ABSTRACT

DESIGN AND IMPLEMENTATION OF AN AUTOMATED OIL DISTRIBUTION SYSTEM FOR A HOMOGENIZER MACHINE IN GEA MECHANICAL EQUIPMENT – NIRO SOAVI

by
Luca Gandolfi

This thesis shows the steps that have been followed and done in order to improve a critical operation of a technological process of the GEA Mechanical Equipment. The critical operation was the filling with different types of oils the homogenizing machine because it was characterized by a lot of inefficiencies and, in particular, by huge risks for job security. These critical issues gave the opportunity and the chance to realize a project in order to give a process optimization and security improvement.

After having faced all the aspects and steps needed for this project, it has been realized a system of automated oil distribution, but in order to realize this implant have been needed € 35,000. The investment was been anyway approved thanks to the impact that this implant would have given to the company, in fact, the analysis done have been confirmed once the implant was implemented. This system determines:

- Annual saving of € 9,500;
- Payback Period of 4.1 years;
- Internal Rate Return of 11.4%.

Apart from the quantitative aspects, there are a lot of qualitative aspects that have been improved. In fact, it has been made more secure the workplace, there is a new filling technology, that has substituted the old and dirty technology, and it helps to have a more cleaned and organized workplace.

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by
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To my family

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CHAPTER 1

GEA – NIRO SOAVI

1.1 Company History

Figure 1.1 Factory Gea Niro Soavi.

GEA Niro Soavi is today the technological and market leader for high-pressure homogenizers and piston pumps, with over 600 machines produced every year and with an international sales network that allows it to be always close to its customers, everywhere in the world.

The company was founded as “Soavi Bruno & Figli" by Bruno Soavi in 1947, in Parma, as a company specializing in the production of butter machines; a few years later, the company started producing high-pressure homogenizers for the dairy industry. The activity and skills have continued to grow over the decades, exploring new technical opportunities and addressing not only the national market but also the European one, presenting itself as one of the most successful companies in the field of high-pressure technology.

Keeping its strategic interest for high-pressure homogenization unchanged, Soavi has built up over the years a notable reputation for its reliability, with a full range of machines able to face increasing pressure levels for new and increasingly complex applications. In 1990, the company was sold by the family to the Danish group Niro Atomizer, thus changing its corporate name to Niro Soavi SpA. and starting to consolidate its presence on the world market with high-pressure homogenizers and piston pumps installed on Niro's sprayer systems (spray dryer).

In 1993 the Niro Group became part of the GEA AG group (acronym of Global Engineering Alliance), one of the most important international design and production groups of technologically advanced solutions; since 2010, GEA Niro Soavi is present on the market as part of the "GEA Mechanical Equipment" segment, which today represents one of the most important international design and production groups for technologically advanced solutions; quoted on the German stock market MDAX, the GEA group specializes in mechanical engineering, in particular in the engineering of processes and related equipment and in the design of plants, and is one of the technological and market leaders in 90% of its branches of specialization.

The strategic factor most representative of the company's growth over the years is that of continuous innovation, active in the search for new solutions for potential applications able to decline the high-pressure dynamic homogenization technology according to customer expectations, anticipating their needs. Tireless attention to excellence, in terms of quality of production processes and reliability of components, and the presence of an international structure close to customers, with a team of competent people responsible for assistance, sales with presence at the level local, advice on possible applications and development of customized solutions, to solve problems, represent two other important aspects of the mission of GEA Niro Soavi. In fact, it operates in accordance with the procedures and g\uidelines of the ISO 9001: 2008 Quality System, meets all international standards for hygienic design in the food and dairy sectors (3-A), for biotechnological and pharmaceutical compliance (cGMP, FDA) and is an active partner in the development of the EHEDG guidelines for hygienic and safe food processing plants.

GEA Niro Soavi is, moreover, the only manufacturer of homogenizers in the world able to supply ATEX compliant machines for hazardous areas, ie in an explosion-proof version not only in electrical parts, but also for the whole machine configuration, suitable for areas of classified installation and special applications, as specified by the European ATEX directive.

The success of GEA Niro Soavi, therefore, depends on understanding and adapting to present and future needs and expectations of current and potential customers.

Figure 1.2 Corporate mission.

1.2 The Factory

The GEA Niro Soavi plant is located in the Municipality of Parma and covers an area of over 20,000 square meters.

Figure 1.3 View from the top of the factory.

Inside there is an operative area comprising the department of mechanical machining, assembling, testing and finishing, a structure used for the storage of materials, divided into three different areas depending on whether they are housed raw materials, semi-finished products, and pieces finished, finished machines (Kopron), a supermarket, an area dedicated to ITC (Innovation Technology Center), a laboratory, in addition to the various offices: Administration, Costs and Personal Data, Commercial, Marketing, Production, Quality, Planning, Strategic Purchasing, Technical and After Sales.

Figure 1.4 Mechanical machining.

Figure 1.5 Assembling.

Figure 1.6 Testing.

Figure 1.7 Finishing.

The company also has several Sales Offices located in various strategic areas of the continent:

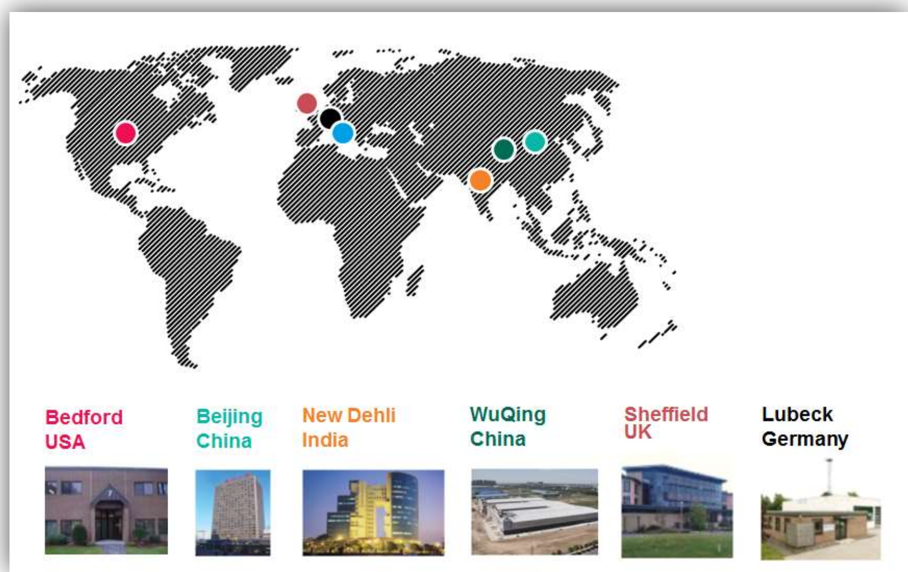


Figure 1.8 GEA Niro Soavi in the world.

1.3 The Sector

In different industries the homogenizer is nowadays an essential process component for the optimal preparation of different products, also thanks to the need to find solutions to the requests coming from the markets richest in extended shelf-life and product quality; so that the specific design and manufacturing features of the Niro Soavi homogenizers have been progressively improved and customized to meet the requirements of hygiene, aseptic process, and integration in automated process plants. The homogenizers sector is a niche market, where companies that deal exclusively with the production of homogenizing machines are few in the world. The fact that the company Niro Soavi was one of the first pioneers of this market and its strategic position at the center of the Italian Food Valley, has allowed it to become known all over the world and to maintain its status thanks to continuous innovation and improvement, ensuring a high quality and efficiency that the customer recognizes; such as to become the world technology leader in the supply of homogenizers.

1.4 The Homogenization

The homogenizer is a machine consisting of a volumetric piston pump and a specific adjustable valve, specially designed to generate the pressure used to divide the particles or globules present in the fluids to reduce them to the smallest possible size (micrometers nanometers), creating thus a stable dispersion, which can also be used as a starting point for successive phases of the production process. It can apply high dynamic pressure under continuous flow conditions and is able to process liquid products such as emulsions and dispersions with a wide variety of applications, viscosities, and physical properties. The homogenizer is mainly composed of a pump and a homogenizing valve. The pump has the purpose to force the fluid towards the valve where homogenization takes place. In this valve, the fluid is pushed under pressure through a narrow orifice which is created between the valve and its seat (to adjust the pressure it is sufficient to vary the distance between these two elements).

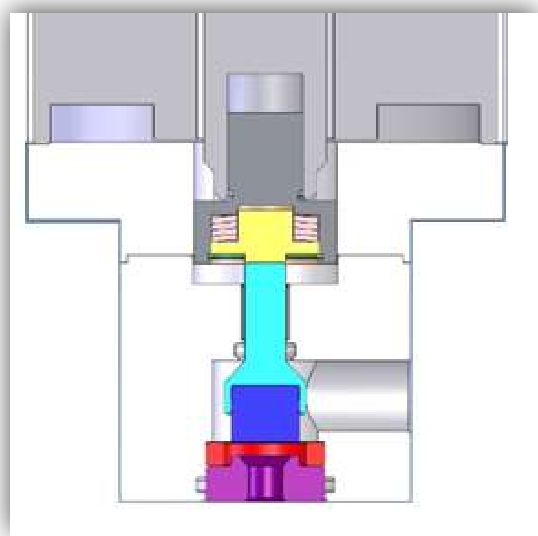


Figure 1.9 Homogenizing valve section.

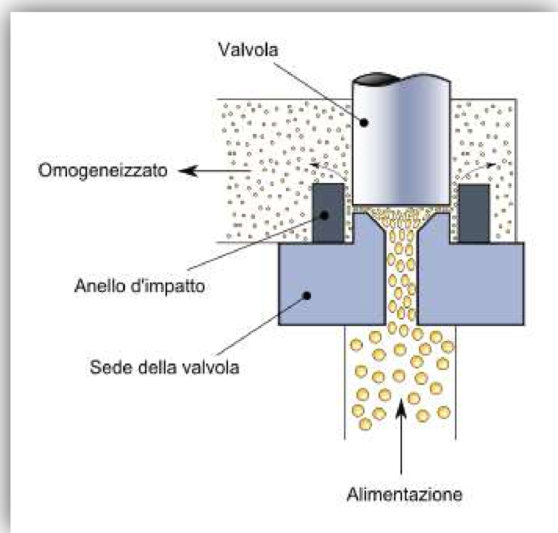


Figure 1.10 Homogenizing valve operation.

In the passage it is subjected to numerous forces that cause the micronization of the particles: a violent acceleration with immediate deceleration generate cavitation with explosion of the cells, intense turbulence, combined with high-frequency vibrations, impact forces derived from the laminar passage between the surfaces of the homogenization valve and consequent impact with the impact ring.

This application allows to obtain a series of effects on the treated product, which vary according to the considered matrix, but which can be summarized in:

- Inactivation of microorganisms, as this technology induces changes at the morphological, membrane and wall level in the microorganisms present;
- Structural and conformational changes at the level of macromolecules characterizing the system (proteins-lipids-polysaccharides);
- Modification of the activity of enzymes present in the treated substrate, through activation or change of the structure of the enzymatic substrate 27 or of the active site of the enzyme, also operating at temperatures of 40-50 ° C;
- Increased stability over time of the homogenized product;
- Viscosity variation, related to an increased instability;
- Exaltation of the organoleptic characteristics of the treated product, following a greater micronization of the particles.

1.5 Functional Groups

The main functional groups constituting the Gea Niro Soavi machines are shown below.

1.5.1 Compression Head

The compression head is the part of the homogenizer in which the product is pumped under high pressure.

It is designed according to the different pressure levels using 3D CAD modeling systems and is characterized by an extremely clean configuration (with 3-A approval) suitable for food and non-food applications.

Depending on the application, the structure of the head can be:

- **Monoblock**, the result of design optimization aimed at simplicity, reliability, hygiene requirements and ease of cleaning. Accumulated in 60 years of experience, the company has specific know-how in the selection of materials, in production technology and in the fluid-dynamic and structural analysis;
- **Multi-block VHP**, fully developed with the aid of advanced FEM structural analysis tools, presents a specific configuration for machines operating at very high pressures. It is based on the construction of separate blocks, produced and controlled individually, which minimize the stress and stress of the material caused by the pulsating pressure peaks;
- **NiSoCLEAN**, tested with a design expressly designed for products of the food industry, especially for probiotic foods containing fibers and solid parts, baby food, viscous condiments and foods rich in protein. The technological evolution based on the OpenXFLO header has optimized some technical details in order to make NiSoCLEAN perfectly hygienic and cleanable: reducing dead spaces, removing springs and spacers and using gaskets that directly interface the product. The innovative mechanics of the NiSoCLEAN head, designed following the EHEDG guidelines, allows the product to flow continuously, reducing shear stress passages and facilitating the entry of the fluid into the valve with consequent optimization of the entire homogenization process. Finally, the special configuration of this head allows a substantial saving of water and energy during the process activity.

The materials of which it is composed are duplex stainless steels (SAF 2205 or SAF 2507) so as to have a higher fatigue strength than stainless steel AISI 316.

This group is in turn composed of 3 functional groups:

- Suction manifold;
- Piston group;
- Pump valves group.

The product enters the compression chamber through the opening of the suction valves and then the pressure generated by the action of the piston pushes the product: the suction valves close again and the delivery valves open, in order to let the product flow towards the homogenizing group.

The suction and delivery valves, which are usually automatic spring valves, are in most cases constituted by a shutter, a valve cover, a spring, and a seat.

The intake manifold is the first functional group that the product to be homogenized meets. In fact, thanks to the inlet flange, the product is conveyed into the duct which has the function of sorting it in the different intake valves. The manifold, made of steel to be suitable for food contact, can have different sizes and shapes depending on the various types of attachments requested by the customer.

In the machines belonging to the One series, unlike all the other models, the manifold is obtained inside the block of the head.

Figure 1.11 Compression head.

1.5.2 Homogenizing Group

The Homogenizing Groups have the function of homogenizing the product, ie reducing and standardizing the particle size, through the high pressure applied by a special valve, which can be divided into the following types:

- **NanoVALVE**, a high-efficiency valve conceived using fluid dynamic analysis and CFD modeling, which allows, with the same operating conditions, to obtain a better homogenization of the particles, compared to the standard design valves. The high-efficiency valve, now also available in the high-pressure NanoVALVEHP version, uses the energy of high dynamic pressure better to achieve excellent product stabilization and better use of additives. The NANO VALVE is suitable for various applications (not only for food and dairy products but also for beverages and chemical emulsions) and is made with special internal parts that ensure durability even with abrasive products;

- **Re + VALVE**, developed in collaboration with the University of Parma, it inaugurates a new era for high-pressure valves: reversible, reliable, resistant, it is a unique valve for every pressure. It lasts 6 times longer than traditional valves, easily adapts to each machine, allows to adjust the homogenizing effect to the required performances, resists corrosion, has a symmetrical profile that allows it to be used on both sides and, thanks to its special design, it is very easy to clean. For this Re + VALVE allows better performance (about 20% less homogenizing pressure compared to traditional valves with the same results, in laboratory tests) and is ideal for biotechnological, cosmetic and chemical applications, in nanoparticle processes, nanodispersions, nanoemulsions, and cellular rupture.

The homogenizing valve is the fulcrum of the process. Through this adjustable valve, able to create a very high pressure, the product is treated following the combination of different fluid dynamic effects with high energy density:

- Turbulence;
- Cavitation;
- Shear effects;
- High-speed impacts.

By means of the fluid-dynamic effects generated by the high pressure applied to the fluid, it is possible to obtain a more "homogeneous" distribution of micronized particles.

1.5.3 Transmission System

This functional group includes all the components necessary for moving the pistons.

The transmission system is mainly composed of:

- Electric motor;

- Transmission body;
- Speed reducer;
- Belt transmission system.

The electric motors installed are of the three-phase type, ventilated or not, with four, six or eight poles (generally four). The motion is transmitted to the crankshaft through a system of toothed belts and pulleys.

The pistons are available in different materials, which GEA Niro Soavi suggests based on their experience according to the type of application and product.

The available materials are:

- Stainless steel with chrome coating;
- Stainless steel with tungsten carbide (detonation);
- Integral ceramics.

Figure 1.12 Transmission body.

1.5.4 Casing

The machine is equipped with an outer casing in satin stainless-steel sheet that allows:

- Protection of the internal components of the machine from dirt, water or dirt from the product;
- External cleaning;
- Protection of operators from moving parts, under voltage or at high temperatures, which may pose risks to personal safety in compliance with the EC and Safety Regulations in force in the country of installation.

1.5.5 Overpressure Valve

The pressure relief valve has been designed and built by GEA Niro Soavi for the protection of the machine from possible overpressures that can be created inside the compression head following the pumping action of the machine itself.

The valve consists of a ball held in position within its seat by the load of a spring which allows it to be opened when the calibration value set during the test is exceeded.

If the calibration value is reached, the valve opens automatically, unloading product from the outlet pipe; it closes when the pressure falls below the opening value.

Figure 1.13 Overpressure valve.

1.6 The Machines

Gea Niro Soavi designs and manufactures different types of homogenizers: some for the food industry sector, others for the pharmaceutical sector and, finally, for laboratory research. The machine can treat liquids with low or high viscosity, with pieces or less, with abrasive particles and in aseptic and sanitary conditions. The volumetric flow rate and the operating pressure represent the starting point from which the designer configures the machine.

Figure 1.14 Machines range.

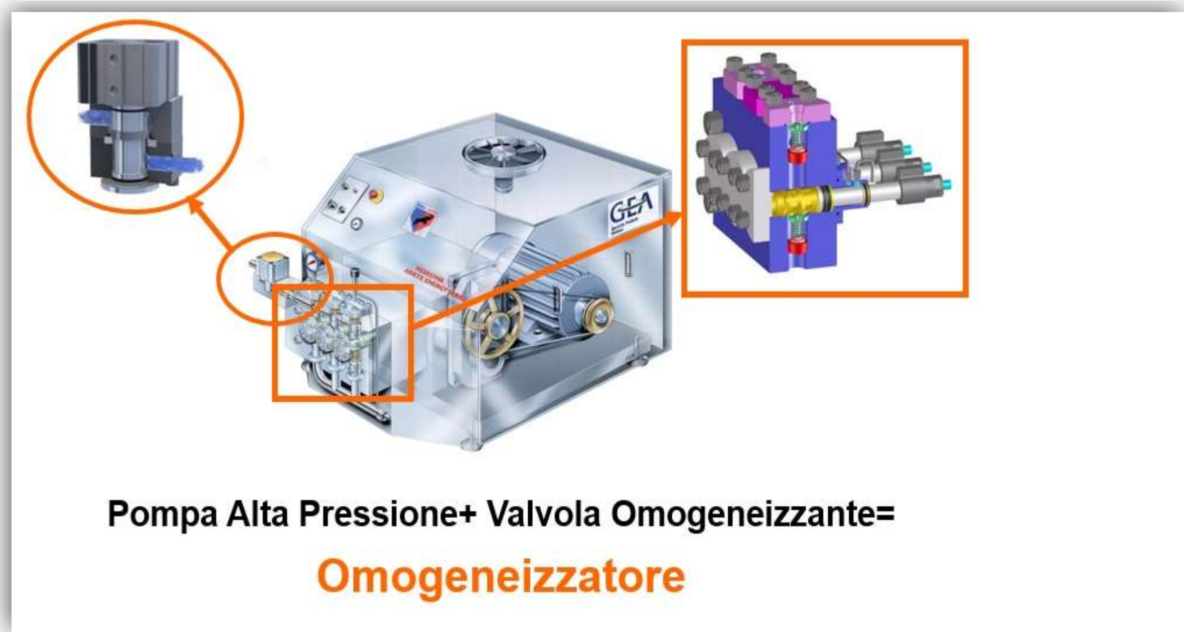


Figure 1.15 Homogenizer.

The classic machine configuration consists of two main elements: the high-pressure piston pump assembly and the homogenizing valve assembly. The piston pump unit will be composed of a number of variable pistons driven by a crank-crank system with the crankshaft. The customer, according to his needs, can request the configuration with only a piston pump. However, it will be very specific cases where generally high pressures (above 50 bar) are required.

Gea Niro Soavi supplies all its machines with the CE certification. GEA Niro Soavi operates in compliance with the ISO 9001: 2008 certified Quality System. For optimal quality control, the basic process and mechanical components are built into the company. Special materials and components produced on request are supplied by a network of subcontractors of proven experience under careful control, in accordance with the procedures and guidelines of ISO 9001: 2008, and directly involved in the design process.

GEA Niro Soavi meets all international standards for hygienic design:

- European conformity marking;
- (3-A): Standards for the dairy industry for the American market;
- (cGMP): For biotechnological and pharmaceutical compliance;
- (FDA): Food and Drugs Administration;
- (USDA): United States Department of Agriculture;
- (ATEX): GEA Niro Soavi is the only manufacturer of homogenizers in the world able to supply ATEX compliant machines for hazardous areas.

GEA Niro Soavi is an active partner in the development of the EHEDG guidelines (for hygienic and safe food processing plants). The European Hygienic Engineering & Design Group (EHEDG) is a consortium of equipment manufacturers (plant, machinery, and equipment), food companies, research institutes, as well as public health authorities, founded in 1989, whose purpose is to promote hygiene during processing and packaging of food products.

The workhorse of GEA Niro Soavi is definitely the Ariete machine available in different flow and pressure configurations. The pressure range can vary from a minimum of 100 bar up to a maximum of 1500 bar. The flow rate can vary between 50 dm3 / h and 60000 dm3 / h. For laboratory applications, the customer can opt for the machines of the Panda family able to reach very high pressures (up to 2000 bar) with limited volume flow rates (max 9 dm3 / h). Panther and Pony machines are machines designed for laboratory research and development for the pharmaceutical and food industries. The ONE family of machines is relatively young: it was created to offer machinery on the market at a competitive price compared to competitors but with limited customization, in line with customer requirements. The following are the machines that GEA Niro Soavi produces correlates from the main information on the construction and operating conditions.

Table 1.1 Gea Machine Models

Series	Model	Pressure Range (bar)	Flow Range (dm^3/h)	Number of Pistons	Max Power (kW)
Ariete	NS2006	100 ÷ 1500	650 ÷ 35	2	5,5
Ariete	NS3006	150 ÷ 1500	1000 ÷ 50	3	5,5
Ariete	NS3011	100 ÷ 600	3000 ÷ 550	3	11
Ariete	NS3015	100 ÷ 1500	4500 ÷ 250	3	15

Ariete	NS3030	100 ÷ 1500	7500 ÷ 330	3	30
Ariete	NS3037	100 ÷ 1500	12000 ÷ 800	3	37
Ariete	NS3045	100 ÷ 400	12000 ÷ 3600	3	45
Ariete	NS3055	100 ÷ 600	14000 ÷ 2800	3	55
Ariete	NS3075	100 ÷ 1500	14000 ÷ 1000	3	75
Ariete	NS3090	100 ÷ 600	17500 ÷ 4900	3	90
Ariete	NS3110	100 ÷ 1500	22000 ÷ 1800	3	110
Ariete	NS5132	100 ÷ 600	28000 ÷ 7000	5	132
Ariete	NS5180	100 ÷ 1500	37000 ÷ 3000	5	180
Ariete	NS5250	150 ÷ 600	45000 ÷ 11000	5	250
Ariete	NS5355	120 ÷ 1500	60000 ÷ 5000	5	355
PandaPlus	1000	1000	20 ÷ 24	1	2,2
PandaPlus	2000	2000	9 ÷ 10,8	1	1,85
Panther	NS3006L	1000 ÷ 1500	120 ÷ 50	3	5,5
Pony	NS2006L	1000 ÷ 1500	80 ÷ 35	2	5,5
TwinPanda	400	400	55	1	1,5
TwinPanda	600	600	30	1	1,5
One	7TS	100 ÷ 250	1050 ÷ (300÷650)	3	7,5
One	11TS	100 ÷ 250	3300 ÷ 1300	3	11
One	15TS	100 ÷ 250	4500 ÷ 1800	3	15
One	37TF	100 ÷ 250	8000÷(4000÷4800)	3	37

The average annual production is around 650 ÷ 700 machines. Most of them, around 300, are totally customized by the customer based on their production needs and the product to be treated. It will be up to the designer to choose the best solution and materials to meet the customer's requirements. All the machines, during their long journey along the assembly line, undergo continuous checks and checks on the components and assemblages used and carried out. Finally, all the machines are tested in their hydraulic, electrical and mechanical components before leaving the factory. Once the tests have passed, the machine is started for the cleaning, packing, and shipping process.

1.6.1 Models of Homogenizers

1. **Laboratory and Pilot Unit**: laboratory homogenizers and pilot plants are the ideal solution for the treatment of nanoparticles, nanodispersions, nanoemulsions, cell breakage and can be used to process milk, dairy products, fruit juices and foods in general. They can reach 2000 bar of pressure even working on samples of low volume and equal the results obtained by larger machines.

Figure 1.16 Panda.

2. **ONE series**: the homogenizers ONE series has a design designed to meet the needs of flexibility and ease of installation and maintenance, simplifying the integration of the machine in small systems. The ONE TS series can reach a pressure of 250 bar and is particularly recommended for the treatment of dairy products and beverages.

Figure 1.17 ONE series.

3. **Pharma Skid**: semi-industrial homogenizers with a production capacity of 5000 l / h of flow and a maximum pressure of 1500 bar. The main advantage of this solution is the guarantee of having a hygienic solution suitable for aseptic productions, totally tested and validated. GEA Niro Soavi is able to provide all the documentation necessary for cGMP and offer support for IQ / OQ certification and product tests (FAT and SAT).

Figure 1.18 Pharma Skid.

4. **Ariete series**: the Ariete series of homogenizers represents the most advanced technology in the field of high-pressure machines and customized solutions; they can be used in the dairy, food, pharmaceutical, biotechnological, chemical and cosmetic industries. Easily implemented in remotely controlled systems and complete process lines, they are available in both sanitary and aseptic execution. Designed for CIP (Cleaning In Place) and SIP (Sterilization In Place), they are suitable for abrasive and viscous products; the pressure can reach 1500 bar according to the configuration adopted.

Figure 1.19 Ariete series.

In addition, the homogenizer can be made in aseptic version, in fact, GEA Niro Soavi has a long experience in the supply of aseptic homogenizers for the most important global companies of sterile products, not only in the food and dairy industry but also for pharmaceuticals and biotechnology. This machine uses sterile condensate (instead of steam) to flush the aseptic chambers installed on the machine. This prevents the sterile product from being contaminated during the homogenizer process once the entire system has been steam sterilized.

