Escola Tècnica Superior d'Enginyeria Industrial de Barcelona

UNIVERSITÀ DEGLI STUDI DI TRENTO

MASTER THESIS

The implementation of Lean Six Sigma methodology in the wine sector: an analysis of a wine bottling line in Trentino

Master Thesis in Industrial Engineering by *Sergio De Gracia*

Directed by *Prof. Roberta Raffaelli*

Academic Year 2013-2014

Table of Contents

Index of Figures

Index of Tables

Abstract

Lean manufacturing and Six Sigma are both considered part of the business excellence. These techniques have already been implemented successfully in several areas of business in the last decades. In particular, they have been implemented in manufacturing companies due to their improvement on costs reduction, delivery on time and quality product, always thinking in a continual improvement.

This work was focused on the bottling process of a wine-making company where these management strategies are not so developed as manufacturing companies. Thanks to Mezzacorona winery there was the possibility to visit and develop a study of the bottling lines, based on data collected and provided by the winery.

In order to develop a proposal implementation strategy based on this new philosophy to the company, the bottling lines of the winery were studied from the Lean Six Sigma view. The DMAIC (Define-Measure-Analyze-Improve-Control) was the methodology used for the identification of compatible Lean techniques and strategies for the reduction of defects and rejected bottles in the winery.

The Lean Six Sigma implementation proposed was supported by an extensive literature of most of the techniques involved in both management philosophies. Afterwards, there was an introductory research of some applications in different phases of the wine-making sector. This overview theory and applications were the pillar for the comprehension of the winery methods. These were explained for developing the best proper proposal strategy. Therefore, the proposal involves all the areas involved with the bottling lines.

Thus, the efforts of this work were focused on the minimization of the line wastes such as time, overprocessing, overproduction or defects. As a result, it provided solutions for equipment configurations, standardizing work, collection of data, capability and control of processes and other little changes to achieve the best results.

Acknowledgements

I wish to thank to my tutor Roberta Raffaelli for her mentoring in this work, helping me with her experience to find the best way for the development of the thesis to achieve the best result.

Then, I would like to acknowledge winery Mezzacorona and specially Umberto Pichler, director of Production and Quality of the winery, for giving me the opportunity to study the winery, the bottling lines and all I needed for the development of the work. Umberto Pichler and all the personnel from the laboratory and bottling plant were really kind, collaborative and generous with their help all the time. The contact to the winery was thanks to Prof. Gios for giving me the chance to contact with them for the implementation in a real case.

Last but not least, special thanks go to my family, to my parents, and my sister, and also to my girlfriend. All of them were essentials with their emotional supports at every moment during my stay abroad.

Introduction

Nowadays, companies are more competitive and every detail is important if the business wants to improve its competiveness. For this, it is relevant to keep the customers satisfied offering to them what they are expecting. Moreover, the companies must upload their management techniques to be able to compete with their rivals, get better performance to do their best for their customers and improve every day.

Lean manufacturing and Six Sigma, which currently are together a unique management strategy called Lean Six Sigma, one of the best managerial methodologies applied in companies as of today. Currently in many companies, Lean Six Sigma is improving their results from the last years.

As the literature of the thesis explains accurately, Lean manufacturing focuses its efforts on the 'waste' reduction and everything that do not generate value for the customer. Then, Six Sigma dedicates to what the customer wants and to produce the best quality products with a new methodology based always on data to optimize the processes under statistical tools. Lean manufacturing and Six Sigma have different origins, the first one, in Toyota, a car company, and the second one, in Motorola, a producer of electronics and telecommunications products. Both are manufacturers that had different aims, but at the end, both strategies have become together the business excellence for its complementation.

The challenge of this project is the connection of Lean Six Sigma in the wine-making sector because is not as developed as in other areas even though it can be implemented in all kind of business. The wine sector is based on long century tradition and this is one of the most important reasons why the process is not as updated as in other manufacturing companies.

This century long tradition has made the wine-making being focused on the creation of the wine, which is the essence of the business. Nevertheless, to keep the customer satisfied, the company has to go further and optimize all the processes of the wine. To achieve the best high quality and value for the product, the final bottling phase has a lot to say because it is in the bottle where the wine reaches the clients. This last phase has to be treated with the same attention as the creation of wine.

The principal phase of the investigation has been the bottling process of the winery because it is where the company can get more benefit from the Lean Six Sigma techniques. This last phase of the wine-making involves many machines, automatic equipment, materials flow, replacement of material, line operators, managerial decisions and so on.

The reason why it is the best area of implementation is because this phase involves routine problems, unexpected problems, not optimized processes and generation of mistakes i which most are the principal objective of improving in Lean Six Sigma.

Consequently, thanks to the winery Mezzacorona, this philosophy can be implemented in the bottling process of the wine-making business as it is being implemented in other industrial and services companies. Mezzacorona has not implemented Lean or Six Sigma yet although some concepts are known by them. So, in the bottling lines of Mezzacorona, the processes can be improved by this new thinking introducing changes and new ways to collect data to enjoy all the benefits of Lean Six Sigma.

In this work, the important steps to know based on this new methodology are to know the company, its philosophy, their processes efficiencies, activities, material flows, employee's routines, customer and company requirements to develop the most effective strategy of improvement using the DMAIC methodology characteristic in Lean Six Sigma.

When a lot of information is collected, the objective is to identify wastes, because thanks of that, many production concepts can be improved such as waiting times, bad material flows, overprocessing, and defects. It will reduce the delay time of the batch production. Also big inventories of all kind of materials, overproduction or unnecessary movements or inefficient transports are using resources that are not valuated by the customers. Lean techniques like Value Stream Mapping helps to focalize where are the wastes to try to not use any resource that is not needed at that moment. Also, the understanding of the process production makes together with all the other main techniques associated with Lean that new improvement changes could maintain in the future.

Six Sigma also influences waste reduction with its statistical analysis aimed to forecast possible changes in the performance of the processes base in data. Even more, it is used for controlling and improving the real process when the variability or specifications are not the desirable by the customer or the winery. Some available variables such as the extraction force of the cork and the volume of wine filled are information provided by the winery and gives the opportunity to analyze this data to find out the best Lean Six Sigma solutions.

As a result, as Mezzacorona does not control many processes related with the number of defects, a simple methodology will be proposed to the Lean Six Sigma solution for measuring and controlling this number of rejected and defective bottles. Moreover, some changes are proposed in the current collection of data to take advantage of all the information. The number of defects in each machine can inform the company what is happening, and why these problems are occurring. For instance, if there is a maintenance problem, configuration or equipment out of order. Therefore, if the data is collected, there is the possibility to analyze, find the cause of the problems and fix the problem root. Obviously, this solution for measuring defects complements the lean waste reduction, because the improvement of rejected bottles and defects reduce the waste of time of reprocessing, waste of materials, waste of resources like employees' time and it improves the final quality performance of the product.

In conclusion, the company can improve its processes, reaching a more optimized bottling process, increasing, its competiveness against the rivals saving resources and of course, money.

Chapter 1

Lean Manufacturing

1. Lean Manufacturing

The term “lean” defined by Oxford English Dictionary in a general definition means; “thin, especially healthy so, having no superflous flat” and regarding a company; “efficient with no wastage”. Lean term inside the industry was created by a research group which wanted to reflect both the idea of the Toyota production System and to compare with the mass production of the American system. (Womack, et al., 1990). Likewise, it refers to lean manufacturing or lean production and is directly descended from the Toyota Production System (TPS) (Shah, et al., 2007).

Two illustrative definitions from Ohno, who is considered the father of Lean manufacturing and Toyota Production System (TPS) and Womack, who is the founder and chairman of the Lean Enterprise Institute, about lean production and Toyota Production System are; the basis of TPS is the absolute elimination of waste. The two pillars needed to support the TPS are the just-in-time (JIT) (see 1.5.1.) and autonomation (see 1.5.8.) (Ohno, 1988) and also the definition of Womack is “lean production uses half the human effort in the factory, half the manufacturing space, half the investment in tools, half the engineering hours to develop a new product in half the time. It requires keeping half the needed inventory, results in many fewer defects, and produces a greater and ever growing variety of products” (Womack, et al., 1990 p. 13).

Lean production is generally defined with two diferents points of view. The first one is the philosophical perspective which seeks the leading principles and the achievement of the goals (Womack, et al., 1996), and the second one refers to the practical side related with the management practices, techniques, tools that the company can monitor directly (Shah, et al., 2003).

More recently, it can be found newer definitions. One of these it relates to the two different points of view in the last paragraph; “Lean production is an integrated socio-technical system whose main objective is to eliminate waste by concurrently reducing or minimizing supplier, customer, and internal variability" (Shah, et al., 2007). Sociotechnical system refers to any practical implementation of the interrelatedness of 'social' and 'technical' issues to take care about people, society, machines and technology. All of this is integrated in the organization with the employee's participation (Walker, et al., 2007).

Nowadays critics have not found better management alternatives to the lean production and it is accepted that "lean production will be the standard manufacturing mode of the 21st century" (Rinehart, et al., 1997).

1.1. TPS in Lean Manufacturing

The beginning of this production system started in the early of the 20th century. There were two different kind of manufacting, the American and the Japanese system. In the American system, F.W. Taylor and Henry Ford formalized and structured the concepts of mass production which had started in the last years of the 19th century with the production of armament in EEUU and stream vapor in Eupope. F.W. Taylor was who began to take care about workers and their work methods (Villa, et al., 2009). Henry Ford was focused on the improvement of the efficiency and productivity and Ford Motor Company created a line worker factory. With this thoughtful H. Ford was thinking in the reduction of wasteful aspects. Ford's mass production put into action the basics in the organization based on the scientific method to process, standardization, inventory, cycle times, teams, people, movements (Zarbo, et al., 2006). Afterwards, Henry Ford executed the first mass productions, with products normalization, the use of elementary machines for one task and sequences. On the other hand, there was the Japanese system. After the Second World War, the Japanese manufacturers encountered with problems about lack of suppliers, materials, financial and human resources. It was when the lean manufacturing concept appeared (Womack, et al., 1990). Early on, Kiichiro Toyota, the President of Toyota Motor Company admitted that American auto production were producing ten times more than them. American production was focused in a mass production; on the other hand, the Japanese produced many types of cars in small quantities (Zarbo, et al., 2006). Toyota knew that they did not enjoy the economies of scale of Ford or General Motors, so, Shingeo Shingo and Taiichi Ohno. Ohno developed a new management system which was supposed by the Japanese that H. Ford might have implemented to achieve this production. This management system was the Toyota Production System (TPS) (Ohno, 1988). According to Ohno, the main goal of TPS is the cost reduction and the waste elimination, and it needs the quality control, quality assurance, and respect for humanity. He recommends the manufacture of the units needed, at the time needed of the kind needed. In this new system, Ohno valuates two basic pillars as it JIT and autonomation. Firstly, the Just in Time in Toyota changes its way of producing and decided to produce small batches manufacturing every one unit at the right time instead of forcing mass production of the same product in large quantities. Besides, others ideas were to reduce the changeover times or setups to improve the continuous production flow, because it supposed a better reaction time to the market demand (Zarbo, et al., 2006). The JIT production included in the TPS was defined with the last two ideas based on the notion of eliminating waste through simplification of manufacturing processes such as elimination of excess inventories and overly large lot sizes, which cause unnecessarily long customer cycle times (Flynn, et al., 1995). As a second pillar, Ohno includes Jidoka, which can be translated as an "automation with a human touch" and it is the notion of stopping immediately the equipment when a problem occur to do not continue producing a defective product and it includes a role for the workers (see 1.5.8.). Ohno found out that stopping the production line to solve the problem improved the performance in long run. Thus, Jidoka gives to the operators the power to stop when it is necessary "human intelligence" or thanks to sensors in the machinery. (Ohno, 1988)

In conclusion, the JIT technique and Jidoka are the base for this new discipline called today "Lean Manufacturing".

1.2. Types of waste and value added

Most of the principles explained before are good intentions and also are included in the business industries, but, it is necessary to know how to develop them. For this reason, with Lean Manufacturing they ought to analyze and measure the efficiency and productivity in the company with 'waste' and "value added" terms.

The 'waste' can be defined as any loss produced by activities which cost directly or indirectly to the company but do not add value to the final output from the point of view of the customer (Alarcon, 1997). Waste is measured in terms of costs, there are other kinds of waste that are not related to the product and they are also waste because they reduce the efficiency of the processes, equipment or employees, but these are more difficult to measure. Therefore, those activities which are consuming resources, time or space and are non-value adding activities can be defined as a 'waste'. In contrast, value adding activities cannot be defined as a waste. These activities make the product being what the customer is expecting. In other words, value adding activities transform inputs like materials or information to another superior state which is a customer requirement (Alarcon, 1997).

Regarded Ohno thinking, the present capacity is the work plus the waste. So, it is necessary to reduce waste to achieve the 100 percent of the capacity. The responsibility of the managers is to identify this excess and use the resources effectively. The original 7 non-adding value 'waste' (Japanese: 'muda') were defined by Ohno philosophy which are (Ohno, 1988; Formoso, et al., 1999);

1. *Overproductio*n: is when the production is higher than the required or it is produced before the right moment.
2. *Waiting time:* is a lack of synchronization, delayed operations or changeovers times.
3. *Transportation*: is referred to internal movements of the materials, so it should try to create the best for routes of the materials and the layout for the products.
4. *Processing*: appears when there are mistakes in the process and could be avoided.
5. *Inventory*: is excessive or unnecessary inventory and this create deteriorations and stock.
6. *Movement or unnecessary motion*; is when the workers made usefulness movements due to a bad workshop situation.
7. *Making defective product*: appears when the final or intermediate product does not achieve the requirements.

More recently, it has appeared a new one 'waste' after the 7 main wastes of Ohno;

8. *Underutilized People:* is very linked to personal motivation of the employees, because it can be wasting their creativity, skills and so on (Goodson, 2002).

In the manufacturing process the main aim is to transform the inputs into outputs adding some extra value which the customer is willing to pay for it.

The most common and useful indicators of Lean Manufacturing are linked with the wastes in the Abdul Wahab article (see below Fig 1.1.) (Abdul Wahab, et al., 2013). It can be useful to identify where the main wastes are inside the organization. The research shows that there are seven main management areas in Lean which are supplier relationship, workforce management, manufacturing process and equipment, manufacturing planning and scheduling, visual information system, product development and technology and also customer relationship. The Fig 1.1 shows how Lean wastes can be identified from the input up to the final output and its relationships.

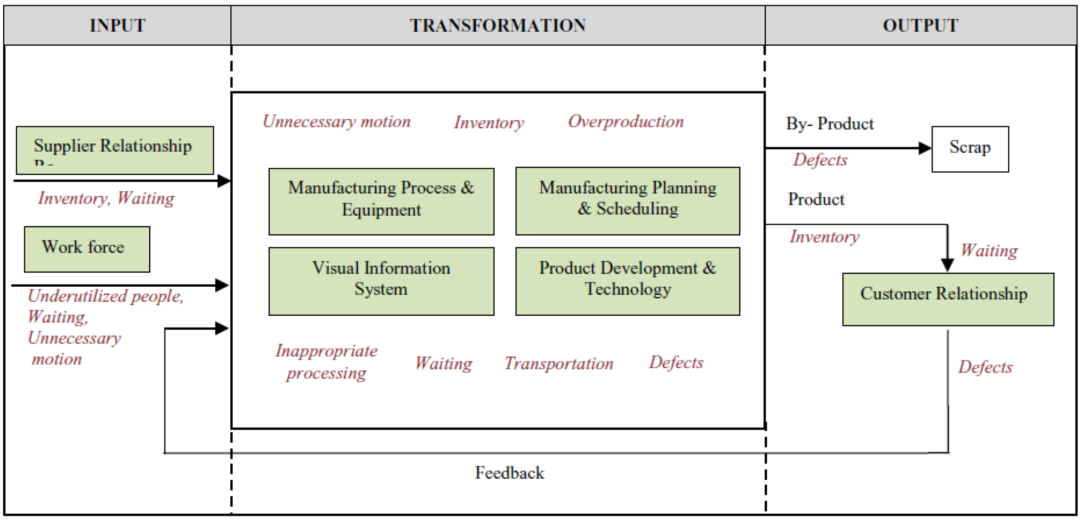


Fig. 1.1. Lean dimensions in a manufacturing system and its relation to wastes. Source: (Abdul Wahab, et al., 2013).

1.2.1. Value Stream Mapping (VSM)

Value stream mapping is the tool used to collect all the activities (value added as well as non-value added) that are needed to produce a product or group of similar products which use the same resources through the same processes and flows, starting from the raw material and finishing on the customer . The main goal is to detect all types of waste in the value stream and try to eliminate them (Rother, et al., 1999). This tool identifies lean improvements opportunities because it links all the material and information flow inside the company using standardized characteristics icons for processes, inventories, material flow and others. It is focused on worker smarter rather than harder (Plenert, 2006).

The VSM is one of the five principles of lean thinking (see 1.4.) and is fundamental to know the current state of the processes and transactions to implement lean principles and realize about the inefficiencies. It is like a picture of the real moment of how things are being done. Then, to reduce these wastes, the step is to create the future value stream mapping after the removal of the inefficiencies and this should show how it looks after the changes.

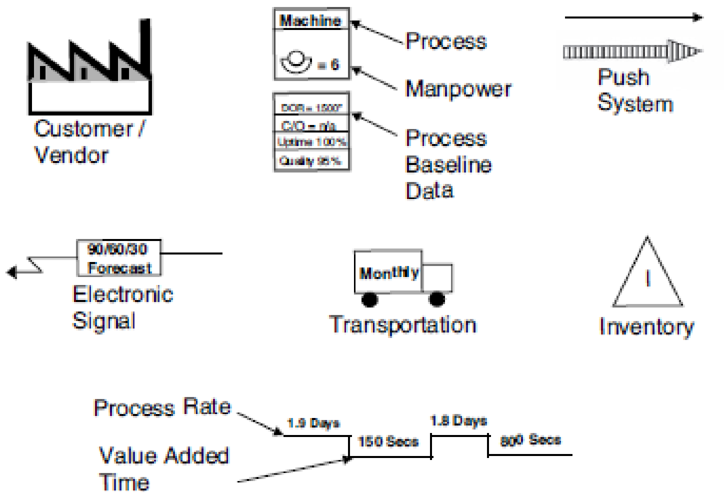


Fig. 1.2. Some value stream icons. Source: (Plenert, 2006).

At this point, the three movements; material, workers and information are shown in the map. So, the process to identify improvements is the next:

- Create the future Value Stream Map. Identify new changes about what the company thinks, but what it is actually and what is achievable.
- Develop a schedule to follow an action list of points from an improvement list.
- Classify the action list based on issues such as: impact, cost, time for the implementation, management priorities.
- Select improvement events based on the highest priority areas of improvement. For this implementation, it should be necessary the training of any tool that will be used, set goals, create an improvement team with its leaders, assign the tasks and monitor and measure the improvement.

1.3. Continual Improvement process and KAIZEN

The continual improvement (CI) has always been an idea present in the companies because the continuity on the improvement thinking the continuity of the improvements achieved. However, it was associated to the quality (see *quality* 1.5.9.) movement in the 1980s, the continual improvement is based on many other principles, organizational development systems, human relations movements, and 'lean manufacturing' (Bessant, et al., 2001).

The Japanese word Kaizen means "continual improvement", KAI-Thinking and ZEN-Good. Kaizen looks for a change in people, involving everyone from employees to managers to a better attitude to use all of their skills to achieve the improvement (Imai, 1986).

Kaizen is a method for implementing continuous improvement of business processes. It was created to get the excellence in the processes (Van Scyoc, 2008) . The improving quality, reduction of costs and delivery times are essential to reach the excellence in this continual improvement. Kaizen focus these objectives on the elimination of waste as well as lean manufacturing and promotes the improvement teams. The beginning of this approach was by the Japanese of Toyota Production System which lately worked with the idea PCDA cycle of Dr. William E. Deming, who was a pioneer of the a continuous improvement process for quality management (see 1.5.9). Consequently, the continuous improvement is based on the next thinking PDCA cycle (Plan-Do-Check-Act) which is the principles of Kaizen (Imai, 1986).

- PLAN: Analyze information, solicit ideas, and decide the best plan for improvement.
- DO: Implement the plan.
- CHECK: Gather information to prove the results the changes.
- ACT: Keep the improvements and make course corrections needed.

Obviously, this needs a continual change in the company to get better. The idea is too easy, but it is not always so easy to implement this spirit. If the company does not change his mind in how they produce and act in a long term the profits will not be the expected. For this reason, these theories or philosophies must be understood in the lean thinking (Imai, 1986).

Kaizen is consider by the Japanese companies the key to the competition and the success. Step by step, the idea is to improve getting little improvements involving the employees and managers. Of course, they must recognize the lower-level worker's opinion. Top managers ought to pay attention in the areas that can get improvements. As well, in Kaizen the decisions must be taken based on facts and data. Then, the main rule in this philosophy is to accept that always there are problems to solve, and one way could be by the recognition of the sources of waste (Van Scyoc, 2008).

1.4. Lean Thinking

Up-to-date it is known that Lean was originating from Toyota Motor Company and based on its philosophy Toyota Production System. Lean it can be defined with the reduction of the seven wastes explained before. However, Lean is much more because it is also built under a theory that the organizations are formed by processes. There are the five Lean principles (Womack, et al., 1996) which are a sequential way for organizations to add value, eliminate waste and improve thanks to a repeating continuous improvement 'kaizen' process.

The five Lean Principles (Womack, et al., 1996):

1. *Define accurately the value from the customer view and specify the value desired of the customer associated to the product, capabilities, price and time.* It is important because it might be adding value to the company but not to the end customer, so, it could be resulting the wrong product or service and generating waste.
2. *Identify the value stream for each product or service and eliminate the waste.* There are three critical activities, product definition (from design to launching), information management (from order taking to delivery), and physical transformation (from raw materials to finished goods). Identifying the value stream it is an indeed way to realize about unnecessary steps in each product and department.
3. *Make the remaining value creating steps flow.* Standardizing processes based on kaizen and also in the thinking that there is no waiting, downtime or scrap within or between the steps of production.
4. *Design and provide what the customer wants at the time the customer wants.* It means a 'pull' system (see 1.5.2.) reducing inventory 'muda', so, a JIT application, because the company does not produce any product which is not desired. The idea is to create, on the same way, a flexible production process.
5. *Pursue Perfection.* There is no end in the search of perfection in the processes but constant re-evaluation and upgrading and optimization is the way.

1.5. Factors and techniques involved in Lean Manufacturing

In this literature it has already been defined the main objective of Lean but the techniques used in the Lean Manufacturing are many. The most important are Just in time, which involved others like Kanban and Heijunka, Setup time reduction and SMED, standardization, 5S, Total Productive Maintenance (TPM), Jidoka and Total quality management (TQM)

1.5.1. JIT

The Just in Time technique has already been mentioned and it is one of the main pillars of the Lean Manufacturing. This philosophy is popular since the effectiveness appeared in the manufacturing world, and many companies in the world have been implemented successfully (Ohno, 1988; Mondem, 1993). JIT production systems need both input stock, which can be the parts, pieces or row material, and output stock already manufactured as a final or intermediate product at each stage but, these outputs have to be reduced under the "zero inventories" approach (Mondem, 1993).

JIT involves some main tools to implement Lean which are more specific about planning, organization, controlling the production and logistic chain. The first tool is the *Kanban* system and the *pull system*, which is totally related with it. The second is *Heijunka* and it is created by several tools that are used to manage the customer demand helping the aim of the JIT too. Both are explaining in the following points.

1.5.2. Kanban

Kanban system (kahn-bahn) is a Japanese word which translated it literally means “visible record” or “visible part” (Surendra, et al., 1999). This system is a pull system approach that allows the plan production to manufacture a specific rate and time in order to reload the necessary materials or products which the customer has already acquired and it is used for coordinating the stages of production (Singh, et al., 1990). This definition is the idea of Kanban, because it is defined as a Material Flow Control mechanism (MFC) and it controls the correct quantity and right time of the products needed in the production. It has been recognized in the world by its cards because it based on a card system to manage the delivery and production of parts, items, or raw material (Graves, et al., 1995). Kanban system is characterized by a card system that synchronizes the material flow of the suppliers which is the external card kanban and on the other side, in the workshops which refers to the card internal kanban. So, in the kanban card appear the exact quantity of pieces are needed from the previous stage and for this reason, the principle of Kanban system is to not produce or move until the customer sends the order to do it (Surendra, et al., 1999) because the customer is the last stage and is who starts to pull the material flow. This kanban cards are sent from the operators of one process to the operators of the preceding process.

