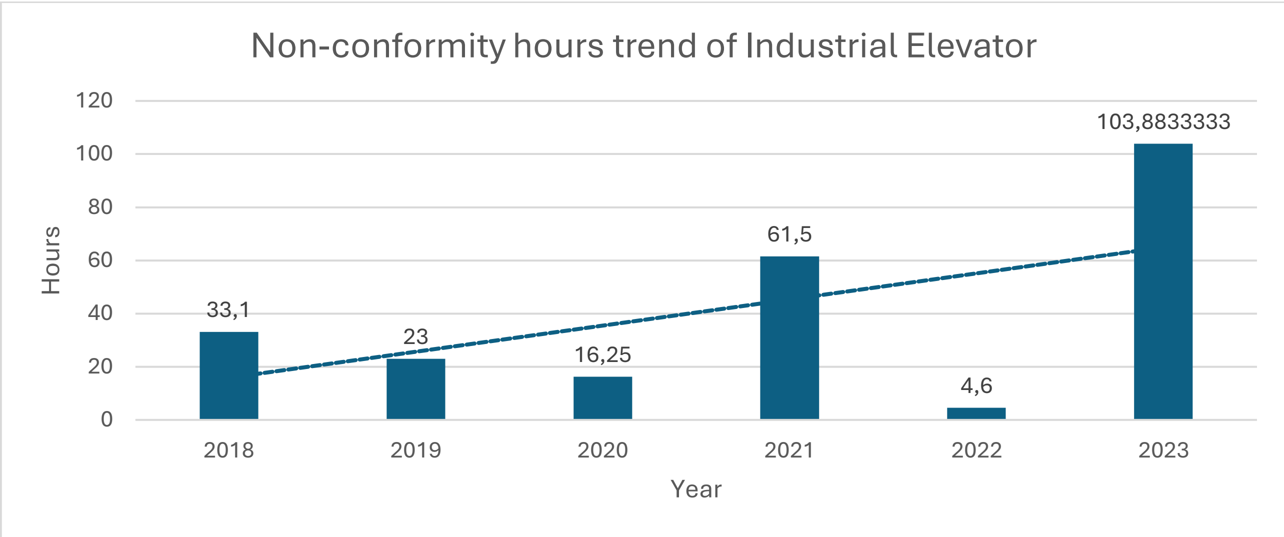


Figure 32.3 - Trend hours of non-conformities of elevators

The growing trend shows a greater awareness of the importance of reporting non-conformities to the system, to improve and grow as a company; the year 2022 has the lowest number of system reports, while 2023 has the highest number. This year the company structure assigns the task of the loading to system to a specific person and this, in fact, increases the number of reports; in previous years, no person had this task.

After defining the annual hours and costs and the reporting period, the thesis analyses the departments that manage the non- conformity and are therefore responsible for an additional cost. The following table shows the company cost centers:

Tabella 10. 3 - Cost centre

COST CENTRE	HOURLY COST [€/h]
Laser	125,40
Thread	43,26
Bending	46,38

Welding	39,75
Assembly	33,86
Production office	40,00
Sales office	40,00
Technical office	40,00
Shipping warehouse	40,00
Purchasing office	40,00

Laser is the department with the highest cost because of the cost of energy, depreciation and equipment. The cost is not fixed and varies monthly; also, the fluctuation of cost of the raw material affects and affects a lot the necessity of current purchases of the department (inserted in the item *Various*). From the management software it is possible to derive the hours and the number of the non-conformities; the process is not immediate as there is no extractable field dedicated to the reporting of the time, but the operator must open every single non-conformity document and extract the time manually and sum all times. For this reason, the analysis is particularly expensive; the company should implement a simpler and easier non-conformity data extraction system to adequately carry out the due considerations a posteriori. The following table shows the hours and the number of non-conformities per department in the five-year reference period:

Tabella 11.3 - Non compliance cost for department

ANALYSIS BY DEPARTMENT				
Cost Centre	Hourly Cost [€/h]	Hour Of Non-Conformity	Number Of Non Conformity	Total Cost By Department [€]
Laser	125.40	2.50	4	313.50
Thread	43.26	0.00	0	-
Bending	46.38	5.50	4	255.09
Welding	39.75	13.50	12	536.63
Assembly	33.86	35.10	42	1,188.49