1.7 Applications

The range of GEA Niro Soavi homogenizers is able to meet every possible application need in a variety of sectors:

- **Milk and Derivatives**

  High-pressure homogenization is an industrial process widely used for various dairy products in order to improve the stability and durability of milk and dairy products. Niro Soavi homogenizers are the reference models for aseptic processes, hygiene, and automation requirements.

- **Pharmaceutical**

  Homogenization allows a more stable dispersion for liquid pharmaceutical products: this means better clinical efficacy, with higher tolerability of the drug and reduced dosage.

- **Food**

  Homogenization is widely used in the food sector to obtain a much more stable product with the better durability of its quality characteristics. It allows to reduce the use of additives and to optimize the composition of the products.

- **Biotechnologies**

  Homogenization is used for the breakage of yeast and bacteria cells: it allows the extraction of intracellular substances without using solvents or chemicals to break cell walls. In this way, it is possible to release proteins, enzymes, and vitamins.

- **Cosmetics**

  For the cosmetic products, high-pressure homogenization is used to effectively reduce the size of the particles, obtaining a uniform dimensional distribution, with a longer and more stable shelf-life and with a better active dispersion of the ingredients.

- **Chemistry**

  The high-pressure homogenization applied to the chemistry allows to create emulsions, dispersions and stable mixtures are able to improve chemical reactions and extraction processes, the properties of polymers and the color of the pigments.

The following table shows the various types of products related to the food sectors:

Table 1.2 Product Types

Milk and Derivatives	Alimentary
– Baby food	– Animal fats childhood
– Butter oil	– Baby food
– Products based on casein	– Casein walnut paste
– Condensed milk	– Desserts
– Sweetened condensed milk	– Eggs
– Spreadable cheese	– Concentrated sweetened fruit pulp
– Coffee cream	– Arabic Gum
– Spoon desserts	– Honey
– Bases for ice cream	– Ketchup
– Milk's proteins	– Margarine
– Fresh milk	– Meat pasta
– Recombined milk powder	– Vegetables
– Pasteurized milk	– Puree
– UHT milk	– Syrup
– Low-fat milk	– Tomato juice
	– Tomato concentrate
	– Fruit juices
	– Food emulsions

CHAPTER 2

LEAN THINKING

The lean production represents the evolution of the Toyota model and is based on the so-called Lean Thinking: “a way to do more and more with less and less – less human effort, less equipment, less time, and less space – while coming closer and closer to providing customers with exactly what they want.”.

A system can be considered lean when all the materials move within a flow as continuous as possible, passing through processes that increase its value. The application of this new line of thought, first to the production system, then to the entire company has led to surprising improvements in company performance. The results of the implementation of lean production in Toyota have contributed to its diffusion that goes far beyond the simple rethinking of production lines but considers all aspects of the company reality. Slender thinking is based on five fundamental pillars. Through the pursuit of these five principles, the company that decides to adopt lean logic aims at the progressive elimination of all waste (Muda) referred to the production process and, more broadly, to all business processes.

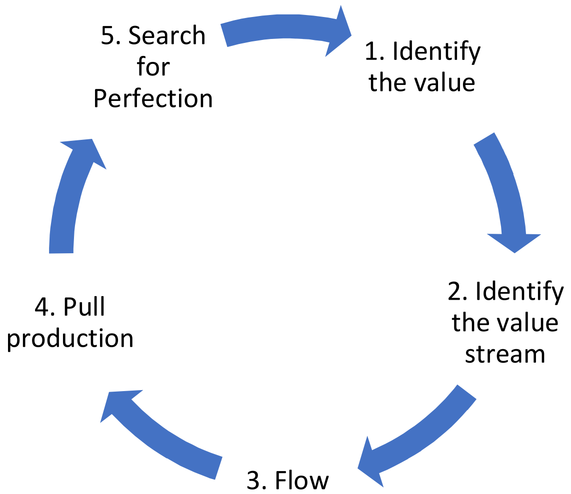


Figure 2.1 Fundamental principles of Lean Production.

2.1 The 7 Wastes of Time

Muda is a Japanese term that identifies activities that do not add value. The "Seven Wastes" identify and classify activities that usually represent waste. They were identified by Taiichi Ohno, Toyota chief engineer, as part of the Toyota Production System.

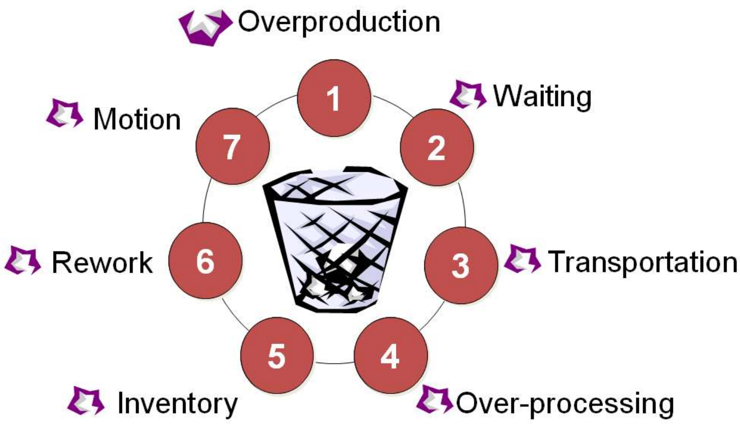


Figure 2.2 The 7 wastes.

1. **Overproduction**: it means a production superior to the requests, at any stage of the work. We often produce more to compensate for downtimes, defects, staff absences. Producing more, however, should be considered a negative thing just like producing less. The remainder entails an increase in costs: the value of the unsold product, the storage of a quantity of "unsolicited" products with the consequent "waste" of space. The goal is therefore to produce only the minimum necessary to avoid producing for the warehouse.
2. **Transportation**: They are all transport operations from one place to another, from one department to another, which undoubtedly have a cost in terms of resources but not only. Every time a product is transferred it risks being damaged, lost, delayed, so the transport becomes a cost that does not produce value. Transport is an operation that

generates added value for the customer so they must be reduced as much as possible. Normally there are two aspects to analyze and on which to intervene:

1. Understand the reason for which the transport is necessary, reducing the constraints that make the movement necessary (for example: modifying the layout of the line);
2. Analyze and optimize the transport method, in terms of frequency, distance to travel, necessary time, equipment and operating procedure.

3. **Waiting**: It refers to all the waiting times not strictly necessary for the production cycle of the product, in practice, it is the difference between the Lead Time of the production flow of an asset and its manufacturing time. Among the most common causes we can include:
   - Synchronization errors of process steps (machining);
   - Arrival delay of materials;
   - Sudden queues;
   - Delays due to plant failures;
   - Lack of operator;
   - Waits for machine set-up;
   - Delays due to plant failures;
   - Lack of operator;
   - Waits for machine set-up.
4. **Inventory**: whether they are in the form of raw materials, the material being processed (WIP), or finished products, they represent a capital that has not yet produced a profit for both the manufacturer and the customer. The presence of pieces/materials in the process generates a quantity of "trapped value" in the process (Working Capital)

proportional to the number of pieces and function of the state of progress in the production flow itself.

5. **Motion**: Apparently the movement could appear the same thing as transport but in this case, we talk about handling within the processing cycle. In other words, we talk about transport when it comes to transferring a piece/material from one area (workstation, department, line) to another area, handling when this transfer takes place within the same processing cycle in one defined location. This category, therefore, includes all movements performed by both the operator and the product in a processing cycle.
6. **Defects/Rework**: In this case, the gap is understood as the realization of a piece that does not conform to the specifications and in some cases the rejection by the end customer. In the Lean philosophy, it is considered wasteful the realization of a defective piece, whether waste or requiring additional work, re-working, compared to the standard.
7. **Over-processing**: Using resources that are more expensive than necessary for productive activities or adding more features, in addition to those that had originally requested the customer, only produces waste. Wastes due to the process are the use of operators with more than necessary qualifications, low plant performance, excessive variability of process parameters, excessive variability of materials, inadequate equipment or tools.

2.2 Some Techniques/Instruments of the Lean Production

2.2.1 The Just In Time (JIT)

Just in time is an industrial philosophy that has reversed the previous method of producing finished products for the warehouse waiting to be sold ("push" system) in the "pull" system for which aims to produce only what has been sold or which is expected to sell quickly. In more pragmatic terms, but also reductive, it is a recovery inventory management policy that uses methodologies aimed at improving the production process, trying to optimize not so much production as the upstream phases, to lighten up raw materials stocks as much as possible. and semi-finished products necessary for production (among the objectives there is that of zeroing intermediate stocks). Just in time combines elements such as reliability, stock reduction and lead time, with an increase in quality and customer service. In this way, the costs of storage and inventory management are greatly reduced.

2.2.2 Kanban

The Kanban is certainly the most characteristic of the JIT tools (Womack and Jones). Associated with the cells, it allows, through simple racks with pickup and production cards, to synchronize the flow of products between the cells, reducing the decoupling buffers and the total lead time. Each cell has two cassettes: one for Kanban-withdrawal and the other for Kanban-production.

Looking at the boxes, the operator understands the quantity and type of products to be produced or supplied (according to the box). Downstream and upstream of the cell are the containers that make up the stocks. Those upstream hung a Kanban-levy. The cell operator picks up the container with the products to be processed, detaches the Kanban-withdrawal and inserts it in the Kanban-withdrawal box which highlights the quantity and type of products to be supplied to restore the stock of products to be processed. On the other hand, the containers of stocks of products already worked have hung a Kanban-production. When a container of the latter is withdrawn, the Kanban-production is removed and placed in the corresponding box. The Kanban-withdrawal is hung from the container carried in the downstream cell. The goal is to reduce or eliminate stocks. As restrictions are eliminated, stocks should decrease and eventually be replaced as much as possible by a "one-piece flow".

The Kanban, if well applied, leads to a considerable reduction in stocks (up to 90%), to fast responses to changes in demand, to an improvement in the accuracy of the stock and to the simplification of the planning.

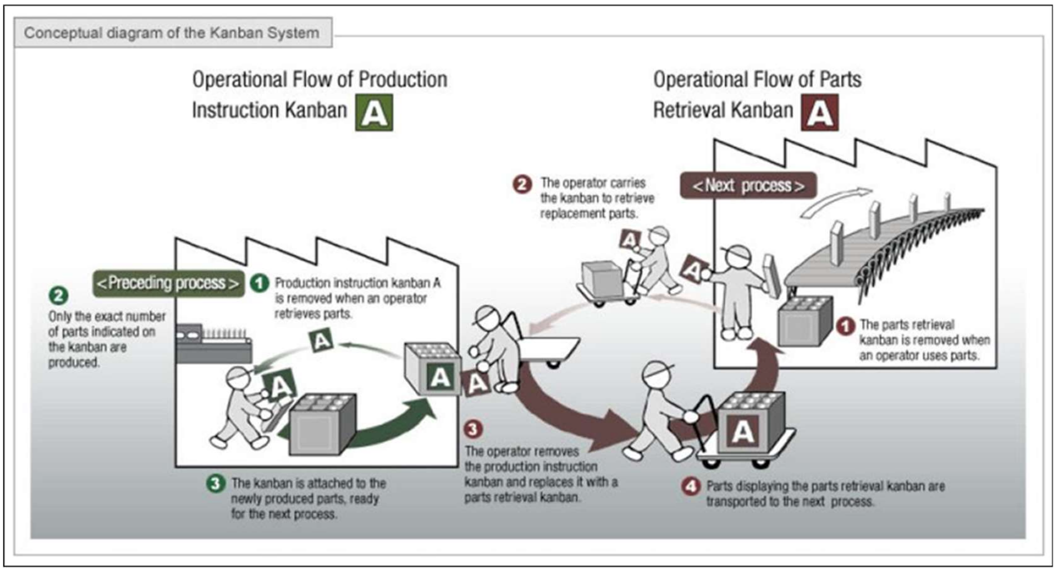


Figure 2.3 Conceptual scheme of the use of Kanban.

2.2.3 Poka-Yoke

It is a tool used to achieve the "zero defect" objective and finally eliminate quality control inspections.

The Poka-Yoke or foolproof approach is aimed at preventing errors and consists in determining operating conditions such that the operator is unable to perform a wrong maneuver.

Shigeo Shingo, a Toyota engineer, was one of the leading exponents of Zero Quality Control, an approach that makes extensive use of the Poka-Yoke principles. These mechanisms are used both to prevent the specific causes of errors and to control at low cost that each item produced is free from defects. A Poka-Yoke method is any mechanism that can prevent an error from being committed, or that can make the error immediately obvious. The ability to find errors "at a glance" is crucial because, as Shingo says, product defects are caused by workers' mistakes and therefore such failures must be carefully identified and analyzed.

2.2.4 Kaizen

The Kaizen, initially presented by Toyota and applied more and more all over the world, is based on the principle that dictates the foundation of this 'philosophy': "Energy comes from below", that is, on the understanding that the result in a company does not is achieved by management, but by direct work on the product. The Kaizen is based on the system of suggestions that consists of proposals made by all employees to make improvements to the production cycle and to avoid the emergence of problems that are not yet manifested but of probable onset: the so-called Warusa Kagen.

The simple yet innovative system that represents the strength of this method is the reduction of waste.

The Kaizen logic is to look for results not through a radical reorganization or large-scale investment, but through the cumulative effect of a succession of small incremental improvements.

The highlights of the kaizen philosophy are:

- Establish priority;
- Standardize;
- Make measurements;
- Improve.

Considering the Kaizen simply as "continuous improvement" reduces the scope of the concept, it is in fact a new way of operating that requires a radical change in management, in work, in the relationship between manager and worker, in the discipline, in decision making and in the organization of knowledge: the organization becomes a "federation of problem solvers".

2.3 Lean Six Sigma

Lean Six Sigma is a discipline of rigorous and systematic improvement based on the use of data and their statistical analysis; it focuses on measuring and improving operational performance by identifying and eliminating "waste" in business processes.

Six Sigma was born in Motorola in the early 80s and was later developed, and integrated with the philosophy of Lean Thinking, by companies such as General Electric and Caterpillar.

The merger of Lean and Six Sigma was appropriate because:

- The Lean alone cannot bring a process into statistical control;
- Six Sigma alone cannot drastically improve the speed of the process or reduce the capital invested.

Lean Six Sigma is a methodology that maximizes shareholder value by obtaining the fastest improvement result in terms of:

- Customer satisfaction;
- Cost reduction;
- Quality improvement;
- Increasing process speed;
- Reduction of invested capital.

The great success achieved by Lean Six Sigma is due to several factors:

- Structured project development process (DMAIC). The standard process of Problem Solving ensures that the decisions taken are from the analysis of the data;

- Economic return brought by improvement projects. The decision on which projects to work must be based, at least in part, on the potential impact in terms of economic return;
- Linking projects to strategic business priorities. The objectives of the Management are translated into projects and coordinated through the Six Sigma organization;
- Investment on the development of people (Black Belts, Green Belts, Yellow Belts). The best talents enter the program;
- Infrastructure to implement and monitor the progress of the initiative. Organized communication of results and lessons learned;
- Cultural change of the company. The new culture enters the company's DNA.

2.3.1 Dmaic Roadmap

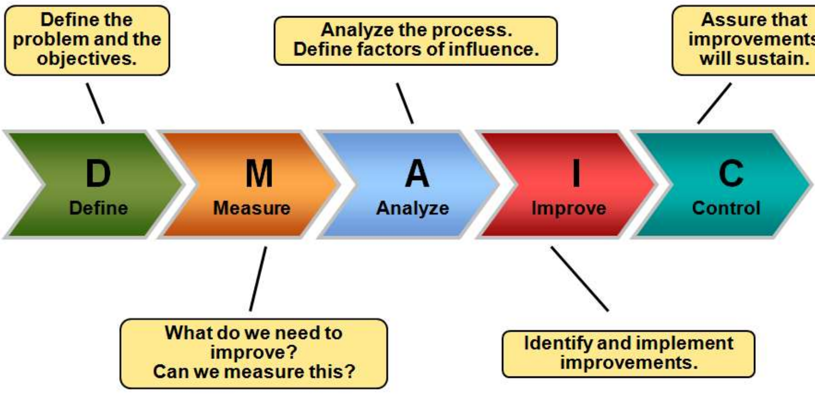


Figure 2.4 Conceptual diagram of the DMAIC process.

The Six Sigma DMAIC (Define, Measure, Analyze, Improve, Control) methodology can be thought of as a roadmap for problem-solving and product/process improvement. Most companies begin implementing Six Sigma using the DMAIC methodology, and later add the DFSS (Design for Six Sigma, also known as DMADV or IDDOV) methodologies when the organizational culture and experience level permits.

Before beginning any process improvement project, it's vital to choose projects that are good candidates for improvement. A good project for improvement:

- Has an obvious problem within the process;
- Has the potential to result in increased revenue, reduced cost or improved efficiency;
- Has collectible data.

DMAIC (Lean Six Sigma) is also a system of management that results in a steady pipeline of projects that are ready for improvement. There are obstacles to smooth operations in any business, and Lean Six Sigma provides guidelines to help to select the right projects at the right time. Once projects are selected, the team can use DMAIC to further refine the projects and deliver quantifiable, sustainable results.

Table 2.1 DMAIC Phase Steps

DMAIC Phase Steps	Tools Used
D – Define Phase: Define the project goals and customer (internal and external) deliverables.	
➢ Define Customers and Requirements (CTQs) ➢ Develop Problem Statement, Goals and Benefits ➢ Identify Champion, Process Owner, and Team ➢ Define Resources ➢ Evaluate Key Organizational Support ➢ Develop Project Plan and Milestones ➢ Develop High-Level Process Map	**Project Charter** **Process Flowchart** **SIPOC Diagram** **Stakeholder Analysis** **DMAIC WBS** **CTQ Definitions** **Voice of the Customer**

M – Measure Phase: Measure the process to determine current performance; quantify the problem.	
➢ Define Defect, Opportunity, Unit, and Metrics ➢ Detailed Process Map of Appropriate Areas ➢ Develop Data Collection Plan ➢ Validate the Measurement System ➢ Collect the Data ➢ Begin Developing Y=f(x) Relationship ➢ Determine Process Capability and Sigma Baseline	**Process Flowchart** **Data Collection Plan/Example** **Benchmarking** **Measurement System Analysis/Gage R&R** **Voice of the Customer Gathering** **Process Sigma Calculation** **Spaghetti Diagram**
A – Analyze Phase: Analyze and determine the root cause(s) of the defects.	
➢ Define Performance Objectives ➢ Identify Value/Non-Value Added Process Steps ➢ Identify Sources of Variation ➢ Determine Root Cause(s) ➢ Determine Vital Few x's, Y=f(x) Relationship	**Histogram** **Pareto Chart** **Time Series/Run Chart** **Scatter Plot** **Regression Analysis** **Fishbone Diagram** **5 Whys** **Process Map Analysis** **Statistical Analysis** **Hypothesis Testing**

	Non-Normal Data Analysis
I – Improve Phase: Improve the process by eliminating defects.	
➢ Perform Design of Experiments ➢ Develop Potential Solutions ➢ Define Operating Tolerances of Potential System ➢ Assess Failure Modes of Potential Solutions ➢ Validate Potential Improvement ➢ Correct/Re-Evaluate Potential Solution	**Brainstorming** **Mistake Proofing** **Design of Experiments** **Pugh Matrix** **QFD/House of Quality** **FMEA** **Simulation Software**
C – Control Phase: Control future process performance.	
➢ Define and Validate Monitoring ➢ Develop Standards and Procedures ➢ Implement Statistical Process Control ➢ Determine Process Capability ➢ Develop Transfer Plan ➢ Verify Benefits, Cost Savings/Avoidance ➢ Close Project, Finalize Documentation	**Process Sigma Calculation** **Control Charts** **Cost Savings Calculations** **Control Plan**

This project has been realized following the DMAIC procedures and using some of its tools.

CHAPTER 3

DEFINE

DMAIC begins once you have identified a problem to solve with the Define Phase, that is the first phase of the Lean Six Sigma improvement process.

The goal of this first phase is to define the project goals and customer deliverables. This includes developing a problem statement and identifying objectives, resources and project milestones. In this phase, the leader of the project creates a “Project Charter”, create a high-level view of the process. This is a critical phase in which the team defines the outline of the efforts for himself and the leadership of the organization.

3.1 AS-IS Situation

3.1.1 The Assembly Process

The assembly process of the homogenizers of the Pharma Skid, ONE and Ariete series, in GEA, is realized in 2 different methods:

1. **In line**, where are realized the standard homogenizers that respect the takt time of the line to get the operations for that specific workstation finished in time. For this type of assembly, the worker follows the semi-finished assembly from the first workstation to the last workstation, visiting all of the workstations that compose the line. Each workstation is characterized by different components that compose the homogenizer and the different operations are realized following a logic of technologic priority, according to it is not possible to realize an operation if the previous one is not finished. All the needed components for the specific workstation are supplied around it before

that the worker arrives at that workstation, to give to him the best conditions to work without waste of time.

There are 2 types of line in GEA:

a. The **<u>Line 1</u>**, where are realized the standard homogenizers that have a cycle time to get realized less or equal to 12 hours, it is composed of 3 workstations with a takt time of 4 hours;

Figure 3.1 Line 1.

b. The **<u>Line 2</u>**, where are realized the homogenizers of the ONE series that have a cycle time to get realized less or equal to 16 hours, it is composed by 2 workstations with a takt time of 8 hours.

Figure 3.2 Line 2.

2. **In isle**, where are realized the most part of the customized homogenizers that take more than 16 hours to get finished, because of some options requested by the customer. In the isle the worker is static, instead of the line where is moving with the semi-finished assembly; because for this type of assembly, the worker and the work in progress (WIP) are still in the same workstation since the starting of the assembly to the homogenizer finished and ready to go to the test. The isle is supplied time to time based on what is needed for continuing the assembly without wasting to much time and the cycle time is variable and depends on the complexity of the machine.

Figure 3.3 Isle 1.

3.1.2 The Phases of Testing And Finishing

- **Testing**

  Once the assembling of the homogenizing machine is finished, the machine needs to go to the testing area where it will be tested at very high-pressure using water as testing fluid. This is the most important phase because ensures that the machine has been assembled correctly and the homogenizing group and transmission system components are working properly.

The testing area is composed of 4 different Bays, that everyone can supply a different amount of voltage and volumes of water.

Figure 3.4 Testing area.

- **Finishing**

  After the releasing of the machine by the testing manager, who ensures that the homogenizer has been tested and falls within the parameters, the machine is sent to the finishing area. Where there will be applied the casing to close the machine, the customized adhesives, and at the end there will be realized the final cleaning of the machine. Then the homogenizer, that is finished with all the options that had been requested by the customer, will be stored inside a warehouse of the finished products ready to be sent around the world.

Figure 3.5 Finishing area.

3.2 AS-IS Scenario About the Critical Operation

3.2.1 The Critical Operation

During the assembling process, before to deliver the homogenizer completely assembled to the testing area, there is the last operation to do that consists of filling with different types of oil the motorization components, transmission body and gearbox, and for the machines with the Re + VALVE there is the further operation of filling the 1 or 2 little hogsheads.

These operations are made using, based on the type of oil that is needed, the specific barrel of oil that is placed on a mobile fluid handling cart, that is brought from its place where these barrels are stored to the last workstation on the lines or near the isle that needs to do this operation. Then the filling operation is realized connecting the compressed air to the pump that is inserted inside the barrel and then, using a nozzle with the presettabled quantity, is realized the operation filling the component with a specific quantity of oil that is presettabled previously.

This operation is characterized by the following aspects that make it as a critical:

- **Handling of the barrels of oil** inside the establishment, when needs to be done the operation. This determines:
    a. **Waste of time**, that causes an increase in the cycle time of the homogenizer;
    b. **Operation not valued** for the customer, because he is not paying for this kind of operation.
- **Safety risk**, because the handling and the fact of keeping a barrel of oil inside the establishment could cause pouring of oil inside the workplace.

- **High fire load**, because the oil is a combustible fluid with not so high flash point, so keeping barrels of oil inside the establishment cause an increase of the fire load, making less safety the workplace.

Moreover, it has been worked out that, under the point of view of the safety and the fire load, the handling cart where the barrels are placed has a containment tank that has not sufficient capacity. Because the law says that the containment tank under the barrel must contain the utter quantity of the full barrel of oil, in a way that in case there should be losses of oil, the amount of oil will not go over the tank, limiting the cause of injury or of fire.

So, for the point of view of the law and the safety is needed, respectively, to change the handling carts with ones that have enough capacity to contain the whole quantity of oil of the barrels and to have the store of the barrels of oils outside of the establishment, not inside as is today. This one should be the solution for this critical phase.

Figure 3.6 Current handling cart with the barrel of oil.

Being the GEA a company that is investing a large amount of money in the optimization of the process to make its products realized with the fewer efforts and the less waste of money, this critical operation is characterized by a large waste of time that is going against the GEA's mentality. So, it is necessary to realize a project to respect the aspect of the safety and the law, but to get on with the continuous improvement of the factory, in order to realize a reduction of the waste of time and making more fluent the process it is needed a system of automated oil distribution.

3.2.2 Types of Oils

At the moment, the types of oil that are possible to put inside the homogenizer are 5:

1. **OSO 150**, that is the type of oil that goes into the **transmission body**. This oil is the trademark of a line of high-quality hydraulic oils specially developed for use in all types of hydraulic systems and equipment. The oil is formulated from selected paraffinic base stocks treated with antirust, antioxidant, and anti-wear additives (ISO-LHM). The number 150 identifies the ISO VG GRADE of the oil.

   It is recommended for use in all hydrodynamic power transmission machinery, in hydraulic controls and hydrostatic systems widely used in all fields of technology, such as transport, construction, and mining, as well as in chemical and metallurgical machinery, machine tools, marine, and aviation equipment, etc. Due to the great influence of viscosity on the efficiency of hydraulic machinery, the grade chosen should be that recommended by the system designer; the heavier grades are used in low-speed machinery with high hydrostatic pressures. It is recommended not only for use as hydraulic fluids but also as heavy-duty lubricants for bearing, reduction units, etc., where operating conditions call for special antiwear characteristics. They can be adopted, too, where saving can be made by using a reduced number of grades throughout a plant.