The running of the Kanban system in a production line can be divided into different stages. In each stage there is only one machine and there should be a fixed number of ‘cards’ or ‘tags’ to achieve a smooth circulation of kanban cards in the production line. In addition, the traditional kanban system can be implemented with a single or dual card (one-card or two-cards). The classic version kanban developed by Toyota makes a distinction between production kanban and retrieval or move kanban. The production kanban indicates the number of new parts produced and ready for the next process and the retrieval or move kanban the number of parts that must be replaced (see below Fig. 1.3.) (Toyota Motor Corporation, 2014). This fact makes the need to work with two-cards system. The difference in the one-card kanban is that the system does not have two different containers to put the cards, it works moving the single card informing the previous process the number pieces or products needed. (Mondem, 1981). One-card is easier for companies which have little range of end products.

The fig. 1.3 shows how a two-cards Kanban system works and its methodology to communicate the demand to produce or materials from the preceding station to replace. The information starts from the demand, receiving a number of products to produce. This kanban goes to the production container and they produce the order. Then, when they take the needed parts from the stock point for manufacturing the order following they move the retrieval or move card to the previous stage, the outbound point, indicating the parts that has been used to be replaced again. When the previous stage has the material produced, they return the retrieval card to the inbound stock point of the following station. These cards are continuously moving to produce what is required.

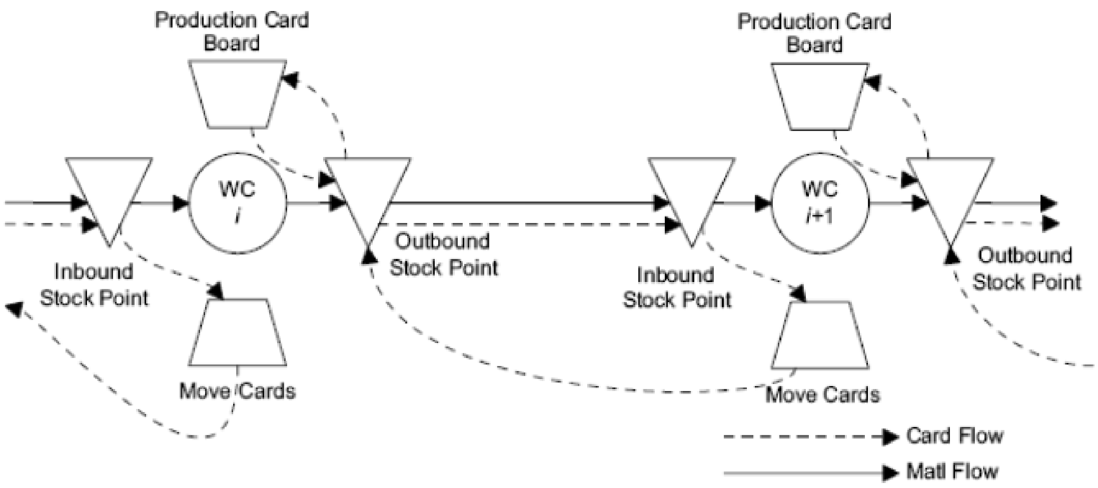


Fig. 1.3. Two-cards Kanban system. Source:(Hoop, et al., 2004)

In contrast, there is an important problem with the Kanban system because it is useful when the process is standardized, with short setup times, predictable demand, stable process times with low variety of products and a reliable supplier. Otherwise, the Kanban system will not work under effectively production and market conditions (Ohno, 1982). It is necessary to replace the material and parts in the appropriate times to not create excessive waiting and queues.

The implementation of Kanban is changing due to new adoptions because they can be more useful than the execution of the original method. There are many variations or adaptations from the original Kanban because every company has its own characteristics. Thanks to new technologies, there are some very clear examples and one of them is the e-Kanban that only changes the physical signal or tag by electronic signals. It can be used independently of the distance and improve the relationship with the suppliers and of course, the reduction of the paperwork (Lage Junior, et al., 2010).

Nowadays, most of the Japanese companies implement the Kanban system. It is considered essential to achieve the manufacturing excellence. Kanban helps to save costs due to the elimination of the overproduction and the inventory. As a result, the waste elimination in the company creates flexible work stations and reduces the waiting times (Surendra, et al., 1999).

1.5.3. Heijunka

Lean production seeks the high capacity utilization combined with low inventories. Many of the lean techniques reduce the inventories like kanban, but Heijunka minimize inventories on a different way, with high variability of production.

Heijunka technique refers to the smoothing production or leveling production (see below) and it is fundamental in the Just in Time production and an essential element of the Toyota Production System (Liker, 2004). This practice controls the variability of the product sequence during production cycle (Mondem, 1983). Therefore, the production schedule of the products is planned in a period of time with the proper sequence and the idea is to sort the orders to produce with a sequence which is relatively smooth. Their goals are to balance or level the production volume but also the mix production using the same sequence of items for every production cycle (Coleman, et al., 1994). The aim is also enhancing production efficiency by the reduction of waste, unevenness and overloading of people or equipment (Liker, 2004).

In Heijunka it is listed some principles for the uniform plant level; (1) there is a fixed and level schedule; (2) the company produces the same mix of final product or families each day, and it colud be also each hour to match it with the daily demand; (3) the production has better reaction to the changes and a reduction of upstream inventory swing; (4) there is little or no expediting or acceleration in the production. (McLachlin, 1997 p. 287). Toyota introduced this levelling production because the programme of big batches avoids a lot of changes, but when there are differences in the mass production, the problems appear. As a consequence, the programme must be the most well-balanced as possible; otherwise, the company cannot react to the problems. Factories often produce big volumes of products in a week, so, they pay overtime and stress people and equipment, and the next week they have lower orders. This management hide some problems and generate poor quality because of the unbalanced utilization of the resources. In the same way, these little changes generate uneven demand on upstream that produce the unbalance (Coleman, et al., 1994).

The Heijunka idea is to hold little finished-goods inventory. When this production is supported by Heinjunka principles, the processes have a constant flow of small lots and they generate a constant demand for upstream processes. Teece et al. (1997) talks about Heijunka and says that is a dynamic manufacturing and it can increase the competitiveness of the company when the company operates with these capabilities or routines (Teece, et al., 1997).

Leveling Production

The *production levelling* or *smoothing production* is one of the main topics inside the Heijunka. In this case, one of the better solutions is to create a mix balanced as much as they can. It tries to avoid the variability in the production programme due to the changes in the customer demand. Without the smoothing, this demand leads to waste resources in people and machine times, what it means under use of the capacities or quality problems, breakdowns and defects, because a overburdened use of them (Liker, 2004).

Following a levelling production they should manufacture small batches that it means low volume of one model with high mix model production besides the creation of families. A family of products can keep the same section plant avoiding many changes in the stages due to their similarities in the characteristics, so, it allows the higher number of changes along the shift without an extra long time. In order to produce high variety of products the creation of families helps the mix production taking advantage of the similarities in the production and reduction of times. The formation of families has to be created according to many specific attributes which represent every selected group and its criteria. Therefore, this creation can save time with the setup times for changeovers (see 1.5.5.) because of some identical raw materials, parts and so on reduce setting times (Birkmann, et al., 2007).

In the next example, it is shown some differences against the mass and Lean production to produce the demand of products (Stevenson, 2005):

- The mass producer will produce: *AAAAAAAAA BBBBBBBBBBBBBBBBB CCCCCC*
- Lean producer sequence: *AAA BBBBBB CC AAA BBBBBB CC AAA BBBBBB CC*

In the last sequence, they produce the same but the lean thinking mix the production to not create big inventories. Of course the benefits of lean and production levelling makes the possibility react better if they need to change the production plan and produce some more units more of one model and less from another. Also for example, if the customer cancels a demand of model ‘A’ at the middle of the month, the company is going to generate extra stock which it will not need for the next order because it is cancelled. In the opposite case, the company can increase the production in some units more in the sequence if the market demand is higher in the middle of the production cycle.

Additionally, there are two requirements for implementing; one is to use general machinery and equipment as a goal, and the other one, flexible and multi-skilled workers (Coleman, et al., 1994). It is because the equipment has to be useful for much variety of products and sequence them, and the workers need to be trained for the production of every model, the execution of the frequent changeover and setup configurations. As always in just in time, the quantity of products to manufacture has to be the quantity that the customer needs and also happen if it is based on the levelling production, so, the supplier has to adjust his production to orders of the customer and the supply company has to produce following the takt time (see below) to produce the quantity desired.

Takt time

Takt time is the maximum time allowed to produce a product and it is used to know what pace of production is needed to synchronize it with the pace of sales. To calculate the pace the formula is the available working time per day by the customer demand rate per day (Rother, et al., 2003). The available working time refers to the period that the machines can work. This value is the time without planned stoppages like lunch time or regular breaks or time planned for maintenance revisions. The other term, customer demand rate, is the total demand of final product regarded to the line product.

$$Takt\ Time = \frac{avaliable\ working\ time\ per\ day}{customer\ demand\ rate\ per\ day}$$

Obviously, it can also be calculated using the rate per period or interval of time in both terms like available working time per shift or month. For example, if the shift of the operator is 9h but 1h to have lunch and breaks, so, the available working time would be 8h per day, and the demand per day is 400 units; the takt time would be 0,05h/unit, it means 3 min/unit (see Fig. 1.4.). Consequently, the takt time indicates that every 3 minutes a unit must be finished from its stage, what it means that in the last stage, it will be producing a final product (if it is the last cell of the production) every 3 minutes to reach the expected demand. Moreover, inside the line production with the piece running as a continuous flow (see below *one-piece flow*), every takt time the piece or part have to end its stage where it is being manufactured to go forward to the next to achieve the number of units demanded by the customer. If the production line is sequencing more different models, it is the same but with a change in the machines' configuration. These machines will need to be adapted to the new model. At the end of the takt time, every part from all models must have finished its stage to produce the number of products at the end of the day.

The takt time is not easy, it requests a lot of effort to not stop the production and have a very quick response to the problems, elimination of downtimes and reduction of changeover times. Otherwise, delays can appear and do not obtain the output demanded.

Cellular manufacturing

Cellular manufacturing is a manufacturing approach for a layout design that includes a group of machines in which each part manufacture in the cell, it is from the same family of products. Thus, each part is processed by machines in the same cell taking advantage from the similarities. Common processes and standardization of these are benefits causes by the cellular layout (Black, 1991). With this layout design concept the company deals with the efficiency and flexibility inside the manufacturing process. This concept takes advantage of the similarities of the products, pieces, components, processes to enjoy the benefits regarded to setup time, reduced work in progress and inventory, reduced material handling costs and throughput time, improving the quality of the products and creating a simplified scheduling (Wemmerlov, et al., 1997).

The steps to design a cellular manufacturing system are; (1) cell formation, which related products are processed in the same cell because they have similarities, so these families of products can use related machines; (2) group layout, where intra-cell layout sort the machines within each cell and the inter-cell layout arranges cells paying attention to each other cell; (3) group scheduling, which plans the schedule of the families; (4) resource allocation, which match the tools, resources about material and workers and devices needed. (Wemmerlov, et al., 1986).

Inside the cell the employees can be one or more, looking for the output performance and delegating the responsibility of the planning, control, support, and improvement tasks to one or more employees. The creation of the cell is not only a simple grouping of products using group technology, it is very important to ensure that a socio-technical approach is done and where the work design between operator and machinery is structured, otherwise the cell will not be an efficiency and suitable system (Hyer, et al., 1999).

In the Fig. 1.4. there is an example of the cycle times of the parts in each stage inside the cell. The times are under the takt time which let the company achieve the expected production in normal continuous flow of production. It shows also the distinction between the machine work and the internal manual work when the machine must be stopped (see 1.5.5.).

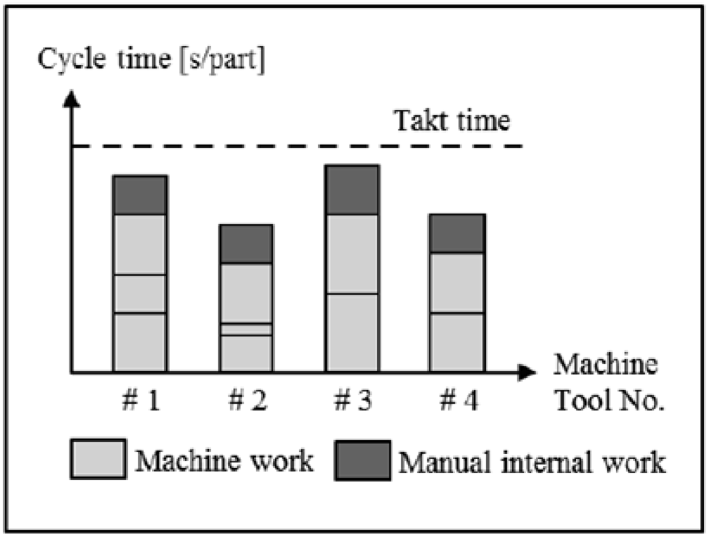


Fig. 1.4. Example of a balance Cellular Manufacturing system. Source: (Metternich, et al., 2013)

One of the main layouts of the cells appeared when the Japanese rejected the American system of specializing workers in a unique job. The Japanese trained factory workers to handle several jobs because they wanted what it is now called multiprocess handling. To do it, they developed the U-shaped cells.

The U-line layout situates the machines around a U-shaped, which improves the production performance. In the Fig. 1.5. there is the example of one-operator at the left, and two-operators at the right. The first one shows how one operator can control the entrance and the exit of the line. When a product is running in the line no one more can enter, it must come in when the current product finishes and it is pulled off the line. The cells are designed with the equipment close for easier operating and the worker chase the product from stage to stage. When there are more employees, which is the normal case, they organize the cell by stations and each worker to their station. They can sub-divide the cell and they can work by zones or stations as it is showed in the Fig. 1.5. at the right, so, every worker follows the process of a product in their station (Edwards, 1993).

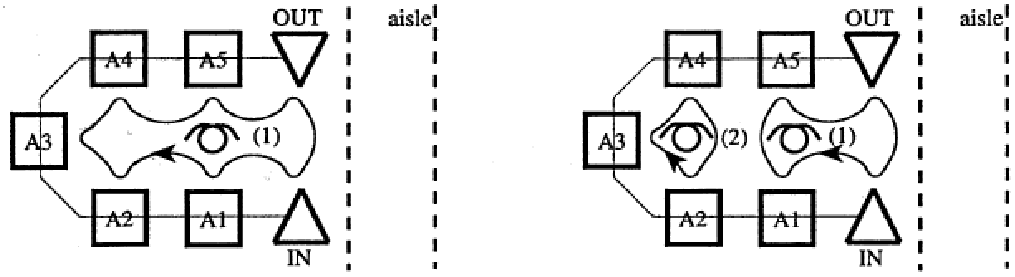


Fig. 1.5. Representation of 1-operator U-line and 2-operator U-line. Source: (Miltenburg, 2001)

Furthermore, more studies have thought about the strategies to create dynamic layout due to the market demand variability. This fact can make the company change to completely the layout if they want to continue with a proper efficiency. Strategies like modular layouts, reconfigurable layouts, agile layouts and distributed (scattered) layouts are the options of Benjafaar et al. (Benjafaar, et al., 2002).

One-piece flow

Finally, inside Heijunka and the last techniques explained, there is another concept which is fundamental in all of these, the one-piece flow.

One-piece flow refers to the idea of moving one piece at a time between operations within a work cell or product line. On the same way, produce benefits because reduce the work in process or parts on intermediate stages to the lowest level, promotes better quality and internal improvements and work balance. It has the same aim as all Heijunka techniques, because the high use of the machinery and the high production volume are not fundamental, but the Just in Time is vital because the one-piece flow helps to achieve the expected production. The aims are also the reduction of several values such as the *cycle time*, which is the time since an item starts its manufacturing process until it finishes, changeover times, cell load variation with a continuous flow and the reduction of number of cells. Therefore, it tries to maximize the products manufactured in the cell production line.

1.5.4. Standardization

The word standards and standardization are sometimes mentioned in Lean manufacturing and continual improvement methodologies. The first word *standard* is defined as "A standard is an approved specification of a limited set of solutions to actual or potential matching problems, prepared for the benefits of the party or parties involved, balancing their needs, and intended and expected to be used repeatedly or continuously, during a certain period, by a substantial number of the parties for whom they are meant” (De Vries, 1999). This definition provides a description with an appropriate level of freedom and can define much kind of standards.

Standardization specifies a process becoming widely used and accepted for its purpose by its users and it can be achieved through a formal, semi-formal, or informal process where formal and semi-formal standards are decided by a committee work (De Vries, et al., 2005).

This tool is enjoyed by most of the areas and applications, for example, tourism and hospitality, construction, health and used by Information Technologies (IT) which often manipulate data of repeatable and continuous activities and create a common language between all users and patterns to improve the customer’s use (Information Technology Industry Council, 2014) .

This concept is really important in the Toyota Production System besides it is one of the most powerful lean tools. Of course, it is also connected with the techniques already explained because most of the Lean techniques want to be able to solve the problem fast to reduce wastes like time and to behave in the same way. Standardization makes the solutions to a problem and with the idea of apply them continuously, as a result, the worker know the steps to act and can perform better, improving the safety, quality, variability, because it is not related with who executes the process.

The standardization work is the base of the Kaizen methodology that means continual improvement. Masaki Imai in his seminal work said “there can be no Kaizen without standardization” (Liker, et al., 2006 p. 111). The standardized work is a way to encourage the employees of the organization to be more efficient and produce a higher quality in their products at a lower cost. It is understood by Linker and Meier (Liker, et al., 2006) that a process must be a work which is repeatable to be carried out for being able to standardize, otherwise is not recommended to standardize. Likewise, the process should work under certain quality because it cannot be stopping continuously if the company want to achieve some profits.

The process of standardization was defined by MacInnes in eight steps (MacInnes, 2002):

1. Form improvement teams.
2. Determine the takt time.
3. Determine the cycle time.
4. Determine the work sequence.

5. Determine the standard quantity of the operator work in progress.
6. Prepare a standard workflow diagram, which shows the repeatable patterns on the process.
7. Prepare a standard operations sheet.
8. Continuously improve your standard operations.

When they create the standardized papers the steps must be identified and explained in a table for the correct implementation by the workers. The table should show the elements, work time, walk time and workflow. Then, the concept of standardizing is to not stop the continual improvement, and standardize with the next improvement (Liker, et al., 2006; MacInnes, 2002).

1.5.5. SMED (Single-Minute Exchange of Die)

In the manufacturing business, the change in the configuration settings is a common activity which is usually repeated several times per day and it is where some quantity of time is wasted. The *changeover* time is defined as "the period of time between the last good product from the previous production order leaving the machine and the first good product coming out from the following production order (see Fig. 1.6.) (Gest, et al., 1995). The most famous tool to reduce the changeovers is the Single-Minute Exchange of Die (SMED) (Shingo, 1985). It was developed by Shigeo Shingo, who was an Industrial Engineer from Japan.

SMED: It was defined by Shingo as "a scientific approach to setup time reduction that can be applied in any factory to any machine". The aim is to reduce the changeover time to a single digit, it wants to achieve a time inferior of 10 min. (<10min), this is the reason of the name SMED.

For an optimal utilization of the resources, the workers have to minimize the waste of time in the changeovers, because it is an activity that does add value neither the final product nor the customer. Because of this difficulty, there was a tendency to programme big-batch production minimizing the number of changeovers, but the new trend is to produce small batches and with a short changeover times (see 1.5.3.). Therefore, a fast changeover capability is vital for being able to produce small volume of a big quantity of products and manage to be able to offer the products despite the changes in the demand without the necessity of big inventories. This fact makes the company takes advantage against their competitors (Van Goubergen, et al., 2002). There are three reason that indicate why the setup reduction is important for a company; (1) It increases the flexibility of the production allowing more changeovers and reducing the lot size; (2) Thanks to this reduction of time it increases the bottleneck capacities and the production line as well; (3) The minimization of the production costs due to the higher utilization of the equipment.. (Van Goubergen, et al., 2002). All of these improvements without purchasing any new machine.

The idea is to perform as much as possible activities during the running process enjoying its benefits because it will not be necessary to stop the process. The setup activities carried out when the machine is stopped are called internal activities. On the other hand, the external activities are while the machine is running, (Shingo, 1985).

In the Table 1.1. there are the main steps in a manufacturing process and the time that regarding Shingo required before the implementation of SMED. For example, there are activities like mounting or removing blades that has to be an internal because they need to stop the machine to change the setup. On the other hand, activities like transporting of pieces or tools necessaries are the external activities, performed without stopping the machine.

The basic setup steps procedures before the SMED implementation based on Shingo are:

Steps in setup	Proportion of time before SMED
Preparation, after-process adjustment, and checking of raw material, blades, dies jigs, gauges (tools).	30%
Mounting and removing blades, tools, and parts.	5%
Calibrating, dimensioning and setting of other conditions	15%
Trial runs and adjustments	50%

Table 1.1. Steps in the Setup Process. Source: (Shingo, 1985 p. 27)

The original methodology to reduce the changeover time is explained in four stages (Shingo, 1985);

Preliminary stage: Internal and external setup conditions are not distinguished.

Stage 1: Separating internal and external setup.

Stage 2: Converting internal to external setup.

Stage 3: Streamlining all aspects of the setup operation.

However, currently there have been more studies because it is know about some failed implementations. The four stages might not be the best efficiency way to reduce the setup times in all situations. In the article of Guzmán Ferradás and Salonitis propose the SMED methodology based on McIntosh et al. (McIntosh, et al., 2001) improving the original Shigno steps. This implementation of the SMED technique includes the same stages with some improvements to make it more effective and it is proposed in 5 stages in Guzmán et al. (see Fig. 1.7.) (Guzmán Ferradás, et al., 2013):

<u>Stage 1:</u> *Classify activities into Internal and External or to be eliminated.* The "set-up", "run-up" and "run down" must be distinguished (see Fig. 1.6.). The *run-down* period appears occasionally in the equipment because a line might be gradually run down at the end of the prior batch instead of stopping abruptly. The *run-up* refers at the time from the manufacture of the first part of the new batch until the steady-state production. The run-up period is typically dominated by adjustments to the manufacturing hardware to enable a new batch production to achieve full-scale capacity and quality products to begin. So, in the middle of the two running periods there is the *set-up* period. This period is identified between the manufacture of the final piece of the previous batch and the first piece of the next batch. The line is stopped during this interval (McIntosh, et al., 2001).

Finally, the aim of this phase is to classify the intern preparation to an extern time because it means that the machine does not require stopping the process.

<u>Stage 2:</u> *Separate External work and Internal Work. Internal setup operations reduction by the improvement of the operations:* The external has to be moved to the beginning or the end of the changeover. The options considered are the organization of the external work in the operators' schedule of the changeover or manage all the external activities to the same operator and optimize their movements. Regarding the internal work, it must be standardized to make it more efficient and faster because are activities that makes the machines to be stopped, so, it would minimize this stoppage time and of course, activities which are not necessaries can be eliminated. In this stage appears the possibility to implement a 5S methodology (see 1.5.6.) to reduce the times due to the application of techniques in the workshop like sort, clean or layout of the line.