Production office	32.00	41.40	18	1,324.80
Sales office	28.00	2.00	4	56.00
Technical office	18.00	102.20	21	1,839.60
Shipping warehouse	30.00	25.5	6	765.00
Purchasing office	18.00	14.5	6	261.00
TOTAL			**117**	**6,540.10**

The total cost of non-conformities in the reporting period is € 6,540.10; the value is slightly lower than the one previously obtained because on the latter the thesis performs an analysis using an average cost of department, while in this case the costs are the real ones associated with each machining center. The average annual value of waste is:

$$\frac{6{,}540.10\ €}{5\ years} = 1308{,}02\,\frac{€}{year}$$

The average monthly value is:

$$\boxed{\frac{1308.02}{12} = 109\,\frac{€}{month}}$$

The value is also spread over the years that have recorded few n.c.; the value is expected to increase significantly in 2024. In July, August, and September 2023 (fiscal year 2024) the production office recorded 17 non-conformity for the *Elevator* product, more than were recorded in the years prior to 2023. and, in total, 114 non-conformities (relating to all production). The year 2024 will lead to more reporting and greater awareness of the importance of pursuing solutions.

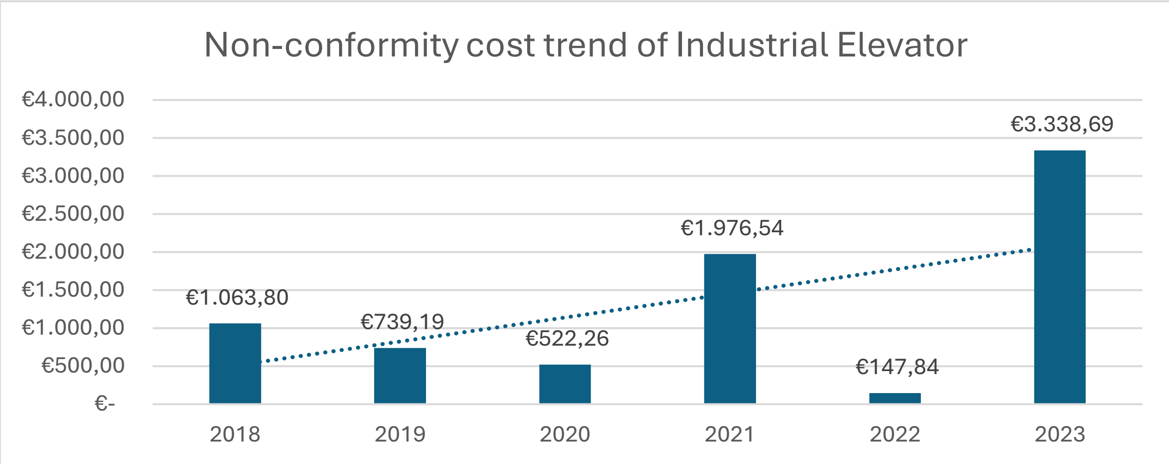


Figure 33.3 - Non conformity cost performance from 2018 to 2023

The technical office faces most of the non-compliance. Sometimes it is the cause, sometimes it has to resolve the situation. Incorrect odds, wrong drawings, failure to publish the drawing: these are examples of problems that lead to system reporting. The error can be born from part of the customer, but the technical office company is charged to resolve the situation and the cost that the company supports derives from that department. The errors caused by the technical design are easily measurable, compared to other departments, in terms of time and cost probably, for this reason the company loads more this type of errors rather than others more difficult to quantify and costify. The assembly department reports the n.c. on a dedicated sheet and delivers it to the production office; this process facilitates the control and loading of n.c. The reports concern work to be carried out not previously carried out, changes to parts, testing problems, holes to be drilled, etc. which involve a time, and therefore a cost, greater than that estimated. The task of the production office, the controlling body of all departments, is to ensure that the process flow flows smoothly and, when it occurs, must solve the situation; For this reason, the production office affects the cost of managing non-conformities and wastes time that could be invested in another. The n.c. are part of the process, but the company must reduce them as much as possible and above all ensure that the same error is not repeated. Below, in descending order of cost, the departments associated with the n.c.: warehouse shipments (non-delivery of details or shipping error), office purchases, welding, bending, laser cutting, commercial office. The following pie chart shows, in a more intuitive and direct way, the cost source associated with non-conformity management:

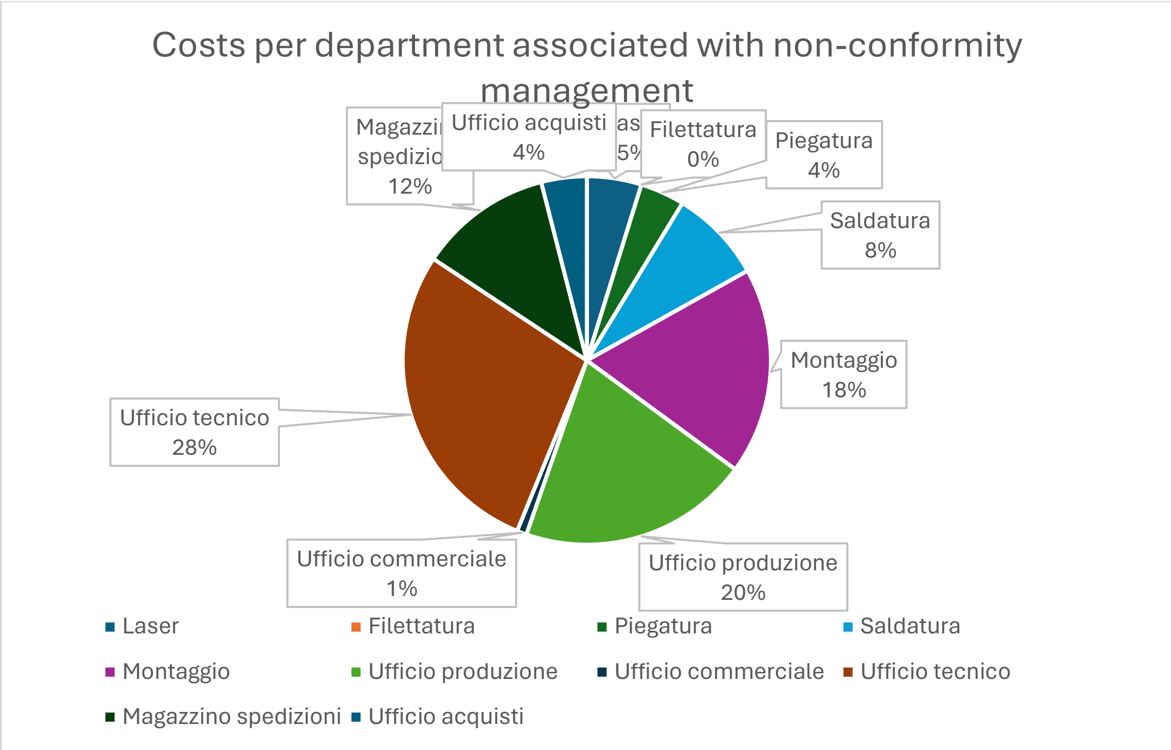


Figure 34.3 – Costs per department

The non-conformities involve every business department, and the proposed solutions are common to the analyses carried out previously. Here are some proposals to reduce the presence of non-conformities:

1. Implementation of a product design control method: this includes guidance on technical drawings, correct bill of materials, correct dimensions, etc. The solution is also proposed in the analysis E on the waste of time of requests for project indications. A clear and complete knowledge of the product to be processed leads to minimizing mistakes and errors on it. This implies a clear commercial communication and a definition of the details of the project.

2. Implementation of the order. Research the way things are placed in order to meet safety, quality and efficiency and avoid loss and loss of material deliveries. Implementation of a system of automatic reordering of the stock of raw materials to meet urgent requests. Currently, the cutting operator orders the steel sheets for the following week and may not be able to meet the urgencies due to lack of material. Create a weekly report check routine that allows analysis and troubleshooting.
3. Creation of a Quality Control Office to ensure the proper execution of the work carried out and that the departments have all the necessary resources to carry it out (incoming and outgoing quality). At present, the company does not have a quality department to reduce non-conformities; the work is divided with those responsible for their department.