Table 3.1 OSO 150 Characteristics

Characteristics	ASTM	Unit	OSO 150
Density at 15°C	D 4052	kg/l	0.895
Viscosity at 100°C	D 445	mm^2/s	15
Viscosity at 40°C	D 445	mm^2/s	150
Viscosity Index	D2270	dimensionless	100
Flash Point, COC	D 92	°C	250
Pour Point	D 97	°C	-21

2. **OSO 32**, that is the type of oil that goes into the **hogsheads**. The number 32 identifies the ISO VG GRADE of the oil. The oil is designed for energy transmission in plants requiring the use of hydraulic fluid, and also provide adequate lubrication by creating a strong lubricant film that withstands high loads between the sliding parts of high-pressure hydraulic systems. The lighter grades are generally used in high-speed machinery and in precision equipment.

Table 3.2 OSO 32 Characteristics

Characteristics	ASTM	Unit	OSO 32
Density at 15°C	D 4052	kg/l	0.870
Viscosity at 100°C	D 445	mm^2/s	5.36
Viscosity at 40°C	D 445	mm^2/s	31
Viscosity Index	D2270	dimensionless	102
Flash Point, COC	D 92	°C	220
Pour Point	D 97	°C	-27

3. **BLASIA 220S**, that is the type of oil that goes into the **gearbox**. It has been developed to meet the widest range of requirements of EP (Extreme Pressure) lubrication such as, for instance, gears, operating under a severe duty (ISO-L-CKD classification). It is formulated from paraffinic base stocks and additives such as sulfur compounds (which

ensure good high-speed and shock-load performance) and phosphorus compounds (for low-speed and high-load performance). It, thus, satisfies the widest range of operational requirements. The number 220 identifies the ISO VG GRADE of the oil This oil is recommended for splash or circulation lubrication of all types of enclosed gears, especially where operating conditions involve heavy loads, high speeds and high relative sliding velocities, at elevated ambient and operating temperatures. It can also be used to lubricate other heavily-load parts and components such as couplings, transmission screws and low-speed plain bearings.

Table 3.3 BLASIA 220S Characteristics

Characteristics	ASTM	Unit	BLASIA 220S
Density at 15°C	D 4052	kg/l	0.898
Viscosity at 100°C	D 445	mm^2/s	19.2
Viscosity at 40°C	D 445	mm^2/s	220
Viscosity Index	D2270	dimensionless	98
Flash Point, COC	D 92	°C	260
Pour Point	D 97	°C	-12

4. **BLASIA 220SX**, that is the type of oil that is utilized for the **ATEX homogenizers**. It is an oil developed for the lubrication of gears bearings operating at high temperatures. It is formulated from a synthetic base (polyalphaolefin) additive-treated to impart appropriate antirust, anti-wear properties, and exceptional oxidation and thermal stability. The number 220 identifies the ISO VG GRADE of the oil. It is best used for the lubrication of bearings of marine separators, gears operating at high temperatures (glass forming machines, steel strip mills, furnaces, and ceramic and paper-making machinery). Suitable for continuous bulk temperatures up to 120 °C with peaks in the hottest points up to 200 °C.

Table 3.4 BLASIA 220SX Characteristics

Characteristics	ASTM	Unit	BLASIA 220SX
Density at 15°C	D 4052	kg/l	0.850
Viscosity at 100°C	D 445	mm^2/s	31.0
Viscosity at 40°C	D 445	mm^2/s	316
Viscosity Index	D2270	dimensionless	135
Flash Point, COC	D 92	°C	255
Pour Point	D 97	°C	-33

5. **CASSIDA CHAIN OIL 150 [food grade]**, that is the type of oil that goes into the transmission body of the homogenizers that will treat food fluids. In the edible oil processing industry, the use of food-safe machine lubricants can mean the difference between a good name and no name at all.

   Incidental and direct oil contamination during the whole process is avoided by edible oil manufacturers who process millions of kilograms of food for global markets every year. The production of edible oil and related products puts the highest requirements on the lubricants used in the manufacturing process.

   CASSIDA CHAIN OIL 150 is a fully synthetic high-performance, anti-wear chain oil which has been specially developed for use in machinery used in the food and beverage processing and packaging industry. It is based on a careful blend of synthetic fluids and selected additives chosen for their ability to meet the stringent requirements of the food industry. Certified by NSF for ISO 21469 and registered by NSF (Class H1) for use where there is potential for incidental food contact. Produced according to FLT Quality Standards, in facilities where HACCP audit and Good Manufacturing Practice have been implemented and form part of the quality and hygiene management systems ISO 9001 and ISO 21469.

Table 3.5 CASSIDA CHAIN OIL 150 Characteristics

Characteristics	ASTM	Unit	CASSIDA CHAIN OIL 150
Density at 15°C	D 4052	kg/l	0.885
Viscosity at 100°C	D 445	mm^2/s	13
Viscosity at 40°C	D 445	mm^2/s	148
Viscosity Index	D2270	dimensionless	98
Flash Point, COC	D 92	°C	250
Pour Point	D 97	°C	-21

6. **CASSIDA CHAIN OIL HT 220 [food grade]**, that is the type of oil that goes into the gearbox of the homogenizers that will treat food fluids. CASSIDA CHAIN OIL HT 220 is a synthetic, high-performance ester oil which has been specially formulated for the food industry to lubricate drive and transport chains at an elevated temperature. Registered by NSF (Class H1) for use where there is potential for incidental food contact. It is characterized by: conveyorized oven chains and anti-friction roller bearings, continuous proof and bake systems for industrialized production of bread, rolls, and buns, and chains and other mechanisms exposed to high temperature in food processing plant.

Table 3.6 CASSIDA CHAIN OIL HT 220 Characteristics

Characteristics	ASTM	Unit	CASSIDA CHAIN OIL HT 220
Density at 15°C	D 4052	kg/l	0.895
Viscosity at 100°C	D 445	mm^2/s	18.4
Viscosity at 40°C	D 445	mm^2/s	218
Viscosity Index	D2270	dimensionless	97
Flash Point, COC	D 92	°C	260
Pour Point	D 97	°C	-12

3.3.3 Oil Storage and Warehouse

These types of oils are stored and placed in different points of the establishment depending on the needs of the particular types of oil for the homogenizers and on the available space inside the establishment.

- **Placement**

Inside the establishment are placed closed to the FIFO area, that is at the end of the Line 1, the 3 types of oils that are mostly utilized for the filling of the machines; that they are the OSO 32 for the hogsheads, BLASIA 220S for the gearbox, and the OSO 150 for the transmission body. They are placed in that position to realize the filling operation in the Line 1 as fast as possible because this line has the highest productivity and needs to respond to some specific productive cadences.

For the type of oil that is used for the hogsheads, it is realized a complex system of little containers to make easier the filling operation of the hogsheads using a transfer funnel to get a correct connection with the plug of the hogsheads. Whereas 2 barrels of the different types of oil are placed each over its own handling cart, each barrel has inside its own pneumatic pomp and nuzzle with the quantity presettable, and to realize the filling operation needs only the connection with the compressed air and the setting of the quantity that is necessary for the homogenizer.

Figure 3.7 The barrels of oil and the system of containers placed in the FIFO area.

Outside the establishment, closed to the polishing area, there are placed the IBC tank of the OSO 150 over a containment tank. This IBC is very important because it is used for a double purpose: the first utility is to fill the barrel of OSO 150 when it is empty using a pump with a nuzzle to realize the filling of the barrel, and the second utility is to be filled with the OSO 32 that comes from the homogenizers that are ready to be sent to the customer, because when it is sent a homogenizer to the customer the machine needs to be emptied from the body transmission oil. Also, there are: the barrel of BLASIA 220S, that is placed over its own handling cart, that it is utilized to fill using a manual pomp the little containers, that are used for the hogsheads, and the barrel of BLASIA 220SX, that is placed over its own handling cart, that is utilized to realize the filling of the homogenizers that need an ATEX oil inside their mechanic components, and to realize this filling the barrel of oil is brought, thanks to the cart, near to the machine and then using the pomp, that is already inside the barrel, and the nozzle it is possible to realize the operation after the connection with the compressed air.

Figure3.8 IBC tank outside the establishment.

Figure 3.9 Handling carts of BLASIA 220SX and OSO 32.

- **Storage**

The storage of the oils is placed outside at 25 meters far away from the establishment, according to the European standard EN14470-1 about the storage of flammable liquids. This storage is a double level container, that contains all the different types of oil that have been explained in the previous paragraph, this type of container must have a resistance class equal to four to be able to resist at the fire for 120 minutes. This amount of time leaves enough time for the workers to leave the environment and to the Fire Department to arrive in the deposit, before a small fire that cannot be extinguished occurs uncontrollably because of the flammable substances stored.

Whenever a barrel is empty, the designed person for the procurement of the new barrels of oil brings the empty barrels, using a forklift with a particular gripping device, near to the storage and then he brings the new barrel and he puts it over its own handling cart.

Figure 3.10 Oils storage.

3.4 Definition of the Project

According to what is come out about the filling of oils of the homogenizers, it is obvious that is necessary a project, first of all, to solve the safety critical issue, and about this aspect, the company wants to have the best work environment for the workers, so they can work in safety. Also, another reason to realize this project is to continue the improvement and the pursuit of reducing the waste during the process, in order to optimize the costs and to increase the profit.

For this reason, it has been realized a Project Charter, that is the first step in the Six Sigma methodology, and the charter can make or break a successful project. It can make it by specifying necessary resources and boundaries that will turn in ensure success; it can break it by reducing team focus, effectiveness, and motivation. In our Project Charter has been pointed out:

- The **problem statement**, which has been explained the problem, as it has been done previously, and the purpose of this project. For to the purpose, during the first meeting has been come out that the solution of all the problems is to realize a system of automated oil distribution inside the establishment putting near to the establishment the area for the oils placement, from which to realize withdrawal of oil for the system;
- The **team charter**, which has been added the sponsor of the project, the team leader, the process owner, and the team members that will be taken part in this project;
- The **master plan**, which has been defined the start and the end of the different phases, that are the Define, the Measure, the Analyze, the Improvement, and the Control Phases. Also, it has been defined the budget that has been given to this project, and this amount is equal to **50,000 €** to realize this project.

Table 3.7 Master Plan

PHASE	June	July	August	September	October	November	December	January
Define								
Measure								
Analyze								
Improve								
Control								

CHAPTER 4

MEASURE

The Measure Phase is the second stage of the DMAIC model.

During the Measure Phase, the overall performance of the core business process is measured, and also in order to quantify the problem.

There are three important parts of Measure Phase:

1. Data collection plan and data collection, in which a data collection plan is prepared to collect the required data. This plan includes what type of data needs to be collected, what are the sources of data, etc. The reason to collect data is to identify areas where current processes need to be improved;
2. Data evaluation, at this stage, the collected data is evaluated;
3. Failure mode and effects analysis (FMEA), the final segment of the Measure Phase is called FMEA. It refers to preventing defects before they occur, about in this study they have been identified and they will be used in the following phase, the Analyze Phase.

4.1 Spaghetti Diagram

The Spaghetti Diagram is a visual representation of the route employees take through the office or on the factory floor every day or of products that make their way through the production halls. This representation is often complicated and when visualized, it resembles a jumble of spaghetti on a plate. That's where the name comes from. A Spaghetti Diagram shows the continuous flow of activity during a process. It provides insight, making it easier to identify and remove redundancy in the workflow, which will speed up the whole process. This diagram is also known as a Spaghetti Chart.

It follows the Spaghetti Diagram that has been realized to show the movements of the employees and of the handling carts with the tanks of oil, that are done whenever the homogenizer needs to be filled with the oil. I have analyzed the situation of a classic machine in the Line 1, Line 2 and in the Isle that needs the filling operation of oils, that are the most used oils, I am talking about: OSO 150 (transmission body), OSO 32 (hogsheads), and BLASIA 220S (gearbox).

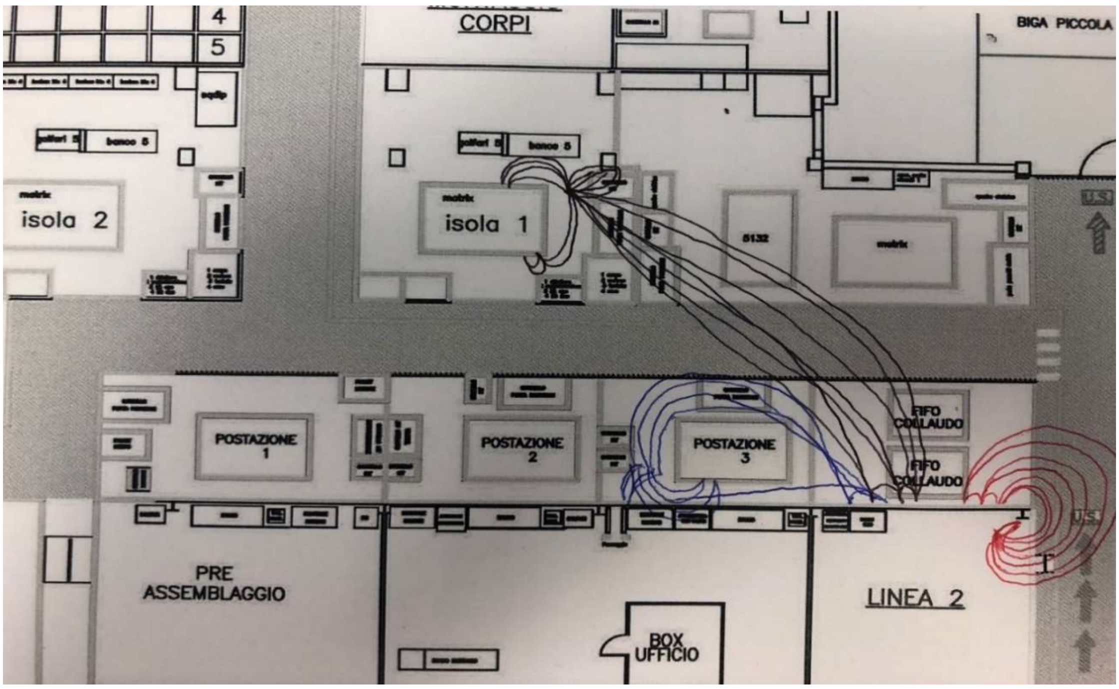


Figure 4.1 AS-IS Spaghetti Diagram.

The diagram shows three different types of movement that are needed depending on the way that the homogenizer has been assembled, so depending on the place where it is positioned:

1. The blue lines describe the movements that are done for the homogenizer in the third and last workstation of the Line 1, that has completed its assembling process and needs the last operation before to be sent to the testing, the filling of the oils. The employee movements are the following: going to the FIFO area to take the cart with the OSO 150 barrel, placing it near the machine, taking the plug of the compressed air and connect it at the nozzle of the pump, that is inserted inside the barrel of oil, and, after finishing the filling of the transmission body, bringing back the cart to the FIFO area. Then he has to take the cart with the BLASIA 220S barrel and realize the filling of the gearbox, and after that, he has to take the OSO 32 and realize the filling of the hogsheads;
2. The red lines describe the movements that are done for the homogenizer in the second and last workstation of the Line 2 that needs of the filling operations. The employee movements in this situation are the same for the same reasons of the previous case, except for the route that he has to do, because of the different placing of the homogenizer. But, the length traveled is the same if not minor of the previous;
3. The black lines describe the movements that are done for the homogenizer that is placed in the Isle 1, that needs of the filling operations. The employee movements in this situation are done for the same reasons, but, for this situation and for the others filling operations that are done in the other Isles, there is a long route to do for the barrels of oil, that determines the risk increase of spill and accident. Because of the

route that must be done to reach the Isle from the FIFO area with barrels of oils, that it is the central way, who is utilized by forklift and as walkway for the employees.

This diagram has given a lot of information about these critical handlings, that should be avoided to get a safe work environment, and about the large number of meters that the employee is forced to do for these ultimate operations. Regarding the last point, in a lean thinking point of view, the fact of the employee going away from the workstation means an operation that is not valued, so the customer is not paying for that operation. So, it must be found a solution to avoid these wastes of time, that means waste of money.

4.2 Time Measurement

In order to quantify these wastes of time, it has been done a detection of the time that is needed to realize the filling operation. Being this operation composed of different operations, I have focused on detecting the time needed for every operation that composes the filling. This refining of the measure of the time has been fundamental, because it has allowed to split in simply operations that have helped to find a better solution to avoid different types of wastes, and also to give the better technology for the filling operation to the employees that it makes easier and less dangerous this operation.

4.2.1 Time Detection Method

It has been decided to adopt the empirical method of timing as a method for detecting times, which requires the taking of chronometric measurements of the employee who carries out the operations in question. The choice of the method of detecting times was taken with the awareness of the important advantages that it brings, that is:

- Practical and rapid method;

- It allows direct and concrete feedback.

These are very important advantages to facilitate the analysis and, above all, to allow the detection of the assembly times of several machines to have as much data as possible from which they can always draw during the analysis process. Like any method of detecting times, it has its disadvantages, which have also been considered when choosing the most ideal method for detecting times, and they are:

- Risk of obtaining falsified measurements based on the person chosen for the test, behavior of the persons subjected to the test and description of them along the experience curve;
- It needs to do some tests before actually carrying out the measurement.

For the sake of completeness, the other two methods taken into consideration are explained, but which have not been used:

- MTM (Method of Time Measurement), which allows the splitting of each elementary operation in the analytical list of the movements that compose it; through specific tables, drawn up by specialized companies, it is possible to assign a time for each elementary movement that must be performed in the assembly, composing them it will be possible to calculate the average time and the estimated standard deviation for each operation. This method has the following advantages:
    - A rigorous method that is not affected by the context;
    - Does not require practical tests;
    - Provides an analytical view of individual operations.

  While the main disadvantage of this method is that it is a very complex, laborious and onerous method. Precisely because of this complexity and burdensome this method has not been used;

- The method by analogy of similar operations, very simple method that uses the experience as a test bed to obtain information on what will be achieved, comparing similar operations between them. To use this methodology, it was necessary to have solid surveys of simple operations already taken previously, but these were not present; thus, preventing the use of this method.

4.2.2 Detected Times

Therefore, it has been realized a detection of the times using chronometric measurements, and the detected date has been put in an Excel file, called “Time detection Template”. A file that I created previously to give a standard, and an approach every time it is needed a measure of times. In particular, it permits to realize quick and accurate detection for every operation and to write them on the file during the measurement process.

Thus, it has been realized three different measurements of the filling process in three different places, where the homogenizer was placed. For these measurements, I did not consider the efficiency of the employee and the rest factor, due to the fatigue that builds up to the worker doing these operations. In fact, I am not focused on its performance, but on the determination of the simple operations that compose the filling process and in the way that they are done. Doing these detections, I have considered only the phase since the beginning to the end of the filling operations, that was my goal, and I have found the elementary operations that composed this process and I have measured them three times: one on the homogenizer that was on the third workstation of the Line 1, one on the homogenizer that was on the second workstation of the Line 2, and one on the homogenizer that was on Isle 1.

Follow the data detected:

Table 4.1 Data Collected

# op.	Type of operation done by the worker	Duration [sec] Line 1	Line 2	Isle 1
1	Bring the cart with the body oil closed to the homogenizer	53	46	68
2	Connect the compressed air to the nozzle	27	33	35
3	Check the amount of oil to put in the body	6	5	10
4	Body filling	620	370	730
5	Disconnect compressed air and nozzle removal	10	12	14
6	Bring the cart of the transmission body oil back	37	31	48
7	Bring the cart with the gearbox oil closed to the homogenizer	43	38	54
8	Connect the compressed air to the nozzle	5	4	5
9	Gearbox filling	450	200	580
10	Nozzle removal	10	8	11
11	Disconnect compressed air	6	7	7
12	Bring the cart of the gearbox oil back	36	35	46
13	Bring the cart with the hogsheads oil closed to the homogenizer	39	40	50
14	Connect the compressed air to the system of tubes	6	8	6
15	First hogsheads filling (1 l)	98	90	108
16	Removal of the tube from the first hogsheads	14	16	15
17	Connect the tube to the second hogsheads	2	3	3
18	Second hogsheads filling (0.5 l)	40	38	39
19	Removal of the tube from the second hogsheads	13	12	17
20	Disconnect compressed air	20	22	18
21	Bring the cart with the hogsheads oil back	41	35	55
22	Come back at the workstation	17	15	20

The homogenizers, that have been taken in object, were:

1. For the Line 1, a homogenizer Ariete 3090 with 38 L of oil needed for the transmission body and 30 L for the gearbox;
2. For the Line 2, a homogenizer Ariete 3015 with 13,5 L of oil needed for the transmission body and 10 L for the gearbox;
3. For the Isle 1, a homogenizer Ariete 5132 with 71 L of oil needed for the transmission body and 37 L for the gearbox.

The data show that, as I said before and even with different types of series of Ariete, the operations, needed to realize the filling operation, are the same, with the only difference that it could take more or less time depends on the type of the homogenizer for the different capacity of the gearbox and transmission body. Using these new data and the old data, that I have taken in the previous detection during the realization for another project, I have determined the numbers of seconds needed to fill with 1 L the gearbox and the transmission body with its specific oil: 16.5 $\frac{sec}{L}$ needed for the transmission body and 18 $\frac{sec}{L}$ for the gearbox. Instead for the hogsheads, it has not been defined a standard time needed due to the different type of filling, and also because this study is unnecessary information.

This information will be useful for the following analysis that will be done during the Analyze Phase.

4.3 Observations

These Measurement Phase has helped me to become aware of a lot of aspects that criticized and characterized the filling operation, in particular about that:

- The filling operation in Winter is slower than in the other seasons, because of the cold weather that makes less fluid the oil, so the pump can pump less quantity of oil, taking more time to do the filling. Besides, the pump could stop working and could even break down, causing an extraordinary operation of changing the pump. That means a waste of time and money;
- The emptying of the barrel of oil, that could happen prior to the filling operation or during the operation. This problem determines that the employee has to: refill the barrel going outside the establishment where there are the tanks of oil or change the

barrel taking a new one going to the barrels' storage, leaving the empty barrel and out on the cart the filled barrel. This is obviously a not value operation, that should not do from the worker that is on his workstation, but by the person for the supply of the lines and of the isles. Unfortunately, it is always done by the worker forcing him to leave the workstation.

- The impossibility of doing two or more filling operation in different lines or isles at the same time, due to the number of the carts left available with the specific oils for these operations. Causing blocks and stops to the production, that reduce the daily performance.

These observations and the data that have been taken will be useful and important for the following phase of the project, the Analyze Phase.

CHAPTER 5

ANALYZE

The Analyze Phase is the third phase of the Six Sigma DMAIC.

It is the phase of identification of the causes, through qualitative analysis, to then identify the root causes by means of quantitative analysis, to eventually confirm the analyzes with further measures. The team brainstorms potential root causes (not solutions), develops a hypothesis as to why the problem exists and then work to prove or disprove their hypotheses. Verification includes both process analysis and data analysis and has to be completed before implementing solutions.

5.1 The Idea

The collected data and the observations that have been come out during the Measure Phase have highlighted the need of new technology to realize the filling operation in safe, removing the not value operations, reducing the time needed and optimizing this process.

For this reason, it has come out the idea of realizing a system of automated oil distribution, with the following characteristics:

- An insulated container in where it will be put the different tanks and barrels of the specific oils that want to be automated for their filling operations. It will be placed outside the establishment, but closed to that to be easy to reach by the supply person to realize quickly the changing of the empty tanks or barrels with the filled tanks or barrels using a forklift featured with a salvage drum lifter;
- Some dispensing points to fill the homogenizing machine, featured with the types of oils that would be decided to automate, using nozzles to realize the filling. They will

be supplied the oil from the barrels inside the container thanks to the pumps that they will be inserted inside the barrels and a system of piping that collect the barrels, outside the establishment, to the dispensing points, inside the establishment. This dispensing point will be done in different points of the establishment, according to the needs of optimizing the process and not to do disturb the other operations that the workers do in their workstations or in different areas;

- A piping system, that takes the oils from the barrels placed inside the container and brings the oil to the dispensing points. That means that it will be necessary an important system of piping that it will connect the outside of the establishment with the workstations or the filling area, depending on where the dispensing points will be placed. This piping system will have to respect the safety criteria, to avoid possible pouring of oils in different areas of the establishment that could be caused by welding defects of the piping or piping breakages, that could increase the fire load and the fire risk.

This possible solution allows to:

- Realize the filling operation at the same time in different Isles, in the workstation three of the Line 1, and in the workstation two of the Line 2. Removing the possible causes that determined waste of times and stops of the process;
- Remove the handling of the cart with the barrel of oil inside the establishment done by the employees to do the filling of the homogenizing machine. That will: determine more the place of work more safety, because it will be any more dangerous handling of oils, reduce the not value operations, due to the abandon of the worker of its workstation, make more efficient the process, removing a lot of unnecessary operations, that means an increase of the productivity;

- Monitor constantly and easily the level of the oils inside the container by the supply person, to permit him to realize the changing of the oils quickly without affecting the work of the employee in the workstation. So, the worker will not be forced anymore to do an operation that is not his competence, allowing him to continue working on his homogenizing machine. Also, remove the pouring of oils that occurred every time during the cart handling due to the spill containment (drip pan) that was full of oil.

5.2 The Container

The container will be insulated, because during the Measurement Phase it has come out that in Winter the filling operation is slower and more complicated, due to the cold weather that makes the oil less fluid. In fact, the pump has difficulty to process the oil, making the pump works bad, pumping less oil and causing a lot of stress to the pump, that it could break down. As it happened in these last two years, in which the responsible of assemblings had to change three times the pumps in 2016 and twice in 2017.

The container has to be suitable for the oils storage, thus needs to be featured with a containment tank to contain the eventual spill of oils, that could occur inside the container. The containment tank must have enough capacity to contain at least 50% of the total amount of oil that is stored in the container.

Besides, the container has to be REI 120, because being the mechanic oils inflammable at a very high temperature, the Italian law recognizes the oils as inflammable fluids and wants that the storage structure has to be REI 120, so it can resist the fire for 120 minutes.