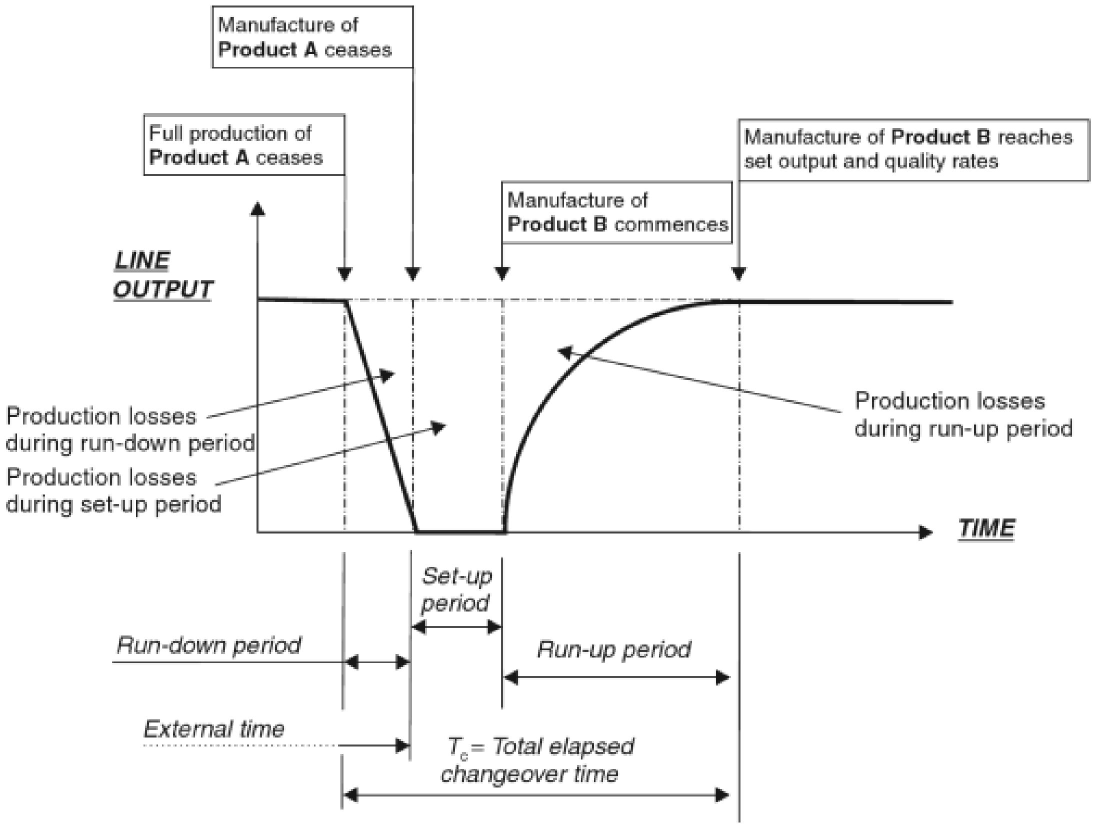


Fig. 1.6. Line output during changeover when including a run-up, set-up and run-down periods. Source: (McIntosh, et al., 2001)

<u>Stage 3:</u> *Convert Internal work into External work:* It is necessary a detailed analysis of the internal activities and using the standardization to try to convert them into external. This stage is made by improvement teams.

<u>Stage 4:</u> *Streamline and reduce internal work:* The setup operations cannot be external, consequently, they have to be the aim of the control and continuous improvement.
In this phase, the internal must be optimized as much as possible to reduce the time, with parallel operations, functional clamps, increasing the mechanization of different machine components, reducing adjustments and designing new tools more effective for the internal tasks (Shingo, 1985).

<u>Stage 5:</u> *Streamline and reduce external work:* It is the main different stage from the original from Shingo. The third stage is split into two states. The idea is to reduce internal activities before streamlining the external, like stage 3 and 4. Then the next step is to realize the external streaming reduction because the external activities do not decrease the setup time, so they are not as proprietary as internal ones. These external are performed when the equipment is not working, so, they can be performed while the machine is working, with full capacity for this reason, in the stage 3, it wants to move to activities to external side because

of the possibility to do it without stopping the machine and at the end, reducing the changeover time. They should stream the external activities to the beginning or finish time of the changeover as it is shown in the solution of the Fig. 1.7.

In conclusion, the reduction is carried out in the internal work, and all the external work is placed out the setup period. For this reason the efforts have to be focused on the internal firstly.

The implementation of this new SMED methodology in welding cells, as the article explains, it reduced 33% the changeover time at the end of the project. So, they consider it successful (Guzmán Ferradás, et al., 2013).

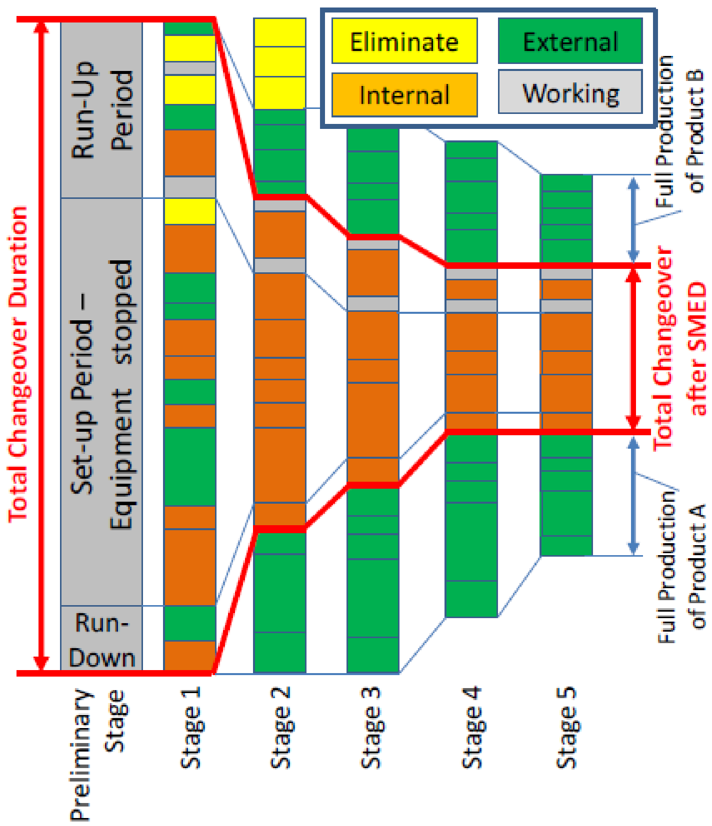


Fig. 1.7. Proposed tailored SMED methodology. Source: (Guzmán Ferradás, et al., 2013)

The organization needs to encourage people work, focusing on a more disciplined behaviour, more appropriate hand tools and the pattern sequence and parallel work. All of this has to be tried to do it while the machine is working. Moreover, In the SMED methodology, obviously, the perfect changeover time is zero, so, this is the final desire. With a flexible design and grouping by families can prove really good benefits.

1.5.6. 5S

5S: The five 'S' it is because they are the beginning of 5 Japanese words which are used to maintain a workplace suited for visual control and the lean manufacturing application. The 5S are (Womack, et al., 1996)(Ohno, 1988):

1. Seiri (Sort): Clearly differentiate needed tools, parts, and instructions from the work area from unneeded items and eliminate what is not useful, adding a Red Tag to the waste items.
2. Seiton (Set in order): Place the needed parts and tools in the correct place to allow using it again immediately.
3. Seiso (Shine): Keep the workshop swept and clean, so, a cleanup campaign.
4. Seitketsu (Standardize): This is the condition we support when we maintain seiri, seiron, and seiso daily and frequently to keep the workplace in perfect conditions.
5. Shitsuke (Sustain): Make a habit of maintaining established procedures of the previous 4S.

Hiroyuki Hirano, and expert of JIT philosophy provided the 5S structure that implements in Toyota (Ohno, 1988). The 5S are the five pillars of the Visual Workplace. A visual workplace is a self-ordering, self-explaining, self-regulating, and self-improving work environment, where what is supposed to happen does happen, on time, every time, day or night, because of visual solutions (Galsworth, 2005). It is the idea of keeping all what you need, information, tools or materials at the point of use.

In conclusion, it is a method based on the principles of cleaning, sorting and standardization and it also can be implemented by all departments of the organization like sales, marketing, administration or management, and of course, the departments or workshops areas where they develop and manufacture the product.

1.5.7. TPM (Total Productive Maintenance)

As it has been mentioned, the losses in the shop floor are very common in the industrial companies. Some wastes are generated by the same workers, lack of row materials in time, machines problems, wrong maintenance, disorder, etc. Likewise, the invisible wastes like machines operating under the rate speed or bottlenecks in processes what it means less than their full capacity increase the productions costs. There are waste due to the idle machines and idle manpower, and break down and rejected pieces as well, which are also reducing the effectiveness and the quality and reputation of the company.

Total Productive Maintenance (TPM) is defined by the Japanese Institute of Plant Engineers (JIPE) and Nakajima as a design to maximize the efficacy of the equipment and improvement of the efficiency thanks to a creation of a widespread productive-maintenance, including the whole life of the equipment and involving all the fields related with the equipment such as planning, use, maintenance and so on. He also related the production and maintenance, because it was necessary for the continual improvement of the quality of the products, capacity guarantee and safety. In the TPM are included the employee participation, motivation and job satisfaction in all levels of the organization, from top management to the workers on the shop-floor. All of these together with small group activities based on self-discipline aimed to zero defects and zero breakdowns (Nakajima, 1988; Tsuchiya, 1992).

Seiichi Nakajima, who defined this technique, was the pioneering in the TPM, he is known as the father of this operational methodology. He was the vice-chairman of the Japanese Institute of Plant Engineers (JIPE). The Japanese introduced the concept of the Total Productive Maintenance (TPM) the 1971, where the key concept is the autonomous maintenance (Nakajima, 1988).

The factors involved in the autonomous maintenance are the creation of teams to stabilize conditions, proper lubrication to avoid deterioration and prevent breakdowns, techniques like 5's to keep the shop-floor clean and the daily philosophy of cleaning. Another one is the importance of the operator's knowledge about their own equipment, organizing some programs to teach the workers to know about an active maintenance (Nakajima, 1988; Suzuki, 1992). If the workers learn, they can improve the procedures in most of the daily activities such as changeovers, setups, maintenance of the machinery, and they will be better trained for the tasks. Therefore, it will decrease the unit costs of production due to the reductions of time waste and the production of a better service.

TPM is looking for a successful methodology for managing the combination of the maintenance concepts and the organizational activities. As a result, it needs to involve operational and maintenance employees and work under the same aim to reduce the waste that can create if there is no efficient maintenance. It is also based on the idea of the continual improvement of performance, TPM encourages the philosophy "you operate, I maintain" (Robert, 2002), because it needs the commitment of all employees, the standardization and the concept of constant improvement. TPM is built on the concepts already explained like Just in Time, concepts about the quality of the processes (Total Quality Management) (see 1.5.9.), minimization of the life-cycle cost. As a result, the better cost-effective option is the improvement of the use of the workforce and the resources (Eti, et al., 2004).

Nakajima (1988) used the word 'total' as three different concepts; *Total effectiveness* focusing in economic performance; *Total maintenance system* which refers to techniques for designing a free maintenance, trusting in the reliability, maintainability and supportability characteristics of the equipments; *Total participation* of the employees, which it means Autonomous Maintenance by the workers thanks to small groups activities. They should take care about their equipment.

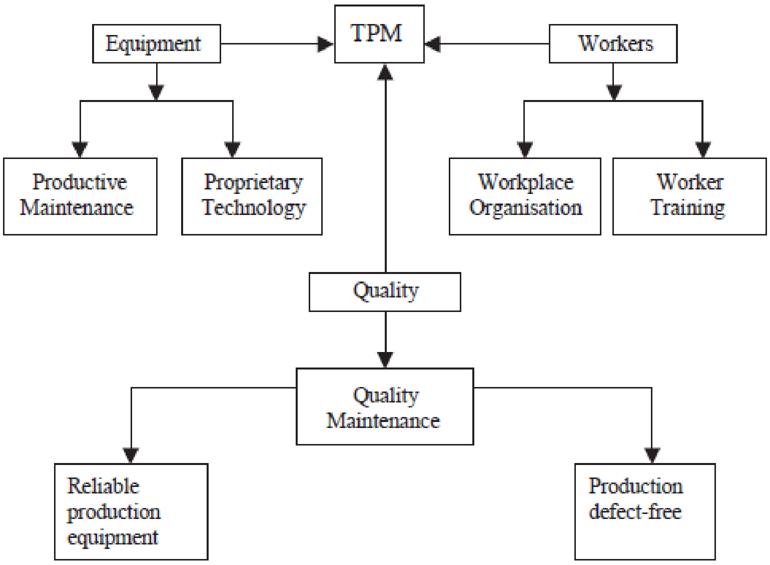


Fig.1.8. Key supporting elements of TPM. Source: (Chan, et al., 2005)

In the Fig. 1.8. is represented the most key elements involved in the TPM. It is indicated the relationships between the workers and equipment in the TPM, and also how TPM seeks for the quality inside the company because it is totally related with them. Consequently, if there is quality in the processes, then, the efficiency of the equipment and the workforce needs to be good too for a correct development of TPM in the company..

Inside the implementation of the TPM, it can be found in two perspectives, the short-term maintenance, which is found in the low level of the organization based on the autonomous and planned maintenance actions in departments and personnel. The long-term efforts focused in the acquisition or design of new equipment and the sources of time lost by the equipment (McKone, et al., 1999).

Inside the processes, when the company is working inside the continual improvement of the machinery and there are the standard pattern to follow a correct maintenance, it must be controlled by the company to see what are the productivity of the machines. There are other influence factors such as the organization of the maintenance and the resources available like tools, workers or skills. For this measurement of this machinery performance, there is the OEE (Overall Equipment Effectiveness). It is used every day in a group of machines to compare against the pieces that could have been produced.

The goal of TPM is the maximization of the equipment effectiveness, the OEE rate is the value used as a measure (Waeyenbergh, et al., 2002) .

The equation applied to this coefficient is the following (Eti, et al., 2004):

$$OEE = Availability * \; Performance\ Rate * Quality\ Achieved$$

The *availability* is the fraction of time that the equipment is working including the time of breakdowns, setup and adjustments, waiting and others. So, it is the operation time without the dead times of the cycle or another programmed stops. The loading time is the operation time planned per period of time, and down time, the time when is not operating for the previous reasons. This rate is obtained by the operation factor.

$$Availability = \frac{loading\ time - down\ time}{loading\ time}$$

The *performance* number measures the main breakdowns, dead times, speed losses, and unimportant stops.

$$Performance\ Rate = \frac{output}{loading\ time}$$

The *Quality Achieved* is the number of the production fraction obtained that passes the standards, so, there are included the defects and reprocessing of the products.

$$Quality\ Achieved = \frac{number\ of\ good\ products}{used\ inputs}$$

Therefore, to get a 60% means that 60 pieces are good from the 100 pieces that could have been produced in the available time.

In conclusion, the OEE (Overall Equipment Effectiveness) is a good tool to measure the systems performance. It also needs better improvements in the measurements because according to Lungberg (1998) the definition does not pay attention to other important factors important in the machines performance. For example, planned downtime or when there is lack of materials or orders. It is not inefficiency of the machine in these cases (Lungberg, 1998).

1.5.8. Jidoka

The Lean Manufacturing involves a large quantity of concepts. The following two points of the Lean techniques (Jidoka and TQM (see 1.5.9)) are more related with the organization, the managers, the intermediate positions and workers including the quality as well. Jidoka forms the other big pillar in the Toyota Production System.

Jidoka is "the practice of stopping the process when a problem occurs" (Osono, et al., 2008 p. 135). It is very focus on the people of the company because they need to be able to realize about the wrong running of the process and stop it to solve the problem just in that instant and at the same process. Jidoka is also called autonomation because it comes from a Japanese item that means that word. Autonomation is defined as intelligent automation or automation with a human touch (Ohno, 1988). This technique wants to enhance the roll of the employees and allows them taking decisions to fix the problems. For this reason, the automation of the machines needs the supervision of some people or even devices (see below) to realize about the mistakes. Jidoka looks for intelligent machines working as if a human were controlling and when the defect occurs the employee must be able to solve it. The idea is not only the automation in the processes, it is also the objective to have a process that has its own quality autocontrol including tools to detect automatically the errors or making it easier for the operators in the production.

The methodology of Jidoka includes the basic steps which are the following (Ohno, 1988):

1. Detect the problem.
2. Stop the process.
3. Re-establish the process to proper function.
4. Find out the root cause of the problem
5. Install countermeasures.

Consequently, the process stops when a defect appears, with an automatic or human decision. It is great due to only the correct pieces pass the process, so it follows the thinking of zero defects, improving the quality, reducing following mistakes in the production. Ohno (1988) found out that despite stopping the process, in long term, solving the problems as Jidoka philosophy generates better results and performance(Ohno, 1988). He wanted to teach that it is better to stop and lose some time to fix the problem than continue with that defect along the production line, because it would be a waste of resources further on. With it is possible to make the processes stop by themselves using sensors, or by the human action on an easy way.

For this technique, automatic machines are used, they are connected to electronic systems to realize when the defects are. Thanks to that, the machine can work without a worker most of the times, only when an abnormal situation happens. As a result, an only worker can control more than one machine, incrementing the efficiency and the performance.

The more important tools in Jidoka are Andon and Poka-Yoke.

Andon is a visual control that helps the operator to notify the status of the machines and manufacturing line in the manufacturing process. The main item is the display to represent the state of the processes. Also a system alarm can alert the workers when there is a problem. The responsible of the process can be able to stop and ask for help or solve the problem if they know to do it. Thanks to this tool they can control the quality and reduce the defects, so, it is a help for the process of quality inside the company (Li, et al., 2006).

Another Andon functionality makes the production line workers recording cases to report the information to a centralized database. The monitoring also can be checked by the manager in real time (Helo, et al., 2014).

A Jidoka benefit is the introduction of an approach for mistake proofing design called Poka-Yoke.

Poka-Yoke is a mechanism for detecting errors and defects. These devices avoid the 100% of the defects even with human mistakes and are simple very usefulness devices (Shingo, 1988). Poka-yoke devices can be sorted in three different types; (1) physical, if they block the flow of the piece, mass, energy or information. There is no interpretation of the worker; (2) functional, when they might be turned on or turned off to an occasion; (3) symbolic, when it is necessary the interpretation and it should be the worker at the moment to realize about the signal (Hollnagel, 2004). The poka-yoke devices are made for mistake-proving pieces because of that they can be classified in proactive and reactive devices. The proactive prevents the defects and the reactive detects the defects once they are already produced. The proactive devices are used as a source inspection and avoid the incidence of a defect. There are other inspections which use reactive devices such as self-inspection, performed in the same stage, successive inspection in the following process or judgment inspection with a group of operators(Shingo, 1988). Another classification by Shigno (Shingo, 1988) separates the control and warning. The control function can make to turn off the machine when a defect is detected and do not allow the entrance of the next piece or it can automatically exclude the piece that is not good from the production. The warning function of poka-yoke devices creates lights or alarm to show the occurrence of a defect (Shingo, 1988).

1.5.9. TQM (Total Quality Management)

Total Quality Management is an approach for improving the quality of goods and services through continuous improvement of all processes, customer driven quality, and production without defects, focused on improvement of processes rather than criticism of people and data-driven decision making (Flynn, et al., 1994). The Deming Prize Committee (see below *William E. Deming*) includes in its definition also that are a set of activities carried out by the entire organization to be effective and efficient to satisfy the customers at the appropriate time and price. Consequently, the practices of this management philosophy are related with the organization of the company to improve the processes and the continual improvement to improve the quality.

Quality can be defined from different points of view like product, user, manufacturing or value based. A global approach described by customer is “good enough” or “gets the job done” (Jones, 2014). An easy way to understand it is if no one complains about bad quality, it is because it is good quality. From a product approach, the quality can be considered an attribute that the customer is willing to pay for it. For example a product made from a material that deteriorates less along time is valuated on higher quality and the clients will pay more if they want the better material. From user point of view, the product must fit with the user and their expectations. In the manufacturing-based approach, quality is related with quality standards, so, it can be measured. The last point is the quality based on value. It is related with the idea that the customer pays more for the higher quality products. There are several attributes which are associated with this value such as performance, features, reliability, conformance, durability, serviceability, aesthetics and perceived quality (Jones, 2014).

William E. Deming is often considered the father of the modern quality. He was a US quality consultant and introduced the quality principles in the Japanese manufacturers after the World War II. Currently, Deming principles are the basis of the quality initiatives that companies implement today like control charts. He developed knowledge to make breakthrough improvements to get higher efficiency. The PCDA cycle is also called Deming cycle which is used in the continual improvement presently. His main point was the psychology of the employee and also organizational understanding, the necessity of information and theories about process variation was appreciated from him (Jones, 2014) .

The quality management is characterized by its principles, practices and techniques. The principles give general guidelines implemented by multiple techniques (Dean, et al., 1994).

The seven main practices in this approach are top management, customer relationship, supplier relationship, workforce management, quality information, product/service, and process management. (see *relationship between quality practices* 2.4) (Xingxing, et al., 2010)

The descriptions for each practise are the following (Xingxing, et al., 2008):

- *Top management support* is based on quality performance. It participates in quality improvement efforts and makes strategies and goals for the quality improvement.
- *Customer relationship* measures the customer satisfaction. The customer needs and expectations are assessed.
- *Supplier relationship* is involved in the product development and the product quality, the suppliers need to be evaluated and they can receive training and technical assistance.
- *Workforce management* is important because the employees can give their opinions about quality decisions. Their contributions are recognized and the team work is encouraged.
- *Quality Information* is available to managers and employees. It is used for improvement.
- *Product/service design* involves people from different departments as manufacturing, marketing, purchasing departments. The product is reviewed before production. Simply standardization is encouraged.
- *Process management* emphases on mistake-proofing, also the use of statistical process control (SPC) and preventive maintenance. All the employees should maintain the good workshop conditions and schedules.

TQM is the most related technique with quality in the processes of the Lean manufacturing management. The production processes need to be stable and predictable to work with no interruptions at the production line, so, the encouragement of TQM is a fundamental for implementing Lean production. Another philosophy which is based on the organizational culture practices of TQM is Six Sigma (see chapter 2.). Six Sigma is a new approach of the TQM practices and many TQM practices are adopted by Six Sigma. Both promote the value from the customer and the product/service design, defined processes, top management leadership and support, employee’s involvement but TQM empathizes more in the shop floor operators, importance of collecting and reporting data and the importance of the need of the customer (see 2.4) (Schoroeder, et al., 2008). There is also links with TPM because is widespread improvement, which is based on the concept of zero defects of TQM for the equipment improvement in its performance (Seth, et al., 2006).

As one can see, the quality and specially the Total Quality Management are totally related with the organization. The effort from all the employees is the main key to improve the quality and regarded benefits, but it is not enough. The quality of the products needs the control of the processes to reduce the defects and process variability, so, this means a good implementation of the continual improvement, like Kaizen spirit, to maintain the idea of improvement always in mind. For this reason a proper organizational culture is widely considered necessary for a successful implementation of TQM. (Buch, et al., 2001) The PLAN-DO-CHECK-ACT explained in the continual improvement and Kaizen methodology is the base for the TQM (see 1.3.).

Nowadays the quality in the products is one of the most important issues in business success because it is necessary for a better satisfaction of the customers. As a result, more recently companies are implementing the new perception to quality management Six Sigma. It improves the strategy of implementation of TQM, including a better structured process of improvement and some performance metrics to define better the quality in the company.

Chapter 2

Six Sigma

2. Six Sigma

Six Sigma was indicated by Motorola Inc. in the 1980s and has been defined as “an organized and systematic method for strategic process improvement and new product and service development that relies on statistical methods and the scientific method to make dramatic reductions in customer defined defects rates” (Linderman, et al., 2003).

The key elements of the Six Sigma are focused on the customers’ needs, business improvement processes by a reduction of inherent variation in the processes, and then, a very structured improvement process by specialists with their role to solve the problems with proper methodology and the earning of tangible results in the company (Linderman, et al., 2003)(Schoroeder, et al., 2008).

Motorola engineering scientist Bill Smith was who developed the philosophy and is known as the father of Six Sigma. He and other pioneering engineers and scientist worked on concepts such as variability reduction, quality improvement and productivity like mainly W. Edwards Deming and also S. Shingo and T. Ohno, each one form a different perspective.

Regarding the definition, one of the main Six Sigma aims is the customer focus. It realized that in any organization customer satisfaction should be the priority because means profitability. Motorola believed that producing higher quality products had not to be too expensive as others companies thought in the 1980s. So, Motorola changed its philosophy to a higher quality production because greater customer satisfaction generates higher benefits.

Six Sigma philosophy includes an amount of tools to develop and use this ideal in the business. It is related with statistical process, non-deterministic control and engineering process control. Consequently, the use of these techniques requires data analysis, optimization methods, design of experiments (DOE), analysis of variance, statistical methods and consistency assurance. It is the process capability (see below) which is always looking for a better quality of the product and improving the productivity (Taghizadegan, 2006).

It is true that Six Sigma also shares some techniques with the quality management methods, but it introduces a new different concept and practices for achieving the quality management. It provides an organizational structure that had not been seen before. So, it is claimed that "Six Sigma is an organized parallel-meso structure to reduce variation in organizational processes by using improvement specialists, a structured method, and performance metrics with the aim of achieving strategic objectives" (see Fig. 2.4.) (Schoroeder, et al., 2008).