3.2 Analysis of "to control" economic impact waste (E, F)

3.2.1 Waste E analysis – Requests for technical drawings

Sometimes, the designers of the company's technical department or the client (depending on who drew the project) do not adequately insert the processing instructions on the 2D file necessary for the production department and this involves a waste of time by the operator to understand how they must work. There are two actions: stop processing and ask the technical office or the customer (through the sales office) or decide to continue the work based on the memory of similar details already worked and experience. In the first case, the operator wastes time to request information and must wait for the answer (while working another detail but will then have to reset the machine for that piece), in the second case it is possible that the work carried out is wrong and creates the need to cut the piece, resulting in a waste of material and time. Even the designer loses time managing a process that he could have managed from the beginning with continuity; the waste is twofold.

Here are the causes of this waste:

CAUSES	Systemic	Drawings not published in management
		Mirrored files (t.laser)
	On 2D drawing (technical office, internal or customer error)	Missing or unclear quotas
		Type of welding not indicated
		No indication type of finish
		No indication of post-welding machining
		Unclear drawings

Reasons:

Why?
Incorrect communication with the customer
Incorrect internal communication
Lack of personnel highly specialized in mechanical processing
Lack of precision
Tight time in job design

Below the analysis to derive the cost of waste described:

DATA	Wasted time h/day	0.5
	Cost average hourly operating resource	40.00 €
	Daily cost	20 €
	Weekly cost	100.00 €
ANALISYS	Monthly cost	400.00 €

The thesis estimates 20 minutes per day (0.33 hours per day) of wasted time to request information on drawing indications. The daily cost is:

$$Wasted\ tme * hourly\ cost\ resource$$

$$0.5 \frac{h}{day} * 40 \frac{€}{h} = 20\ €/day$$

The weekly cost is:

$$20 \frac{€}{day} * 5 \frac{day}{week} = 100\ €/week$$

The monthly cost is:

$$100\ \frac{€}{week} * 4\ \frac{week}{month} = 400\ €/month$$

The data request always requires the relationship between two people; the operator wastes time to report to the colleague the lack of drawings, or writing a message or going, in person, to the office in question (perhaps it also waits for the publication of the drawing before beginning the working), and the operator to whom the problem is addressed, who wastes time to look for the drawing in question and publish it. For this reason, waste is twofold, and the average monthly cost of waste is:

$$\boxed{400 \frac{€}{month} * 2\ resources = 800\ €/month}$$

Following the previous analysis, the thesis proposes some solutions that could optimize the waste described:

- Creation of a document associated with the order in which the customer checks the type of processing, finishing and post processing necessary for his type of machine/article. Subsequently the document will be connected to the store clerk on the managerial one.
- Implementation of a pre-publication design check/check method. At present, the production office is creating a control board that designers must use before publishing a design on the company server, checking the entries to be inserted on the project in order not to forget some indication.

3.2.2 Waste F analysis – Errors due to internal transport

The previous chapter analyses in detail the causes upstream of the problems on internal transport. In this section, the thesis defines a cost to this problem and identifies possible solutions to reduce it.

The thesis deals with two main issues in this field:

- Material delivery error to department.
- Loss of items.

Analysis 1 - Material delivery error to the department

Below the data used:

DATA	Cost per hour resource	40 €
	Cost per hour two resources	80 €
	Lost time h/day	0.25

The experience of internship leads to estimate a time of 15 minutes per day of problems related to the transport of the details between the company departments; the calculation considers the hourly cost of two resources as the transport worker involves a second resource for solving the problem (usually a production office operator).