5.2.1 Bonds of Placement

1. First of all, the container has to be placed outside of the establishment, because the Italian law establishes that for the storage of inflammable fluids with a capacity more than 1500 liters they shall be placed outside of the establishment, away from the place of work of the employees. So, in case of fire, thanks also to the structure REI 120, the employees have enough time to be safe without passing near to the fire or being choking by the smoke. This is the first bond of the problem of finding a place in the company to the placement of the container;
2. The second bond, perhaps the most important aspect to take into account to find this solution, is to give enough space in front of the container to the forklift to make possible and easy the changing of the empty barrels with the full ones using a salvage drum lifter. In order to give more space to the forklift maneuvers, it has been decided to feature the container with sliding doors, so the container can be easily opened without taking up to the forklift;
3. The third aspect that bonds the placement of the container is, of course, the overall dimensions of the container. These dimensions depend on the numbers of the barrel of oils and on their capacity that we want to store inside this container.

5.2.3 Types of Oils Stored in the Container

Follows the types of oils that have been decided to store inside the container, so the types of oils of which we want to automate the filling operation:

1. OSO 150, that is the transmission body oil. It has been decided to store this oil because it is the most used both in terms of the most quantity used and of the most numbers of time that it is realized the filling with this oil. It will not be used a barrel, but inside an IBC tank, that it has the capacity of 1000 liters of oil. This is been chosen because at

the moment an IBC of OSO 150 is used to fill the barrel of OSO 150 that it is then placed over the handling cart. The IBC is also necessary because of the emptying operation from the transmission body oil to the machine during the finishing process, in which it is pumped the oil inside a tank that actually is the IBC used for filling the barrels. Thus, it will be stored an IBC with the OSO 150;

2. BLASIA 220S, that is the gearbox oil. It will be stored this oil inside the container because is the second type of oil that is the most used in terms of quantity and numbers of utilization. It will be used an IBC tank too, because of the large amount of oil that is used, so it can be substituted the empty tank with the fill tank less frequently. At the moment are used barrels of BLASIA 220S, and not IBC, so it will be necessary to inform the purchasing office, that it will have to buy not any more barrels, but IBC of BLASIA 220S. That determines an economical saving in terms of the cost that are incurred every time is done an order because they will do less order of oil, thanks to the increase in the quantity of the oil purchased. Thus, it will be stored an IBC with BLASIA 220S;
3. OSO 32, that is the hogsheads oil. It is not used in some much quantities, but it is commonly used every time the homogenizing machine has the hogsheads. In fact, in order to avoid the large numbers of handlings that are required to fill the hogsheads with this oil, it has been decided to store this oil and it will be used a barrel with 200 liters of capacity. Thus, it will be stored a barrel with OSO 32;
4. BLASIA 220SX, that is the type of oil used whenever there is an ATEX homogenizing machine. It will be placed inside a barrel of 200 liters of capacity, because it is the standard dimensions and because it is the current type of barrel that is purchased. It has been selected this type of oil because, according to my analyze, there is still enough

space for another type of oil that is used more frequently between the ATEX type and the FOOD GRADE type. This type of oil is not been selected because it is not so much utilized, and also because it is frequently that the customer requests for a specific type of FOOD GRADE oil. Therefore, it will be stored a barrel with BLASIA 220SX.

About the FOOD GRADE oil, it will be considered as an extraordinary filling, that, in fact, is requested by the customer, so it will be realized putting the barrel over the handling cart and bringing it to the workstation to realize the extraordinary filling. Anyway, this type of oil has been chosen not commonly used, so it is chosen not to include it in the container to avoid oversizing the container and the system of automated oil distribution.

5.2.4 Overall Dimensions of the Container

After being selected the type of oil that will go inside the container, it has been defined the dimensions that the container should have to allow easy placement of the oils inside, that permits also to substitute them easily.

So, the numbers of barrels are 2, that it is the 55-gallon barrel that has a diameter of 572 millimeters, but for security, I have assumed 600 millimeters, and the numbers of IBC are 2, that its footprint is of 1000 millimeters × 1200 millimeters. Using these data and considering that it should be left enough free space to allow the placement of the oils inside the container with any problems and to permit the operations of removing the pumps from the barrels easily. Watching to the standard dimensions of containers that are available on the market, I have done these sketches of how the container should be, and these dimensions will be used as a footprint for defining the necessary space needed to the container in order to find its better placed outside the establishment. The containment tank in this model of the container has 2 liters of capacity, that is more than the minimum quantity requested by law, that for this case should be the 50% of the total capacity of oils, that is 2.4 liters, so 1,2 liters.

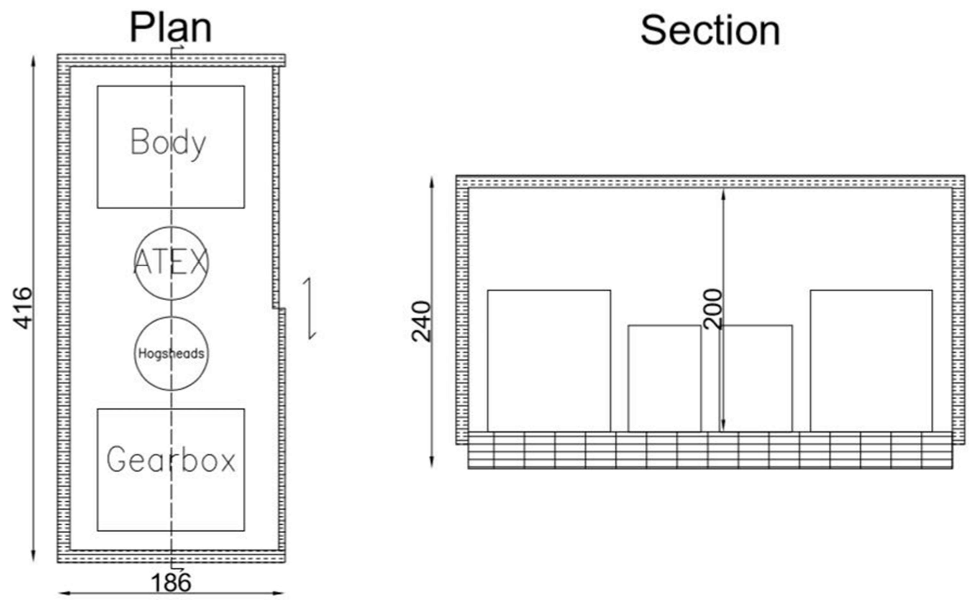


Figure 5.1 Container model used.

Thus, for this type of container that is assumed is needed at least an area of 8 square meters (4.16 meters × 1.86 meters).

5.2.5 Identifying the Container Place

At the beginning of this project, the place that was identified for the container was in the storage of the panel boxes, that meant to find another place to store the panel boxes, moreover, to tear down the steel ladder for the thermal power plant, and to rebuild the steel ladder. This solution would have given enough space to the forklift to change the barrels, but it has not realized because of the impossibility to rebuild the steel ladder that was safe and functional for the employees. Also, the place where it would have been built the ladder had been in conflict with the path of loading and unloading vehicles. So, this solution has been abandoned.

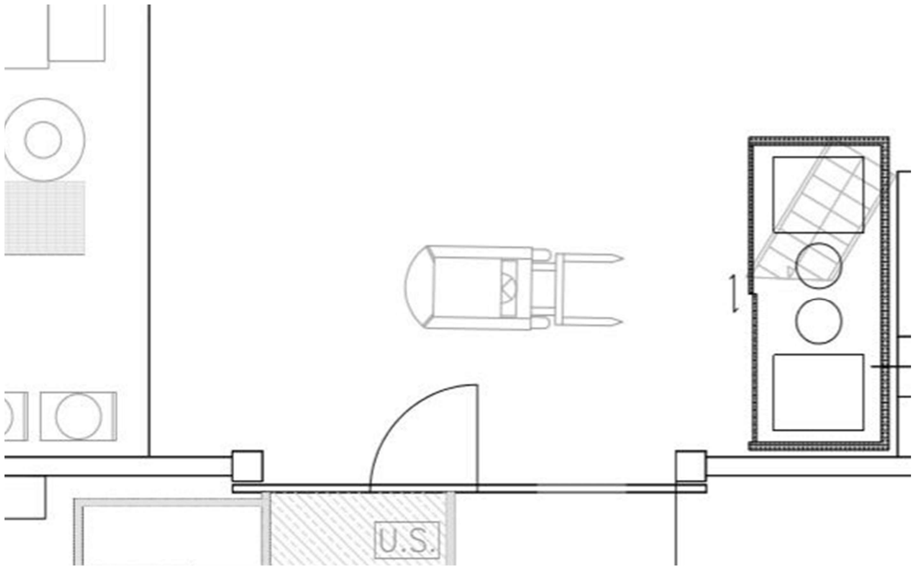


Figure 5.2 Sketch of where would have put the container.

Figure 5.3 Box panels storage.

In front of the box panels storage, there is a small area used for the polisher machines, that it presented messy, with a lot of useless stuff that was put without any reason and left in disarray. But, this area has been identified for the perfect place where put the container, because it has enough space to allow the changing of the barrels to the forklift without any obstacles. Also, it is closed to the assembling area, allowing to the supply person to reach the storage quickly, and, in particular, this means that the system of piping it will not be too much long and complicated, reducing the cost of the implementation of the system. The problem of placing here the container is that it needs to put in order the polisher machines, the other things that are placed there, and, also, to put away the useless things.

Figure 5.4 Polisher machines area.

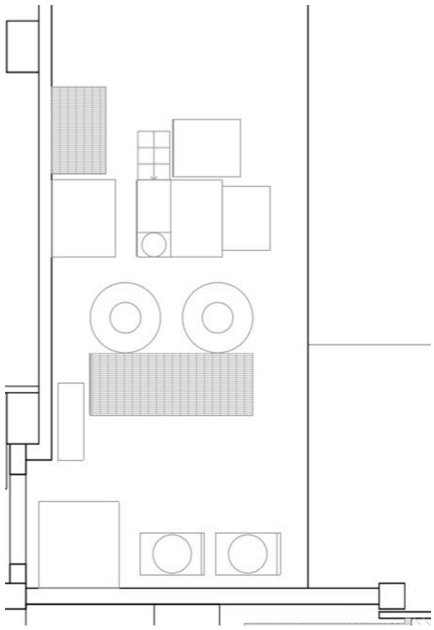


Figure 5.5 Plan of the polisher machines area.

Thanks to the services manager and the responsible for mechanical machinings they have made to free more than 4 meters that are necessary for the placement of the container. Thus, it has been identified the place for the future container, that is functional for the forklift movements, it has enough space for the container of 4 meters, and it has been found without building or tearing down anything, determining an important saving of money.

At the moment of the placement of the container, it will be placed in the corner but leaving enough space by the wall of the establishment, in order to allow the operator to go behind the container to install the necessary devices, that will be fixed behind the container, for the correct working on.

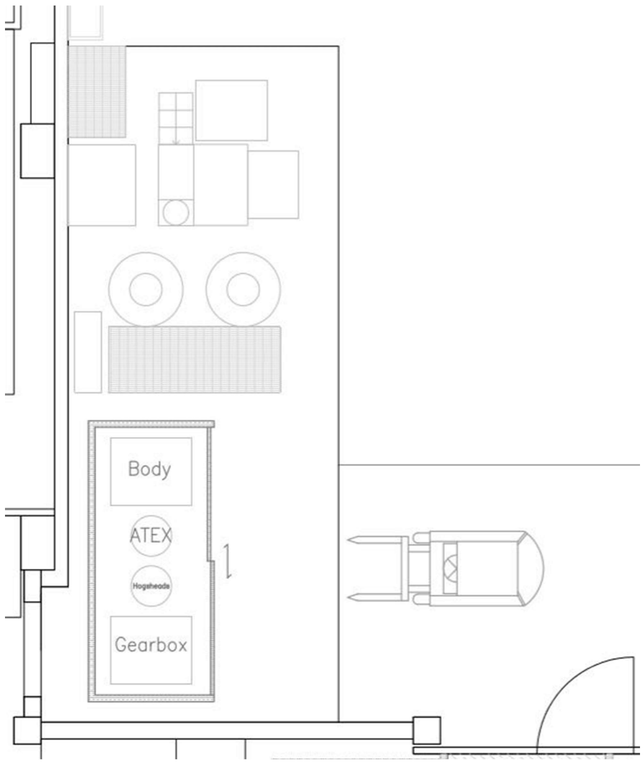


Figure 5.6 Sketch of how it will be the polishing area with the container.

Figure 5.7 The free space that has been done for the container.

5.3 The Dispensing Points

Once it has been identified the place for the container, the further step now is to define how to realize the filling operation, the number of the dispensing points, and where position them inside the establishment.

5.3.1 The Filling Operation

To do the filling operations it has been thought to realize a dispensing point featured with a single-column portal or, depending on the needs and on the functionality, a double-sided structure, that allows two-faced used. This structure will be utilized to fix the equipment needed, that it will be:

- Nozzles with the quantity presettable, that are the current type of nozzles used by the worker. It has been selected this type of nozzles to give technology to the worker that they already know, and because it is functional and efficient the possibility of presetting the quantity that it wants to supply. It could allow the worker to leave the nozzle working inside the tank that is filling, and to do something else, increasing the efficiency, and reducing the cycle time;

- Oil hose reels, that connect the piping system to the nozzles. They will be utilized a 10 meters flexible tube for oils, in order to allow every kind of filling operation of the homogenizing machine even if it is placed in the workstation incorrectly;
- Drip trays, so that the nozzles once have finished the filling operation can be placed over their own drip trays, in order to avoid pouring of droplets of oil around the workstation, due to the remaining oil inside the nozzle used.

The pressure needed for this type of system it will be supplied by the pneumatic pumps that will be inserted inside the barrels and the IBC, thus it will be necessary to connect them to a compressed air system.

5.3.2 The Placement of the Dispensing Points

This topic has been the object of various meetings in order to find the better place in where realizing the filling operation, that gives the better performance in terms of time, the least number of handlings of the homogenizing machine, and the better safe to the operation. Following the options that have been considered and the option that it has been identified as the better placement of the dispensing points:

- **In the finishing area**

  It was chosen as the option as the area in where realizing the filling of the homogenizing machine because this solution would have not modified the flexibility of the establishment and would have determined an important reduction of the cycle time of the machines inside the assembling area. The finishing operator would have gotten enough time to realize the filling operation without affecting the finishing operations, even because they already are used to remove the transmission body oil during the finishing of the machine.

This option was not realized because it required of a further movement of the machine from the workstation to the finishing area before to be delivered to the testing area, causing an increase of the not value operations and of the risk of accidents inside the establishment with pouring of oils, due to the movement from the finishing to the testing area, in which the machine is filled with oil. Moreover, this option would have caused waiting times, in case more than one machine was ready to be filled with the oils, determining queues to the filling area. Another problem was that not all of the sizes of the machines could have fitted inside without disturbing the finishing operations, and the adding of further an area to visit before of the testing was in conflict with the lean ideology.

Figure 5.8 Where it would have been realized the filling area in the finishing area.

- **In the testing area**

  It was taken into account the possibility of placing the dispensing points in the testing area, because it would have allowed keeping unchanged the establishment flexibility, to reduce the cycle time of the machines in the assembling area, and, especially, to do the movement from the assembling to the testing area with more safe, because it would have been done with the machine without oils inside. But this option has been discarded because it would have caused an increase of the throughput time of the homogenizing machine in the testing area, that today represents the bottleneck of the entire process, so it did not want to decrease the productivity due to the testing operator that did to do the filling operation prior to start the testing of the machine. Also, this option would have had to add a piping system in an area that is already full of piping, so there is not enough space for another one, and, in particular, there is not an available place in where placing the dispensing point. Moreover, the number of piping systems and the needs to supply all the testing Bays would have decreased a lot the safety of the testing area.

Figure 5.9 Where it would have been realized the filling area in the testing area.

- **In the assembling area**

  The other option was to place the dispensing point in the assembling area in order to realize immediately the filling operation to the homogenizing machine once the assembling operations are done in the same workstation, without doing further movement to a specific filling area, or charging the testing operators of an operation that it always has been done inside the assembling area. In fact, this is the solution that has been selected, because it allows giving to the testing area a machine ready for the testing, without affecting the bottleneck, that is the testing operations. This solution is possible because in the workstations of the assembling area there is enough space to place the dispensing points, so much that it could be possible to place one for every workstation.

  There are anyway a disadvantage for this solution, that it is about the flexibility of the establishment, in particular of the assembling area, because of realizing these dispensing points it is going to block a fixed place for a specific utility, so it is creating some bonds that in the future could cause problems if there will need to change something in the assembling area. For this reason, the piping system will be featured, at every certain number of meters of horizontal piping that will be fixed to the ceiling of the establishment, with T fittings plumbing. In order to allow to change the place of the dispensing points in case of a renovation of the layout of the assembly area, keeping the flexibility of the establishment still high.

5.3.3 The Number of Dispensing Points

Once it has been decided the area where there will be placed the dispensing points, now it is necessary to define where there will be put in the layout. The goal is to give: the maximum productivity to the assembling area, reducing the wastes of times and the waitings due to another machine that occupies the filling area, and the possibility to realize the filling operation in every workstation, reducing at the minimum the movement of the homogenizing machine, that is a not value operation, but this target has to consider the cost of realizing the system of automated oil distribution. In fact, it is not economically convenient to place in each of the seven workstations (for the lines it has been interested only on workstations that are the last), also because this brings to oversize the system, and I reminder that the filling operation is an operation that occurs twice per day, or at the most three times per day. These are the aspects that have been taken into account during the identifying of the better position and the optimal number of the dispensing points, that I have done with the help of the production manager and the assembly responsible.

Follows the layout of the assembling area featured with the dispensing points:

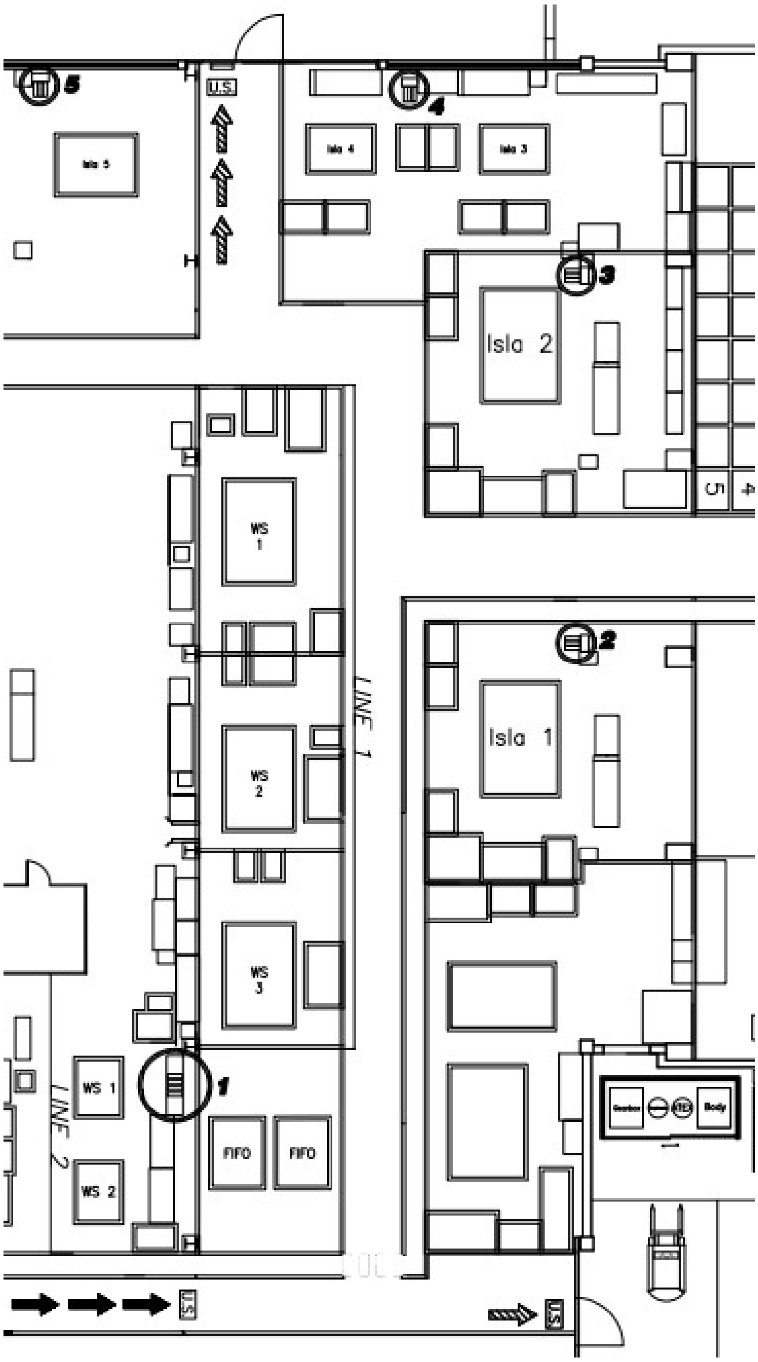


Figure 5.10 Layout of the assembling area with the dispensing points.

According to the above plan of the layout, there will be realized five different dispensing points in different positions:

1. Between the third workstation of the Line 1, the second workstation of the Line 2, and the FIFO area will be constructed a double-sided structure, which will allow a two-faced used. So, it will be possible to realize the filling operation of the homogenizing machine in the third workstation of the Line 1 and in the second workstation of the Line 2, using the same structure, thanks to the double-faced structure. This structure will be provided with 4 types of oils: OSO 150 (body), OSO 32 (hogsheads), BLASIA 220S (gearbox), and BLASIA 220SX (ATEX). The ATEX oil will be provided only by this structure, because it is not so much requested, and we did not want to oversize the filling of oil that is not so used. Anyway, in case it would be requested by an Isle machine, this machine once finished the assembling operations it will be brought to the FIFO area to realize the filling with the ATEX oil, using the structure that can supply this area, and also the Line 1 and 2. In this case, it will be considered as an extraordinary filling, so the machine needs to pass to the FIFO area before to be delivered to the testing area;

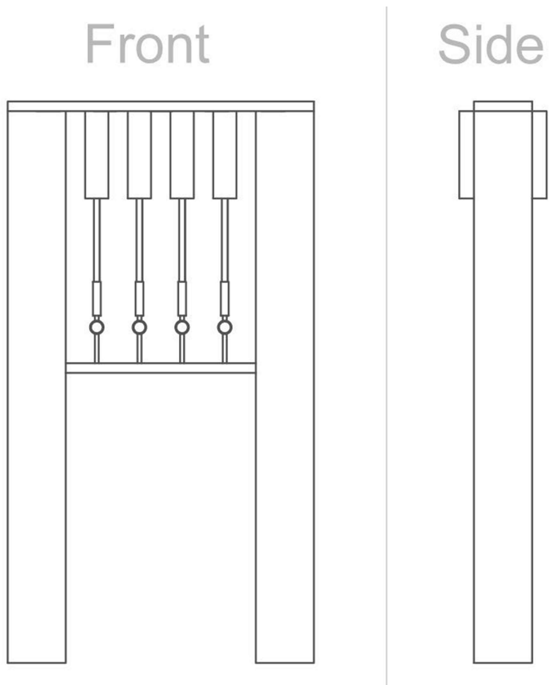


Figure 5.11 Double-sided structure for oils supplying.

2. In the Isle 1, it will be constructed a portal for fixing single-column equipment, that it will provide 3 types of oils, that are the OSO 150, OSO 32, and BLASIA 220S. It will allow realizing the common filling operations easily for the machine that will be placed on the Isle 1. Instead for the ATEX filling, the machine will be brought to the FIFO area, being this one for the major of the time empty, because it is not used correctly by the employees;
3. In the Isle 2, it will be placed the same portal for fixing single-column equipment featured with the same 3 types of oil, that it will allow the filling operation for the homogenizing machine placed in this Isle;
4. Between the Isle 3 and Isle 4, it will be placed the portal for fixing single-column equipment provided with the 3 types of oil. This portal will realize the filling operation for both Isles, thanks to the length of 10 meters of the flexible oil tube, and to the small sizes of both Isles, so with only one portal it will be possible filling the machines, saving money for not doing a further portal;

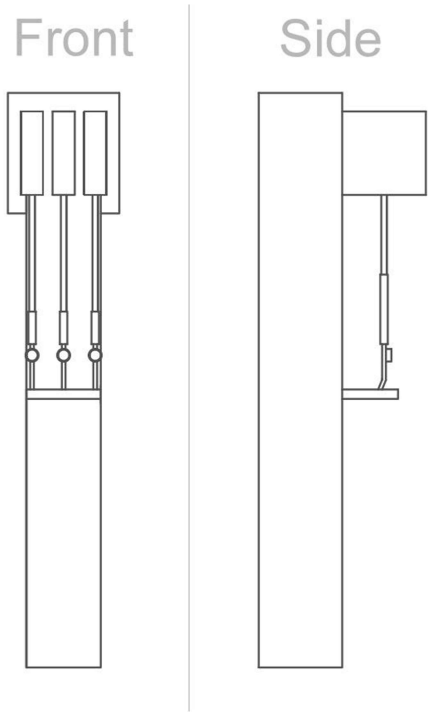


Figure 5.12 Portal for fixing single-column equipment.

5. In the Isle 5 will be realized the portal with the 3 types of oil, that it will permit to realize the common filling operations even in the last Isle.

5.4 The Piping System

The piping system that will connect the oils stored in the container to the dispensing points in the establishment, it will be designed by the supplier, in which they will select the type of the pump to use depending on the density of the different type of oils and the diameter of the piping. So, it is necessary to decide the supplier, but before doing this, it needs to discover if this project could really give an improvement of the performances that could turn into an economic saving. Besides, it is necessary to justify the management of the investment that will be necessary for the realization of this project. So, it will be realized an economic analysis of the impact of the system of automated oil distribution in order to convince them to spend an important amount of money for this project, prior to design the piping system and to ask for quotes from specializing companies in the realization of these types of implants.

CHAPTER 6

ECONOMIC ANALYSIS

In order to give a correct and suitable economic analysis, that can give to the management a correct forecast of the impact that this system of automated oil distribution could give to the company and convince them to invest in the realization of this project, I have realized an analysis that simulates the future of this company with this implant.

Thus, first of all, it is necessary for a market demand forecast for the coming year, 2019.