Six Sigma uses statistical distribution curve based on a normal distribution (see Fig 2.1.) which is the most common probability distribution in the real processes. Normal distribution is defined by mean (μ) and variance (σ^2) which are basic statistics concepts. Therefore, Six Sigma means six times its standard deviation (σ). The objectives are to eliminate defects from every process, product or transaction up to 6σ levels and have the process controlled. The defects are situated in the both queues of the normal distribution of the process outside the specification values LSL (Lower Specification Limit) and USL (Upper Specification Limits).

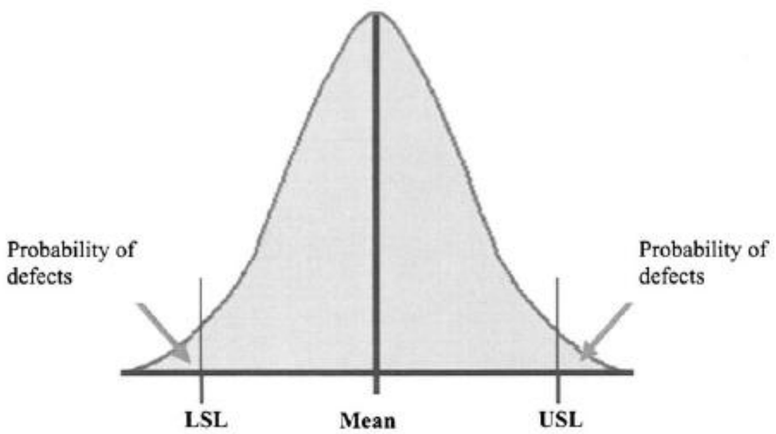


Fig. 2.1. Distribution curve of sample dimensions. Source: (Taghizadegan, 2006)

A manufacturing process that produces parts, pieces or products, must achieve certain requirements established by the customer or even by the same company. It could be any kind of requirements such as dimensional or physical like size, weight, volume or chemical properties, mechanical, etc. Otherwise, it is a defect product and the customer does not accept it. For this reason, it is important the specifications limits and to produce as many items as possible inside them. So, when a process remains inside the limits it means that the process is capable.

The capability is divided into Short-term capability and Long-term capability. Six Sigma *short-term capability* occurs when the process is centred on the target and there is no shift supposing that in this short-term the process is uniform without changes. The *long term* *capability* is based on an experience assumption in which the mean of the processes changes from time to time and more often when they produce big quantities of items. These changes can be caused by machine's performance, operator or machine reasons and also because a minimum of variability always exists, because there is always some natural variability. Here it is where the defect rate (DPMO) is calculated (see Fig. 2.3.), assuming this possible variation in the mean of the process in an average of 1.5σ (see Fig. 2.2.). This shift means a distance of 7.5σ from one side and 4.5σ to the other (grey distributions) in a 6σ design process and with this shift the number of defect showed in Fig 2.3. is calculated by statistical probability to define the number of defects depending on the sigma σ level achieved (Taghizadegan, 2006).

Moreover, Six Sigma aim is to achieve the 'zero defects', with the statistical 6σ number, which means 3.4 defects per million opportunities (DPMO) for a defects to occur. In fact, it is a 4.5σ due to the variability explained in the long-term capability. Consequently, the efficacy will be 99,99966% of good products (Linderman, et al., 2003). It is very difficult to change drastically from a lower sigma performance to a 6σ Six Sigma. As a result, the process has to be implemented progressively, improving from 3σ to 4σ, and then 5σ, 5.5σ and at the end, to be able to achieve the excellence 6σ reducing the number of defects step by step.

Inside the Six Sigma processes, business should produce with the excellence of 6σ but there is another essential issue. The production can be in the right number of defects but the product has also to achieve the limits of capability. The process of capability represents the allowable tolerance interval spread when the process follows a normal distribution (Breyfogle III, 1999).

$$Cp = \frac{USL - LSL}{6\sigma}$$

If the company is working with another sigma level the formula will be the same but with the width of the design process for example; 3σ, 4σ or 5σ.

The general rule of interpreting Cp is:

Cp < 1.0 inadequate; process variation is higher than specification and has more defects.

1.0 ≤ Cp < 1.33 adequate; the process is acceptable and just meets specifications. The process still requires to be centered.

Cp ≥ 1.33 good; the process variation is less than specification, but possible defects and process are required to be centered or to be maintained in control.

The USL and LSL are the upper and lower specification limit. The 6σ is the range where the product is inside the tolerances. Another value to consider is the mean (μ) of the specific value to control. The Cpk used to control the mean and spread of the process (Breyfogle III, 1999).

$$Cpk = \min\left[\frac{USL-\mu}{3\sigma}, \frac{\mu - LSL}{3\sigma}\right]$$

Where: $CPU = \frac{USL-\mu}{3\sigma}$ and CPL= $\frac{\mu-LSL}{3\sigma}$

Thanks to that capacity number, it can be evaluated if the process is not centred inside the tolerances and if it is capable from each side. CPU gives information if the process is centred on the upper side and CPL on the lower side.

The right values are the same as the Cp values mentioned before.

In the Fig 2.2. the grey distribution show the long-term capability with the 1.5σ shift. The white one is representing the short-term normal distribution which is centred in the middle of both specification limits.

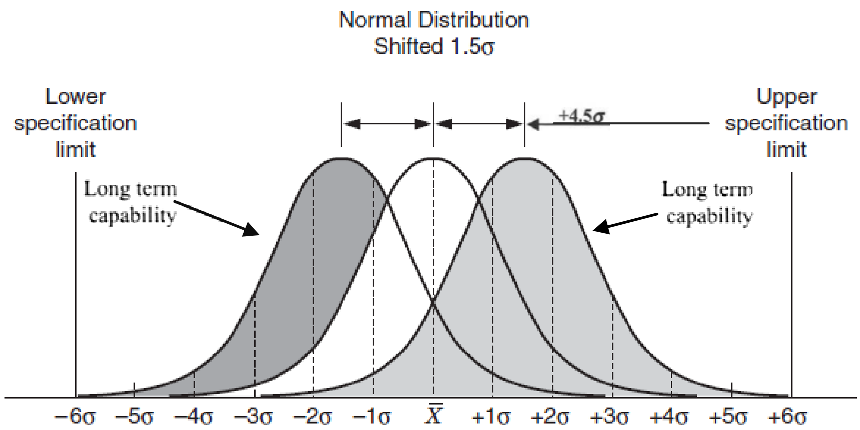


Fig. 2.2. Effects of a 1.5σ shift where only 3,4 ppm are out the specifications. Source: (Breyfogle III, 1999)

In the Fig 2.3. is showing the reduction of defects in defect per million opportunities regarding the long-term normal distribution.

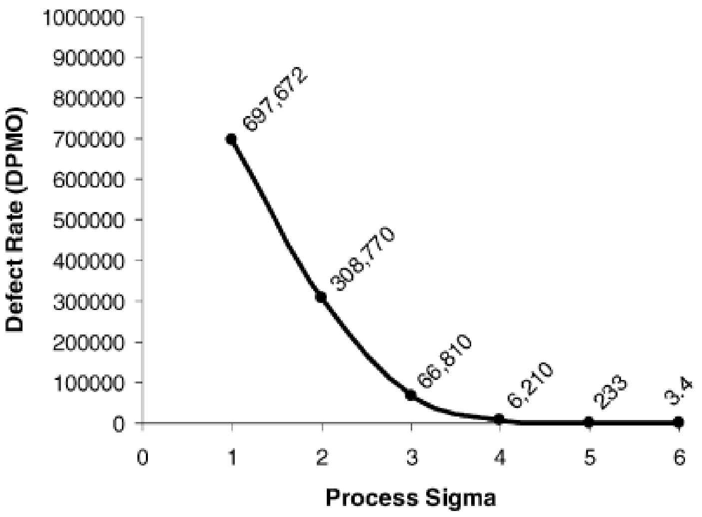


Fig. 2.3. Defect rate (DPMO) and the Process Sigma Level. Source: (Linderman, et al., 2003)

2.1. Six Sigma practices

After the definition and the explanation of all statistical concepts involved in Six Sigma, the new three practices of this philosophy complement the Total Quality Management practices explained before. The new Six Sigma principles and methods are; Six Sigma role structure, Six Sigma improvement procedure and Six Sigma focused on metrics (see below) (Xingxing, et al., 2010).

For the implementation of Six Sigma practices, of course the new philosophy must be accepted by the managers, but then, the Six Sigma journey is not easy, takes some years, two or three years, to train and teach the organization to increase the sigma level from a lower level to Six Sigma. During this time the company will improve each year its productivity, profitability and sigma level (Taghizadegan, 2006).

2.1.1. Six Sigma role structure

The new organizational structure developed by Six Sigma is a parallel structure and requires the full integration of all departments in the company. There are some specialists which form the parallel organization; Champion, Master Black Belt (MBB), Black Belt (BB), and Green Belt (GB) or project leader.

The quality groups used for improving the quality do not have enough authority usually to change totally bad habits of the organization, so their suggestions are implemented but after a long time, problems usually come out again. There are other reasons like resistance from managers or ideas without information and in the end they are not successful (Lawer III, 1996) but a hierarchy is needed to carry out the projects. Here is where the organizational structure has more value because it creates a better alignment to achieve the aims of the organization. For this reason, the "meso" theory integrates micro and macro levels, affects the organization and it returns the affects individual and groups (Schoroeder, et al., 2008). Thanks to these parallel organizational levels ensures that the strategy in the business is well coordinated with all of the tasks of the processes (Sinha, et al., 2005).

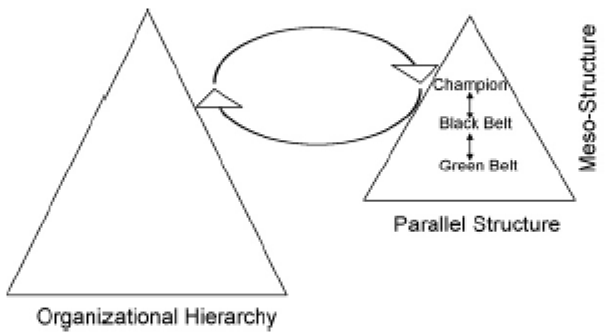


Fig. 2.4. Six Sigma parallel-meso structure. Source: (Schoroeder, et al., 2008)

On the top of this hierarchical structure there are the leaders or *Champions,* who start and review the improvements. They should be from the executive members of the company and some upper-level managers could also be included. They should have managerial and technical skills for planning, use of resources and know about the tools to the correct supervision of the results. This leader is the main responsible of the financial results and he or she has to achieve the planned objectives The Champion will evaluate the impact of the projects and its outcomes. Moreover, Champions are the responsible to train Master Black Belts and Black Belts in leadership, and Six Sigma philosophy.

The *Master Black Belts (MBB)* are the quality managers. They know about advanced statistical analysis, business strategies, leadership, and Six Sigma methodology. They are the tutors of Black Belts. To become a Master Black Belt, they have to work in many projects before get this certification level and they must have completed several BB projects in a year as well. The MBB can be as a help for Black Belts or other working groups inside the company to try to find the solutions. However, it is not always a fundamental piece and not all the companies which implement it, have one because the Six Sigma strategy can be developed by Champions and Black Belts.

The *Black Belts (BB)* are the project leaders. They also have to demonstrate about leadership and communication skills. They have to carry out many activities such as mentoring other leaders (Green Belts) and lead the improvement team to higher levels. They should teach, train and coach the Six Sigma techniques to the other employees and to the customer oriented team. Some skills they have is that they are mentored in problem solving. The BB are the leaders of the project so, they create the strategies to improve the key processes to achieve the goals and to have an active participation with the process of production. In this position, they should be also able to carry out more than one project and support other project leaders throughout the company. For better aspirations, they have to be able to develop managerial abilities to control time, money, performance, and organization dynamics (Taghizadegan, 2006).

The *Green Belts (GB)* work with the Black Belts to solve the problems. They need to have statistical knowledge and training in basic Six Sigma, problem solving and statistical analysis. It is a team which participates in the projects, and this participation is needed to get the certification of GB. The basic training is a period of one week to provide them an overview of the basic concepts and strategies in problem solving.

A Six Sigma project involves a team of employees that might have some Green Belt training and they work together with the Black Belt to improve their knowledge. The team leader is the Black Belt who reports the improvements to the Champion and the Champion has a general view of the problems, benefits, improvements of the organization. The roles are assigned with different ranks depending on their expertise. (Schoroeder, et al., 2008).

2.1.2. Six Sigma structured improvement procedure

The Six Sigma improvement procedure is a method structured based on the continual improvement of the PDCA cycle. As it was explained before, the Six Sigma method is more detailed, it has specific quality tools to implement in each step, which are exclusive for the Six Sigma. The methodology follows the DMAIC (Define, Measure, Analyze, Improve, and Control) procedure. (Linderman, et al., 2003). This method is always seeking the excellence and trying to reduce the defects and all of the Six Sigma aims. It is found that with this procedure there is always a desire to find the cause root of the problem based on the DMAIC. The method uses some standards quality tool such as cause-and-effect diagram, statistical process control (SPC), Pareto or Control charts, benchmarking (Breyfogle III, 1999).

The Six Sigma DMAIC phases are defined as follows (De Koning, et al., 2006; Tenera, et al., 2014; Taghizadegan, 2006):

1. **Define:** problem selection and benefit analysis.

   D1: Identify and map the main processes in the company

   D2: Identify stakeholders to focus the Process Mapping on them. The SIPOC (Supplier, Input, Process, Output and Customer) diagram could be very useful for specify the related stakeholders and the main project activities.

   D3: Identify the customers, their needs and requirements. Detect the Voice of the Customer (VOC).

   D4: Make the project charter elaboration. Business case.

2. **Measure:** translate the problem into a measurable form to evaluate what is the current situation. Updating the goals which were defined in the first phase.

   M1: Select the CTQs of study, which are considered necessaries. The CTQs are the Critical-to-Quality process factors. Measure internal parameters of quality that are considered by customer's opinion a priority in Lean Six Sigma philosophy.

   M2: Determine operational definitions for CQTs and requirements.

   M3: Gather data to validate measurements systems of the CTQs and make good decisions about what criteria are needed.

   M4: Assess the variables based on statistical tools such as Pareto charts, histograms, with a data collection plan.

   M5: Define the target.

3. **Analyze:** identification of factors and causes that determine the CTQs.

   A1: Identify root-causes and potential influence factors with an exhaustive analysis. It is used to identify root-causes to determine variance components and sources by identifying the process factors (most dominant X's), process delay factors, and estimating process capability such as hypothesis testing, p-value, and other statistical tools. Then, the Value Stream Mapping is used to obtain a detailed view of the improvement process opportunities.

   A2: Prioritize the vital few influence root-causes and factors.

4. **Improve:** design of solutions and implementation of adjustments to increase the CTQs performance.

   I1: Quantify relationships between Xs and CTQs, with techniques like design and analysis of experiments or statistical models.

I2: The implementation of a design to improve the process or changes in the settings in order to optimize the CTQs. So, the idea of robust designs is the aim to produce inside the tolerances.

5. **Control:** Empirical verification of the results and adjustments to ensure a long-term improvement, monitoring process and control to remain the changes to ensure that it is producing the product attributes inside the specific conditions all the time.

   C1: Determine the new performance of the process and its new capability using statistical and process capability analysis tools.

   C2: Implement a process control to keep the changes they have created with run control charts.

DMAIC also is formed by different members in the different steps of the method. In the first one, Define step, the Champion plays an important role and a supporting role in the others steps. In contrast, Process Owners take more participation in the Control step and supporting the others. In the Measure, Analyze and Improve steps the Green Belts are more active. Finally, Black Belts work as a project leaders and control, and create reports in all of the steps of the process (Schoroeder, et al., 2008).

Thank to these roles, the methodology creates a common language in the company. It is a problem-solving mentality.

2.1.3. Six Sigma focus on metrics

The methodology of Six Sigma uses a variety of quantitative metrics in continuous improvement. As it was talked before, the measurements are critical-to-quality metrics, defects measurements, the process capability, and also financial and strategic measures. These performance metrics can be used for organization, manufacturing processes and also in services, administrative processes (Schoroeder, et al., 2008; Linderman, et al., 2003).

Consequently, Six Sigma metrics seeks two aims based on its philosophy and wants the customer's satisfaction and this satisfaction must prove that it generates a better financial results. For that reason, the VOC (Voice of the Customer) is included in the DMAIC method because customers are one of the aims of the Six Sigma.

The statistical tools are recommended but they can be implemented in any phase of the strategy because it can be helpful in each stage. The main tools which are used for the implementation of the project (see chapter 5) are the next (Taghizadegan, 2006):

Histogram

Histogram illustrates frequency data in the form of a bar graph with bell-shaped referring the normal distribution. It is used to learn about the distribution of the data collected in the measure phase. It is a highly effective tool in identifying the mean and capability of the process. Each rectangle is proportional to the number of observations within the internal of the x-axis. The frequency represents the dependent variable (y-axis) and independent variable (x-axis).

Box Plot

A box plot is used to show the distribution of a single variable. It is a graphical representation of data using 5 values; Median, First quartile (25% of the values), Third quartile (75% of the values), and largest and smallest values. This helps to visualize the center and the spread of a data and to compare data by categories.

Pareto charts

The Pareto chart creates and prioritizes the defect factors to determine which issue has the most effect in the process. A Pareto chart is a column chart and is used to prioritize the problem solving order. The Pareto chart applies to all the frequencies (outputs or effects or defects) of any process in any organization. It is another form of histogram, with the frequencies starting form the highest to lowest. The rule is to pay attention on the 80% of the causes that generate the problems.

One-Way ANOVA

The one-way (also called the one-factor) ANOVA (Analysis of variance) is used for determining if the mean of one or more population is different or not from the independent factor. Normally is used a 95% of confidence interval, so, the hypothesis is that if the p-value $\geq$ 0,05 the hypothesis that the independent factor is irrelevant for the mean's population is true. In the other case, the factor would influence the population results.

Cause and effect diagram

Cause and effect diagram is used to study a problem or improvement opportunity in identifying root causes. The cause-and-effect diagrams (also called fishbone or Ishikawa diagram) are used to explore all the potential real causes or inputs that result in a single effect or output.

It is used in the Analysis phase because it can help for finding root causes and identify areas where there may be problems.

Scatterplot diagram

The diagram shows the visual view of the qualitative relationship with linear or nonlinear relation that exists between two variables input and output using an X and Y diagram. It is used to provide the data to confirm that two variables are related. The data must be a paired data collection, it mean, to know the two values of the variables in the same sample to find the relationship when these values change.

Control Charts

It is also known as Statistical Process Control. The objective of control charts is to distinguish between random variation and variation due to an assignable cause and then, the monitoring of process performance along the time for checking its stability. It also helps to identify opportunities and to understand and control variations.

The common types of control charts depend on the circumstance and type of data available to determine and construct the following charts:

- X and R -average and ranges
- X and S -average and standard deviation

The subgroup size of the data is important to decide the right chart. I-MR charts are for subgroup sizes of 1 and Xbar-R charts are for subgroup sizes greater than 1 (and typically less than 9 or 10). Xbar-S are recommended for bigger subgroups.

2.2. Relationship between quality practices

Regarding all of these practices and principles, the relationship between the quality management practices and the Six Sigma (abbreviation SS) is really high in the organization and it is proposed in the model of Flynn (1995) (Flynn, et al., 1995).

The practices are creating an atmosphere in the company supporting the seven traditional quality management split in traditional and core practices with the three from Six Sigma. As a result, the objective is the improvement of the performance of the company, where the Quality and Business aspects are the result.

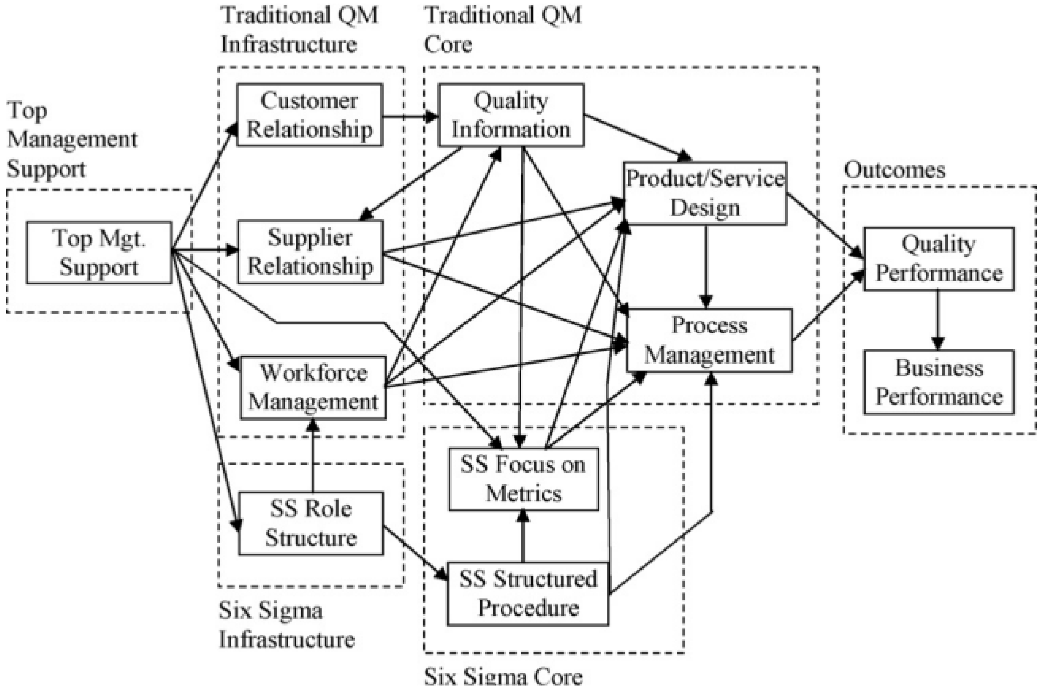


Fig. 2.5. Proposed model of traditional quality management, Six Sigma and performance. Source: (Xingxing, et al., 2008)

As one can see and regarded to the Fig 2.5., the model starts with the Top management support. It makes sense because the managers are who take the leadership for the implementation of the practices. The traditional core takes places in the customer, the product, suppliers and the employees. The Customer Relationship is necessary to know about the Quality Information. Moreover, to satisfy the customers, they need the information from the anterior practices and accurate and timely information to create the appropriate Product/Service Design and implement approachably Process Management. On the lower part, the Six Sigma role structure is very important for the Workforce although it is always important to find the correct people with the required skills. Besides, the Black and Green Belts are the system to maintain the leadership in the process methodology in the organization (Schroeder, et al., 2005). The SS Structured Procedure and SS Focus on Metrics received the information to know how to act and how to implement the continual improvement to lead the Product/Service Design and Process Management. These two practices also those which affects directly the performance and quality outcomes. (Xingxing, et al., 2008)

2.3. Performance in companies

As it is mentioned before, Six Sigma was launched by Motorola in 1986. The implementation of Six Sigma allowed Motorola to win the Malcolm Baldrige Quality Award in 1988 for his performance excellence. The success in Motorola has earned revenues of $356.9 billion from the 1986 to 2001 using the Six Sigma programme and saving in manufacturing costs of $1.4 billion from 1987-1994 (iSixSigma, 2002).

The continuity of the first Six Sigma was implemented by General Electric in the mid-90s. At the beginning it was a Total Quality programme but finally, a managerial approach for the whole company.

Afterwards, there are a few cases of companies that they implement Six Sigma which are being applied by many companies today. Some examples of Six Sigma developments are several companies are explained following.

General Electric: General Electric is one of the first successful companies which implement Six Sigma. GE adopted this approach after Motorola. The CEO Jack Welch was who applied the Six Sigma in the company. J. Welch put all his enthusiasm and effort in the new way, but some surveys indicated that it was not going enough good to improve the quality. He made some mistakes in the implementation such as central management and too formal and without specifically agreed-upon measures (Brun, 2011; Welch, 2005).

The change arrived in the 1995, because Welch were exploring more robust quality improvement methodologies, and in that year he talked with Larry Bossidy, a former GE employee, and he convinced him that Six Sigma was the best for General Electric. Larrry Bossidy had outstanding results in Allied Signal (Brun, 2011)l. Welch's thinking was focused in the reduction of costs but then he realized about the quality from the customer's perspective. Welch said "We found out that it was all about being better for the customer" (Welch, 2005, para. 2).