Daily cost:

$$Daily\ cost = hourly\ cost\ 2\ resources * wasted\ time$$

$$20\frac{€}{day} = 80\frac{€}{day} * 0.25\frac{h}{day}$$

Weekly cost:

$$100\frac{€}{week} = 20\frac{€}{day} * 5\frac{day}{week}$$

Monthly cost:

$$400\frac{€}{month} = 100\frac{€}{week} * 4\frac{week}{month}$$

The thesis estimates a monthly cost of 400 €, a "low" share to support an average annual turnover of about 9,800,000.00 € (0.004% of turnover), but it is also a high share to be reinvested to make improvements where necessary or to increase corporate welfare, buying the necessary tools or tools or organizing team building activities.

Analysis 2 - Loss of items

Below the data used:

DATA	Cost per hour resource	40.00 €
	Lost time h/week	1

Weekly cost:

$$Weekly\ cost = resource\ hourly\ cost\ * wasted\ time$$

$$40\frac{€}{week} = 40\frac{€}{h} * 1\frac{h}{week}$$

Monthly cost:

$$160\frac{€}{month} = 40\frac{€}{week} * 4\frac{week}{month}$$

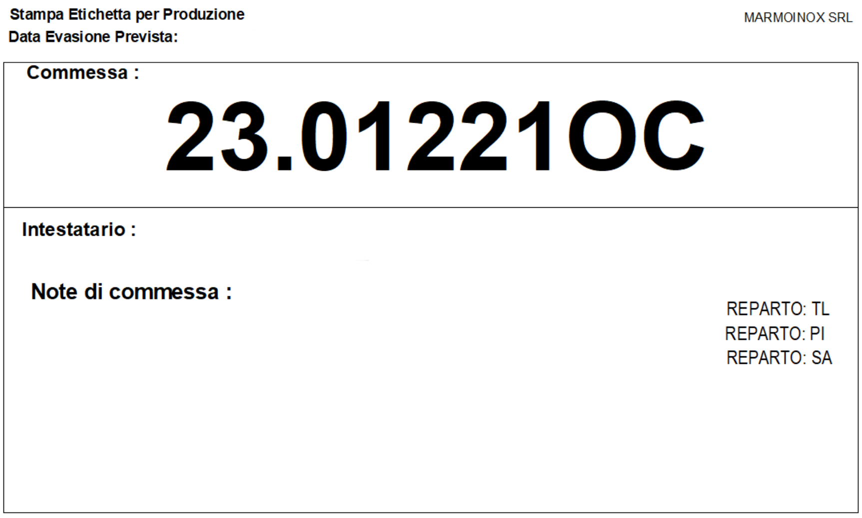
As in the previous case, the company is able to bear the cost of 160 € per month, but the cost is not justified because of a loss that occurs weekly.

Summing the cost deriving from the analysis 1 and from the analysis 2, the total cost salary due to the problem of the inner transport is:

$$400\frac{€}{month} + 160\frac{€}{month} = 560\frac{€}{month}$$

Following the previous analysis, the thesis proposes some solutions that could optimize the waste described:

1. Introduction of the indexes of the working cycles on the printed label of the order, which will follow the details during the production process, as in figure 35.3.
   The operator can visualize the process sequence and deliver to the department the parts to work, minimizing expectations, losses, and errors.


Stampa Etichetta per Produzione
Data Evasione Prevista:
MARMOINOX SRL

Commessa :
23.01221OC

Intestatario :

Note di commessa :

REPARTO: TL
REPARTO: PI
REPARTO: SA

Figure 35.3 - New label with applied solution

2. Use of Walkie-Talkies for communication between the operator of the production office and the operator of the internal transport. Communication is direct, simple, and efficient and does not require waste of movement by resources. The headset connected to the walkie-talkie is always on the ear of the operator, allows better audio and less movement to answer, while the communication by phone is not effective because the workshop is full of noise due to the work and never feels good.
3. Use of signs to be deposited on the pallets to identify the state of the machined parts, to avoid that the material is transferred to the next department in advance or stored.
4. Coloring the pallet or coloring the floor on which the material is placed to identify a specific stage of the process, such as acidification. Sometimes, the person responsible for the acidification operation is undecided whether or not to have to

work the workpiece; in this case, it requires a consultation from a manager, and this generates a waste of time.