6.1 Forecasting Demand

A good forecasting demand provides as input the forecasts of the year to come, that is a result of a careful study of the trend of the demand for previous periods.

6.1.1 Analysis of the Historical Series of the Market Demand

The forecast model based on time series bases the forecasting procedure on the past behavior of the demand, thus using a historical series of data relative to the actual trend of the demand and assuming, tacitly, that the future trend of the demand reflects the past one.

The application forecasting procedure must follow three main steps:

1. Analysis of historical data and identification of the most suitable forecasting methodology, so the methodology, if it is applied to the past history series, involves the minor error;
2. Use of the methodology identified in the previous step to make the forecast;
3. Periodic review of the methodology adopted in the previous points once the new available historical data is available.

It must be emphasized that a perfect prediction is normally unattainable because too many factors are not predictable with certainty. Therefore, rather than aiming for perfection, it is much more important to establish the practice of continuous verification of predictions and learn to live with inaccurate forecasts; this does not mean that we will have to try to improve the model or the forecast methodology adopted, but that we will try to identify and use the best available forecasting method, within reasonable limits.

One thing that needs attention is the level of aggregation to consider for prediction. In this regard, it should be emphasized that as the aggregation level of the demand to be expected increases, the reliability of the forecast also increases. In fact, it is much easier to make predictions on a product family, rather than on a specific personalized type.

As regards the analysis of the historical series, it is decided to analyze the trend in demand over the last eight years in order to identify the most suitable forecasting technique for each family, that for this situation, the machines are aggregated based on where there were been assembled in the assembling area. So, follows the trend of the machines assembled in the Line 1, in the Line 2, and the five different Isles:

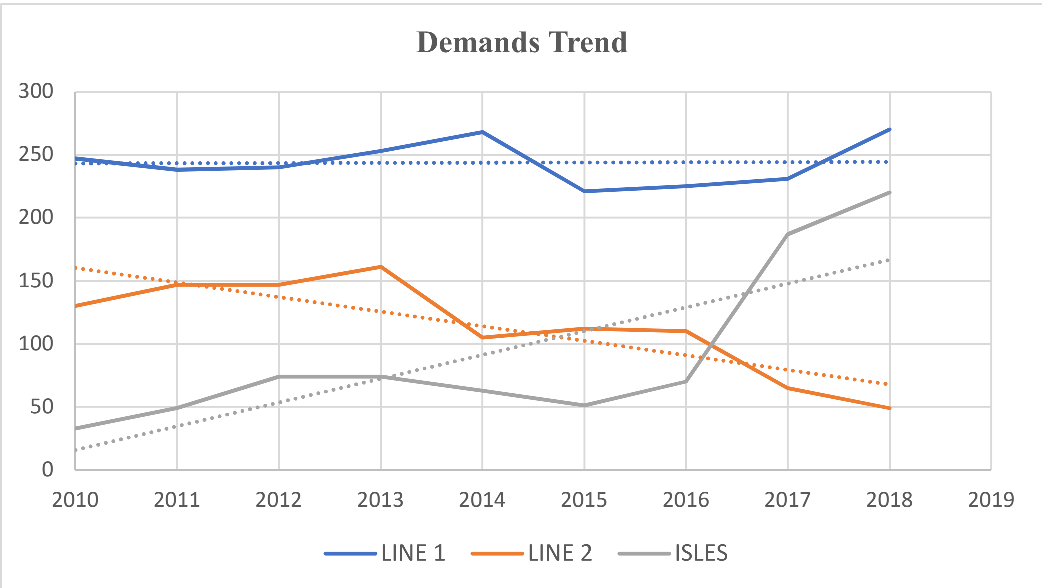


Figure 6.1 Demands trend of the machines in the Line 1 and 2, and in the Isles.

6.1.2 Holt's Linear Trend Method

Given the presence of trends for all the machines grouped by assembly site, it has been decided to use the Holt's linear trend method that computes an evolving trend equation through the data using a special weighting function that places the greatest emphasis on the most recent time periods. These algorithms are useful for forecasting non-seasonal time series using local trend equation, that is modified from period to period. The forecasting equation changes from period to period. The forecasting algorithm makes use of the following formulas:

$$a_1 = D_1$$

$$b_1 = 0$$

$$a_2 = \alpha \times D_2 + (1 - \alpha) \times (a_1 + b_1) \qquad \text{(Equation 6.1)}$$

$$b_2 = \beta \times (a_2 - a_1) + (1 - \beta) \times b_1 \qquad \text{(Equation 6.2)}$$

...

$$F_{2019} = a_{2018} + b_{2018} \qquad \text{(Equation 6.3)}$$

Where:

a_n = Y-intercept for the n-th year;

b_n = Slope of the trend for the n-th year;

F_n = Forecast for the n-th year;

D_n = Demand for the n-th year;

α = Smoothing constant, that dictates the amount of smoothing that takes place and it ranges from zero to one;

β = Smoothing constant, that is the trend coefficient and it ranges from zero to one.

For the forecast for the period (n + 1)-th, the presence of the increasing/decreasing trend is taken into account, increasing/decreasing the value of the forecast of the n-th period and inserting the term b_n. The presence of the trend, represented by the term (F_{n+1} - F_n), is damped with the trend coefficient β applied to the correction of trends relative to the previous period.

The smoothing constants determine how fast the weights of the series decays. The values may be chosen either subjectively or objectively. In which, values of a smoothing constant near one put almost all weight on the most recent observations, instead values of a smoothing constant near zero allow the distant past observations to have a large influence. To select the value of the smoothing constants objectively, it is searched for values that minimize the size of the combined forecast errors of the currently available series. Three methods of summarizing the amount of error in the forecasts are available, considering n as the total number of periods:

1. The mean square error (MSE $= \frac{1}{n}\sum e_i^2$ (Equation 6.4));
2. The mean absolute error (MAE $= \frac{1}{n}\sum|e_i|$ (Equation 6.5)), also called mean absolute deviation (MAD);
3. The mean absolute percent error (MAPE $= \frac{100}{n}\sum\left|\frac{e_i}{D_i}\right|$ (Equation 6.6)).

The forecast error is the difference between the value of the series at the current period and the forecast of the current period made in the last period ($e_i = D_i - F_{i-1}$ (Equation 6.7)).

In order to evaluate the best pair of values of α and β, it has been selected to carry out simulations on the historical data by identifying the pair of values that allows obtaining the lowest mean absolute error (MAE). In this case, the procedure is simple, but it is extremely costly from the computational point of view, having to evaluate a large number of possible combinations between the values of α and β. For this reason, it has used a file Excel VBA macro, in which I have developed a VBA code, that allows running the all of the possible combinations for the smoothing constants, giving back the relative MAE. Follows the VBA code that I have developed:

```
Private Sub MAE_Click()

'Statement
Dim alpha As Double
Dim beta As Double
Dim r As Double
Dim c As Double
'Initialization
alpha = 0
beta = 0
r = 0
c = 0
'---CODE---
    'Writing the axis of the abscissas
    For alpha = Cells(3, 10) To Cells(3, 11) Step Cells(3, 12)
        Cells(9, 12 + c) = alpha
        c = c + 1
    Next alpha
    'Writing the axis of the ordinates
    For beta = Cells(4, 10) To Cells(4, 11) Step Cells(4, 12)
        Cells(10 + r, 11) = beta
        r = r + 1
    Next beta
    'MAE Simulation
    c = 0
    r = 0
    For alpha = Cells(3, 10) To Cells(3, 11) Step Cells(3, 12)
        r = 0
        For beta = Cells(4, 10) To Cells(4, 11) Step Cells(4, 12)
            Cells(13, 7) = alpha
            Cells(13, 9) = beta
            Cells(10 + r, 12 + c) = Cells(24, 8)
            r = r + 1
        Next beta
        c = c + 1
    Next alpha

End Sub
```

Figure 6.2 VBA code for MAE in function of the α and β values.

In this simulation, the α and β values change from 0 to 1 with a step of 0,05 determining 400 different iterations, these values are connected to the previous algorithm, so they change the results of the Holt's linear trend method, that are the demand forecasts. In this simulation, it is also calculated the mean error (ME), the mean square error (MSE), and, in particular, the mean absolute error (MAE). This means that the MAE is changing during the iterations, that are 400 different values, so changing of MAE's values are rewritten after every iteration in a table, and, once the simulation is finished, it allows finding the better combination of α and β that minimizes the MAE value.

MAE		α																			
		0	0.05	0.1	0.15	0.2	0.25	0.3	0.35	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9	0.95
	0	34.25	34.15	33.74	33.08	32.25	31.31	30.29	29.23	28.16	27.10	26.06	25.05	24.08	23.15	22.27	21.43	20.64	19.89	19.57	19.57
	0.05	34.25	34.31	33.96	33.31	32.44	31.43	30.32	29.16	27.99	26.82	25.69	24.59	23.55	22.55	21.61	20.73	19.89	19.11	19.00	19.03
	0.1	34.25	34.46	34.17	33.51	32.58	31.47	30.26	28.99	27.71	26.44	25.21	24.03	22.90	21.85	20.86	19.93	19.06	18.49	18.56	18.81
	0.15	34.25	34.61	34.37	33.67	32.67	31.46	30.13	28.73	27.33	25.96	24.63	23.37	22.18	21.07	20.03	19.12	18.46	18.27	18.52	18.85
	0.2	34.25	34.76	34.54	33.80	32.71	31.38	29.92	28.40	26.88	25.40	23.98	22.64	21.39	20.23	19.28	18.62	17.95	18.20	18.59	18.95
	0.25	34.25	34.89	34.70	33.91	32.71	31.25	29.65	28.00	26.36	24.78	23.27	21.86	20.56	19.47	18.80	18.14	17.82	18.29	18.72	19.12
	0.3	34.25	35.03	34.84	33.98	32.66	31.07	29.33	27.54	25.78	24.10	22.51	21.05	19.71	19.01	18.35	17.68	17.93	18.44	18.92	19.34
	0.35	34.25	35.15	34.97	34.02	32.58	30.84	28.95	27.03	25.16	23.38	21.72	20.21	19.24	18.57	17.91	17.51	18.10	18.66	19.17	19.77
	0.4	34.25	35.28	35.08	34.03	32.45	30.56	28.53	26.47	24.49	22.63	20.91	19.52	18.82	18.16	17.51	17.68	18.33	18.93	19.47	20.56
	0.45	34.25	35.39	35.17	34.02	32.30	30.24	28.06	25.88	23.79	21.85	20.09	19.10	18.43	17.78	17.20	17.92	18.62	19.26	20.23	21.36
β	0.5	34.25	35.51	35.25	33.99	32.10	29.89	27.56	25.25	23.07	21.06	19.44	18.72	18.06	17.43	17.41	18.21	18.96	19.78	20.99	22.16
	0.55	34.25	35.62	35.32	33.93	31.88	29.50	27.02	24.60	22.33	20.27	19.05	18.35	17.72	17.14	17.69	18.56	19.35	20.51	21.76	22.95
	0.6	34.25	35.72	35.37	33.85	31.63	29.09	26.46	23.92	21.57	19.47	18.69	18.02	17.42	17.06	18.03	18.95	19.91	21.23	22.52	23.74
	0.65	34.25	35.82	35.41	33.74	31.36	28.64	25.88	23.23	20.82	19.10	18.35	17.72	17.14	17.37	18.42	19.38	20.60	21.96	23.28	24.52
	0.7	34.25	35.91	35.43	33.61	31.05	28.17	25.27	22.53	20.06	18.75	18.05	17.45	16.99	17.74	18.84	19.85	21.29	22.70	24.05	25.30
	0.75	34.25	36.00	35.45	33.47	30.73	27.68	24.65	21.82	19.30	18.43	17.77	17.21	16.91	18.15	19.30	20.49	21.98	23.43	24.81	26.07
	0.8	34.25	36.09	35.45	33.30	30.38	27.17	24.02	21.11	18.94	18.14	17.52	17.00	17.29	18.59	19.79	21.14	22.67	24.16	25.57	26.84
	0.85	34.25	36.17	35.43	33.12	30.01	26.65	23.37	20.40	18.62	17.87	17.30	16.90	17.70	19.07	20.29	21.79	23.37	24.90	26.32	27.59
	0.9	34.25	36.25	35.41	32.92	29.63	26.10	22.72	19.69	18.32	17.62	17.11	16.86	18.15	19.57	20.81	22.45	24.08	25.64	27.07	28.32
	0.95	34.25	36.32	35.37	32.70	29.22	25.55	22.07	18.99	18.05	17.41	16.95	17.04	18.63	20.10	21.41	23.11	24.78	26.37	27.82	29.03

Figure 6.3 MAE iteration for the demand forecast of the Line 2.

Employing the Holt's linear trend method and this VBA code, I have been able to forecast the demand for 2019 of the homogenizing machines based on where they will be assembled, minimizing the mean absolute error selecting the better smoothing constants.

Table 6.1 Line 1's Forecast Demand

LINE 1				α =	0.9	β =	0.05
Period	Demand	a_n	b_n	F_n	$e = D_n - F_n$	$\|e_n\|$	e_n^2
2010	247	247	0.00	247.00			
2011	238	238.90	-0.41	238.50	-9.00	9.00	81.00
2012	240	239.85	-0.34	239.51	1.51	1.51	2.27
2013	253	251.65	0.27	251.92	13.49	13.49	181.92
2014	268	266.39	0.99	267.39	16.08	16.08	258.54
2015	221	225.64	-1.09	224.54	-46.39	46.39	2151.60
2016	225	224.95	-1.07	223.88	0.46	0.46	0.21
2017	231	230.29	-0.75	229.53	7.12	7.12	50.68
2018	270	265.95	1.07	267.02	40.47	40.47	1637.43
2019				**268**	2.97	16.81	545.45
					ME	**MAE**	**MSE**

The forecast demand estimated is 268 machines that will be assembled in the Line 1 in 2019. This result has been considered an appropriate result because it is similar to the last year, in which there has been an increase of the machines assembled in Line 1 due to the improvement of the cycle time, thanks to the redesign that was done in 2017.

Table 6.2 Line 2's Forecast Demand

LINE 2				**α =**	0.55	**β =**	0.9
Period	**Demand**	a_n	b_n	F_n	$e = D_n - F_n$	$\|e_n\|$	e_n^2
2010	130	130	0.00	130.00			
2011	147	139.35	8.42	147.77	17.00	17.00	289.00
2012	147	147.34	8.04	155.38	-0.76	0.76	0.59
2013	161	158.47	10.82	169.29	5.62	5.62	31.58
2014	105	133.93	-21.01	112.92	-64.29	64.29	4133.10
2015	112	112.42	-21.46	90.95	-0.92	0.92	0.86
2016	110	101.43	-12.03	89.39	19.05	19.05	362.78
2017	65	75.98	-24.11	51.87	-24.39	24.39	595.07
2018	49	50.29	-25.53	24.76	-2.87	2.87	8.22
2019				**25**	-6.45	16.86	677.65
					ME	**MAE**	**MSE**

The forecast demand estimated for the Line 2 is 25 machines for 2019. This result follows the last trend about these types of machines that are done in this line, and it is correct, also because when this line was designed to assembly high customized machines, but today at the moment of the planning they are put in the Isles, if they are available, because in Line 2 it would not be respected the takt time, in fact it needs a well-studied renewal.

Table 6.3 Isles's Forecast Demand

ISLES				α =	0.95	β =	0.3
Period	**Demand**	a_n	b_n	F_n	$e = D_n - F_n$	$\|e_n\|$	e_n^2
2010	33	33	0.00	33.00			
2011	49	48.20	4.56	52.76	16.00	16.00	256.00
2012	74	72.94	10.61	83.55	21.24	21.24	451.14
2013	74	74.48	7.89	82.37	-9.55	9.55	91.23
2014	63	63.97	2.37	66.34	-19.37	19.37	375.15
2015	51	51.77	-2.00	49.77	-15.34	15.34	235.30
2016	70	68.99	3.77	72.75	20.23	20.23	409.40
2017	187	181.29	36.33	217.61	114.25	114.25	13052.09
2018	220	219.88	37.01	256.89	2.39	2.39	5.69
2019				**257**	16.23	27.30	1859.50
					ME	**MAE**	**MSE**

The forecast demand for the Isle is 257 machines for 2019. This result determines a huge increase in these complex machines because it follows the last trend. So, it would seem too much high, but this result is perfect for what it will happen in the assembly area, because it is already planned to realize a sixth Isle, in order to grow the productivity and to help the production to respect the delivery dates and to accept all of the demands that the market does for very customized machines. Also, as I said in the previous paragraph, most of the machines that should be assembled in the Line 2, they will be realized in the Isles. Thus, I consider more than valid this forecast.

Therefore, the forecast productivity for 2019 for these areas will be of 550 machines, 11 machines more than 2018. In fact, the forecast done takes precautions, because the positive productivity trend of the last three years productivity is equal to the 15%, instead of for this forecast is less than the 5%, so it is an underrated forecast. That means that it is more likely that the demands increase instead of decrease, that brings to the system of automated oil distribution more economic advantages, that determines a faster payback.

Using the historical demands, they have been identified the seasonal factors, in order to get seasonalized forecasts, that will be useful to determine the number of machines that will be assembled in Winter. Follows the seasonal factors identified based on where machines are assembled:

Table 6.4 Seasonal Factors

	Winter	Spring	Summer	Autumn
LINE 1	27%	24%	17%	31%
LINE 2	25%	23%	23%	29%
ISLES	28%	23%	27%	22%

6.2 Economic Saving

Once it has been determined the forecast demands, they will be used to estimate the economic saving that the system of automated oil distribution could give in terms of the time savings to realize the filling operations, management costs, performances improvement, non-compliances, and time wasted.

6.2.1 Production Saving Time

It has been used the data collected during the Measure phase, about the time needed to realize the filling operation in Line 1, Line 2, and in the Isles. During this phase, it has come out that are done, in different places, the same types of operations, with the only difference that is the time needed for these operations. Regarding the wasted time going to take and bring back the cart from its place, that for the isles is higher than for the lines, due to the much distance between the isles and the FIFO area in where the carts are placed. Instead of the elementary operations, they are realized at the same time.

On doing this analysis of the savings time, it has been assumed the impact of the implant that could have on the ordinary filling operations. So, for all of the filling operations that were measured it has been picked the operations that the system could affect, and it has been done a comparison between the current times needed, the AS-IS scenario, and the future time needed, the TO-BE scenario, that they have been supposed. The time needed to the filling operations of the different components has not been considered as affecting aspect by the new implant, because it could be increased the speed of the filling, but in order to give an appropriate and reliable economic analysis to the management it has not taken into account, also developing a worst-case analysis it has been considered that the filling performance will be the same of the AS-IS scenario. The savings, due to a filling performance improvement, will be possible to measure and to determine only in the design phase, in fact this aspect will be considered in the Control phase once the implant will be realized and it will work properly, when it will necessary to verify the real performances and impacts of the system.

- **Line 1 and Line 2**

  The workstation 3 of the Line 1 and the workstation 2 of the Line 2 are at the same distance from the FIFO area to take the oils handling carts, so it has been assumed similar the time needed for the filling operations for Line 1 and Line 2 and for this reason they have been aggregated in the same time-saving analysis. It has been defined the means time for the operations that have been considered that the system of automated oil distribution will affect and for each of these operations it has been supposed the time that the worker will take to do this operation using the new system. The relatives time to bring and put back the carts are supposed to be, for the TO-BE operations, the time needed to take the nozzle from the dispensing point and to put pack the nozzle in the dispensing point.

  Then, it has done the difference between the AS-IS time and the TO-BE time in order to define the savings time. Once obtained this result, it has been used to determine the economic savings that this saving of time gives. Being an analysis of the homogenizing machines assembled in Line 1 and Line 2, it has utilized the sum of the forecast demand for the Line 1 (268 machines) and Line 2 (25 machines). Finally, in order to determine the economic savings, the time saved from the cycle time of the machine, that is 0.08 $\frac{h}{machine}$, it has been multiplied by the 293 machines and by the hourly pay wage of the employees, that is 48 $\frac{€}{h}$, so it has determined an economic saving of 1,094 $\frac{€}{year}$.

Table 6.5 Total Savings Time for Line 1 and 2

AS IS operation done in the Lines	Duration of AS-IS operation [sec]	Duration of TO-BE operation [sec]	TIME SAVED [sec]
Bring the cart with the body oil closed to the machine	50	10	40
Connect the compressed air to the nozzle	30	0	30
Disconnect compressed air and nozzle removal	10	0	10
Bring the cart of the transmission body oil back	35	5	30
Bring the cart with the gearbox oil closed to the machine	40	10	30
Connect the compressed air to the nozzle	5	0	5
Disconnect compressed air	10	0	10
Bring the cart of the gearbox oil back	35	5	30
Bring the cart with the hogsheads oil closed to the machine	40	10	30
Connect the compressed air to the system of tubes	5	0	5
Disconnect compressed air	20	0	20
Bring the cart with the hogsheads oil back	40	10	30
Come back at the workstation	10	0	10
TOTAL TIME SAVED (in hours per machine)			**0.08**
ECONOMIC SAVED (in € per year)			**€ 1,094**

- **ISLES**

It has been followed the same reasoning in order to determine the economic saving for the 257 machines that have been forecasted for the Isles. Regarding the times needed for bringing and putting back the oils handling carts, they have been increased a bit more than the data collected during the time detections because the Isles are placed in different positions in the assembling area, and the Isle 1, that has been the Isle that was object of the detection of the times, is the closest to the FIFO area than the others, so, for this reason, these data have been increased a bit in order to utilize a more reliable and realistic meantime. Anyway, it is an underrated meantime, thus it is still an analysis underrated, and it is a precautionary estimation.

It is important to underline that, in both cases, the connection and disconnection of the compressed air will be removed by the new system, because it will be already connected to the compressed air implant.

So, it has determined the saved time from the cycle time of the isles machines, that is $0.11 \frac{h}{machine}$, then it has multiplied by the 257 machines and by the hourly pay wage of the employees, and it has obtained an economic saving of $1{,}336 \frac{€}{year}$. That, of course, it is higher than of the line's machines, due to the meters needed to take the carts.

Table 6.6 Total Savings Time for the Isles

AS IS operation done in the Isles	Duration of AS-IS operation [sec]	Duration of TO-BE operation [sec]	TIME SAVED [sec]
Bring the cart with the body oil closed to the machine	75	10	65
Connect the compressed air to the nozzle	30	0	30
Disconnect compressed air and nozzle removal	10	0	10
Bring the cart of the transmission body oil back	50	5	45
Bring the cart with the gearbox oil closed to the machine	55	10	45
Connect the compressed air to the nozzle	5	0	5
Disconnect compressed air	10	0	10
Bring the cart of the gearbox oil back	50	5	45
Bring the cart with the hogsheads oil closed to the machine	55	10	45
Connect the compressed air to the system of tubes	5	0	5
Disconnect compressed air	20	0	20
Bring the cart with the hogsheads oil back	55	10	45
Come back at the workstation	20	0	20
TOTAL TIME SAVED (in hours per machine)			**0.11**
ECONOMIC SAVED (in € per year)			**€ 1,336**

6.2.2 Management Costs

In terms of management costs, that the system of automated oil distribution could affect, it regards the savings in the buying of new pumps. Because, during the Define phase, it has come out that in Winter the production manager always buys 2 or 3 pumps due to the breaking down of the pumps that are in in the barrels or in the IBC. After an accurate checking done with also the supplier, it was discovered that the pumps of the barrels and IBC stocked outside of the establishment break down due to the cold weather that makes the oils denser, so less processable by the pumps. In fact, for this reason, it wants to take an insulated container, in order to avoid these problems and to give an economic saving.

So, the economic saving due to the saving of the management costs it has been estimated looking at the historical data of the pumps that in Winter were been substituted: 3 pumps in 2015, 4 pumps in 2016, 2 pumps in 2017. It has been assumed two pumps that break down in Winter, not 3 to give an underrated analysis that is not considering all of that broken downs due to the cold weather. Knowing the cost of 400 $\frac{€}{pump}$, the management costs saved determined by this project are of 800 $\frac{€}{year}$.

6.2.3 Performances Improvement

The implementation of this new filling technology will determine a changing in the current filling phase because it will be modified the operations that the worker is used to do during the filling. In particular, the workers once they will have started the filling of the body, in which they will set the quantity of the necessary oil previously thanks to the presettable feature, they will not stay there keeping the nozzle until the body it will be filled, but they will leave the working nozzle inside the body and they will start filling up the gearbox. This operation will be possible thanks to the type of nozzles that will be bought, that they will have the feature that allows to the nozzle closing automatically the valve stopping the dispensing. This means that it will be realized the filling of the gearbox in the meantime the body will be filling up, giving a performance improvement that allows reducing the time needed to the filling of the machine, so a reduced cycle time. The operation of the gearbox filling cannot be realized leaving the nozzle inside the gearbox, due to the complex architecture of the gearbox and to the need of visual inspection by the worker of the oil's level.

In order to determine the economic impact of this performance improvement, it has been utilized as filling speed for the transmission body 16.5 $\frac{sec}{L}$, that it was defined during the Measure phase, and it has been identified the average liters needed to fill a hypothetical transmission body. In order to define this value, it has been used the total number of the machines done in 2017, they have been separated based on the types of machines done because for every machine is needed a different amount of oil for the body and for the gearbox. Using these data, I have estimated the total consumption of these oil in 2017 and the mean liters needed to realize the filling of the transmission body for any type of homogenizing machine, I have done also for the gearbox because this data will be useful for the further analysis.