In General Electric, after the change in mind of the CEO, they did two strategies; 13-days training for every employee; and promotion depending on the performance of the Green Belt Training. They trained more than 100,000 employees in Six Sigma. So, the benefits were also for the employees because they learnt some new skills. After the new strategy, the benefits from 1996-1997 were more than up 10% in the revenues and earnings per share. They also registered a record in the company a risen about 16% in the operating margin (from the GE Annual Report 1997). In 1999 the costs saving were more than 2 billion dollars (from the GE Annual Report, 1999)(Brun, 2011). The total revenues in 1996-1999 were $382.1 billion dollar, increasing more than $20 billion dollar comparing the benefits in 1996 and 1999 (iSixSigma, 2002)

Sony: This Company enjoys one of the most worldwide reputations in customer and professional electronic goods for the excellence of its products. Sony introduced Six Sigma methodology into the strategy of the corporation in Japan at the late 90s. Sony trained the employees, to develop and implement Six Sigma. It was focused on the Define phase of the methodology to decide the best aims to get. The first projects were developed in the manufacturing area, generating improvements on the reduction in costs and increasing the efficiency and the productivity (Brun, 2011). To achieve the strategic goals Sony used a Management based on value creation, a supply chain management, and the implementation of Sony Six Sigma. By using Sony Six Sigma they earned more than 30 billion yen in the first three years of its implementation. Nowadays, as other companies, Sony is implementing the methodology of Six Sigma not only in the manufacturing area, but also in transactional and service operations (Akpolat, 2004).

Dow chemical: This chemical multinational company is one of the biggest in the world in its area. Dow began their Six Sigma journey in 1998. They wanted to incorporate this philosophy in the business. The success made them to set up Six Sigma in 1999 as a management strategy. Dow realized about the new customer commitment and the idea of the customer value (from the Dow Annual Report 1999). Moreover, Dow achieved productivity improvements due to the new Six Sigma organizational structure and the commitment to the philosophy (from the Dow Annual Report 2004). The first implementation was in the headquarters but after the success they included it in every country. The success of Dow Six Sigma Services is proved with 75,000 projects throughout during 12 years, more than $10 billion of verified EBIT in the first 10 years, and upon 12,000 trained projects leaders (Dow Chemical Company, 2014).

These are three big companies which implemented Six Sigma and continue with the improvement philosophy. Then, in Italy for example, there are companies implementing Six Sigma such as Fiat Services, Avio, ITT-Lowara, and International companies from varied areas such as Axa, Whirpool, SKF (Brun, 2011).

2.3.1. Critical Successful factors in Six Sigma

Recently, Six Sigma studies are becoming more popular. In the article of A. Brun (2011), the base factors of successful Six Sigma implementation in companies after his researchare presented afterward. This Six Sigma study exploited an extensive literature of more than 100 articles in international publications and 96 books.

The critical factors that are the successful items pointed out in this research are varied and depending from the company, size, area, type of industry, etc. The highlighted “Critical Successful Factors” (CSF) are (Brun, 2011):

- Management involvement and commitment.
- Cultural Change.
- Communication.
- Organization infrastructure ad culture.
- Education and training.
- Linking Six Sigma to business strategy.
- Linking Six Sigma to customer.
- Linking Six Sigma to suppliers.
- Understanding tools and techniques within Six Sigma.
- Project management skills.
- Project prioritisation and selection.

2.3.2. Six Sigma performance studies

Linderman et al. (2003) claimed that Six Sigma has had a significant impact on the industry. However, there is a lack of theory for the Six Sigma research.

The investigation of Lee and Choi (2006) on corporative performance showed positive results about the four management activities of Six Sigma. The results said that these four activities, information system, communication, education and training and policy system have influence in the process innovation, quality improvement, and corporate competitiveness improvement. The main weakness is that it was only studied in different headquarters but all of them from Samsung Corporations (Lee, et al., 2012).

Thanks to the research of S.M. Shafer et al. (2012) an empiric research about Six Sigma performance was done. The research developed a study to know the positive impacts in the organization performance and efficiency of employees. There is no evidence of negative impacts of Six Sigma in the companies (Shafer, et al., 2012).

In this study of S.M. Shafer et al. (2012), there are many companies included from a huge variety of benchmarks, so, there is no interaction regarding the area of the business. It is investigated the impact of Six Sigma in companies which have been operating with it for over six years. The firsts three years prior the implementation, the year zero is the year of the adoption of Six Sigma, and the six years post Six Sigma implementation. This time is given to ensure that they have enough time to perform the benefits. So, the year 0 is the event year when the company adopted Six Sigma.

Also, the commonly measures that are used are the *OI/A* (Operating Income/Sales), *OI/S* (Operating Income/Sales), *OI/E* (Operating Income/Number of Employees), *S/A* (Sales/Assets), and S/E (Sales/Number of Employees). Operation Income is calculated as Sales minus Total Cost (costs of goods sold + selling and administrative expenses). OI illustrates clear the cash that is generated from operations. They divide the OI value per assets (A) or sales (S) to control the capital expenditures and the size of the business, and the sales are divided by assets or number of employees for the same reason (Shafer, et al., 2012). Moreover, all of the values are compared against industrial adjusted results to know if the firms are outperforming in comparison to their sector. It is also compared a sample Six Sigma company's performance to other companies' performance that are the closest matched firm and a portfolio of control firms matched to it on the basis of industry.

The purpose of the research of .M. Shafer et al. (2012) was to study the impact of the Six Sigma implementation. The result is that impacts positively on the organizational performance and the efficiency of the employees involved in the implementation. The study shows dynamic and static analysis. In the dynamic are included a range of years in the comparison and the static shows the performance of that specific year and in both were observed benefits.

The study shows that the prior years of the implementation of Six Sigma, there is no many significant results between the Six Sigma firms and the group of similar companies. The interesting point is that after the adoption the Six Sigma firms outperformed their competence in the years following on OI/A, OI/S, OI/E, and S/E although there was no interesting results in S/A being similar.

One interesting result is that the Six Sigma firms outperformed their group of similar companies in the year -3, and then, they decrease the next years prior to Six Sigma adoption. But at the end, when they have already implemented the new excellence methodology, they react with a quick rebound leading. This occurs in the OI/A, OI/E, S/E between the years -1 to +1. The reason is because the group of similar companies are having advantage while the others are implementing the new strategy. However, the Six Sigma companies after their beginning they know to respond better to the unexpected problems of deteriorating performance. It is one of the most improvements observed in the companies with Six Sigma against their competence.

Another characteristic was the higher productivity of employees. It is better than their industries' and related group of companies. The results in OI/E and S/E in comparison with the benchmark groups are outperformed. Besides, the employees' productivity performance increases after adopting the Six Sigma due to the skills and experience that the workers learn with Six Sigma in the running of the processes. With this new way they increase the results in S/E thanks to this additional experience after the set up of Six Sigma (Shafer, et al., 2012).

To sum up, there are better benefits after the adoption of Six Sigma and then, the continuity of the benefits is showed. The greatest improvement is in the employees' productivity. Nevertheless, the benefit of the asset productivity is not so significant after some years from the implementation.

Chapter 3

Lean Six Sigma in the wine-making

3. Lean Six Sigma

The Lean Six Sigma is an improvement methodology of the two management philosophies, which have been explained before, implemented together to increase the power and the benefits in the industries.

The Lean Six Sigma concept was published by George (2002) and his definition was:

“Lean Six Sigma is a methodology that maximizes shareholders value by achieving the fastest rate of improvement in customer satisfaction, cost, quality, process speed, and invested capital” (George, 2002 p. xii).

George (2002) also said that the combination is necessary because Lean cannot have a statistical control process, and on the other hand, Six Sigma cannot get totally better results in the process speed or in the reduction of the invested capital (George, 2002). Thanks to the synergy of their methods and principles, the Lean Six Sigma integrates the DMAIC cycle (Define, Measure, Analyze, Improve, Control), which is the main methodology of Six Sigma, used as a tool in the continual improvement implementation and also focusing on the reduction of defects and variability in the processes through the standardization, waste reduction and lead time reduction of the products, which are some of the aims of Lean Manufacturing by optimizing the current value stream. Both together attacks directly to quality and costs more effectively than another previous improvement strategy, it comprehends quality and speed process (George, 2003).

Regarding an only Six Sigma strategy, it lacks of three lean manufacturing benefits which according to Devane, are the following (Devane, 2004):

- Inventory reduction.

- Speed process improvement.
- Financial benefits in short-term because it requires time to learn, collect data, analysis and apply the methodology.

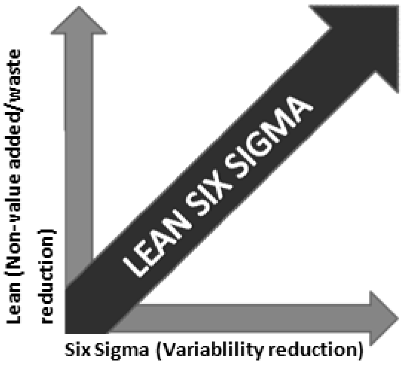


Fig. 3.1. Lean Six Sigma approach. Source: [Author]

On the other hand, if the strategy is based only in lean manufacturing techniques, there is lack of other three main benefits from Six Sigma which are (Devane, 2004):

- Control process under statistical tools.
- Measurement of the variations in the processes.
- Practices related with quality and mathematical tools to find out the roots of the problems that are hidden and after a waste reduction remains there.

In contrast, the combination of both strategies together is an integrated approach. The key Lean Six Sigma approaches based on Devane are (Devane, 2004):

- The Voice of the Customer and the Critical-to-Quality (CTQ).
- Six Sigma metrics
- Elimination of waste and non-values added activities.
- Process study.
- Accidental variability is main problem.
- Value Streams.
- The "DMAIC" improvement process.

The benefits that DMAIC cycle will provide is that it is focused on finding solutions to problems and opportunities, and to do it, it is based on data and information to manage the decisions, rather than assumptions. Therefore, the project management standards will create the formal steps to the implementation of the solutions.

Lean Six Sigma is considered as an operational excellence strategy model. Both Six Sigma and Lean management involve cultural changes in organizations, new ways to produce and customers' service, higher training of the employees form management to operators (Arnhneiter, et al., 2005). This methodology manages with a more intelligent management in the organization.

As it has been explained in the previous chapters, the customer requirements and his satisfaction are the key. The methodology works always using data and facts to elaborate the solutions and strategies to follow. For achieving the maximum benefits the employees must be encouraged with the change and its implementation. It generates better confidence in the employees and promotes more creativity and innovation in the job. These improvements in the employees' skills can be useful to a better participation in the continual improvement. So, regarding Lean Six Sigma and the organization, if the company invests in the employees, then, they will have better skills influencing on their positive spirit and confident in their workplaces and organization. Always they look for the aim of achieving the maximum efficiency for the company. Furthermore, there is a good point with this implementation because it has the power to deploy a continuous organizational change by aligning the objectives of the organizational vision to the excellence model. (Pamfiliea, et al., 2012)

As a result, the application of the excellence model Lean Six Sigma can be a solution to survive in the business environmental because it is known that the market is dynamic and always changing. The quick answer to these changes will take advantage of the situation. Lean Six Sigma can provide the tools and resources needed to the development of the company.

3.1. Lean Six Sigma in the viticulture and winemaking

Inside the agricultural and agrofood business there are some problems that there are not present in the manufacturing companies. So, it could be thought that the management and implementation of these strategies explained in the previous chapters are more difficult to carry out. One of the reasons is the life cycle of the food which is an aspect that it cannot be avoided in most of these food industries. These industries are much related with the environmental and conditions such as the weather, climatic conditions or the ground properties influencing directly in the yield and quality and quantity of the production.

Except for these aspects, the agricultural and agrofood factories are similar to other type of industry. For this reason they should try to incorporate and implement the best management strategies to remain in the market and be able to compete against the rivals. These sectors are usually not optimized or standardized enough and they could improve their yield performance, resource consumption, cost saving and the improvement in the quality of the products (Bettini, et al., 2010). Thanks to Lean Six Sigma, it is possible to recognize the areas where the processes can be improved and find some inefficiency areas, their causes in order to generate solutions to improve the quality of the processes. The benefits of this methodology have been proved in manufacturing industries. However, more recently, other companies have successfully applied Lean Six Sigma in very different sectors (Brady, et al., 2006).

In the viticulture or agriculture there are still few applications of continual improvement techniques or more sophisticated like Lean Six Sigma. As the same level as other sectors, these techniques might generate benefits in the viticulture sector because there is no reason to not do it. Nowadays, the viticulture and winemaking is more industrialized and with more modern machinery trying to increase the efficiency of the production and the reduction of operation times. It is similar to other sectors of the economy because they use resources to create a product that the customer wants.

In the last years there are more winemaking companies applying the new Lean and Sig Sigma techniques. The company *E. & J. Gallo Winery* is one of the most important winemaking companies in the world. They start from growing grapes to the bottling and delivery around the world. E.& J. Gallo Winery works as a normal big company running departments in every area and also more technological areas such as Engineering, Vineyard Management, Information Technology (IT), Production, Operations and Supply chain and so on(E.& J. Gallo Winery, 2014). At E. & J. Gallo Winery, their teams maximize wine grape quality, researching information to minimize the effect on the ground and surrounding environment. They cultivate and maintain the vineyards with the best strategies they know, with good instinct and skills, turning what nature provides into a great harvest with the aim of creating the better quality and production as possible.

Obviously, this example shows that it is really necessary to manage many areas from all of different departments to achieve the best. E.& J. Gallo Winery have many areas in which they should improve the processes to reach and maintain the popularity and quality of its products. They pay attention in areas inside Production, Operations and Supply Chain such as Bottling Operations, Distribution, Engineering & Maintenance, Inventory Management, Lean Six Sigma, Operations Strategy & Research, Process Technology, Quality Assurance & Quality Control, Supply Planning, Warehouse Operations, Winery & Cellar Operations, Customer Service, and Glass Bottle Manufacturing (E.& J. Gallo Winery, 2014). In all of these areas there are experts working for the better optimization and the generation of the better quality focused on the customer desires. There is the Lean Six Sigma area in the same company which proves the desire of the improvement of the processes, quality, costs and all the benefits associated.

In USA, there is another Winery which is based on the Six Sigma philosophy. The name's company is *Six Sigma Ranch, Vineyards and Winer*y. The name wanted to show its intention to produce a quality product. This winery was praised in the *Wine Enthusiast Magazine* and rated with of 91 out of 100*.*

This winery has Six Sigma methodology in every stage from the vineyards to the bottle but without large-scale deployment, because there are not full-time Black Belts or Green Belts on staff. Kaj Ahlmann, the owner of the company, applies the methodology Six Sigma at every stage of the wine production. Every stage is understood as a large SIPOC (suppliers, inputs, process, outputs, customers) and they can know what is important in every stage getting an high-level overview. For improve the customer's quality, they also include the VOC (Voice of Customer) to link the customer opinions to understand what they want and need, for this reason is the most important consideration (iSixSigma Magazine, 2009).

Understanding that the customer is vital for the company, and for any business, the winery needs to distinguish who is its customer. The company will have different expectations and requirements if the customer is a winemaker, end customer of the wine, liquor outlet or if it is an online purchaser.

As other Lean Six Sigma projects, the Six Sigma Ranch roadmap is DMAIC and they use data to make their decisions in every process step. Data is really important to know what the roots of everything are inside the processes.

One of the problems related with the new methodologies is thought that it could change the production of the wine and make them loose the romantic essence in the wine business. In fact, the benefits of using data does not lose any essence, every stage can be done on the same way, but the good point is that they can be able to recognize why a glass of wine is not as good as other because they will know much information. For example they can know when the harvest was or what its temperature was. Furthermore, in next more industrialized stages, they can know with detail every parameter and know from the past data what must be the ideal parameters to get the right quality which is desirable by the customer. The idea is that you can go back and look what was the process of making that wine and go forward with the new information. It is the spirit of the continual improvement and DMAIC cycle, collecting some data to measure, analyze, improve and go again to control if the process is correct. So, without gathering data and measures the processes cannot be improved. Moreover, if the company has a constant data control, then it can use it to achieve the customer's aim about the product applying the knowledge from data to the winemaking process. So, for Six Sigma Ranch, they like to say they produce based on science and art.

3.1.1. Integrating DMAIC in the viticulture

During the growing time, the employees in charge of the control of the properties of growing grape need to have control every certain time to register how it is going the maturation of the fruit (iSixSigma Magazine, 2009).

It is always important a database of previous harvest to know about some references and be able to forecast better the future. The integration of the DMAIC cycle to improve the quality in the vineyard could be started from the phase 1 (Define). In this stage, the harvest can be considered the most important moment so; the idea will be to improve the quality of the grapes at the moment of the harvest, when the fruit gets the perfect conditions.

As it has been ilustrated during the Six Sigma philosophy, the final goal is to satisfy the customer expectation. In the wine market, during the stage of the growing and harvest, the winery has to control all the attributes that make the wine be what the customers desires to know the right moment of the harvest. An adaption of the DMAIC could be the next for this stage (iSixSigma Magazine, 2009).

<u>Phase 1: Define</u>

Some Six Sigma tools are used in this phase to define the main aims based on the customer's desires. The SIPOC diagram can help in this phase to realize about how it is the process. Starting from the *Customer* side, in the harvest it would be the same wine-making company because the winery produce their own grapes to produce the wine in the next stages. The winery receives the output, the final grape and the results of the chemical analysis; *Outputs* are the results from the laboratory analysis in this stage. This analysis inform when the grape is ready to collect; *Processes* are all the maintenance processes of the vines, the taking of samples, tests in the laboratory, compilation of the results, to collect the grape at the best moment; *Inputs* are the vines and fruit, samples, machinery, soil, yeasts, chemical products for the analysis and the workforce; *Suppliers* can be chemical companies, tractor companies to transport the fruit to the winery.

Based on the processes and all the information of the SIPOC, the critical-to-quality attributes (CTQ) must be defined. Including the voice-of-customer (VOC), the project should define the attributes to control to achieve the expected quality. So, the PH and sugar and acidity levels and phenol maturity could be good CTQs indicators and all the soil condition, chemicals used in the growing, can be the variables Xs influencing the CTQs. These are probably the most important variables to know when collecting the fruit. These factors will affect to the result of the taste and flavour of the final wine and consequently, in the customer satisfaction which is the same desire as the wine-making company.

After this, a planning of the execution of the phase can include the way in which the analysts are going to take the samples, because they cannot collect samples from every vine. They have to decide the position of the samples. It is possible to have variations because not every brunch received the same light or water for example.

These would be the most important steps to develop in the phase 1. Thanks to the experience they must have some illustrative values to follow, but after some applications of the DMAIC they will improve the reliability of their values and also will control better the final result of the wine.

Phase 2: Measure

Once the CTQ are defined, the chemist, should record the results of the samples of the soil properties, minerals and chemicals. It is possible to take many samples for a following analysis. These variables are the Xs of the processes, which are the inputs and how they develop along the growing of the grape. Then, they can be associated to the CQTs or outputs like PH and sugar level, or even quantity of natural yeast in the fruit, which all these together will give the flavour, aromas and taste to the wine.

The measurements can be compared with the optimal values up-to-date that the company considers and evaluate if the results are better that other harvests. From the samples, statistical tools like histogram can generate a normal distribution to know if most of the harvest is inside the specification limits (LSL and USL) and if it is capable (Cp). It could be possible to calculate the number of kg of grapes which are not achieving the levels and can alter final taste.

Phase 3: Analyze

In this phase, the company tries to define the root of the high variability, thanks to all the data collected and with the use of statistical tools. For example in the study of the grape properties, they can analyse data from one part of the vineyard and from other part and relate the variables from each zone of the vineyard to find some roots to explain what happens in each area, if the results are the same or different. Then, it can be analysed some differences in the speed growing. With a cause-effect diagram, they can recognize the causes to pay attention there.

Then, in this phase the statistical tools are very important to find a solution to improve the process. A scatter diagram or box plot can give an idea of the evolution of the variables X's depending on other variables or if the variables CTQs are related with some X's or with other CTQs. It can be analysed the relationship between the growing speed, maturation and generation of sugar in the fruit with other attributes from the soil or zone of the vineyard, etc. A Time plot series is helpful to study the evolution of these variables along the growing time and check if there is some relationship or not.

Finally, doing an analysis of the variables and capability analysis to know if they are inside the expected results or if there are some defects in the cultivation can lead the strategy to improve the quality. Through the defining of the target and comparison of the mean from the histogram of the samples it can be seen in which situation the process is. Then, the company will take decisions based in data to harvest at the right moment in each zone of the vineyard.

Phase 4: Improve

In this phase, the first step would be to evaluate the situation. The company should check what the capability of the process is and try to improve the quality of vines that are not following the expectations.

In this stage the solutions to improve the vineyard can be the development of a design of experiments (DOE) with high and low values. In this experiment, they can change in the parameters of the soil, and check how they react to these experiments. For example, the experiment can control the acidity on the soil and the PH of the grape or it can be possible bigger experiments with more factors, including also the sugar speed creation in the grapes, phenols and some specific soil minerals. This tool could help to optimize the velocity of the maturation due to the experimentation, checking variables matched with the speed maturation and growth of sugars in the grape. Thank to the experiments, they can decide what the best strategy for the grape growing is and it could be possible to find the values of the parameters which maintain less variation of the main variables and optimize the CTQs variables. An improvement would be the creation of a standard procedure to perform depending on the values obtained in the samples.

Phase 5: Control

In this context, control would mean that the winery always collect the grapes with the same properties every time and with the best values for the best final product. After the new knowledge from the previous steps, and after the implementation of the new changes in the Improve phase, the winery should apply and control the results to check if the results are being the expected. Statistical control of process is a useful tool to monitor the results and get solutions. They should control if after applying the new improvements in soil condition or in the taking of samples, the parameters CTQs such as levels of sugar and PH are more similar in each vineyard zone, or have less variability between zones of the vineyard and achieving if the this parameters have the right values for the moment of the season.

In the author's opinion, interesting questions during the processes can help to get a more stable process such as: What is the most influence Xs in the process? What are the good nominal target of X (soil composition, acidity, etc) values? How often should the winery take samples of the grapes? How many number of grapes should they collect and from which areas of the vineyard? Does another attribute or an uncontrollable parameter need to be measured too?

When the parameters Xs and CTQs are controlled the point is to reduce the specific limits to go step by step reducing variability in the process and focusing on be nearer of the target value. Therefore, the company will try to achieve a more similar grape in every harvest with highest quality.

As a result, some applications in the vineyards can generate benefits thanks to data because it is possible to make adjustments in the vineyard soil to keep always similar conditions every year. They can add some physical and chemicals to change the acidity of the soil, and planting the rootstock in the best position to create better harvest. They can take sample to know when it is the right moment to the harvest and if they planted with the same conditions they could collect the grapes relatively at the same time. Otherwise, it might introduce variability in the products. However, in any case the grape growing is an input a bit unpredictable due to the natural conditions and weather.

Other data can be registered about if the vine shoots were pruned properly or if one shoot grows more than other. So, it is possible to come back and analyze why. Maybe the reason is because it had too much water, fertilizer or lack of competitiveness because there were not enough vines there.

The moment of the harvest can be decided based on the sugar, PH and acidity levels of fruit. These parameters can inform what would be the percentage of alcohol after the fermentation, so they should do the harvest when it is the right moment. Of course taking care about all these data might improve the quality and reduce variability in the properties of the grape. To do these verifications they take samples to control in some specific areas to extrapolate the results in the whole field because it is impossible to take samples of every bunch. In this way, they know how is growing and maturating and if it happening equally.

Outside the vineyard, one of the first stages is the pressing, they check the levels and properties again before the grapes come into the press to make sure all the row material is maturated as it is expected.

During the fermentation process it is possible to monitor and decide the critical-to-quality (CTQs) attributes that will make the wine be what the customer wants. There are several variables which must be measured (iSixSigma Magazine, 2009);

- Temperature.
- Brix level, which is a level to measure the quantity of sugars.
- Acidity levels and PH
- Phenols
- Malolactic fermentation, the main element to add softness to the red wine
- And others attributes.

So, the data and the experience make the company know the best values for the best result. The analysis with statistic charts can explain relation between attributes. The process of capability can show that the attributes are inside the right levels before the bottling or barrelling.

There are different kind of process to treat the grape-juice depending the type, white, red or rosé or sparkling wine. There are different yeasts to use in every type. Some of them received more treatments with their respective temperatures, times, and specific values for their attributes such as sugars and acidity.