5. Implementation of trolleys for internal transport. At present, the trolleys consist of 3 floors; the small details and the large details are arranged randomly on the shelves, and this causes, sometimes, a temporary loss of the same and makes difficult a quality control of all the necessary pieces. The implementation would ensure a space dedicated to smaller details, such as an inclined container on the shelves, and fixed positions or hooks for some standards, to simplify control and counting and avoid leakage.

3.3 Analysis of "negligible" economic impact waste (A, D)

As anticipated, the two types of waste have a low criticality potential and, compared to the other analyses, will not be defined costs, but only some solutions that could improve and facilitate the process.

Waste A (*Inefficient order generation sequence*) has no impact in terms of cost but stresses a process that is far from the principles of the Lean philosophy; the latter facilitates the delivery of a product or semi-finished product in the shortest possible time, so that the next step attendant can start managing it. As described in the previous chapter, the office operator manages, one at a time, all the similar processes of the orders to deliver the paper orders in a single moment. In doing so, the production office operator receives a large number of orders to manage at the same time, while he could have planned one order at a time calmly if delivered in this way.

Waste D (*Paper Labeling*) detects a waste of paper and a negative ecological impact on the environment; the company should invest in a more sustainable process using, for example, a laser marking machine to encode parts directly on the material, without using paper (see previous chapter for more details). With this tool, the operator can deliver the semi-finished products to the intermediate warehouse faster and save maintenance costs of the labelling machine.

Final considerations

The thesis, so far, analyzes individually the seven-waste detected; now, analyzes the impact of all waste together on business turnover.

The table below shows the cost of waste in descending order of cost, considering the two scenarios in the case of steel waste:

Best case scenario (sheet scrap cost = 1,648.00 €/month):

Tabella 12.3 - Best scenario cost

ID	Wastes	Monthly cost [€/month]
B	Laser disuse	21,461.82
C	Scrap metal	1,648
E	Request for technical drawings	800
F	Errors due to internal transport	560
A	Inefficient order generation sequence	-
D	Paper labeling	-

Worst case scenario (sheet scrap cost = 15,450.00 €/month):

Tabella 13.3 - Worst scenario cost

ID	Wastes	Monthly cost [€/month]
B	Laser disuse	21,461.82
C	Scrap metal	15,450
E	Request for technical drawings	800
F	Errors due to internal transport	560
A	Inefficient order generation sequence	-
D	Paper labeling	-

The best and worst case scenario show the range in which the company supports the cost of waste, but do not intervene on the ranking position. The disuse of the laser entails a high cost and the difference with the other wastes is high; the company should pursue actions in favor of the reduction of this waste and increase the exploitation of laser machinery, taking inspiration from the solutions proposed during the previous analysis. The cost of the demands for indications on the drawings is double regarding that supported from problematic tied to the inner transport. The comparison of waste does not include non-conformities as they refer only to the *Industrial Elevator* product and not to all production. In the reference period, the elevator is the product with the greatest non-conformities loaded in the system and emitted more by the assembly department (the thesis recalls that the elevator is the product most processed by the department); the operator writes the reports on a sheet that he delivers to the production office, which will then load to system. The other production departments do not mark the n.c. on a sheet and the office automatically loses the report. For this reason, the reports related to the elevator are the most reliable and the thesis analyzes this specific product. It is estimated that, by expanding the analysis to other company products, the cost of non-conformities could reach, if not exceed, the cost of wasting the uselessness of the laser. The solutions proposed for the n.c. of elevators are also applicable to the n.c .of other products.

Table number 14.3 shows the percentage of cost of waste on the average annual turnover (from 2019 to 2022):

$$Annual\ average\ turnover = average(f.2018 + f.2019 + f.2020 + f.2021 + f.2022)$$

$$9.671{,}335.20 \frac{€}{\text{year}} = 9{,}119{,}395 + 9{,}886{,}961 + 8{,}532{,}976 + 9{,}048{,}460 + 11{,}768{,}884$$

Best scenario (scrap sheet cost = 1.648 €/month):

Tabella 14.3 - % on sales Best scenario

ID	Wastes	Monthly cost [€/month]	Annual cost [€/year]	% cost on turnover
A	Inefficient order generation sequence	-	-	- %
B	Laser disuse	21,461.82	257,541.84	2.66%
C	Scrap metal	1,648	19,776	0.20%