Table 6.7 Mean Liters for the Body and the Gearbox

Type of homogenizer	# of machines in 2017	Gearbox liters needed	OSO 150 comsuption [L]	Body liters needed	BLASIA 220S comsuption [L]
Matrix	20	64	1280	92	1840
NS5180/5132	39	52	2028	71	2769
ONE7	13	1	13	2	26
ONE15/11	35	3	105	9	315
ONE37TF	21	18	378	26	546
ONE75TF	12	27	324	31	372
NS3110/3090	84	32	2688	37	3108
NS3075/55/45	55	28	1540	32	1760
NS3037	62	14	868	27	1674
NS3030	26	10	260	12	312
NS3015/3011	50	10	500	12	600
NS2006	29	1	29	2	58
NS3006	37	1.5	55.5	3	111
TOTAL	483		10069		13491
MEAN LITERS		**21**		**28**	

So, it has been defined that the mean liters necessary for filling the transmission body are $28\ \frac{L}{machine}$, this data today should be higher because it has been estimated that demand for the big machines (Isles) will increase instead that on for the small machines (Line 2) will decrease, but being an preliminary analysis of what it will be the impact of these system, and also I do not want to overestimate the savings, in fact, I am trying to do a worst case analysis, thus I have considered correct this value. Once getting the mean liters ($28\ \frac{L}{machine}$), with the filling speed ($16.5\ \frac{sec}{L}$) and the total machines that have forecasted for the 2019 (550 machines), it has been calculated the total saved time, that is 52 hours. The multiplication should give 71 hours, but the worker when starts filling the body has to check that there are not any pouring of oil, so it has to stay near the nozzle at the beginning to be sure that everything has been done properly, so it has been assumed a check time of the worker during the filling of the body of 2 minutes, that have been subtracted to the saved time per machine. Then, they have been multiplied by the hourly pay wage of the employees (48 $\frac{€}{h}$), obtaining an economic saving of 2,508 $\frac{€}{year}$ thanks to the performance improvement gives for the elimination of the time needed for filling the transmission body from the overall cycle time, because it will be absorbed by the filling time of the gearbox.

6.2.4 Non-Compliances Reduction

Regarding the non-compliances that characterize the filling operations, the new system with the insulated container will allow, not only reducing the management costs, also keeping constant the filling speeds, because the cold weather makes the oils less fluid, provoking a reduction of the filling speed. In fact, it has been detected that in Winter the filling time needed increases of the 60%, causing a higher filling time due to the barrels or IBC that are stocked outside of the establishment. For this reason, they have been used the seasonal factors, that have been estimated during the demand forecast phase, in order to calculate the numbers of machines that will be realized in Winter 2019:

Table 6.8 Numbers of Machines Forecast for the 2019 per Season

	Winter	**Spring**	**Summer**	**Autumn**
LINE 1	268			
	27%	24%	17%	31%
	72	64	46	83
LINE 2	25			
	25%	23%	23%	29%
	6	6	6	7
ISLES	257			
	28%	23%	27%	22%
	72	59	69	57

Once it has been identified that the expected machines for Winter 2019 will be 150, it has been calculated the economic saved due to the utilization of the insulated container that it will keep constant the filling speed. So, it has been identified the surplus time needed in Winter for the filling operation of the body and the gearbox, using their mean liters necessary, comparing the time needed in Winter with the standard time, then the time due to the non-compliance of the filling speed it has been multiply by the hourly pay wage of the employees ($48\,\frac{€}{h}$), and it has been determined an economic saved of $1{,}008\,\frac{€}{year}$.

Table 6.9 Economic Saved Due to the Reduction of the Non-Compliances

Type of operation	Time needed in Winter [sec/L]	Standard time needed [sec/L]	Mean liters [L]	ECONOMIC SAVED [€/year]
Transmission body filling	26.4	16.5	28	€ 554.40
Gearbox filling	28.8	18	21	€ 453.60
			TOTAL	**€ 1,008**

6.2.5 Times Wasted Reduction

The times wasted are referring to the operations of refilling the barrels, in which the worker has to refill:

- The transmission oil barrel every time is empty, that means that he has to go outside of the establishment and filling the empty barrel with the OSO 150 of the IBC;
- The tanks system for the hogsheads oil when they are empty, so the worker has to go outside with the tank system and fill them using a jug that it is filled with the OSO 32 of its barrel.

The times wasted for doing these operations have been detected during the Measure phase, but these times need to be multiplied by the number of times that are done these operations along the year. So, it has been defined that:

- For the barrel, that its capacity is of 200 liters, and knowing the mean liters needed to fill the body (28 L), this barrel is able to fill utterly 7 machines before got empty;

- For the tanks system, when it is full there are more than 4 liters inside, and 4 liters are enough to fill 3 machines because the needed quantity is 1,5 liters (1 L for the bigger and 0,5 L for the small hogshead).

Once got these data and knowing that the forecasted homogenizing machines for 2019 are 550, it has been possible to determine the economic saved due to the elimination of these times wasted thanks to the system of automated oil distribution that will not need any more to refill the barrels, but just to substitute them once they will be empty. That is also what happens currently, but it is needed a further intermediate operation that causes just wastes of time due to the actual technology. So, the wasted time that will be eliminated will bring an economic saved of 2,152 $\frac{€}{year}$.

Table 6.10 Economic Saved Due to the Reduction of the Times Wasted

Operations of refilling the barrels	Duration of the operation [sec]	# of machines filled with one barrel	# of barrels filled in the year	ECONOMIC SAVED [€/year]
Transmission oil barrel	1080	7	77	€ 1,108.80
Tank system for the hogsheads oil	540	3	183	€ 1,320.00
			TOTAL	**€ 2,429**

6.3 Project Approving

The impact of the system of automated oil distribution will determine important savings, in fact, it has been estimated that it will allow saving 9,175 € for 2019, that it is the sum of the economic saved given by the different characteristics that this project will affect.

Table 6.11 Total Economic Saving Assumed

PROJECT IMPACT	SAVINGS [€/year]
Production saving time	€ 2,430
Management costs saved	€ 800
Performance improvement	€ 2,508
Non-compliances reduction	€ 1,008
Time wasted reduction	€ 2,429
	€ 9,175

Once it has been obtained this data, it has been done a presentation of this system of automated oil distribution to the plant manager, giving him all the information regarding this project, explaining how it will work, how it will be, and the economic impact that it will give. After this presentation, the plant manager has approved this project and he has given the go-ahead to start the request for quotes to different suppliers.

CHAPTER 7

IMPROVE

The Improve Phase is the fourth phase in the Six Sigma DMAIC cycle.

The focus of this stage is to determine and to implement the solution which is based on the analysis and on the hypothesis made in the previous phase. This phase requires determination of the KPI's that characterize this project and the solution found, testing the solutions, and assessing the outcome of the executed solution.

7.1 Economic Investment

In order to make the investment needed to implement this project, it is necessary to determine the supplier that will realize this system of automated oil distribution, that it will define the entity of the investment, and, subsequently, it needs to make the investment request to the central office in Germany, that, in case the project will outcome economic convenient for this amount of money, this project will get the approval of the investment, that it will allow its realization.

7.1.1 Request for Estimates

The phase of the request for estimates is a very important phase, because it allows making contact with someone that has experience and knowledge in what he does, and it is a useful opportunity to obtain technical feedback of what it wants to realize, in order to get information that could determine the impossibility to do a particular type of solution or that could allow doing something better and in the easier way.

In order to do an accurate and suitable phase of the request for estimates it is always suggested getting at least 2 or 3 offers by different suppliers, so to have more choice between different offers and to choose the better one with less difficulty; of course more offers are gotten and easier it will be the choice, but it is important not to waste too much time on asking for estimates once there are already enough.

For our situation this phase has not been so much easy, due to the lack presence of specialized suppliers in the Parma's area in these types of implants and, also, due to the will of finding the supplier by the end of October, in order to be able to realize the implant in the 2018. So, to realize the investment in 2018, without affecting the 2019's investments, because there has been left a precise quantity of money to be invested in this project for 2018, and there was not the will of reducing the 2019's budget.

Therefore, it has been found two different suppliers and it has been obtained the following offers from the first supplier, that for privacy has been called supplier A, and from the second supplier, called supplier B:

Table 7.1 Offer of the Supplier A

OFFER A

Description	**Cost [€]**	**Note**
Container REI 120	€ 7,500.00	Transport not included
Pumps	€ 3,100.00	
Dispensing points structures	€ 4,900.00	
Oil hoses reels	€ 5,500.00	
TOTAL FLUID DISTRIBUTION MATERIAL	**€ 21,000.00**	Discount considered
TOTAL FLUID MANAGEMENT MATERIAL	**€ 6,000.00**	Discount considered
PIPES AND INSTALLATION	**€ 8,500.00**	
TOTAL	**€ 35,500.00**	

Table 7.2 Offer of the B Supplier

OFFER B			
Description	**Quantities**	**Cost each [€]**	**Cost [€]**
Insulated container REI 120			€ 8,900.00
Front service column for 3 winders	4	€ 458.00	€ 1,832.00
Drip tray	13	€ 38.00	€ 494.00
Bilateral column for 4 winders	1	€ 1,917.00	€ 1,917.00
Oil hose reel (12m of tube)	16	€ 407.95	€ 6,527.20
Oil hose reel (10m of tube)	1	€ 300.00	€ 300.00
Pressure regulator	5	€ 30.00	€ 150.00
Oil transfer pump (medium viscosity)	2	€ 312.65	€ 625.31
Oil transfer pump (low viscosity)	2	€ 297.25	€ 594.50
Wall oil transfer pump (medium viscosity)	1	€ 277.78	€ 277.78
Wall bracket for wall pumps	1	€ 25.63	€ 25.63
TOTAL FLUID DISTRIBUTION MATERIAL			**€ 21,643.42**
TOTAL WITH DISCOUNT		20.00%	**€ 17,314.73**
Nozzle with presettable quantity	16	€ 520.00	€ 8,320.00
Tank levels management framework	1	€ 682.00	€ 682.00
TOTAL FLUID MANAGEMENT MATERIAL			**€ 9,002.00**
TOTAL WITH DISCOUNT		20.00%	**€ 7,201.60**
PIPES AND INSTALLATION			**€ 9,978.00**
TOTAL			**€ 34,494.33**

It has been considered that 2 estimates were enough, also because it was identified the offer B as the better estimate for to the higher level of accuracy in presenting their offer and for its economic. Also, it has been selected the supplier B for his major experience in these types of implants, instead the supplier A had not enough knowledge for what we needed, and it would lean to another supplier, becoming just the intermediary between us and the real supplier that would realize the implant. In fact, once this was discovered, we took contact with this supplier that he gave us a better offer, that is the offer B.

The supplier B has done a discount from the price list of the 20% and it takes charge of the transport cost for the container, which container's sizes will be 4 m × 2,40 m × 2,40 m, that is shorter in terms of length that it was predicted (4.16 m), that it is the critical dimension that determines if the container could fit or not in the individuated place. That means that it will fit easier in that place, without affects the assumptions done during the Analyze phase.

In the offer there are 4 pumps, that will be inserted inside the 2 barrels and 2 IBCs stocked inside the container, instead the other pump, it is the suction pump that will empty the body during the finishing phase, bringing back the body oil inside its IBC stocked in the container thanks a short piping system.

7.1.2 Investment Approval

Once chosen the supplier, that will take charge of the accomplishment of the system of automated oil distribution, and defined the offer, that amounts to € 34,494.33, it is needed to get the investment approval for realizing this project.

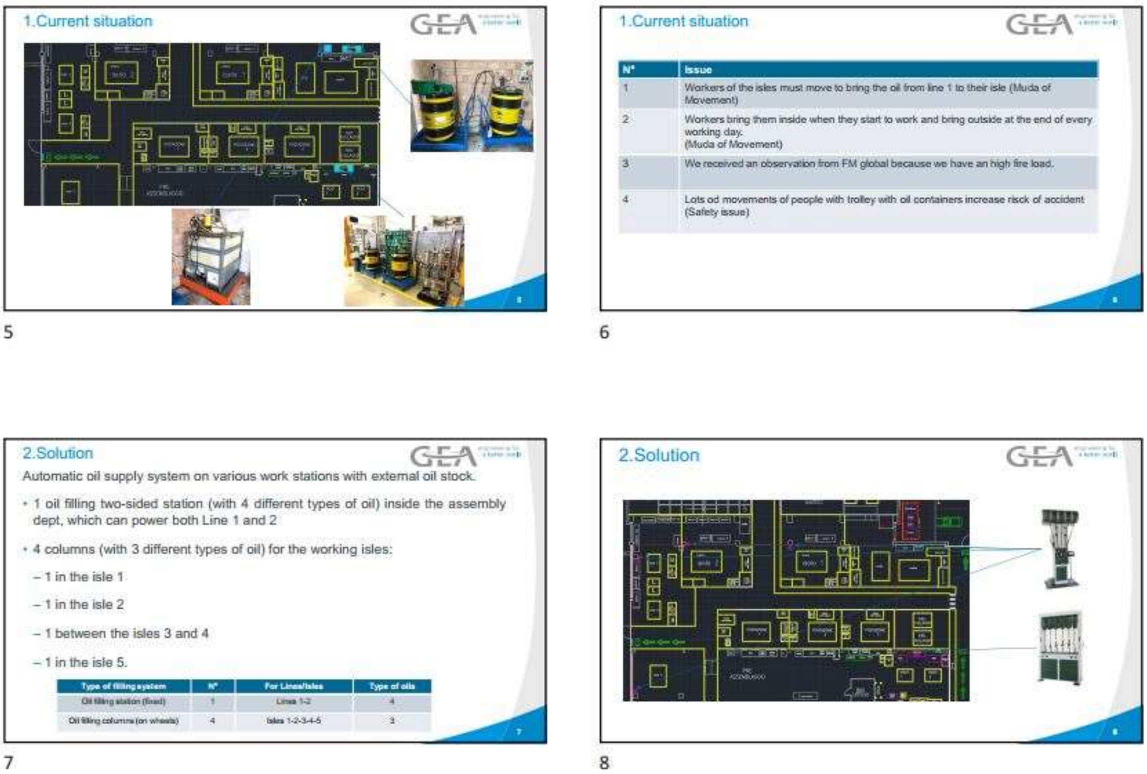


Figure 7.1 Some slides of the Business Case presentation.

In order to get the investment approval, it has been done a presentation of the Business Case of this project, that it has been presented to the responsible of the establishment Niro

Soavi in Germany. It has been explained to him the reason why this project is needed and how this project will optimize the process and improve productivity, and it has been asked to approve the investment of € 35,000 for doing this project.

In order to get this amount of money there have been showed the economic advantages that this project will give to the company, in fact, it has been calculated the Payback Period (PBP), that means the period of time that a project requires to recover the money invested in it and it is mostly expressed in years, and the Internal Rate Return (IRR), considering the following cash flow of 5 years for this project, knowing that the saving that the new implant determines that is of € 9,175 per year and that the investment required is of € 35,000:

Table 7.3 Project's Cash Flow Assumed

Year [n]	Cash flow [C_n]	Discounting factor	Discounted cash flow	Cumulative cash flow
0	€ (35,000)	1	€ (35,000)	€ (35,000)
1	€ 9,175	0.95	€ 8,738	€ (26,261.90)
2	€ 9,175	0.91	€ 8,322	€ (17,939.91)
3	€ 9,175	0.86	€ 7,926	€ (10,014.20)
4	€ 9,175	0.82	€ 7,548	€ (2,465.90)
5	€ 9,175	0.78	€ 7,189	€ 4,722.95

The discounting factor has been calculated with the following formula:

$$\text{Discounting factor} = \frac{1}{(1+i)^n} \qquad \text{(Equation 7.1)}$$

Where:

i: Interest rate, that has been assumed equal to 5%.

This discounting factor has been multiplied by the cash flow (C_n), in order to obtain the discounted cash flow, then it has been determined the cumulative cash flow for 5 years that is been shown in the following figure:

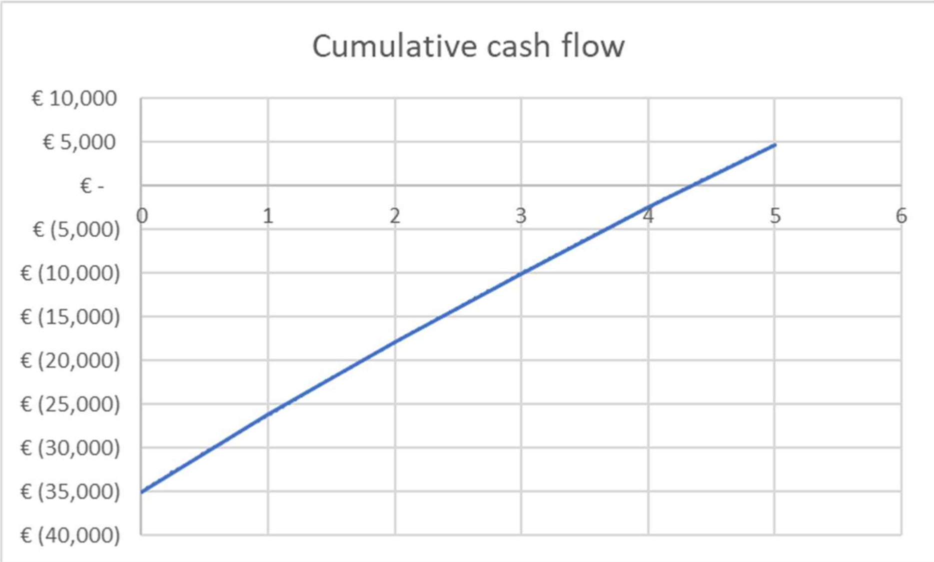


Figure 7.2 Project's cumulative cash flow assumed.

The intercept with the x-axis it is when the cumulative cash flow assumed is equal to 0, so it is the Payback Period (PBP), that it has been calculated equal to 4.3.

In order to calculate the Internal Rate Return (IRR), that is a metric used in capital budgeting to estimate the profitability of potential investments. It is a discount rate that makes the Net Present Value (NPV) of all cash flows from a particular project equal to zero. The Internal Rate Return (IRR) is given by r in the NPV's formula:

$$\mathrm{NPV} = \sum_{n=0}^{N} \frac{C_n}{(1+r)^n} = 0 \qquad \text{(Equation 7.2)}$$

Where:

C_n: Net cash inflow during the n-th year;

n: n-th year, that goes from 0 to 5;

r: Internal Rate Return (IRR).

Resolving the polynomial equation and inserting in the data, the Internal Rate Return has been calculated being 9.8%, thanks to an Excel spreadsheet.

So, the analysis carried out has indicated that the Payback Period (PBP) will be in less than 4 years and that the Internal Rate Return (IRR) will be equal to 9.8%; these results have been considered nice parameters for the approval of this project. Also, it has been analyzed not only quantitative aspects but also qualitative aspects, like the implementation of the newest technology and improving safety. In fact, I remind that this project was born in order to reduce the fire load inside the establishment and to improve safety workplace.

Giving both quantitative and qualitative aspects the project has obtained the investment approval of € 35,000, it has been asked not the precise amount of money (€ 34,494.33), in order to have a little margin in case of extraordinary works and for the workplace safety expert, who will approve the eligibility of this implant in the company.

CHAPTER 8

SYSTEM OF AUTOMATED OIL DISTRIBUTION

Once got the investment has been approved, it has been possible to realize the implant in the month of December, thanks to the availability of the supplier on working until the days before Christmas in order to finish this system. Giving us the opportunity to realize the investment in 2018, without affecting the 2019's investments.

8.1 Realization

The realization of the system of automated oil distribution has respected what it was designed during the design phase, which had been determined the position of the different dispensing points and the placement of the container. The supplier has not had any technical problem on following what had been designed. Follows the features of this implant as they have been accomplished:

8.1.1 Container

Figure 8.1 The container with the barrels and IBCs of oil.

The space, that has been done for the container, has been enough for the placement the container there, leaving also enough space for going behind the container, allowing the installation of the piping easily. The internal sizes of the container are perfect, in fact they allow placing the two barrels and the two IBCs without any problems, leaving enough space for the system of piping and, eventually, for the stocking of two other barrels, in order to realize the changing of the empty barrels quickly, just removing the pump from the empty barrel and inserting it inside the full one.

In order to change the empty IBC or barrel with the full one, the pumps are connected with the piping system with 3 meters of flexible tube, allowing, in particular for the IBC, to get out the empty IBC with the pump still inside, removing the pump and putting inside the full IBC. Realizing the changing operation in safe and easily using the forklift, that it has a lot of space for doing its movements.

8.1.2 Dispensing Points

The dispensing points have been realized respecting what was been designed and which were the needs; follow the characteristics of each dispensing point referring to **Figure 5.**:

1. The double-sided structure, that allows a two-faced used, has been constructed between the FIFO area, the workstation 3 of the Line 1, and the workstation 1 of the Line 2. At the moment of the placement of this structure, the production manager decided to place it nearer the Line 1 than placing in the middle between the two last workstations of the lines, in order to allow a better filling operation in the Line 1, that it is the line that has the highest productivity, even if the filling in the Line 2 will be a bit uncomfortable, but anyway possible without any technological problem. Anyway, the main reason of this placement is due to the need of shifting the Kanban in another place in order to give enough space for the

structure, determining the placing of the Kanban in a not optimal position, causing more distance that the employee would have done to take the component in the Kanban; so to give to the employee the shorter track to reach it from the workstation, the structure has been placed closer to the Line 1, instead of to an equal distance between the two lines. This structure supplies by the OSO 150 (body), OSO 32 (hogsheads), BLASIA 220S (gearbox), and BLASIA 220SX (ATEX), all of the different nozzles are labeled, in order to identify them, and there below them there is the drip pan, that it will gather the accidental pouring of oils of the nozzles;

2. The portal for fixing single-column equipment has been realized in the Isle 1, it supplies 3 types of oils, that are the OSO 150 (body), OSO 32 (hogsheads), and BLASIA 220S (gearbox). Every dispensing point is also provided of an emergency

Figure 8.2 The double-side structure.

button, that in case of pouring or loss of oils in the piping allows stopping the pressure inside the system in order to block the accidental losses. This portal has been placed near the column of the establishment, in order not to occupy too much space of the workstation, allowing also the fixing of the piping to the column using brackets;

3. The second portal has been realized in the Isle 2, it has been placed closed to the column of the crane, using that for the fixing of the piping through brackets. In every dispensing point has been put the table that indicates the quantity of body oil for each type of homogenizing machine;

Figure 8.3 The portal of the Isle 5.

4. The third portal has been realized between the Isle 3 and Isle 4, it has been placed between the workbenches of the two isles, without shifting anything, so without

modifying the layout of the two isles. The piping has been fixed using brackets fixed to the external wall of the establishment;

5. The fourth and last portal has been realized in the Isle 5, fixing the brackets to the external wall for the fixing of the piping.

The hose reel that has been chosen are all of them of 12 meters, in order to allow any kind of filling operation of the homogenizing machine independently from how the machine is placed in the workstation.

About the nozzles, all of them are the same model for every dispensing point, and all of them is featured by its own drip pan. The spout of the nozzles is articulable, in fact, it allows realizing the filling operation in the best possible way, and its sizes fit the dimension of the top of the hogsheads, determining to fill the hogsheads without changing the characteristics of the nozzle for the small dimensions of the top of the hogsheads. These nozzles, also, once the preselected amount has been supplied, they automatically close the valve stopping the dispensing.

8.1.3 The System of Emptying

As it has been said previously, during the finishing phases of the homogenizing machine, prior to sending to the customer its machine, its body oil is removed from the transmission body, using an old system of pump and piping connected with the IBC of OSO 150, that was placed outside of the establishment. So, in order to renew this old system and also to connect the new one with the system of automated oil distribution, during the realization of the new implant it has been realized a new system for the emptying of the machine. In fact, it has been realized a portal with a hose reel of 10 meters with the end a flexible tube of PTFE that will be connected to the hydraulic unit, which is connected with some piping to the transmission body. This system is featured with a pump (Piusi 5.5) for the sucking of the body oil from the machine, and it has been realized a piping system that during the emptying phase, the sucking oil comes back from the transmission body of the machine to the IBC of OSO 150, that it is inside the container, prior to going through a filter to clean the used oil.

Figure 8.4 The emptying

8.2 The Implant

The company has decided to trust into the experience in the realization of this type of system that the supplier has, so it is the supplier that has designed the implant in terms of what types of pumps and what type of piping to utilize. Follows the sketch of the implant of automated oil distribution, in where the different dispensing points are numbered with the same number of the **Figure 5.**, with also the emptying system connected the IBC of OSO 150:

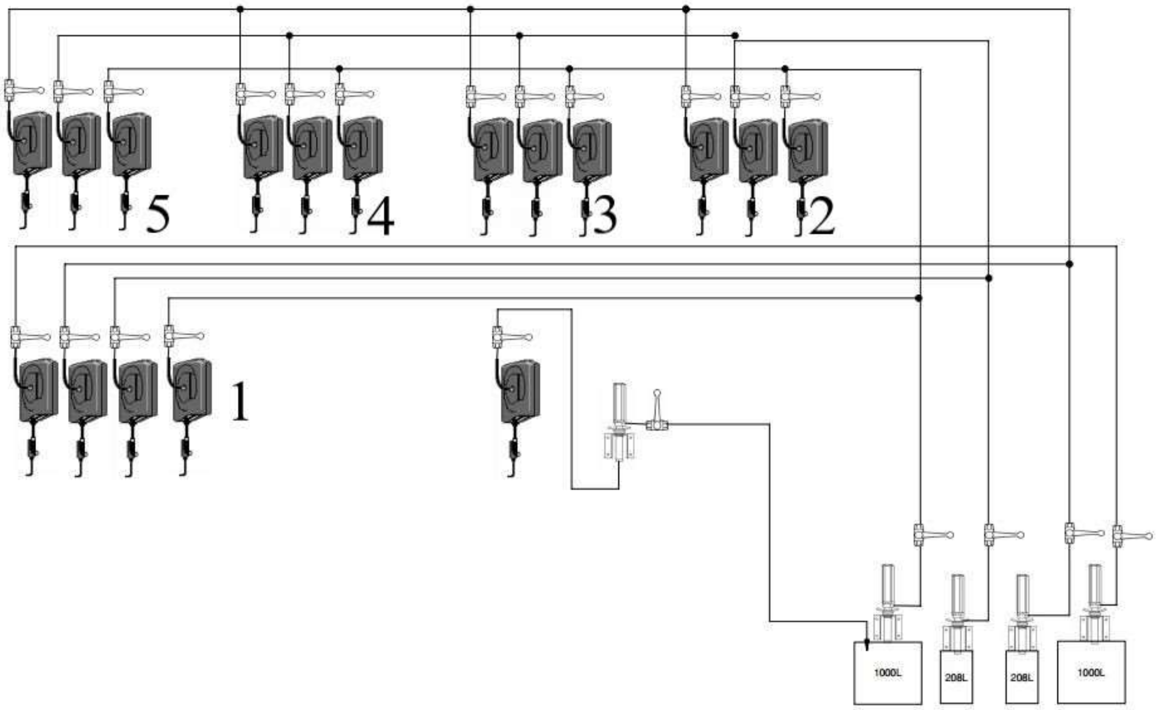


Figure 8.5 Implant of automated oil distribution.