For example, there are differences between types of wine because the sparkling wine does not finish the fermentation in the tanks, it continue fermenting in the bottle, for these reason the gas appear in the bottle. This gas is the carbon dioxide produced as a residue after the conversion of the oxygen and the sugars of the wine. Also the bottle is wider and stronger than the red and white wines for example.

As a result, it can be concluded that the new traditions can enhance the old ones, and continue with the art of the wine. The new ways of running a business make the modern agriculture necessity to work as an industry because it has many components from the heavy industry: production, logistics, marketing, and others. The regularly updated helps the tasks of reduction the waste, improvement of quality, better pricing, and better logistics. These requirements are necessaries to know the growing demands of quality and food standards in the current agriculture and consideration in the resources used. Consequently, the use of scientific methods such as Lean Six Sigma is a way to improve the competiveness in the agricultural sector in the global market and the environmental quality of agricultural and agrofood products (Bettini, et al., 2010).

3.2. Transporting, bottling and labelling the wine

As it is shown, the winery industry is a sector in which there are many opportunities to develop strategies to improve the business as some examples have been given before. There is a case study based in a high quality winery in Tuscany where they focused in the process of the transport of the liquid housed in the cellar to the tanks before bottling (Bettini, et al., 2010). They focus on that because a quantity of wine is loss due to mechanical reasons related with the pump and the long distance between the two tanks. This activity is very frequent in the wineries, so they cannot let themselves to loss significant quantity of wine inside the pipes which is the problem that in the case study they performed.

In this case the improvement is between the finishing tank and the bottling process and pumps and pipes were used and after the transport. It always appeared some losses of wine in every movement. This waste multiplied for the huge quantity of times they do this operation and the number of tanks generated a big economic quantity of cost. Besides, the discharge operation could be also estimated as a long valuable time, and it was another characteristic needed to quantify, so, they performed the time of the discharge increasing the output.

To solve the problem, the main basic statistical tool was the histogram because they needed to measure some interesting metrics to determine the losses and the improvements in the performance solution. Thanks to this statistical tool they could know better the litres of wine wasted and its standard deviation, and the same with operational times of discharging. The regression analysis also is used to study how the losses appear along the weeks to know when they should replace the device selected in the solution (Bettini, et al., 2010).

Before the filling of the bottles some types of wine can be filtered to reduce small particles. With the sparkling wines they have to bottle the wine a first time to continue the fermentation inside the bottle during several moths more and then they will open to expulse the settled yeast after this second fermentation in bottle. After this they fill the lack of sparkling wine with a prepared wine with different levels of sugar and attributes to finish the final product type and they bottle again with the final cork.

Therefore, what all wines must have is the filling of the bottle, so, the good point is that in this process most of the Lean Six Sigma tools can be implemented, besides it is a manufacturing process so it is easier to link the concepts.

In each bottled product there will be their requirements, in the wine bottles case, the machine should create the vacuum to not have oxygen when they seal the wine with the cork and because the existence of oxygen will deteriorate the properties and aromas, what it means to be a bad product and bad quality. Also depending the brand, and the type, the winery can use some inert gases to fill that space like nitrogen, and some sulphur to prevent the oxidation and a possible future new fermentation inside the bottle.

The bottling line production is based in an amount of manufacturing machines. Currently, the process is automatic using robots. Most of the bottling processes have the same stages, so, it can be divides into 5 principal stages as it is shown in the next Fig. 3.2:

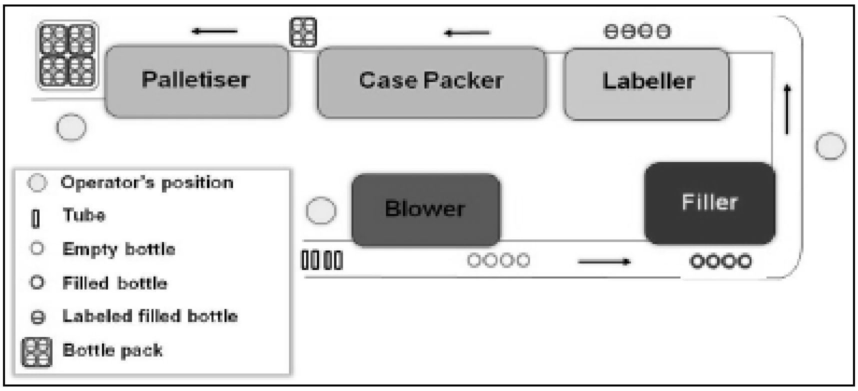


Fig. 3.2. Bottling production line layout. Source: (Veža, et al., 2011 p. 23)

Most wineries start with a stage where empty bottles are uploaded into a belt which moves the bottles to the line production. On the Fig. 3.1. the bottles arrive to the stage that is called *Blower* in that image . The treatment is to wash the bottles to get them ready for use them.

Then, the bottles might also receive some treatment just inside the next step, the *Filler*. It is necessary to eliminate the oxygen in the bottle to avoid the possibility of the development of aerobic microorganisms and to not alter the quality along the years. The good corking is also necessary to block the air come into the bottle.

Afterward, the wine is filled in the bottle and it can be done in the same machine, so, after that, it creates the vacuum and following fill it and seal it with the cork are continuous actions. Therefore, immediately after the filling, the cork is corked in the bottle. The requirements in the sealing are simples, because the cork must fit perfectly to not let the outside air pass through the inside. The cork is used for the wine bottles because it has a very good impermeability to liquids and gases and high compressibility and flexibility (Silva, et al., 2005). Otherwise, the wine could deteriorate and become a “corky wine” what might generate bad smell and bad flavour.

Then, in the same bottling line production there is the *Labelling*. The companies put their front and cover labels, so, they should change the labels regarding the type and brand of wine of the winey. Besides, there is a machine that places the capsules or the plastic that covers the top neck of the bottle. In the Fig. 3.2 is not represented the capsule machine because it shows a normal bottling line, not specifically wine bottling. So now, the bottle is done, so the next operation is the packing, that in the Fig. 3.2. is done automatically by machines but it could be also done manually in boxes and later in pallets all the boxes with the final product.

3.2.1. Problems in the bottling line production

Once the wine process has been explained from the beginning to the bottle giving some details about the different stages, this point is going to focus on the problems in the bottling process. This fact is because it is the area that fits better all the Lean Manufacturing and Six Sigma techniques. To have a better idea about the possible problems that could be found in the bottling, this study is going to introduce common defects, mistakes, wastes, losses of efficiency and so on that can appear in the production.

After a visual observation, some problems can be realized to appear.

- *Supply the material on time. Waiting and inventories waste.* For example in the first stage before the filling, it is necessary to have a control of the material supplied to not lose time waiting for the bottles or in other stages, waiting for the wine, labels or corks. Also it is necessary do not have too much stock in each stage.
- *Ineffective movements of the operators, transport of materials.* Types of waste defined in Lean Manufacturing.
- *Underutilized operators*. If they are not motivated or encouraged it could reduce the output.
- *Apparition of queues. Bottlenecks.* The Lean production always looks for a piece-flow reducing the intermediate stocks.
- *Bad conditions of the workplace.* Implementation of 5S to keep sorted, clean, standardized places for the materials.
- *Defects in the product and stoppages* in the process looking at all the machines.
- *Employee participation and responsibility.* If they can solve the problems on time when the errors appear as Jidoka.

After that, there is the possibility to register some data to know more about the processes. Time studies are the key in the creation of a Lean Six Sigma project. It helps to understand the real costs of work and also the way in which the time is carried out. The time measures are directly observed and registered. With data can be measured human or machines times (Veža, et al., 2011).

Relating the benefits from Lean and Six Sigma, some techniques can be applied in the bottling process. Thanks to data, in the bottling process, there is the chance to optimize some manufacturing waste and problems of this process.

- *Losses in the wine transport* of the wine to the filling tank.
- *Changeover times*. Replacing the different labels, the type of wine and others. In a winery with more than one product they will need to plan changeovers. They will need to set up the characteristics in the filling machine for the next wine if it is necessary some cleaning or adjustments, and prepare the change in the labelling for the new labels optimizing as much as possible.
- *Breakdowns times*. Important to reduce to achieve better efficiency.
- *Reduction of the wine lost* during the filling.
- *Do not fit correctly the cork* and place it in the right place, not higher or not lower.
- *Study and improve the OEE (Overall Equipment Effectiveness)* to know if some machines are more efficient to improve the worst and maximize the equipment.
- *Broken bottles* during the bottling production line.
- *Study which are the most common defects and reasons for stopping the production line.* It is represented with Pareto Chart.
- *Adjust the takt time* to the demand for a Just-in-Time production to be able to supply the customers on time.
- *Minimize customer complaints.* For this reason is important also the VOC.

Six Sigma and the SPC (Statistical Process Control) can assist the control of the variables of the process. Some examples to control can be:

- *Control the liquid inside the bottles.* To fill the bottle with more wine or under fill others it is not a well-balance system. The measures have to be inside the tolerances that the company or the clients want.

  For example, to study the capacity of the filling process, of a 750ml bottle, the process must be capable (Cp), and placed between the limits (Cpk) that the company consider acceptable. The importance will be because if the filling of the bottles is not centred in 750ml, and it is filling 752ml as a mean, the losses can be significant.
- *Control the corking.* To register the position of the cork after the process, and analyze the strength to open it.
- *Control the position of the labels*. An example can be the position of the labels. It is important that the place is following a centred process and inside the tolerances as well. It is necessary to keep the best quality as possible in the products.

- *Control the output and OEE in different shifts and products*. It could be possible that there are some operators who do not achieve the best output generating significant differences.

These are possible aspects to pay attention in the implementation of Lean Six Sigma. All improve the output of the business by benefits about times, costs, effectiveness. As a result, based on the Six Sigma scientific method, the idea is to improve step by step, starting by trying to know the root of the defects, errors or delays which appear more, and also involving all the people in the company to find the solution and then control and standardize the process to maintain the process under the customer and company expectations. In this case, control the processes of the machines like blower, filler, labeller, case packer and palletister and the operator’s processes.

Chapter 4

Bottling line: Case study

4. Bottling Line: Case study in winery MEZZACORONA

The winery Mezzacorona is situated in the north of Italy and it is at the foot of the Italian Dolomites and has a great experience on the winemaking. This zone receives Mediterranean and Alpine breeze which makes a microclimate that beneficiates the creation of the wine , being an area where the winemaking is very popular. Pinot Grigio and Chardonnay are the two dominant varieties in the Dolomites and Mezzacorona is the largest Italian producer of these two. Then, each variety is grown depending on the different climate condition of the zone, trying to produce the better wine possible.

The Mezzacorona winery is also equipped with modern enological equipment for a good control of the quality of the grape and wine. The winery has its own laboratory to control the whole process from the vineyard and grape to the bottle to create the better quality possible in all products. All of these details help Mezzacorona products to have great ratings for its quality what it proves the good practices in the company along the time.

4.1. Research methodology

The author had the chance to meet with the Director of Production and Quality thanks to the contact of the University of Trento and to visit more accurately the bottling lines of the company. So, the first step was the creation of a questionnaire focused on the bottling production line and all the possible matches with Lean Six Sigma (see ANNEX 10.). The main reason was to try to identify the main points of improvement, weakness, and strengths and so on. It was also necessary to know about general information of the company and their practices and a little research questions from all areas from the grape growing to the customer delivery of the final product.

The information research was realized along 3 days during the afternoon. In the next point of this chapter it is explained more in detail the information obtained (see 4.2.).

During the first appointment with the Director of Production and Quality, the schedule was a short introduction of author's interests and topics studied in the thesis and then having a pleasant conversation with him, the author could begin to know how is the philosophy, procedures and objectives of winery Mezzacorona.

Afterwards, the procedure was to make a visit of the bottling plant, which included the tanks with the stored wine, next to them, the bottling, corking, labelling and packing lines where the director explained to the author the function of every machine. Then, it was also seen the storehouse with the stock of final wine bottles and other raw materials. After that, it was answered the prepared questionnaire and finished with a visit of the laboratory of the company. The Responsible of the Quality Control department explained to the author how they control all the necessary attributes to get the best quality in the grapes and wine and how they analyze the grapes and wine properties in the laboratory.

During the visit some questions could be answered and more information was written down. Thanks to the explanation of Mezzacorona's Director of Production and Quality, the process was totally understood and all the machines roles as well. They showed to the author how they collect data for some processes and the procedure of the samples. Moreover, it was possible to take some pictures for a posterior checking.

In the second visit, the author spent the time on the bottling plant, following more accurately the processes in the line. The first step was to find out the best ways to collect data, looking at the displays of the machines, the places where the defects occur, the speed of the processes, the placement of the raw material, how the operators carry out their tasks and others. With some prepared table to write down the information on an easier way, during a couple of hours, the author was collecting data of the processes, materials flow, paying attention on the times and defects produced in the plant where there were two bottling lines (A and B).

The third visit was carried out on the same way as the second and the author continued collecting times due to the unexpected difficulties in the second visit. One of them was that the lines had some changes in the production, another one were the stoppages to check some machines parameters or problems with the bottles and the last one, the changes on the processes speed. The author took data from all displays of the machines about the bottles per hour produced, registered the number of intermediate stock, talked with operators about any doubt and ask them about the number of defective bottles produced in some controls meanwhile the author was checking other part of the line. The third day the objective also was to register all the bottles rejected from one bottling line.

Besides, the personnel of the laboratory department prepared to the author the data of the ‘extraction force of the cork’ and ‘volume of wine’ which are measured accurately in the laboratory beside other attributes of the bottle (see 4.3.3). This data is going to be studied in the following chapter (see chapter 5). This data is the only one they control from the bottling processes. There are other control but without recordkeeping data, only to know if the step it is correct or not.

4.2. Obtained information

The information collected and perceived from different ways during the visits to the company is explained in this point. Thanks to the first appointment with the Director of Production and Quality, the other two visits to the production plant, and the deductions based on the questionnaire, the author could understand how the company works.

First of all, Mezzacorona includes another brand for the sparkling wine which is Rotari. The demand per year is around 45 million bottles of wine and 2 million belong to sparkling wine of Rotari. The number of sold bottles shows the size of the company, which enjoys 3 bottling lines but they bottle in 2 every day, so, each line works around 66% of the year. Moreover, the company has an own laboratory to analyze faster than other wineries that need to pay extern laboratories having repercussions on time, maybe within 2 and 3 weeks. That benefits on the capability to react to the problems in the biological and chemical parts of the wine.

Philosophy

According to winery Mezzacorona, the company does not implement Lean Manufacturing or Six Sigma philosophy. Obviously they know about it, but their philosophy is focused on delivery always, working with big inventories as it could be seen in the storehouse. In the processes of the company, they do not work under variability reduction strategy. There are some techniques which are based on common sense and belong to lean philosophy too and they implement. The company develops continual improvement in all areas, using the suggestions from the employees, controlling the processes but without monitoring, paying attention on the interest of the customers.

Fig. 4.1. Inventories of bottles outside the production line. Source [Author].

In the wine sector, there is the problem with the main raw material which is the grape. It is a fruit and it cannot be ordered when they want, they should start the wine-making when the grape is ready and mature enough. For this reason they do not follow a just-in-time production. They produce wine when they received the grapes in the beginning of the autumn. This fact creates a problem to the lead time from the grape to the packed bottle because it can be from 2 months to 6 years depending on the quality of the wine. For the winery the activity that adds more value to the product is the creation of wine, as a result, they always start the wine-making when the grapes arrive.

For them it is a priority interest to have always stock of products because they want to deliver the orders in time and always. As not all the products have the same fermenting time, it depends on the variety, quality and others properties, the bottle is a bit restricted to the type of wine that is already created. They manage around 400 products, with batches usually about 40.000 bottles of a wine model and they try to sequence to not unbalance the stocks too much.

Organization and operators

In the winery Mezzacorona the communication between departments is open and informal, and between top managements and operators as well. To develop a Lean Six Sigma strategy, it is really important the participation from top managers to plant operators. The company has interest in the opinions of the employees and they collect information and suggestions every day from the production plant. So, the employees are totally involved and encouraged with the company and they would be ready if the managers wanted to develop a Lean production.

Most operators have Lean manufacturing notions because they carry out tasks about maintenance, cleaning, solving problems and they pick the bottles when the defect occurs to be reprocessed. Also the operators receive the production plan to not produce more than what is expected by the predicted demand. They are the responsible of this production and their own machines' maintenance and preventive maintenance, cleaning routine and they have the tools and the knowledge to fix them. As a result, the personnel has the basis for a Lean Six Sigma implementation according to this topic, they have routines which help to reduce the losses of time and reduction of defective bottles but without standardization of the tasks. Therefore, the activities can be improved by Lean techniques.

Production planning

Mezzacorona has a production plan to produce depending the predicted demand, so it does not follow a just-in-time philosophy, because they do not wait for the demand to produce the units that the customers desire. The winery, based on its experience, generates their forecasts that are usually regular with a seasonal increasing in Christmas. It is the way they plan the production. Therefore, they produce and store the product waiting to be sold because it is not easy to handle the wine-making when they want. They have a big number of tanks to store the a big quantity of wine for some weeks until it ordered to bottle, so, they have to plan the bottling to this wine during these weeks to not deteriorate their quality. In author's opinion the best way it could be, thanks to these tanks for storing wine, to try to manage a more just-in-time production. With this overproduction, one strategy that is very common for them is to keep around 20% of the bottles wine production for the next year.

Customers and demand

Regarding the customer approach, the winery know what is the customer opinion from several ways, but they do not have specifically surveys for them to know more details about other aspects of the purchase. They know that customers are satisfied with a very high quality-price opinion.

Mezzacorona is focused on their aromas and taste of the wine because it is what customers appreciate more. Also the winning awards are a consolidation for their wines. The interesting point is that these awards have repercussions on the sales, being important products for the company.

Based on the Director of Production and Quality opinion, the most important factors are the delivery on time and the price for both side of the business, winery and client. As it was said the philosophy is delivery always to not lose or postpone any demand order, so, also time of especial deliveries and send the completed orders are inside their priorities. Currently, they are working in some new products. From the customer's opinion, the company does not have any special way to know the important factors. Only sales reports give them a general idea, but in the interview he considered more important factors related with price, discounts and relationship with the client, always after the delivery in time. The customers are wholesalers, distributors, supermarkets and shops, and when they want the product the winery should have the product for the date. This fact generates influences in others factors because it keeps the confidence, good relationships, creating benefits in mid and long term. According to the forecasts, there are no big differences between types of clients and their demands. They follow the general predictions talked before about and rising of bottles on Christmas season.

Stock

One of the problems for a Lean manufacturing implementation would be the big stock that they have. At least, they always work with one month of stock of all the materials and they order when they achieve the security stock, which is one month of material. Taking into account that they can produce more than 3 million bottles of wine every month, the quantity of raw materials are very significant besides the stock of the final wine bottles. The space that requires is huge. They have a big plant where they store all the materials and this is a cost for the company and a 'waste' from the Lean view. All of these materials are bottles, corks, capsules, chemicals, boxes, adhesives tapes and others. An inconvenient is that they do not have available many different suppliers of bottles, and others main materials, so they do not like to take any risk of delay its production for a lack of raw materials, keeping in mind the idea of delivery always in time.

A good point is that the wine tanks are situated next to the bottling line and the stock is replaced it next to the machine which uses the raw material like bottles, corks, capsules, labels and boxes. Therefore, it tries to reduce moment of the operators.

Then, the final stock of bottles have a benefit to the winery because the wine does not almost deteriorate once is bottled, even it can improve its quality. Consequently, there is 'waste' in the winery. The principal are overproduction and inventory. Anyway, they sell under FIFO (First in first out), so the first wine of a model is sold first.

Suppliers

The replacement is ordered depending on the expected production for the next month. On the other hand, in a just-in-time production, they have to wait until the customer's order to start to produce the right number of bottles, managing better the stocks and consequently, lower inventories. They also need the collaboration of the suppliers to receive the raw material as soon as possible to reduce the inventories. Once the stock is supplied, some employees carry out the task of replacing the raw material to the point of use in the production line.

Wastes

Other wastes considered in the company are the movement of the operators. Despite each worker has their area or workplace, in author's opinion, the movements could be optimized better with a more compacted layout to reduce times. The other one is underutilized workers because most of the processes are automatic and if there is no problem or changes in the settings some workers are waiting for the next activity because the machines do not have the exact speed.

The last waste considered that is happening in the bottling line is the overprocessing. The rejected bottles are continuously fixed and put them in the process again when it is possible (more about rejected bottles see 5.2 and 5.3.). One of the operators' tasks which author could see is that they put the bottles, depending on the defect, in the entrance of the machine when this performed wrong for any reason or just remove the bottle if it not reusable.

Control devices

Mezzacorona bottling lines applies many Jidoka practices from Lean manufacturing. During the bottling process there are electronic devices or sensors which control that the activity is performed correctly. It is a way to reduce the defects after the stages but this controls does not monitor values, they do not register data of the attributes. The lines run automatically because they also have sensors to detect that there are bottles in the entrance of the previous belt. Consequently, the machines stop or reduce the speed when they do not detect enough bottles to fill the machine. Thanks to that, the machines can autocontrol the different speed between stages because not have the same cycle time and for this reason the line works with intermediate stock to avoid the downtimes and stoppages.

There are more sensors which make that only products with the right specifications could pass the step. So, main defect are detected during the processes. These sensors are explained before and are the tools to control at the exit of the processes (see Fig. 4.1.). They let the control system know what bottle reject. In addition, the operators have the power to stop the line when the problem requires it or the responsible consider it.

All the machines have a display where you can get information about the bottles performed in the stage, speed or bottles per hour. Also in each line, there is a display on the computer to monitor the temperature of the wine, pressure, valves of wine pipes and many other parameters.

More accurately, the company has three bottling lines. Regarding the bottling line B (see Fig 4.3.), which has been studied more in detail, the first control is when the bottles are filled and corked. The electronic device control the position of the cork, so, also detects if there is no cork, besides checking the level of wine in the bottle. The display shows the number of bottles that pass through the system. The wine volume must be inside an interval around 25 mm from the ideal height; otherwise, the bottle is rejected. The second control is after the encapsulating machine. It works in the same way, with an infrared system which perceived if the capsule is placed correctly or if it is not placed. After that, the labelling process has its control too. It decides if the label is placed in the correct position, with the correct angle, without wrinkles and so on. In this control the display shows to the operator the number of defective labels and the number of produced bottles of that model, also telling what is the defects percentage in this model. Problems usually appear after the changeover of the label because they should place again the bobbin of the new wine label and generates always some troubles to align it. The last control is situated at the end of the bottling line, where it packs the bottles. It is a scale and detects when the weight is out of the limits. It means that some bottle is missing. This control rarely rejects boxes due to is difficult that a lack of a bottle. It would be likely a problem in the previous processes.

In the next diagram the 4 control places appear represented in the process. These are the 4 automatic controls after the 4 processes more important for the final quality of the product.

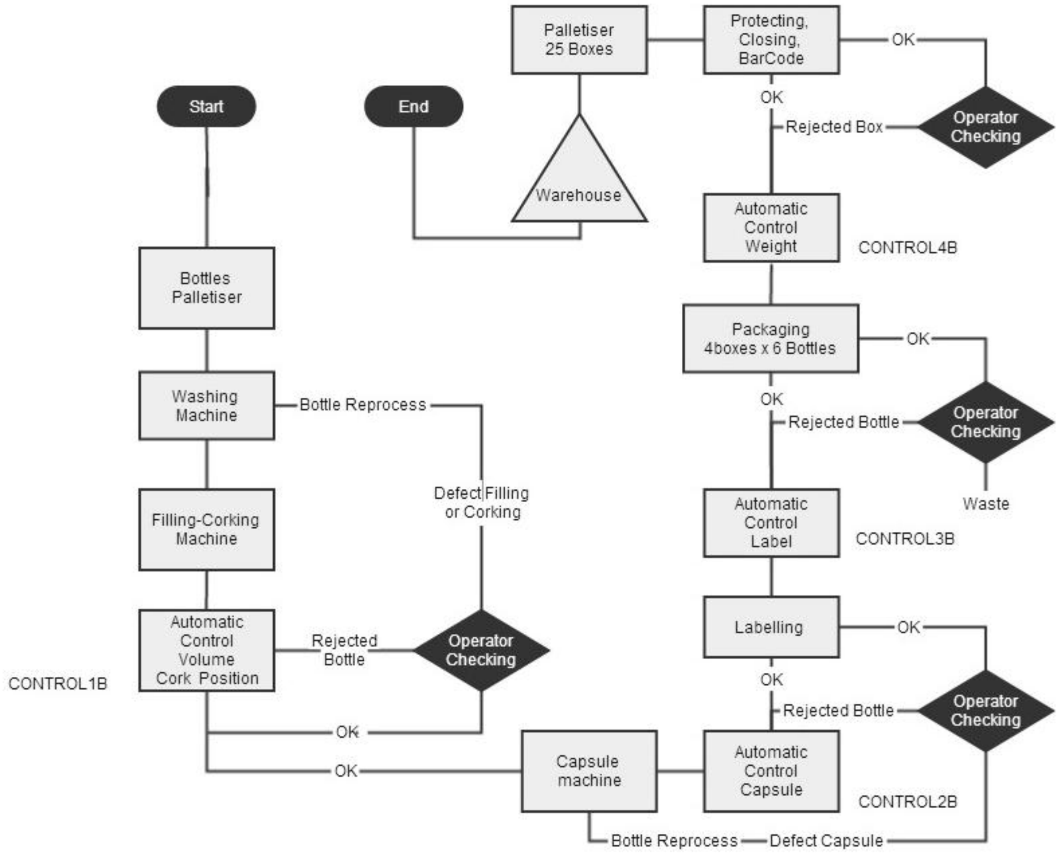


Fig. 4.2. Bottling and Packaging process and the control detectors of the line B. Source: [Author].