D	Paper labeling	-	-	- %
E	Request for technical drawings	800	9,600	0.1%
F	Errors due to internal transport	560	6,720	0.1%
G	Non-conformity - Elevator Parts	-	1,308.02	0.01%
Total			**310,176.00 €**	**3.1%**

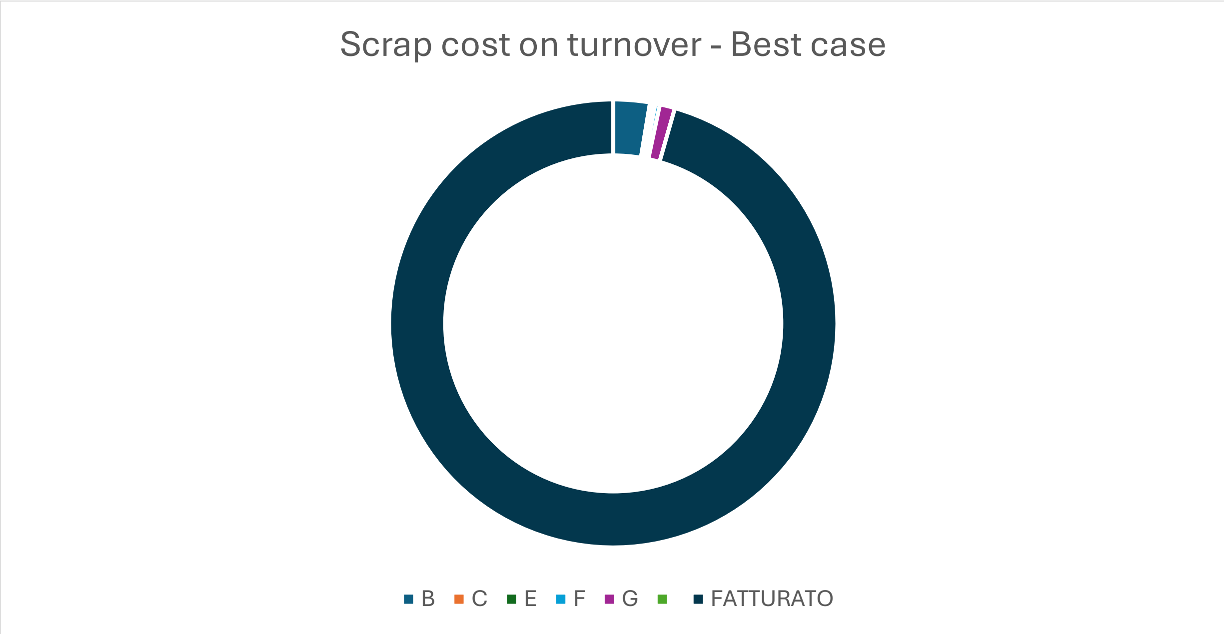


Figure 36.3 - Costs on sales Best scenario

Worst case scenario (scrap sheet cost = 15,450 €/month):

Tabella 15.3 - % on sales Worst scenario

ID	Wastes	Monthly cost [€/month]	Annual cost [€/year]	% cost on turnover
A	Inefficient order generation sequence	-	-	- %
B	Laser disuse	21,461.82	257,541.84	2.79%

C	Scrap metal	15,450	185,400	1.92%
D	Paper labeling	-	-	- %
E	Request for technical drawings	800	9,600	0.1%
F	Errors due to internal transport	560	6,720	0.07%
G	Non-conformity - Elevator Parts	-	1,308	0.01%
Total			**475,800**	**4,8%**