Then, once the implant has been completed, I have verified the operating point that the implant has in every dispensing point for every type of oil, based on the pressure of compressed air that it can be set for every pump. In order to determine the optimal filling speed for every oil, which allows the better saving of time and the higher performances for the assembling process. Follow the sketch of the piping system, where it is shown the different pipings that reach every dispensing point, the piping to the dispensing point between the two lines is just for the ATEX, in order to highlight that this oil is supplied only there, but there should be sketched also the other three types of oil that supply that point:

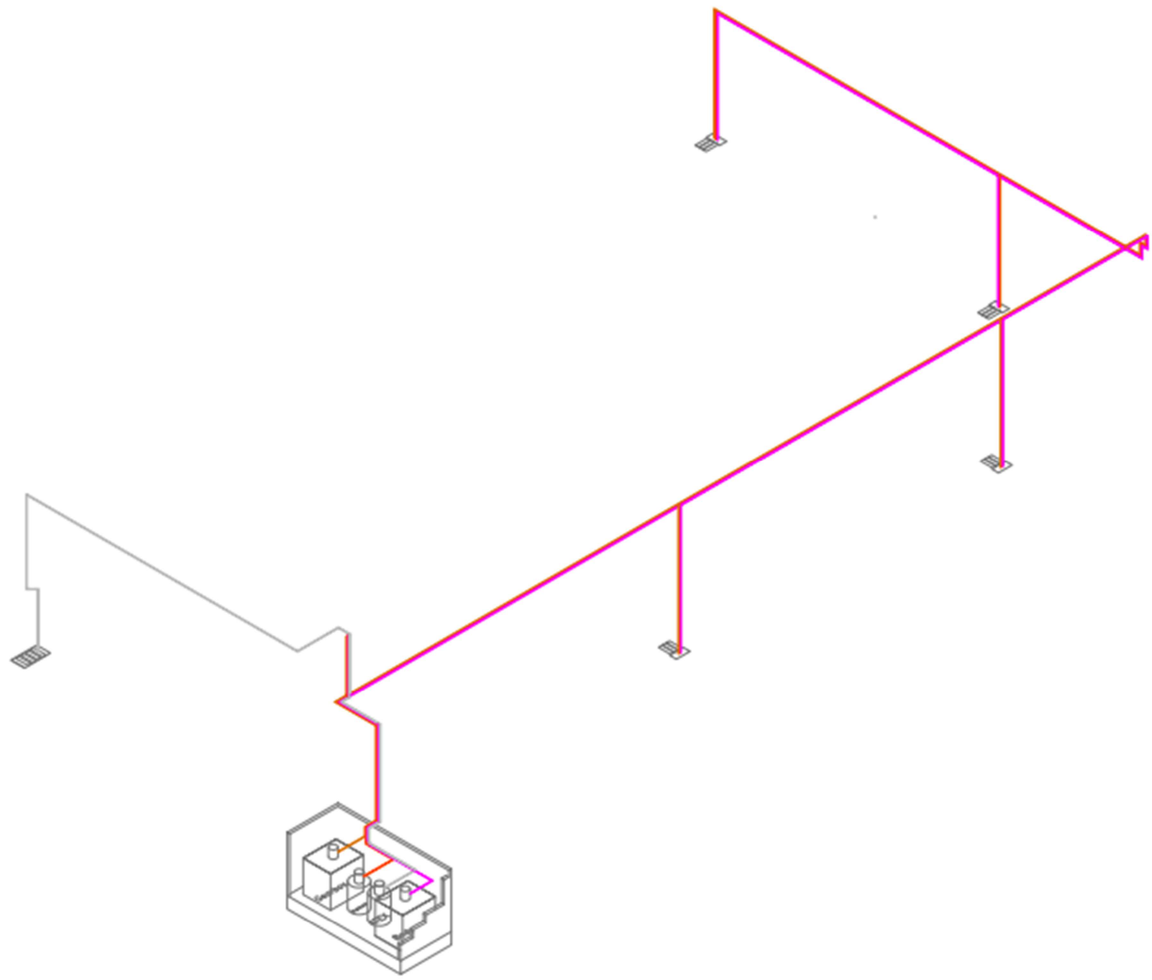


Figure 8.6 Piping system.

8.2.1 The Characteristics of The Implant

For the realization of the piping system has been utilized drawn seamless tubes cold for hydraulic circuits according to EN 10305-4, which pipes of this type are mainly used as pressure pipes in hydraulic and pneumatic systems. The tubes are made of steel E235 (EX ST37.4) of fine quality and fine grain in analogy to the standard. The pipes have anticorrosive protection and have been cold, this treatment allows obtaining excellent cold deformability. The type of pipe that has been utilized for this implant is the pipe with a nominal diameter of 28 millimeters with a tolerance of ±0.08 and a thickness of 2 millimeters, it has a density of

$1.285\ \frac{Kg}{ml}$ and a flow section of 4.52 cm^2, this type of tube can resist to a maximum pressure of 214 atmospheres. The fittings that have been utilized to connect the pipes together are the AR3 rings, which are perfectly interchangeable with all other aerofoil rings to a cutting edge or to two cone fittings 24 ° DIN 2353.

The pumps that have been chosen for the system of automated oil distribution are the Piusi 5.5 and Piusi 3.5. These pumps are designed to be used in special application fields, the pumps are manufactured using selected materials suitable to ensure high performance and durability. Featuring a soundproof protective structure, the pumps are equipped with a pneumatic exchanger and a three-stage air discharging system which, combined with the absence of reciprocating mechanical parts subject to breaks, ensure low operating noise and long working life. The double effect grants enhanced efficiency and reduced air consumption.

The Piusi 3.5 is chosen for the OSO 32 and BLASIA 220SX, for them not too much high viscosity, in fact, this type of pump is especially suitable for transferring medium viscosity oil over short and medium distances.

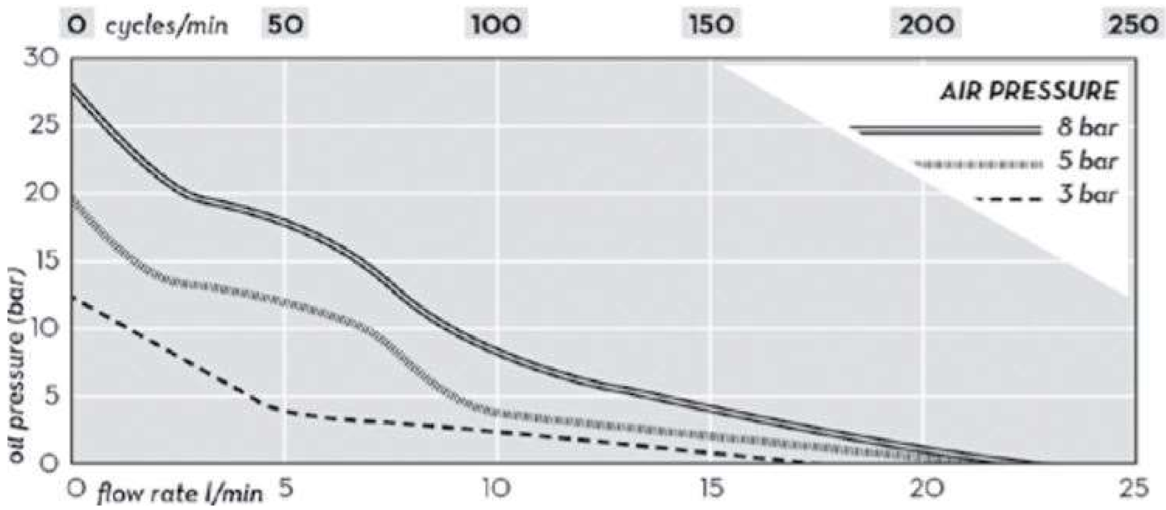


Figure 8.7 Piusi 3.5 performance curve.

The Piusi 5.5, instead, is chosen for the OSO 150 and BLASIA 220, due to their high viscosity and for the length of their piping, in fact, it is especially suitable for transferring medium/high viscosity oil over medium and long distances.

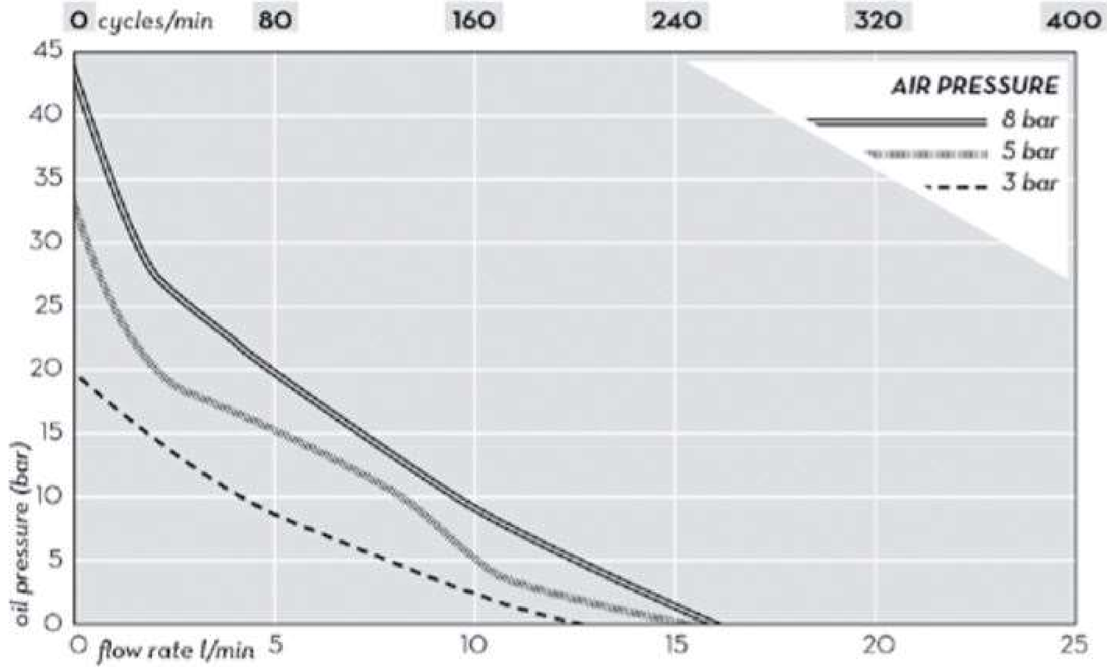


Figure 8.8 Piusi 5.5 performance curve.

8.2.2 Verifying the Operating Points

In order to determine the operating points for each type of oil, it has been chosen for this type of analysis to verify the operation of the dispensing points that they are in the most unfortunate position of the implant, depending on the type of the oil. So, it has been necessary to determine the main branches, that is the path that connects the supply to the most disadvantaged users, for each type of oil of the system of automated oil distribution, that are the following:

- For the OSO 150, the main branch is the dispensing point that is placed in the Isle 5 (that it is the number 5 in **Figure 8.5**), because the oil to reach this point has to go through the longest pipe and the highest pressure drop due to the major number of major head losses and minor head losses. The overall length estimated of this branch is of 77 meters;

- For the OSO 32, the main branch is the dispensing point in Isle 5 too, and the overall length estimated of the branch is of 78 meters;
- For the BLASIA 220S, the main branch is the dispensing point that is placed in the Isle 5, for the same reason of the OSO 150. The overall length estimated for the main branch is of 80 meters;
- For the BLASIA 220SX, the main branch is in the dispensing point between the FIFO area, the Line 1, and Line 2 because it is also the only branch that there is for this type of oil. The overall length that has been estimated for this branch is of 50 meters.

The major head losses are frictional losses, which are associated with frictional energy loss per length of the pipe depends on the flow velocity, pipe length, pipe diameter, and a friction factor based on the roughness of the pipe, and whether the flow is laminar or turbulent. In order to calculate the major head losses in each piping for each main branch it has been necessary to calculate the number of Reynolds, then to be able to calculate properly the Darcy-Weisbach friction factor. So, knowing the density (ρ) and the kinematic viscosity (ν) of the fluid (at 15°C), it has been calculated the dynamic viscosity (μ) with the following formula:

$$\mu = \rho \times \nu \; [\mathrm{Pa} \times \mathrm{s} = \frac{\mathrm{kg}}{\mathrm{m}^3} \times \frac{\mathrm{m}^2}{\mathrm{s}}] \qquad \text{(Equation 8.1)}$$

Then it has been calculated the Reynolds number with the formula:

$$\mathrm{Re} = \frac{\mathrm{D} \times \mathrm{u}}{\nu} \qquad \text{(Equation 8.2)}$$

Where:

D: Diameter of pipe [m] (known);

u: Flow velocity $[\frac{\mathrm{m}}{\mathrm{s}}]$, that is the ratio between the flow rate selected for the analysis and the flow section (known);

ν: Kinematic viscosity $[\frac{\mathrm{m}^2}{\mathrm{s}}]$ (depends on the type of oil).

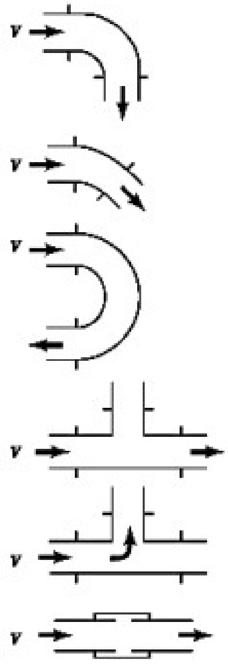
The obtained data are minor than 2.300, that means that for this diameter, these flow velocity, and types of oils, they determine a laminar flow. So, the Darcy-Weisbach friction factor (λ) has been calculated with the following equation:

$$\lambda = \frac{64}{Re} \qquad \text{(Equation 8.3)}$$

The minor head losses, instead, are local losses of pressure in the pipe flow system due to various piping components such as valves, fittings, elbows, contractions, enlargement, tees, bends, and exit. So, for each main branch has been counted the number of valves, elbows, and so on, that the oil has to go through in order to reach the disadvantaged dispensing point. For the value of the minor loss coefficient (K) of any type of piping components has been utilized from the following table:

Table 8.1 The K-Values for Many Different Bends, Joints, and Size Changes

Component	K_L
a. Elbows	
Regular 90°, flanged	0.3
Regular 90°, threaded	1.5
Long radius 90°, flanged	0.2
Long radius 90°, threaded	0.7
Long radius 45°, flanged	0.2
Regular 45°, threaded	0.4
b. 180° return bends	
180° return bend, flanged	0.2
180° return bend, threaded	1.5
c. Tees	
Line flow, flanged	0.2
Line flow, threaded	0.9
Branch flow, flanged	1.0
Branch flow, threaded	2.0
d. Union, threaded	0.08
***e. Valves**	
Globe, fully open	10
Angle, fully open	2
Gate, fully open	0.15
Gate, $\frac{1}{4}$ closed	0.26
Gate, $\frac{1}{2}$ closed	2.1
Gate, $\frac{3}{4}$ closed	17
Swing check, forward flow	2
Swing check, backward flow	∞
Ball valve, fully open	0.05
Ball valve, $\frac{1}{3}$ closed	5.5
Ball valve, $\frac{2}{3}$ closed	210



The elbows and the tees are threaded, so for every main branch has been calculated the total ζ, that it is index analogous to the friction factor that depends on the type of accidentality and on the geometric parameters. Follows the formula for the total ζ:

$$\text{Total } \zeta = \sum(\#_n \times K_n) \qquad \text{(Equation 8.4)}$$

Where:

$\#_n$: It is the number of the n-component in the main branch;

K_n: It is the minor loss coefficient for the n-component in the main branch.

Using this formula, it has been possible to calculate the total ζ for each type of oil:

Table 8.2 Total Minor Loss Coefficient for Each Type of Oil

		OSO 150		BLASIA 220SX		OSO 32		BLASIA 220S	
	K	#	ζ	#	ζ	#	ζ	#	ζ
entrance	0.5	1	0.5	1	0.5	1	0.5	1	0.5
45° regular elbow	0.4	4	1.6	6	2.4	4	1.6	4	1.6
90° long radius elbow	0.7	0	0	1	0.7	1	0.7	1	0.7
90° regular elbow	1.5	12	18	8	12	12	18	12	18
branch flow tees	2	4	8	1	2	4	8	4	8
swing check valve	2	1	2	1	2	1	2	1	2
ball valve (fully open)	10	3	30	3	30	3	30	3	30
exit	1	1	1	1	1	1	1	1	1
TOTAL ζ			**61.1**		**50.6**		**61.8**		**61.8**

Once it has been defined for each branch the ζ_{total}, knowing: the overall length of each branch (L [m]), the nominal diameter of the piping (D=28 mm), its flow section (4.52 cm^2), the density of every oil (ρ [$\frac{kg}{m^3}$]), and the Darcy-Weisbach friction factor (λ); it has been calculated the pressure of the circuit at the exit, so the pressure of the oil that is going out from the nozzle. In order to calculate this value, it has been utilized the following formula:

$$p_{circuit} = \rho \times [(g \times (z_2 - z_1)) + \frac{Q^2 \times 8 \times \lambda}{\pi^2 \times D^5} \times \sum (L + \frac{D}{\lambda} \times \zeta_{total})] + (p_2 - p_1) \quad \text{(Equation 8.5)}$$

Where:

g: It is the acceleration of gravity that it has been assumed equal to 9.81 $\frac{m}{s^2}$;

z_1: It is the elevation at start of pipe, that it is the sum of the height of the barrel (for BLASIA 220SX and OSO 32) that is equal to 0.7 m and the height of the floor of the container 0.4 m, so it is 1.1 m; instead for the IBC (for BLASIA 220S and OSO 150) its height is equal to 1.2 m, so its z_1 is of 1.6 m;

z_2: It is the elevation at end of the pipe, that for all of the type of oils it has been assumed of 1.3 m;

$p_2 - p_1$: It is the difference of the pressure at end and start of the pipe, that they both are equal to 1 atmosphere (or less for little differences of elevation), but before the exit of the oil there is a drop of pressure of 450kPa, due to the nozzle that works as pressure regulator;

Q: It is the flow rate [$\frac{m^3}{s}$], that it is the variable that allows creating a curve of the circuit making it vary.

The curve of the $p_{circuit}$ obtained varying the flow rate, it has been put in the same graph with the p_{pump} of the specific pump utilized for the specific type of oil, in order to determine the operating point, that it is the intersection of the pump characteristic curve and of the system characteristic curve. There have been put the pump characteristic curve with the three different values of pressure, at 3 bar, 5 bar, and 8 bar. Follows the data utilized for each type of oil in order to calculate the system characteristic curve:

Table 8.3 Data of the Different Type of Oils

	OSO 150	BLASIA 220SX	OSO 32	BLASIA 220S
ζ_{total}	61.1	50.6	61.8	61.8
L [m]	77	50	78	80
ρ [kg/m^3]	889	850	870	895
ν [m^2/s]	0.000206	0.00030175	0.00004168	0.000303875
Δz [m]	-0.3	0.2	0.2	-0.3

Using this data and the formula explained above, it has been possible to determine the system characteristic curve. Follows an example of the spreadsheet utilized to calculate the $p_{circuit}$ for the OSO 32, for the other types of oils it has been utilized the same model of the spreadsheet:

Table 8.4 Example of the Spreadsheet for the OSO 32

OSO 32								
Q [l/min]	Q [m^3/s]	p Pump 8 bar [Pa]	p Pump 5 bar [Pa]	p Pump 3 bar [Pa]	p Circuit [Pa]	u [m/s]	Re	λ
0.00	0.00000	4333333	3291667	2000000	451707	0.00	0.00	#DIV/0!
0.39	0.00001	4083333	3000000	1875000	454002	0.01	8.38	7.64
1.05	0.00002	3541667	2500000	1708333	457852	0.04	22.34	2.86
1.97	0.00003	2791667	2083333	1500000	463295	0.07	41.89	1.53
2.11	0.00004	2750000	2000000	1458333	464077	0.08	44.68	1.43
2.50	0.00004	2625000	1875000	1333333	466433	0.09	53.06	1.21
5.00	0.00008	2000000	1513158	875000	481616	0.18	106.12	0.60
6.58	0.00011	1708333	1291667	666667	491440	0.24	139.63	0.46
7.37	0.00012	1500000	1208333	583333	496421	0.27	156.38	0.41
7.63	0.00013	1416667	1125000	541667	498091	0.28	161.97	0.40
8.03	0.00013	1333333	1041667	500000	500606	0.30	170.34	0.38
8.29	0.00014	1291667	1000000	458333	502289	0.31	175.93	0.36
9.21	0.00015	1083333	750000	333333	508220	0.34	195.48	0.33
9.61	0.00016	1000000	625000	291667	510780	0.35	203.85	0.31
10.00	0.00017	916667	500000	250000	513352	0.37	212.23	0.30
10.53	0.00018	791667	375000	208333	516799	0.39	223.40	0.29
11.32	0.00019	708333	333333	125000	522007	0.42	240.16	0.27
12.63	0.00021	500000	208333	0	530789	0.47	268.08	0.24
15.00	0.00025	125000	41667	0	546916	0.55	318.35	0.20
15.26	0.00025	83333	0	0	548733	0.56	323.93	0.20
15.92	0.00027	0	0	0	553298	0.59	337.89	0.19

Then, it has been done a graphical analysis in order to determine the operating point, that for this analysis it has been considered the pump characteristic curve at 3 bar, because the supplier has set the implant at this pressure and it has suggested us keeping it at this pressure, in order to protect the useful life of the pump and to avoid possible spilling of oil from the piping, because after a while without a correct maintenance the fittings could decrease their watertight.

For the economic analysis, also, it has been considered the minimum flow rate, at a pressure of 3 bar supplied by the pump, in order to do a worst-case analysis, obtaining the result of the worst scenario, in terms of flow rate.

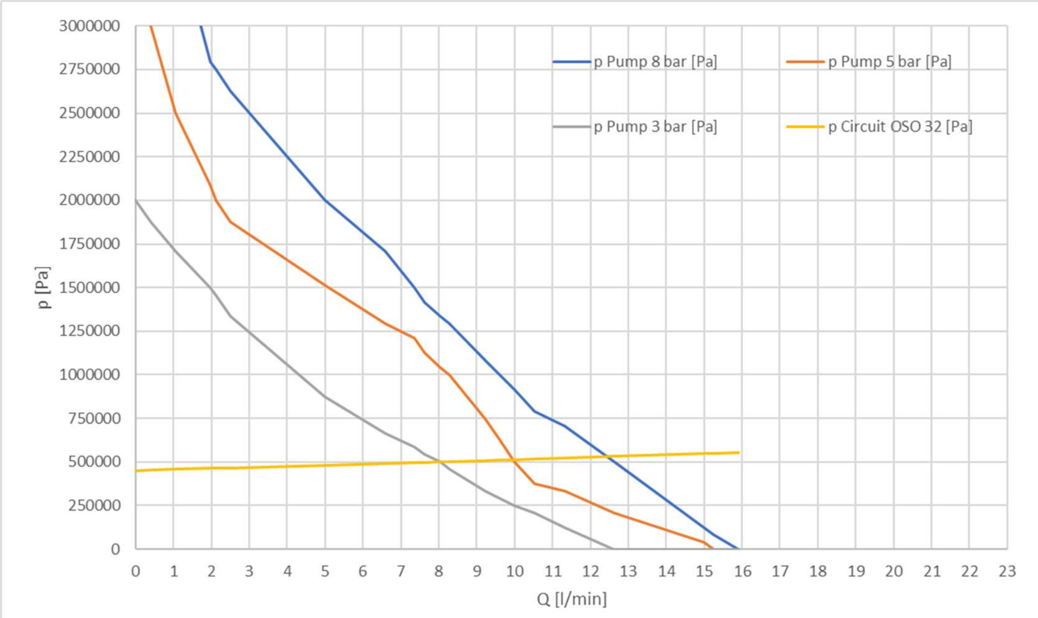


Figure 8.9 OSO 32's curve characteristics.

For the main branch of the OSO 32, that it is until the dispensing point in the Isle 5, the operating point determines a flow rate of 8.03 $\frac{l}{min}$ at a pressure of 500,000 Pa.

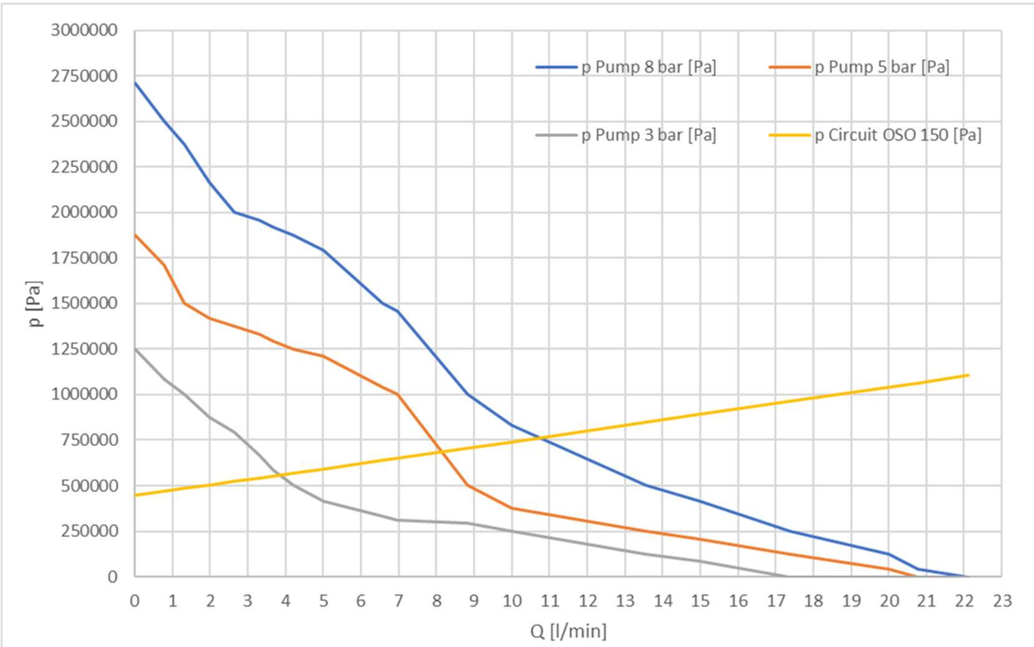


Figure 8.10 OSO 150's curve characteristics.