In the Fig 4.2. appears how the employees operate when the bottles are rejected. When the bottle is not correct, if the bottle has wine inside is returned to the wine pipe and the cork is removed. Afterwards, the empty bottle is put on the line again, before the washing machine to start again the process.

Recordkeeping data

Because of data is not registered in most of the processes, only if it performed good or not, they do not control the variability of the process they cannot implement statistical process control, which is a basic tool for Six Sigma objective. However, the company in the last years has increased its number of controls and samples to check more often the quality of the final products.

In addition, these samples are a bottle every hour at the end of the production. Then, they check in the laboratory all the attributes and they record the information from each batch but they do not analyze this data unless they consider big abnormities in it. If it is necessary to study the problem, they try to seek the root of the cause to avoid the same problem in the future.

These data registered data are the opening or extraction force of the cork, oxygen, vacuum and usually the volume of liquid inside the bottle besides other chemical properties analyzed in the laboratory. Furthermore, the opening force of another type of cap with thread shape is registered by the operators in the same production plant, but this type is not studies in the work. All of these attributes are the controlled variables during the bottling by data (see 4.3.3.).

Lean Efficiency

In the bottling plant, they do not calculate specific parameters to control the efficiency of the machinery, employees, time of breakdowns, downtimes, and changeover and so on. They know an idea of the time but analyzing the time is not an important issue for them. The producers know that they work under a lower speed for many reasons. There are fewer problems with the alignments of the belts, they have intermediate buffers between machines and it reduces the efficiency and productivity values. On the other hand, if the idea is to implement Lean manufacturing concepts they should start step by step taking times, standardize the activities and steps to follow, increase the loading times of the machines and reduce buffers and other lean concepts.

Fig. 4.3. Intermediate inventory between the palletiser and the washing machine. Source: [Author].

According to him, some of these problems with the machines as breakdowns causes are because of problems between belt and machine alignment or occasionally operators do not follow properly the instructions or some of them are untrained. It might be also related with the non-standardized processes like maintenance or changeover steps. Obviously, the workers responsible of the task know the steps to follow and they know the order to perform the changeover but the idea of standardization from lean manufacturing helps to avoid mistakes, differences between operators, and optimize times in the steps. Currently, the changeover between models is approximately not more than 1 hour depending on the characteristics of that model, line, and other factors.

The bottling lines which the author saw during the two visits to the plant, it could be examined during the second shift. They have two, the first from 6 a.m. to 1.20 p.m. and the second continue without stopping until theoretically 8.40 p.m. However, it can be modify depending on the quantity of production planned for the day. As it could seen, they were bottling until 5-6 p.m. and one line for example, finished before at 4 p.m. It is true that then the operators realized the cleaning, maintenance, and all their tasks the leave the workshop ready for the next day.

These concepts related with the sort and cleaning are fundamental in Lean manufacturing, being one of the first steps to pay attention. The 5S implementation helps to keep in order, clean and tidy for a better use of all items necessaries. About this technique there is a lack of more strict levels of items classification. They have a good cleaning routine, when they change the product or finish the day's production. However, they can improve the others 'S', to distinguish perfectly where is the place for each part, tool or material needed for any activity.

Six Sigma Statistical Process Control (SPC)

The last important topic is about statistical process control (SPC). Mezzacorona does not use statistical methods to analyze the processes. The winery collects information from all stages of the wine, but without treating of data, without using any statistical tool, only checking the values of all the attributes necessaries. The information that they mainly keep to control are values of variables of the process, the speed production and bottleneck of the process. With this information, they pay attention on the limits and the value. The product must have all the variables inside the specification limits instead of going further with SPC and control how the behaviour of the variables is.

Therefore, they do not develop a Six Sigma philosophy on reduction of defects or variability because they do not register this data, so, they cannot analyze them. The author saw that they only have software on the labelling machine which informs the operator about the number of bad labels in that batch and showing the last statistics of the 100 units and the percentage of the total bad bottles from the total. Although they do not control the defects in the production with much emphasis, the number of defects according to them is less than 1%, but the philosophy of Six Sigma goes much more far as it is written in the chapter 2, reducing up to insignificants levels.

In author's opinion, as he could realize, there is no statistical process control during the production of the bottles of wine. However, the author consider necessary to distinguish between the wine-making (from when they received the grapes, through the production on wine up to the wine is stored in the tanks before the filtering to be bottled) because the company pays much more attention to this phase because it is its main objective, create wine, and the bottling of the wine, which is more a manufacturing process is not as optimize as the other phase. The good point is that as the author explained before, they have their own laboratory. There, the winery controls the whole evolution of the grape, taking samples of the fruit, analyzing, modifying what they consider to achieve the best grape for their products. The Responsible of Quality Control, explained to the author they always check in all the phases of the growing the all the values such as sugars, acidity, PH, pesticides, proteins, and others biological aspects which influence in the flavour, taste, aromas, in other words, on the final quality of the wine.

This is the essential part, for this reason they invested in that small laboratory to have the power to control all of the growing. They enjoy the laboratory for other checking controls like oxygen or vacuum, which form part of the after bottling process.

Mezzacorona informed its interest to develop new software to optimize the processes in the company and have a better control of these concepts they do not monitor yet in the bottling process. Until now, the principal way to analyze results is the benefits and sales reports, so, based on financial parameters. There is no valuation of operator and machine performance, rejected bottles data or statistical process control to give some examples. This information would improve the results of the winery, which are fundamental for a Lean Six Sigma implementation.

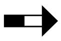
4.3. Collected data

4.3.1. Bottling processes

Once all the information obtained from the company has been explained, during the visit it was possible to take data to analyze the current situation of the processes. The study is about the bottling line B.

The main symbols are going to be explained based on the value stream mapping (see ANNEX 2. and ANNEX 3.).

Process
C/T (s) = Cycle Time (time since an item starts its manufacturing process until it finishes) *Speed (bottles/h)* = Rhythm of production of the machine or process. *Uptime (%)*= OEE (Avaliability) *Batch* = Number of bottles inside te process at the same time. *TAKT* = Each Takt time a unit it is processed and comes out of the process.. (Related with the Speed) 1 Operator 



Push system: The material flow is pushed by the process without pull production.

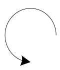
Pull system: The material is pulled by the demand of the next process or customer.

Inventory: It indicates the number of bottles usually in the inventory. At the end of the day, the line remains with this number of units in the inventory, ready for the next day.

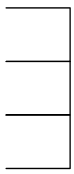
Buffer: It is situated between the processes. The number of bottles in the buffer is indicated. The line usually works with theses buffers full, because during the production there is some variation due to the speeds are not the same in all the processes.

Manual information flow

Electronic information flow



Material pull: The operator remove the material from the ‘supermarket’ when is going to use it. Remove each day the needed material for each batch production of a model.



Supermarket symbol: The processes downstream come to the ‘supermarket’ to pick the material they need. The upstream process should replenish as requires. In continuous flow is common work with batches size but every day its material required.

Other symbols are in the Fig. 1.2.

All the times are showed in the value stream represented in the Annex 2. These values for the VSM were collected during the second visit. All the speeds, times, quantities, correspond to the way that the process was working. Afterwards, this data is explained in the chapter 5.2 inside the Lean Six Sigma implementation.

4.3.2. Defects and rejected bottles data.

The second interest was to collect information about the rejected bottles. Based on the improvement of the quality in the company, the reduction of rejected bottles involves an improvement on this issue. The idea is to know what control rejects more bottles to pay attention on that defect. The defects that occur more often, obviously, are more interesting for the quality improvement and to create a more robust product, which means the product tries to be always with the same quality. The strategy is focus on the main mistakes before others that are working well currently.

Due to the winery does not collect data about this. During the visit, the first defects collected were in the production line A for schedule production reasons. After this time the line stopped its production, so, the author collected data during 3500 bottles. The line A usually works at 10.000 bottles per hour.

This line is different from the line B, because line A was producing thread bottle cap type those days, for this reason the study will be different for each line.

Worksheet 1 ***

↓	C1	C2-T	C3-T	C4-T	C5	C6-T	C7-T	C8-T	
	Day	Line	Defect	Place		Defect_LineA	Defect_LineB	Defect_B_day1	Defe
18	1	B	Corking	Control1B			Fallen bottle	Fallen bottle	Caps
19	1	B	Filling	Control1B			Broken bottle	Broken bottle	Caps
20	1	B	Corking	Control1B			Filling	Filling	With
21	1	B	Filling	Control1B			Filling	Filling	With

Fig. 4.4. Defects of the rejected bottles on data registered. Source [Author].

In the line B, the author collected data during two days. The first day, the defects and rejected bottles were studied during the production of 6.200 bottles, and the second day, during 9.000 bottles. The line runs at around 7.000 bottles per hour theoretical speed, but the final performance is less due to the buffers between machines, stoppages, breakdowns and other unexpected problems. It is programmed close to 7.000 bottles/h although it has power to run at 8.000 bottles/h, it depends on the planning of the day and they can select the best for their production.

It is considered necessary to be commented that sometimes a mistake occurred in the line during the data collection because some of the rejected bottles in the capsule machine were rejected but the bottles were correct, with the capsule. It only happened at that the *Capsule* process. Another comment is that the defect of *Filling* and *Corking* are counted separately despite they are controlled together because they produce under continuous piece flow but they are different machines, so the defects are not influenced each other.

On the same way, it is important to control where the defect was found because it could put out of order ting or in the electronic sensors problem. These control are 4 in the line 4; *Control1B* (Volume and Cork), *Control2B* (Capsule), *Control3B* (Label), *Control4B* (Weight) (see Fig. 4.3.) and also some defects occur on the *Belt* between processes.

The next chapter explains what deductions can be developed to find the best solutions based on the data (see chapter 5).

4.3.3. Laboratory registered data

Regarding the information stored from the laboratory of Mezzacorona winery and thanks to its collaboration, it was possible to have access to data related with the bottling line process. As it has been mentioned, the winery has data about only some attributes that they analyze in the laboratory; extraction force of the cork (Kg), oxygen (mg/l), vacuum (pressure), liquid volume (ml) of wine in the bottle. Of course, all these values are linked with their type of product and so on.

↓	C1-T	C2-T	C3-T	C4-T	C5-T	C6-T	C7	C8	C9	C10
	Date	Line	Product Description	Bottle Volume	Cork Brand	Cork Type	Extraction Force	Oxygen	Vacuum	Volume
1	07/01/2014	A	MEZZACORONA CLASSICA EU PINOT GRIGIO 750 2013	750	NOMACORC	MEZZA LUNGO (43)	33	0,30	0,00	747
2	07/01/2014	A	MEZZACORONA CLASSICA EU MUELLER THURGAU 750 2013	750	NOMACORC	MEZZA LUNGO (43)	32	0,25	0,10	748
3	07/01/2014	A	MEZZACORONA CLASSICA EU TEROLDEGO 750 2012	750	NOMACORC	MEZZA LUNGO (43)	27	0,17	0,00	748

Fig. 4.5. Data provided by the winery. Source: [Author].

In the Fig. 4.5. is showed how the database is provided by the company. The database of the study is all the data they manage from the beginning of the year 2014 to the end of July of the same year. It can be helpful for the company if they are interested in the improvement of the quality of these variables due to the data base is nearby 500 samples and the study can follow along many samples how are their behaviour. More exactly, is about 495 samples but for the analysis, not the study is based on 329 samples of *Extraction Force* for the 'Nomacork Brand'

and 415 of *Volume* of wine, which are the most important variables from this data if one consider only the bottling processes. Furthermore, there is another attractive point of this study because they do not treat these data with statistical methods like statistical process control, which can give information about if the process under control, capable, and give charts to interpret the behaviour.

The data includes samples from the 3 bottling plants; A, B and C besides the cork type depending on its length (Corto (37) and Lungo (43)). In the chapter number 5, the data from all lines is going to be considered to enjoy the whole information and analyze differences between lines too. There are more data about the Line A and C because they produce more bottles per hour, so, the winery takes more samples in these lines.

Chapter 5

Implementing Lean Six Sigma methodology on the bottling line

5. Implementing Lean Six Sigma methodology on the bottling line of winery Mezzacorona.

Once all the data information and processes of the winery are known, the implementation of Lean Six Sigma is not as easy as the theory explains. In the chapter 3, it was summarized most of the characteristics of the wine-making production, growing, harvest, and the following processes until they bottle and package the wine. As a result, Lean Manufacturing involves many techniques but not all of these can be applied totally as if it was a manufacturing company, because suppliers of the main product are not pieces, parts or materials, they are the grapes and they must be treated when their properties are ready for its production.

In this chapter, the techniques are going to be adapted to create the most reasonable solution for the real bottling line. The main improvement areas will be tried to develop to get the better results in a posterior proposal implementation. This study will give the route for this implementation, but it cannot go further and analyse the results after the implementation, for time reasons and because it will be necessary the decision of the winery to change its philosophy to a Lean Six Sigma thinking.

5.1. Phase 1: DEFINE

The first step to follow up to now is the definition of the project's aim. According to the opportunities and possibilities that can be studied of the company, the objective is the implementation, improvement and optimization of the next topics:

- *Application of compatible Lean manufacturing techniques to the bottling line of wine sector.* Identifying the processes, the add-value and non-value activities based on the value stream mapping of the processes and then the reduction of these non-value activities for a reduction on the lead time to produce faster.
- *Reduction of the number of defects and rejected bottles to lower overprocessing of products and waste of material.* The defects and overprocess generate waste in the process, increasing also the lead time, reducing the efficiency, so, focusing on its reduction, the company can beneficiate of a reduction on costs, time and waste of resources.
- *Reduction of the defects and variability on the Extraction Force of the cork* which is the traditional cork type for wine *in this case, 'Normacorc' brand* and *Volume of wine in the bottles*. Study the processes behaviour with statistical tools such as capability analysis and statistical process control (SPC) along 7 months of data thanks the laboratory of winery Mezzacorona.

The last three points are the main issues which are going to be developed. The schedule programmed is going to follow these three objectives according to Lean Six Sigma in which the first phase is the definition of the project. The three projects are going to be developed concurrently.

First of all, the project will give a Lean Six Sigma implementation methodology for the improvement on the bottling processes of a winery bottling line. In this philosophy, the customer is always the target where all the efforts have to be addressed. It is true that behind the expectations of the clients there are many factors that may influence the customer opinion, and as a result, influencing in their decision.

Focusing on the bottling process the Critical-to-Quality (CTQ's) are the attributes which are influenced by the importance of the voice-of-customer (VOC). The objective is to improve the customer's desires so, from the questionnaire explained in the chapter 4, the most important factors for the client are the *delivery on time*, the *price* and obviously, the *quality* of the wine, appreciating the flavours, taste and aromas (see ANNEX 10.). Now, the point is to link these factors to the bottling process to get better results and solutions for this area of work.

Behind the delivery on time, the purpose is to reduce all kind of delays and lead time to have better reaction to the demand.

For a view of the bottling line, it is useful the process mapping. In this step, the whole bottling process will be defined with this diagram and also thanks to a complement overview from the SIPOC diagram. In the process mapping, all the steps are represented and also processes that the operators have to decide when the bottles are not produced correctly what they have to do with that bottle (see below). Moreover, SIPOC of the bottling process complement perfectly to identify all the relevant elements of the process, inputs, outputs as well as customers and suppliers (see Annex 1.).

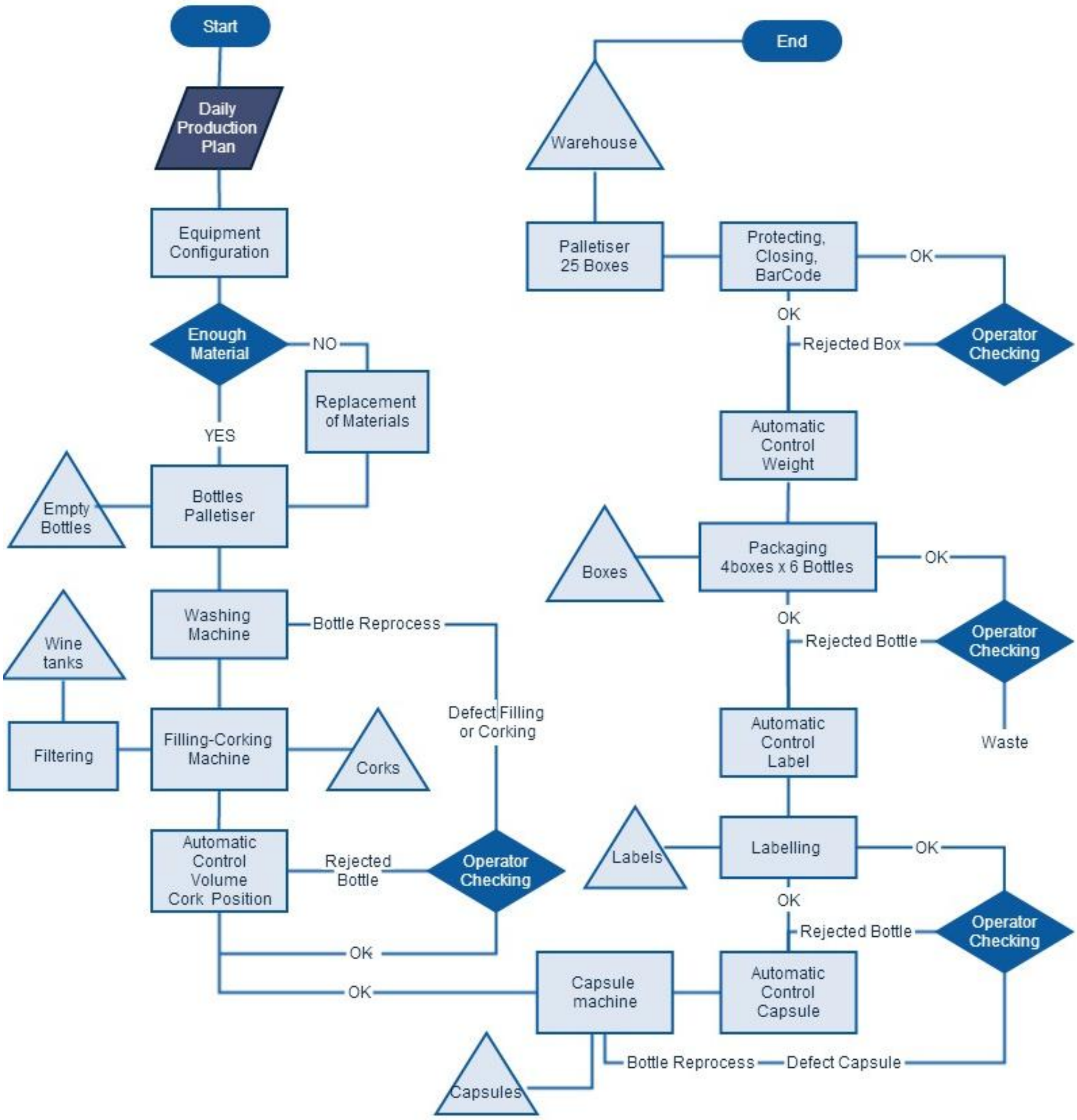


Fig. 5.1. Bottling process mapping of winery Mezzacorona (Line B). Source: [Author]

As it can be seen in the process mapping, the fact that bottles are rejected makes the process putting them into the process again from the beginning of the step. For instance, the first control makes the operator remove the cork (if the defect is the filling or bad position) and put the wine again into the wine pipe for the filling. Then, the bottle is put on the buffer before the washing machine to reprocess again. With the capsule happens the same, the bottle must be put again before the capsule machine to perform again. This fact generates waste of reprocessing and an extra time to perform again. When the defect is on the label machine, the bottle cannot be reused so it produces a defective bottle. These little incidents when are repeated, they generate waste of resources, delay of the production, they create difficulties to the delivery on time and increasing costs.

Regarding the inventories of materials, they have to keep at least the necessary units ready for the production batch such as corks, wine, labels, bottles, etc. This stock should be reduced up to necessary quantities for the reduction of the inventory of these materials in the warehouse and replaced in the right quantities.

The aim is also achieve the best expectations for the customer, the price is always more competitive and attractive if it is low. The minimization of waste of resources can let the company achieve the best competitive price for their products, so, the second objective which is the reduction of defects and also the reduction of variability, will encourage the minimization of bad products, out of specifications or other wastes that influence on the costs of production, increasing the cost per unit.

The last CTQ is the quality of the wine, aromas, taste, flavours, which are attributes that are more associated with the vineyard phase and wine-making. It is when the flavour and aromas create the essence of the wine and then in the bottling process, these characteristics have already created in the wine. After the bottling they can even continue acquiring more aroma and taste, but the way that the bottling process can improve the quality is, keeping always the best properties of the product through the reduction on the variability of the final product, in this work the variables studied are 'extraction force' of the cork and 'volume' of wine filled. It is necessary to keep a cork within specific fitting levels and a distance between the cork and the top level of wine to preserve the best properties of the wine.

Before starting any improvement strategy, the implementation needs the collaboration of all employees. It is always repeated in the literature of Lean manufacturing and Six Sigma, so, for a successful result the company has to be encouraged with the objectives defined at the beginning of this chapter. The employees of the plant need to be motivated to pay attention in all details when to reduce up to the lowest level the waste of resources, time, material, because every detail will be important for a better lean bottling line. In the same way, they need to work constantly to reduction of defective bottles, and variation of the products.

For the implementation of the new philosophy in the areas of study, they have to change their mind and realize about the importance of data because currently, they are not registering too much data. Therefore, this could be a new approach for the organization.

5.2. Phase 2: MEASURE

In this phase is when all the data is exposed to study from the beginning. This first study applies the values stream mapping for identify the bottling process and many basic statistics to get the first impressions of the processes. It allows the comprehension of the data besides knowing in which state the winery is and how to confront the following phases.

5.2.1. Current VSM

According to the Lean thinking, it is necessary to know all the processes as it is explained in the chapter 4. The bottling line processes are represented with the information collected during the second visit. The value stream mapping is implemented on the line B due to the availability of this line was the best when the author visited the plant.

The best way to recognize the waste is through the VSM which it can be seen in the ANNEX 2. Using all the information the actual situation of the bottling line is represented where the main flow material are the bottles of wine. Other raw materials are necessary for the line to produce the final bottle. So, the bottles flow involves the quantity of other raw materials necessary because each bottle needs one cork, two labels (front-back), one capsule, a box every 6 bottles, so the whole stock management can be organized.

The first interesting value is the difference between the lead time of a bottle and the real added time value. The value added is referred to the processes where the bottle received an activity with added value on the final product. As result, most of the 32min from the lead time, are not value added activities.

In this bottling line, it can be seen all the time wasted in the buffer, and in the inventory of bottles during the bottling. The result is that only 28,2% is value added time, so, all of the other time is not generating value. However, not all the non-value added time can be eliminated with lean techniques. For instance, the palletiser is not included in this value added time because the activity does not give anything for the product but it is a process that cannot be excluded. The bottles arrive from the warehouse in pallets of 1624 bottles and in each cycle time 232 bottles are introduced into the line. So, it is an avoidable activity. All the other processes are considered part of the product because without them the product is not the same, so, they contribute to increase the value of the product.