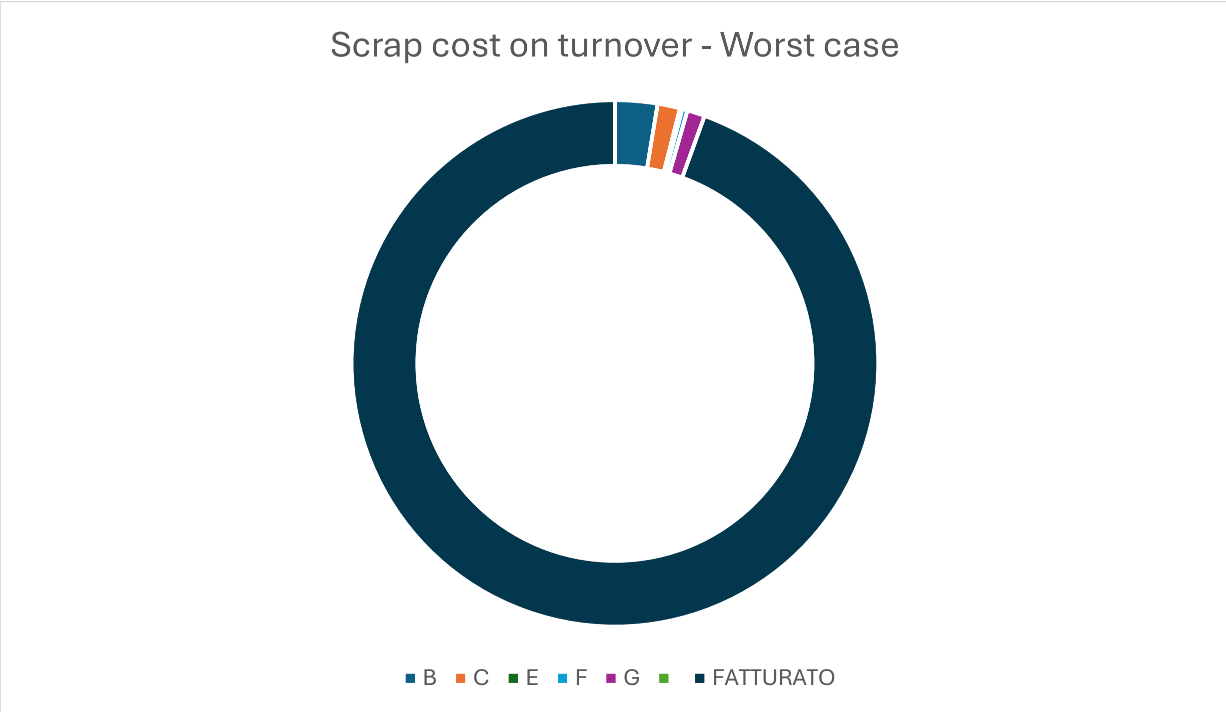


Figure 37.3 - Costs on sales Worst scenario

The above table and the ring chart show how the sum of the analyzed costs affects 3.1% (*best scenario*) and 4.8% (*worst scenario*) on the average annual turnover. The percentage is very high to be due to business waste and it is necessary to underline that the analysis on non-conformities is not complete (for lack of data entry). If the loading of the non-compliances to system had been executed before 2023, it is estimated that the total cost is at least 50% more than that calculated. Thus estimating, the percentage of non-conformities on turnover would be 0.1%, increased the total percentage to 3.3% in the *best scenario* and 6.0% in the *worst scenario*.

The thesis does not pursue the objective of totally eliminating waste, but at least reducing it: the company should set itself the goal of reaching a certain percentage of waste within a total of years, adopting, perhaps, one of the solutions proposed in the thesis. This achievement would decrease costs and increase profits, opening possibilities for possible investments.

A 50% decrease in the percentage of waste within four/five years would lead to the following benefits:

- Savings of 213,180 € per year in the *best scenario* and 278,292 € in the *worst scenario*.

- Improved mood and increased employee satisfaction in facilitating work in a clean and orderly environment

- Increased perceived value of product/service through increased focus on value-added activities.

- Increasing the capacity, empowerment and autonomy of individual resources and teams.

- Reduced working time and efficient work.

- Increased turnover in the acquisition of new customers requiring laser cutting.

- Creating a more sustainable company that increases the trust and interests of existing and new customers.

The path is not immediate because reducing waste requires time and specific resources, but it is important that the company sets goals and works to achieve them. Embracing the philosophy behind Lean Management also implies a profound change in the way we think and act at all levels of the company, from top management to operators.

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