For the main branch of the OSO 150, that it is also until the dispensing point in the Isle 5, the operating point determines a flow rate of 3.73 $\frac{l}{min}$ at a pressure of 560,000 Pa.

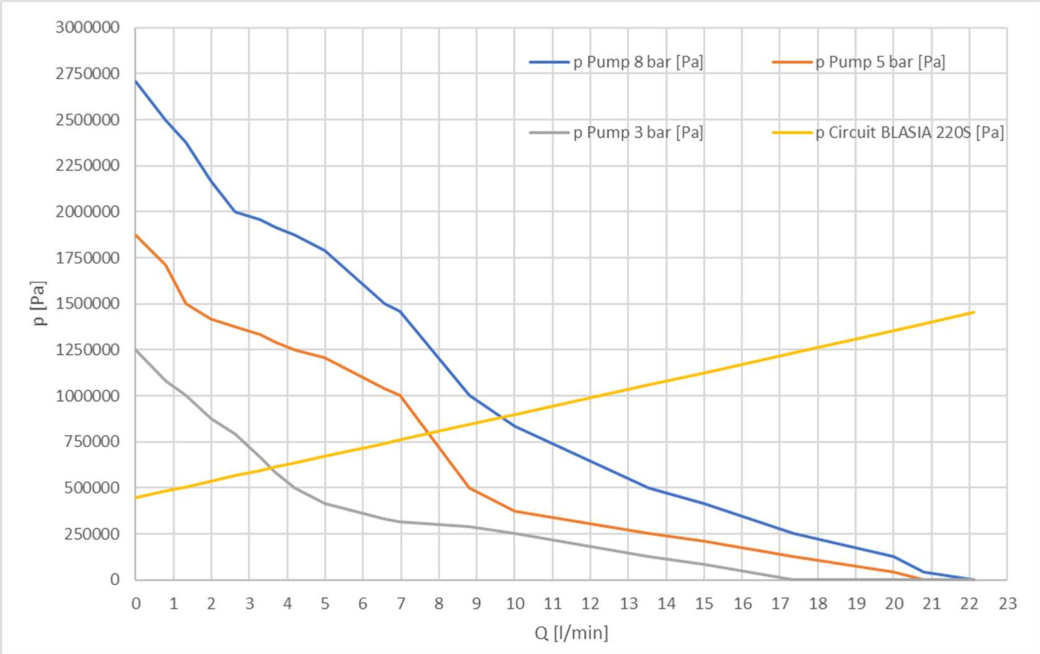


Figure 8.11 BLASIA 220S's curve characteristics.

For the main branch of the BLASIA 220S, until the dispensing point in the Isle 5, the operating point determines a flow rate of 3.64 $\frac{l}{min}$ at a pressure of 600,000 Pa.

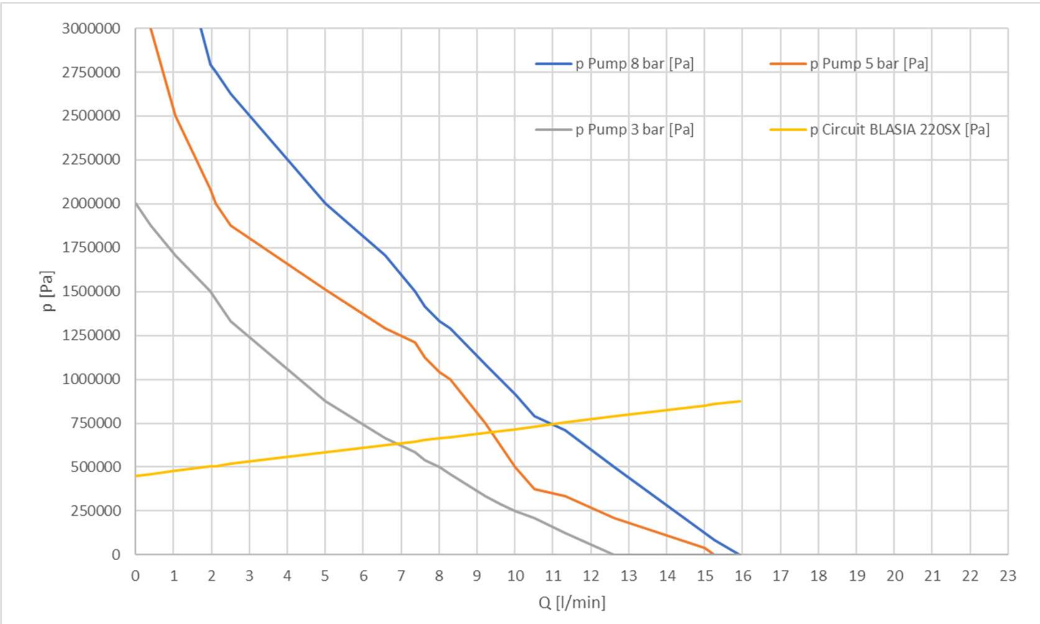


Figure 8.12 BLASIA 220SX's curve characteristics.

For the main branch of the BLASIA 220SX, that it is until the dispensing point for the two lines, the operating point determines a flow rate of 6.92 $\frac{l}{min}$ at a pressure of 630,000 Pa.

These results regarding the operating points have been compared with the real flow rates that are supplied by the different dispensing points, and after brief phase of collecting data (that a part of that will be explained in the following chapter), the data obtained through the spreadsheet can be considered reliable values on which develops the validation and to draw the conclusions for this project of the system of automated oil distribution.

Follow the characteristics of each main branch for every type of oil:

Table 8.5 Operating Points for Every Type of Oil

	OSO 150	BLASIA 220SX	OSO 32	BLASIA 220S
p [Pa]	560,000	600,000	500,000	630,000
Q [l/min]	3.73	3.64	8.03	6.92

CHAPTER 9

CONTROL

The last phase of Six Sigma's DMAIC model is the Control phase.

In the final stage, the focus is to make sure that the action item created in the Improve phase is well-implemented and maintained. There are done different activities such as checking the proper execution of the project and, also, the real effectiveness of the project is evaluated.

9.1 Validation of the Project

The final phase, that it is also very important and should not be skipped, is the validation of the project, where there is the KPIs control, that there is compared the TO-BE KPIs with the KPIs calculated during the design phase, in order to verify the reliability of the calculus that had been done previously, and the process monitoring, that consists in the control of the working of the implant and its utility for the process and for the employees.

9.1.1 Real Economic Saving

In order to verify the real impact of this system of automated oil distribution, it has been calculated the real savings that this system will give to the company. In the design phase some of the savings were been assumed, instead, the others can be considered valid in the TO-BE scenario, because they do not depend on assumptions or hypothesis.

So, the economic savings that should be recalculated and analyzed are the production saving time, because during the design phase the time needed to realize different the filling operations for the TO-BE scenario had been assumed, and the performance improvement, because during that analysis it was not considered the possibility of the improvement of the filling speed due to the new filling technology, also because it was not sure that it would be an improvement of the filling speed. Instead the savings calculated due to the management costs, non-compliances reduction, and time wasted reduction are considered still valid, in particular, it has been verified that in Winter, with the new implant, the filling speed is almost the same of the filling speed calculated from the operating points using the characteristics curves, so it has been confirmed the savings due to the non-compliances reduction.

Watching a filling operation done by the employee with the new system of automated oil distribution and measuring the time needed to do the new types of operations needed to fill the machine, the real production saving time has been determined. It has been followed the same process and the same logic that it was utilized to measure the time needed for the AS-IS operations. Doing this, it has been realized the Spaghetti Diagram of the TO-BE operations, that it a visual representation of the route employees take doing the filling of the machine. This chart was done in the Measure phase in order to determine the amount of not value movement that the employee did during the filling operations. Instead, in this case, it has been done in order to show the impact that this system gives in terms of not value movement. Follow the Spaghetti Diagram of the TO-BE scenario, where the colors used are the same utilized for the AS-IS Spaghetti Diagram, in fact the blue lines represent the movements done by the worker that has done the filling operations in the last workstation for the Line 1, that is its third one, the red lines represent the movement done by the worker in the last workstation for the Line 2, that is its second one, and the black lines represent the movement done by the worker in the Isle 1, these movements are almost the same for every isle, so it has been shown just the movement needed for one isle as example:

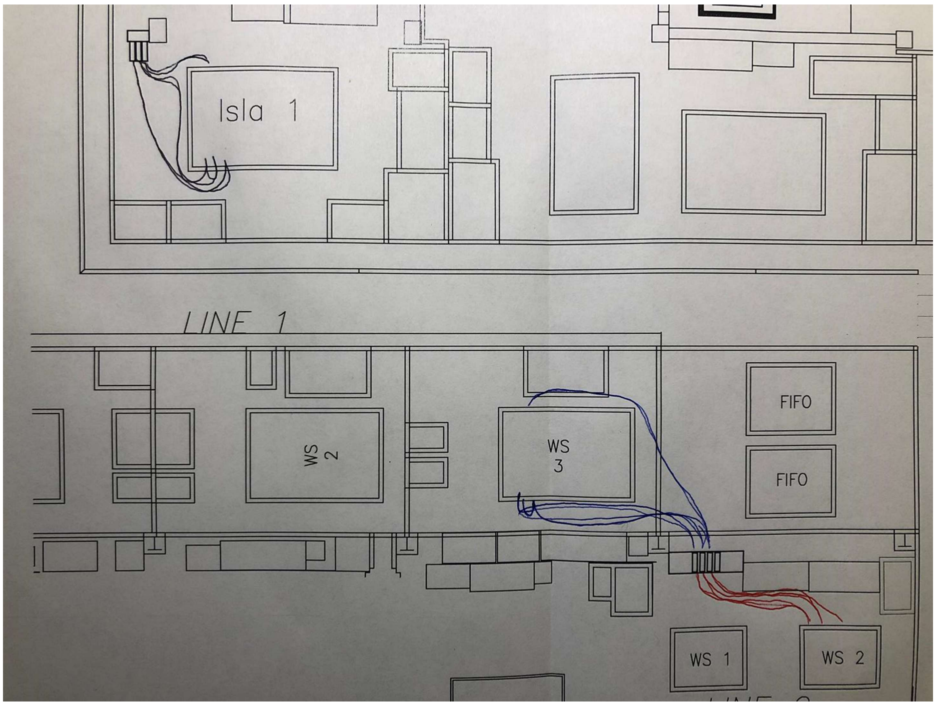


Figure 9.1 TO-BE Spaghetti Diagram.

The above figure shows how much have been optimized the movements due to the filling operations compared with **Figure 4.1**, and how the choice placement for the dispensing points have been correct. Looking to **Figure 9.1**, it can be observed that all the movements are just done to take and to put back the specific nozzle to the closest dispensing point, keeping the worker inside his workstation, without forcing him to go away to take the barrel of oil needed. This is an important impact for the elimination of the Muda of movements, giving also a standard to the employees in terms of the movements needed every time there has to do the filling of the machine, instead before, I am talking in particular about the Isles, the worker had to go, if he was lucky, until the FIFO area to take the cart with the barrel of oil, but if he was not lucky he had to go outside to the establishment to refill the empty barrel. In this way, there are been eliminated also the Muda of movement due to the non-compliances, because this problem it will not deal by the employee that has to stay in his workstation, but by the responsible supply.

Follow the time detected for the Line's machines and for the Isle's machine, that, of course, is the same, being the dispensing points at almost the same distance by their supplied workstation. These times are compared with the AS-IS's time, in order to determine the time saved, and the total saved time is multiplied by the numbers of machines forecasted for 2019 for the Lines (293) and for the Isles (257), and by the hourly pay wage of the employees (48 $\frac{€}{h}$).

Observe that the time needed to take the BLASIA 220S' nozzle is equal to 0 seconds, because, for the new instructions of filling given to the workers they have to start filling the transmission body, and then, during the filling of the body, they have to start filling the gearbox; so when the worker takes the OSO 150's nozzle, he takes also the BLASIA 220S's nozzle, determining the time of taking the BLASIA 220S' nozzle equal to 0 seconds because it has done consequently with the taking of the OSO 150's nozzle.

Table 9.1 Real Savings Time for Line 1 and 2

AS IS operation done in the Lines	Duration of AS-IS operation [sec]	Duration of TO-BE operation [sec]	TIME SAVED [sec]	TO BE operation done in the Lines
Bring the cart with the body oil closed to the machine	50	8	42	Go to take the "body" nozzle to the dispensing point
Connect the compressed air to the nozzle	30	0	30	NOT ANYMORE
Disconnect compressed air and nozzle removal	10	0	10	NOT ANYMORE
Bring the cart with the gearbox oil closed to the machine	40	0	40	Go to take the "gearbox" nozzle to the dispensing point
Connect the compressed air to the nozzle	5	0	5	NOT ANYMORE
Disconnect compressed air	10	0	10	NOT ANYMORE
Bring the cart of the gearbox oil back	35	6	29	Put down the "gearbox" nozzle in the dispensing point
Bring the cart of the transmission body oil back	35	6	29	Put down the "body" nozzle in the dispensing point
Bring the cart with the hogsheads oil closed to the machine	40	8	32	Go to take the "hogsheads" nozzle to the dispensing point
Connect the compressed air to the system of tubes	5	0	5	NOT ANYMORE
Disconnect compressed air	20	0	20	NOT ANYMORE
Bring the cart with the hogsheads oil back	40	6	34	Put down the "hogsheads" nozzle in the dispensing point
Come back at the workstation	10	0	10	NOT ANYMORE
TOTAL TIME SAVED (in hours per machine)			**0.08**	
ECONOMIC SAVED (in € per year)			**€ 1,156**	

The economic saving that the system of automated oil distribution gives for the Line 1 and 2 is of € 1,156.

Table 9.2 Real Savings Time for the Isles

AS IS operation done in the Isles	Duration of AS-IS operation [sec]	Duration of TO-BE operation [sec]	TIME SAVED [sec]	TO BE operation done in the Isles
Bring the cart with the body oil closed to the machine	75	8	67	Go to take the "body" nozzle to the dispensing point
Connect the compressed air to the nozzle	30	0	30	NOT ANYMORE
Disconnect compressed air and nozzle removal	10	0	10	NOT ANYMORE
Bring the cart with the gearbox oil closed to the machine	55	0	55	Go to take the "gearbox" nozzle to the dispensing point
Connect the compressed air to the nozzle	5	0	5	NOT ANYMORE
Disconnect compressed air	10	0	10	NOT ANYMORE
Bring the cart of the gearbox oil back	50	6	44	Put down the "gearbox" nozzle in the dispensing point
Bring the cart of the transmission body oil back	50	6	44	Put down the "body" nozzle in the dispensing point
Bring the cart with the hogsheads oil closed to the machine	55	8	47	Go to take the "hogsheads" nozzle to the dispensing point
Connect the compressed air to the system of tubes	5	0	5	NOT ANYMORE
Disconnect compressed air	20	0	20	NOT ANYMORE
Bring the cart with the hogsheads oil back	55	6	49	Put down the "hogsheads" nozzle in the dispensing point
Come back at the workstation	20	0	20	NOT ANYMORE
TOTAL TIME SAVED (in hours per machine)			**0.11**	
ECONOMIC SAVED (in € per year)			**€ 1,391**	

Instead, the economic saving that the system of automated oil distribution gives for the Isles is of € 1,391, and the total saving due to the production saving time, that it is the sum of these two results, is equal to € 2,548.

About the performance improvement was already considered the time needed to fill the transmission body as a saved time, because the workers, now, start the filling of the transmission body, they watch that there is not any pouring of oil, that this check should take no more than for 2 minutes, and then they can start the filling of the gearbox or doing other needed operations useful for the process that are beyond the filling of oils. In fact, this saved time for every machine in 2019 determines an economic saving of € 2,508, but this is not the only aspect regarding the performance improvement, but it has also to consider the improvement of the filling speed, in particular, I have focused only on the improvement of the filling speed of the BLASIA 220S, speed that has been defined during the verifying of the operating points analysis, for the OSO 150, that there is a very little improvement (from 16,5 $\frac{sec}{L}$ to 16 $\frac{sec}{L}$), it has not been considered because its filling time needed is utterly saved, thanks to the possibility of leaving inside the transmission body the nozzle working. Instead for the OSO 32 its filling speed it has not considered because the hogsheads have a little volume and the worker in order to fill them completely without creating bubble during the supply has to control manually the supply of the oil inside the hogsheads, and the BLASIA 220SX being a not so common filling it has not been considered, because it is considered as an extraordinary filling. So, being this a worst-case analysis, it has been taken the lower value of the new filling speed of the BLASIA 220S with the new implant, that it has been calculated being 3.64 $\frac{L}{min}$, converted in $\frac{sec}{L}$, in order to determine the saved time, it is equal to 16.5 $\frac{sec}{L}$, that compared with its old filling speed (18 $\frac{sec}{L}$), there is a saving of 1.5 $\frac{sec}{L}$. Applying this saving to the mean liters needed of BLASIA 220S for any machine (21 $\frac{L}{machine}$), to the 550 machines for 2019, and to the hourly pay wage of the employees (48 $\frac{€}{h}$), it comes out that the annual saving due to the improvement of the filling speed of the BLASIA 220S is equal to € 231.

So, the economic savings due to the performance improvement are of € 2,739.

Thus, the total and final annual economic saving that this system of automated oil distribution gives to the company is of € 9,523, according to the fields of saving that have been recalculated and implemented, that determines an improvement of almost € 350 by the economic saving that had been determined during the Analysis phase, that it was equal to € 9,175. So, there will be also an improvement of the KPIs calculated previously.

Table 9.3 Total Economic Saving

PROJECT IMPACT	SAVINGS [€/year]	
Production saving time	€	2,548
Management costs saved	€	800
Performance improvement	€	2,739
Non-compliances reduction	€	1,008
Time wasted reduction	€	2,429
	€	**9,523**

9.1.2 The KPIs of this Project

According to the KPIs, that had been calculated during the Analysis phase for the development of the Business Case, in order to get the approvement of the investment, they need to be recalculated because it has been defined the final and accurate total economic saving. So, knowing that the total economic saving that has been recalculated is equal to € 9,523 per year, it is necessary to recalculate the Payback Period (PBP) and the Internal Rate Return (IRR), to find out if there is a real improvement of these KPIs.

According to Equation 7.1 to define the Payback Period (PBP) it is necessary to know the net annual cash inflow, that it has been determined equal to € 9,523 per year, and the investment required, that during the Analysis phase this value has been assumed of € 35,000, because it was an amount of money assumed and it was expected to pay, but being finished the implant it is known that the accurate value of the investment that has been necessary for this project it has been of € 34,850. To the beginning € 34,494.33, there have been added € 100 for the disconnecting and reconnecting of a battery, because it was placed where the container is placed, and € 250 for the sign of the eligibility of this implant in the company by the workplace safety expert. So, considering the following cash flow of 5 years for this project, with the new values that have been recalculated:

Table 9.4 Project's Cash Flow

Year [n]	Cash flow [C_n]	Discounting factor	Discounted cash flow	Cumulative cash flow
0	€ (34,850)	1	€ (34,850)	€ (34,850)
1	€ 9,523	0.95	€ 9,070	€ (25,780.48)
2	€ 9,523	0.91	€ 8,638	€ (17,142.83)
3	€ 9,523	0.86	€ 8,226	€ (8,916.51)
4	€ 9,523	0.82	€ 7,835	€ (1,081.91)
5	€ 9,523	0.78	€ 7,462	€ 6,379.61

Using Equation 7.1, it has been recalculated the discounting factor, assuming also for this time an interest rate of 5%, and it has been multiplied by the cash flow, in order to determine the discounted cash flow. The cumulative cash flow is been shown in the following figure:

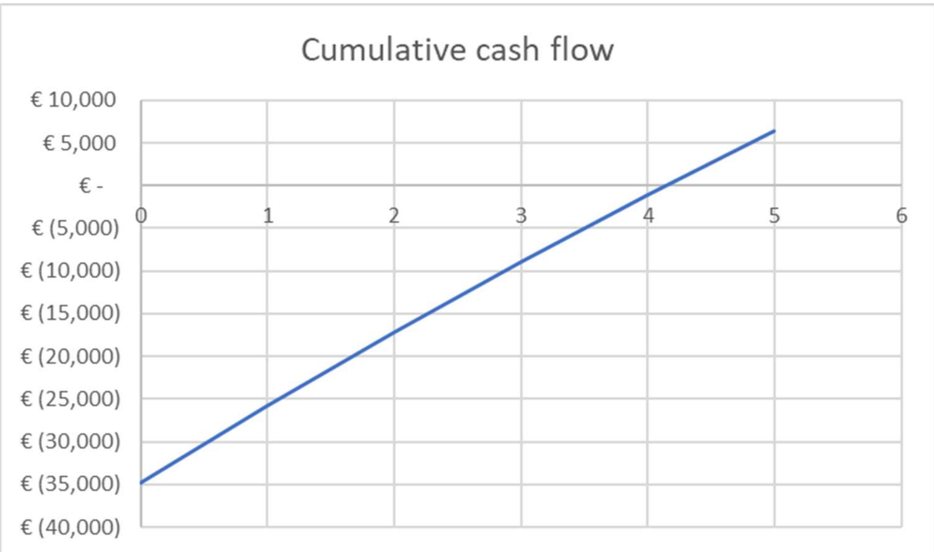


Figure 9.2 Project's cumulative cash flow.

Then, it has been determined the Payback Period (PBP), that it is the intercept of the x-axis, that is equal to 4.1 years, that it has been reduced from the 4.3 years calculated in the Analysis phase.

Instead, in order to determine the Internal Rate Return (IRR), it is necessary to use Equation 7.2, that allows determining the discount rate (IRR) that makes the Net Present Value (NPV) of all cash flows from a particular project equal to zero. So, using Equation 7.2, the Internal Rate Return (IRR) is equal to 11.4%, that it is higher than its first value that has been assumed during the Analysis phase, that was equal to 9.8%, that it is a nice result in particular for the economy of the company.

So, looking to the new KPIs it is easy to say that there is an improvement from the assumptions that were been done during the previous phases, so the worst-case assumptions that have been done are correct.

There are, also, some important impacts to the productivity of the Lines and of the Isles, because this new type of implant allows reducing the non-compliances, as well as a to be an economic saving it is, also, an increase of the productivity, thanks to the reduction of the wastes of time. In particular, the production saving time and the performance improvement help to reduce the cycle time of the homogenizing machine in the Lines or in the Isles. Being the Line 1, as I said before, the line with the highest productivity and the highest usage, in fact, it is always working on, there is an interest in discovering how much it is the reduction of the cycle time of the machine in the Line 1, in particular for the workstation 3, in order to make some considerations about the management of this last workstation. So, follows the time saving for each aspect that gives a reduction of the cycle time of the homogenizing machine:

1. The production saving time, thus the old operations that the workers used to do during the filling of the machine's components that are not any more necessary determine a time saving of 296 seconds (almost 5 minutes);
2. The filling of the transmission body done leaving inside the body the nozzle determines a time saving of 342 seconds (almost 6 minutes), considering the mean machine that needs 28 liters of body oil, and that 2 minutes are spent watching that there are not any pourings and any kind of other problems;
3. Also about the performance improvement of the filling speed for the gearbox oil, that passes from 18 $\frac{sec}{L}$ to 16.5 $\frac{sec}{L}$, determines a time saving of 32 seconds, considering the mean machine that needs 21 liters of oil for the gearbox (this value could be higher, but being a worst-case analysis I use the lower possible value).

Thus, the total saved time is of 670 seconds, that are 0.19 hours, so the cycle time, that for the Line 1 is equal to 12 hours for the mean machine that could be realized in this line, has been reduced to 11.81 hours. That means that there is a reduction in the overall cycle time of 1.5 %, but looking only to the last workstation, the third one, knowing that the tack time is of 4 hours, for the workstation 3 this system of automated oil distribution determines a time saving of the 4.75 % of the tack time, that could reduce the throughput time of the process from 12 hours to 11.8 hours if it will decide to reduce the tack time only for the last workstation in order to improve the productivity of the Line 1.

There is not any interest in calculating the reduction of the cycle time for the Line 2 (even if it is the same as the Line 1), because this line is for most time not working, because the most of the machines that were made there now are done in the Isles, and, also, for the Isles there is not any interest because they are characterized by very high cycle time, so the saving of 10 minutes does not influence much their productivity.

CHAPTER 10

CONCLUSION

After all the analysis that has been carried out and all the studies made, there are shown the final conclusions of this project, there are explained the quantitative and qualitative advantages that the system of automated oil distribution gives to GEA Mechanical Equipment – Niro Soavi.

The quantitative aspects are the following:

1. The annual economic saving determines by the new implant is of € 9,523;
2. From this saving and knowing that the investment done, in order to realize this project, has been of € 34,850, the financial KPIs are the following: the Payback Period (PBP) is 4.1 years and the Internal Rate Return (IRR) is of the 11.4%;
3. The time saved with this new technology determines a reduction of 0.19 hours by the cycle time, this means that the throughput time could be easily reduced from 12 hours to 11.8 hours changing the takt time. This is could give the start to the renewal of the Line 1, regarding its workstations and its takt time, in order to have the better design to be able to face the higher demands that come from the market for the types of homogenizing machines made in this line. In case there will not do any renewal of the layout and of the tack time, anyway it has been increased the probability of finishing in time respecting the tack time in the workstation 3 of the Line 1 and, also, in the workstation 2 of the Line 2.

The qualitative aspects, instead, are the following:

1. The reduction of the fire load due to the elimination of the barrels of oils from inside the establishment, and the elimination of the pourings of oils that could be

caused by the risky movements of the handling carts with the barrels of oils inside the establishment. So, there is an important improvement of the safety at work, that, in fact, it was the first reason that this idea was born;

2. The implant realized is of the latest technology, so there is a technological improvement that helps the continuous research to keep a very high the level of quality for the company, in order to stay always a step ahead respect the competitors;
3. This new system of automated oil distribution determines, also, an important reduction of the non-compliances, that were very common with the old filling technology, but now with the new implant there are not anymore these types of problems, so the filling operations have become simple and easy to do.

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