Nowadays, Mezzacorona winery as it was explained before in the chapter 4.2, does not wait for the customer demand to bottle the wine. It is represented with the push flow of material due to it is an automatic line. Starting from the beginning, the suppliers push material depending on the sales forecasts for the next month. They always keep at least 1 month of material to produce always. The stock is transported to the line where each process has its own stock for the day or product that is ordered to bottle. The other supplier is itself, Mezzacorona, because they make the wine from the beginning, from the vineyard to the bottle. The bottling process starts when the company send the wine already made to the tanks where it is stored until the plan production requires it to finish the product in the bottle.

Between the processes there is represented the buffer where the indicated quantity is usually in the buffer. This number varies because of the different speed of each machine. As it was told in the chapter 4.2., there are sensors in the belts between stages, which work as a buffer too, that control when this quantity of bottles in the previous belt decrease significantly. When this fact happens due to the different speeds, the process that receives the bottles from this belt stops and waits until the belt-buffer recovers the quantity that fit in the buffer.

Thus, the line production suffers some stops and for this reason the uptime available (see 1.5.7. formula 1.3.) is less than 100%. Only the washing machine was working all time because the configuration of the day of the visit was that, and it was the bottleneck with the minimum speed (6450bot/h) and the highest Takt production time (0,558s/bottle)

In addition, the bottling line data was taken in stable conditions, when all the machines were working in continuous flow. There are not considered breakdown because the winery does not register information. Therefore, it was not possible to study that factor to know the real uptime available and more OEE parameters of efficiency (see 1.5.7.).

After the bottling line, the packaged bottles arrive to the warehouse, where they are stored waiting for the customer order. Then, the customer starts the sales process. When the order is sent to Mezzacorona, the winery controls the stock to send out the order to the inventory and prepare the shipping.

5.2.2. Defects and rejected bottles measurement

After the indeed knowledge of the real process, the next step is to continue centring on the defects which were a topic during the visits of Mezzacorona and where the author focused due to his goal of improvement of the bottling line. Defect as it has been mentioned in the *DEFINE phase*, need to be minimize to the minimum level.

The methodology for the collection of the data is explained before (see 4.3.2.) and now the data is going to be showed on an easy way to understand the information simply and quickly thanks to the statistical software MINITAB. The Pareto diagram is one of the best tools to display this kind of information. The tool used construct and prioritize the defects and rejected bottles that occur more frequently.

The charts with the defects information are in the Annex 4. where it can be compared the percentages and the main defects in each scenario. However, the absolute number cannot be compared directly because the quantity of time and bottles were not the same. To sum up, the next tables include this information to compare the data and take decisions.

LINE A (3500 bottles) day1	Filling	Capsule	Labelling	Others	Total
Defect	6	3	2	2	13
Bottles (%)	**0,17**	**0,09**	**0,06**	**0,06**	**0,37**
Defects (%)	46,15	23,08	15,38	15,38	100

Table 5.1. Percentage of bottles rejected LineA (day1). Complement table of Annex 4.1. Source: [Author]

LINE B (15200bottles) day1+day2	Filling	Capsule	Corking	Others	Total
Defect	7	8	13	7	35
% Bottles	**0,05**	**0,05**	**0,09**	**0,05**	**0,23**
% Defects	20	22,86	37,14	20	100

Table 5.2. Percentage of bottles rejected LineB (day1+day2). Complement table of Annex 4.1. Source: [Author]

If we compare the rejected bottles of the two table 5.1 and 5.2 (see above), the line A rejects 0,37% of the produced bottles against 0,23% of the line B. This difference means that line A rejects one bottle every 271 bottles against 1 from 435 in the line B. This fact can be explained because the line A has more power and usually runs at more than 10.000 bottles/h. The other reason is that the bottles were filled a model of 1500ml instead of 750ml in the line B, due to the planning production of the day.

Regarding the line A the problem is placed on the *Filling-Capsule* machine which put a thread type cap and works without cork. This line was installed more recently, and operators told the author that make more mistakes than the line B what we can prove with the data collected. Another comment is that the 2 defects on the *Labelling (Line A)* where found at the beginning of the batch production and it is the moment that appears more problems to set the new label bovines of the new product. At the beginning, the operator produces one bottle labelled, if it is rejected, the operator stops the machine, check distances of the label to fix again the label bovine to produce another new bottle until the bottles are correct performed.

About the line B, the problem is focused on the *Corking*, *Capsule* and *Filling*, so, as it can be seen in the ANNEX 4.3., the bottles are detected most of them in the first control (Control1B), Filling-Corking machine. Likewise, the Capsule machine (Control2B) produces sometimes some bottles without capsule but these three machines do not waste the material due to the operators move the bottles to the proper place to reprocess the bottle. The waste of the line is focused on the generation of overprocessing of some bottles for the mistake of the processes.

LINE B (6200 bottles) day1 6940b/h	Filling	Corking	Capsule	Others	Total
Defect	3	7	4	2	16
% Bottles	**0,05**	**0,11**	**0,06**	**0,03**	**0,26**
% Defects	18,75	43,75	25	12,5	100

Table 5.3. Percentage of bottles rejected LineB (day1). Complement table of Annex 3.2. Source: [Author]

LINE B (9000 bottles) day2 7155b/h	Filling	Corking	Capsule	Others	Total
Defect	3	6	6	4	19
% Bottles	**0,03**	**0,07**	**0,07**	**0,04**	**0,21**
% Defects	15,79	31,58	31,58	21,05	100

Table 5.4. Percentage of bottles rejected LineB (day2). Complement table of Annex 3.2. Source: [Author]

In the last two tables 5.3 and 5.4 the comparison of rejected bottles is focused on the line B which was producing the same product during two following days of a 750ml wine bottle. What one can understand is that in this line the three defects that the winery has to pay attention to reduce the overprocessing are the three steps that generate more rejected bottles; Corking, Capsule and Filling, in that order.

The defects that show more difference are the Filling and Corking. It appears a reduction the second day more than 36% the number of rejected bottles (%bottles). So, an interesting point to study is this defect reduction and thinking on the input parameters of the process, the speed changed from 6940b/h to 7155b/h. It cannot be possible to analyze the evolution of the defects along the time because of the winery has not that information and the data only could be collected two days (see later 5.4.2)

5.2.3. Defects and variability of bottling process variables

Thank to the data provided, the two variables which are studied in the project, are the *Extraction Force* of the cork and the *Volume* of wine inside of the bottle.

The first step is to have a look of the information with the histogram tool. The data is from 7months of data and 3 different lines, Line A, B and C. It is really important to treat the information by categories and study the each line on its own. This is because there is no reasonable relationship between them due to each line has its own filler and corker, and problems or shifts on the machine does not affect to other bottling lines.

These variables are checked at the end of the process with also other variables such as oxygen and vacuum. The type of cork which is analyzed is the Nomacorc cork, which is the typical type of cork for the wine bottles.

Extraction Force data

This variable has a minimum and a maximum value because the company does not want a cork that requires much strength or the opposite. It is specified between 20 and 40 kg of force which is the unit of the data.

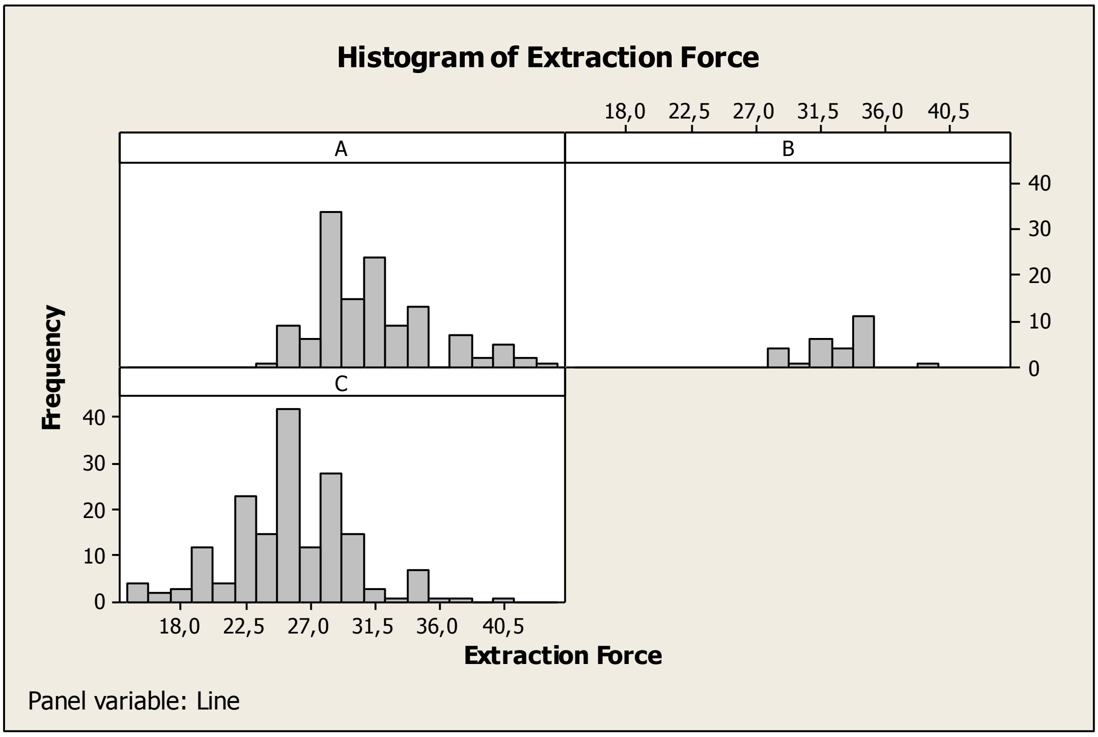


Fig. 5.2. Histogram of Extraction Force categorized by lines. Source: [Author]

Having a look, the line A is quite well centred between the limits 20 and 40 kg. The same happens in the line B although the number of samples is lower. On the other hand, the line C seems to be shifted to the left, having much more samples under the lower specification limit of 20 than the company would desire.

Inside Nomacorc brand, the winery works with two types of cork, short and long (CORTO (37) and LUNGO (43). As one can see in the ANNEX 5.1. the CORTO (37) is not so used by the winery like the LUNGO (43) option due to the number of samples. The CORTO (37) has more standard deviation than the other, but there are no significant differences in the mean. In the next Fig 5.3. the Boxplot chart tries to represent how is the difference between the two corks on the Extraction Force, and apparently the two types of cork can be studied together. The two types might have similar behaviour depending on the line too.

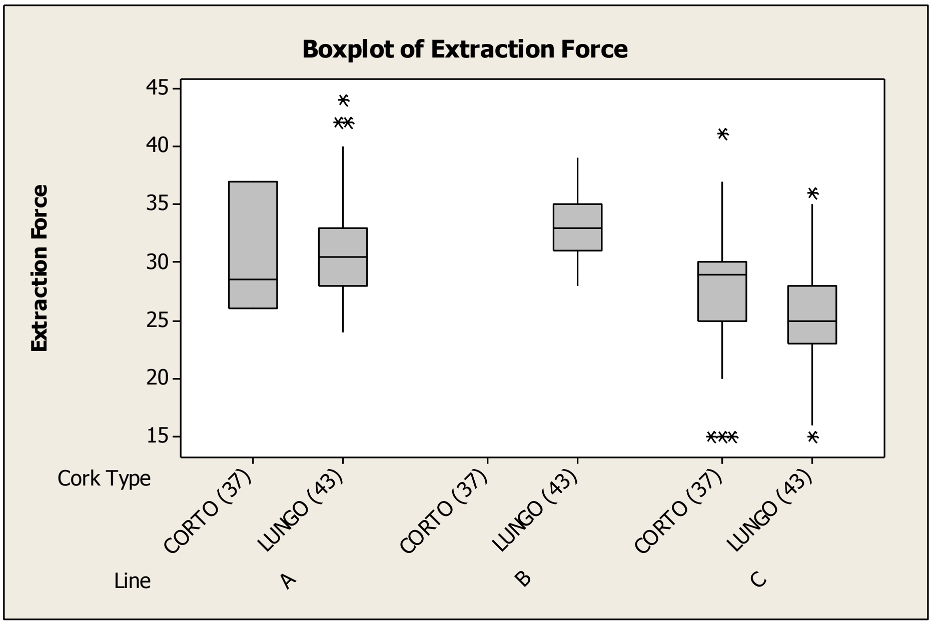


Fig. 5.3. Boxplot of Extraction Force categorized by lines and cork type. Source: [Author]

As a result, the ANOVA analysis comparing the two cork types gives us p-value=0,911>0,05 (see ANNEX 5.3.), so, from now the different types of cork are not going to study separately because they do not generate differences on the results. Both have the same behaviour and can be analyzed together in the same sample to facilitate the analysis.

The evolution along the time is showed in the Fig 5.4. There is stratification by lines and gives a general idea about the changes along the time. The line C is centring better in the last samples because it was producing defective bottles at the beginning of the year.

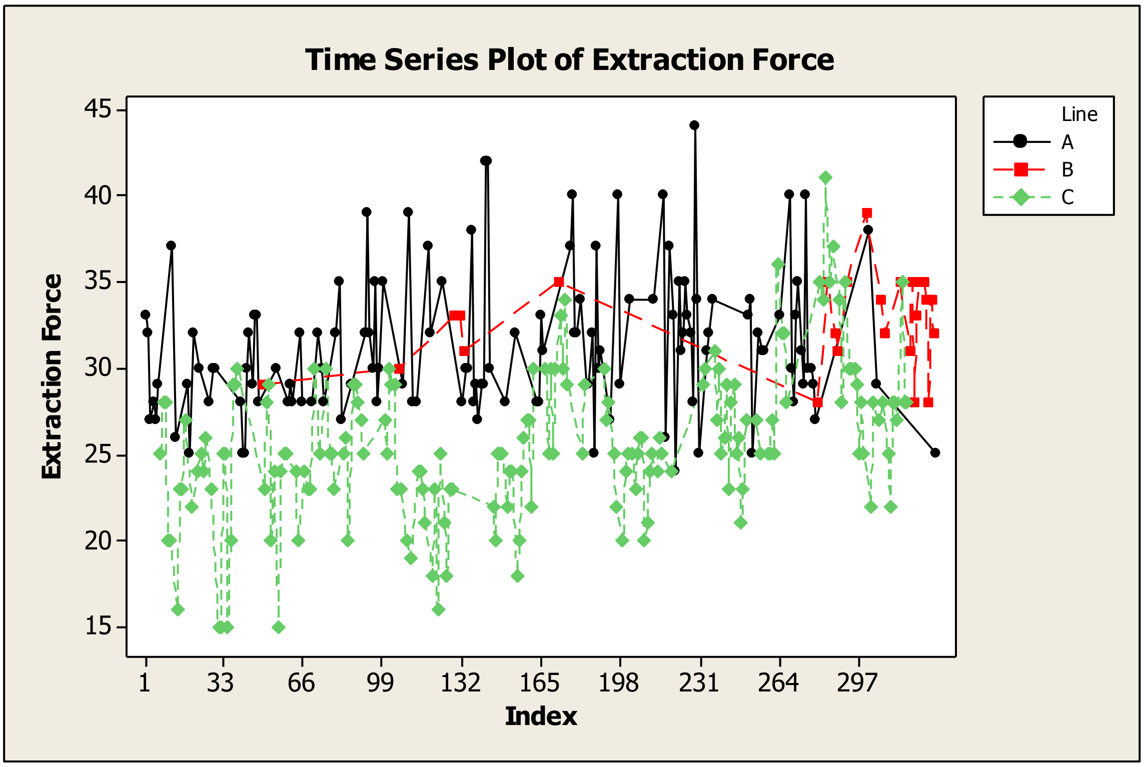


Fig. 5.4: Time Series Plot of Extraction Force categorized by lines. Source: [Author]

Volume of wine data

The variable of filling Volume has to be studied separately for each line, for the same reason as the Extraction Force, because the machine is another one. It generates different behaviour and changes.

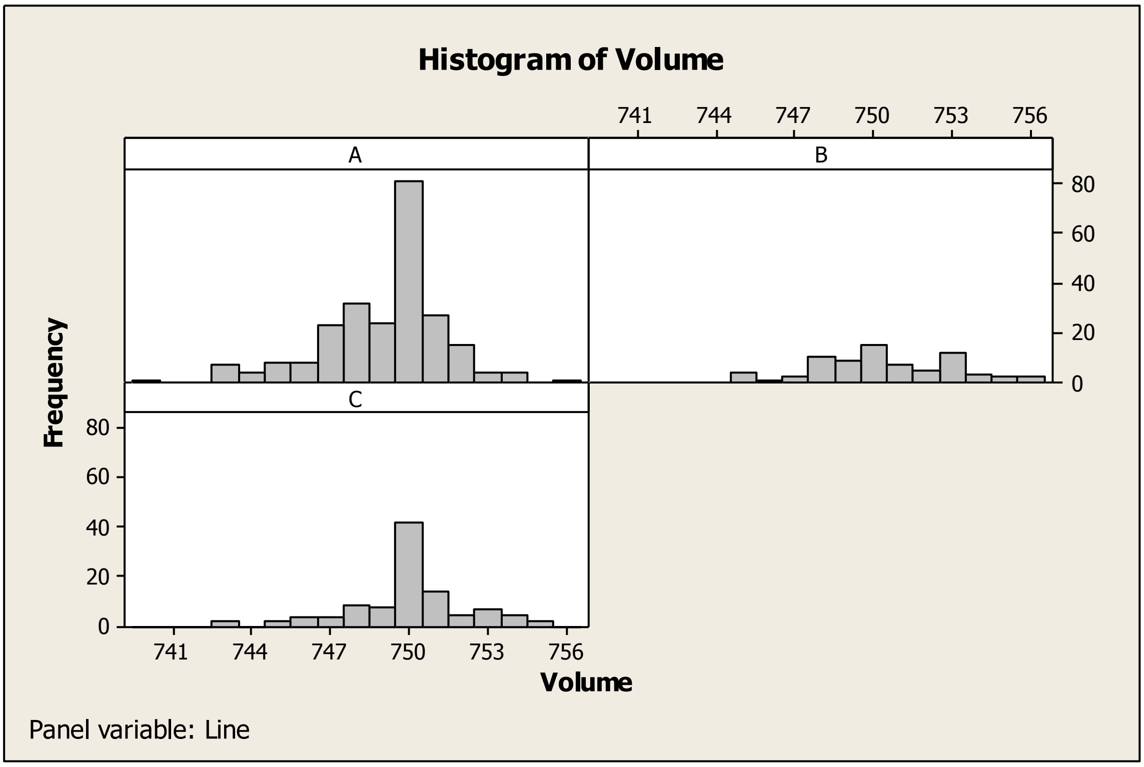


Fig. 5.5: Histogram of Volume of filling categorized by lines. Source: [Author]

First of all, it is necessary to see the histogram of the data (see Fig 5.5.).

The first impression is that is possible that the processes are not capable because the spread of the samples is quite big having samples up to 740ml. It is true that most of the samples are on the correct volume (750ml). Complementing the histogram with the basic statistics of ANNEX 6.1., the line A has a mean of 749,08 ml, as a result, it should be interesting realize why is filling less and try to realize why it is not symmetric, for this reason the mean is lower.

In the ANNEX 6.2 the time series plot seems that has a good process of filling but sometimes occur that some samples are far from the target, which generates the wide spread on the lower side.

5.3. Phase 3: ANALYSE

At this moment, the step is to understand where the best areas of improvement are. In the analysis phase the objective is to understand better why the variables values are what they are, and where the points to focus the improvement are. After the measurement phase, the data is already found it and developed with basic statistic tools to understand better the data. Then, it could be possible to focus on the best methods and areas of improvements to follow a more effective strategy to achieve the aims defined on the first defining phase.

The new improvements for the processes of the value stream mapping are shown in the future VSM. (See ANNEX 3. future VSM).

5.3.1. Future VSM

First of all, based on the information of the company, if one wants to try to produce more 'lean' it is necessary to incorporate the improvements step by step. It cannot be implemented directly this technique because for the nature of the business, the idea is to try the improvement as much as possible.

The first step will be balance the production with the sales. Mezzacorona has sales of 45 million bottles per year. The tendency is a rise on the Christmas time, so, the forecast for the studies of the line B are going to be; 10million line B, 15million and 20 million the other two lines. The number of bottles is proportional to their working speed. Thus, 3.650.000 bottles are expected to sell in a month during the middle of the year by the three lines, which is an approximate number of 810.000 bottles for the line B (proportional to 10 from 45).

Fig. 5.6. Expected demand of wine. Source: [Author]

Therefore, applying the calculation for the takt time in a normal month during middle of the year, for example July, the information from the questionnaire informs about the use of 66% of the time each line. So, if a month has 22 available days of work, the 66% of the days there is production for the line B (see ANNEX 10.); 15days. It is also considered 12 hours of available time, eliminating cleaning time and other planning downtimes. The demand per day would be 54.000 bottles/day, using 810.000 bottles/month.

$$Takt\ Time = \frac{avaliable\ working\ time\ per\ day}{customer\ demand\ rate\ per\ day} = \frac{15days\ x\ 12\ hours}{810.000\ bottles/month} = 0.8\ s/bottle$$

This takt time is a number easy to produce for the company due to the real data was producing less than 0,6s/bottle. The bottleneck process was the washing machine with a unit every 0,558s, so, this ‘extra time’ between the takt time and bottleneck process allows the company to sequence the production to reduce the quantity of stock thanks to the levelling production with its benefits, enjoying that extra time for the changeover of the models of wine.

As a result, the production plan could organize its production realizing more changes on the model sequence. Based on the production of 6450 bottles/h, the bottling of 54.000 bottles and including the new lead time of the first bottle until the line is working stable takes 8h 36min. The available time is 12h, then, it leaves more than 3h for the 3 model changes on the production sequence. The changeover is approximately 1hour each one, and time of the run-up including when the first bottles come into the processes and fill the reduced buffers are inside the time of the changeover; so, the number of possible changeover is 3 every day for this takt time, having around 30 min for solving unexpected problems.

The future VSM is represented in the ANNEX 3. With the update values from the Lean improvement in the bottling line, the objective is going to reduce also the waste between processes.

The main step for reducing this extra lead time is going to be the intermediate buffers. In the case that all the buffers were eliminated the reduction will be 37,7% of value added time, but the great time is in the inventory before the washing machine. Due to the palletiser speed is higher than the washing machine, the stock could be enough with 232 bottles (1 batch of the palletiser) because a bottle enters every 0,558s, but the palletiser comes out 232 bottles at the same time. It means that in 120 seconds, the washing machine will have 232 bottles more, and it still will be using the last units of the inventory. In addition, the buffers are not going to be eliminated totally because when the control rejects a bottle this one disappears from the line, so, having a little buffer only for this expected bottles. It is decided a 10% of the space in the buffer because of the possibility of the fact that some rejected bottles occur and to not slow down the speed of the line. The Packaging 4x6bottles process can work without a bottle in the buffer due to this process does not need any run-up time or run-down. Therefore, reducing the space of the buffer, the layout could be more compact decreasing the movements of the operators, with fewer meters of belts between processes.

Under this scenario, the lead time can be decreased from 13min 57sec up to 837sec (see ANNEX 3.) It reaches the 65% of value added inside the process (see ANNEX 3.).

The last area is the supplying of the process. For the future VSM, there is a change on the way they order and manage the raw material stock, and intermediate stock in the processes like corks, bottles, capsules or boxes. The 'supermarket' with pull removal is introduced to reduce the stock of these materials. The operator will order to the supermarket the necessary items for the next batch or production of the day, and then, the 'supermarket' will inform the production department which must be connected with the supplier by software. This future VSM needs the collaboration of the supplier to introduce lean techniques too to be able of replacing often the warehouse of the company. It also benefits the supplier because they will know how its customer stocks are, so, the supplier company could organize better their batch sizes and know when the winery is going to need the replacement with faster communication.

For continue analyzing lean manners of improvement, one way is the standardization of the activities development to create a patron on their tasks, always performing with the same schedule the routine activities.

There is no 5S implementation, which is universally applicable to all the processes of any kind of business. A place of implementation can be all the workplace of each operator. The main table of the line, the tools wall, the label machine place and all the material for the changeover, the place for the stocks intermediates of corks, capsules, labels. This technique will be associated with the standardization of the activities, for a better schedule and to minimize the movements of the operator.

A good point is that the materials when they are sent from the inventory to the bottling line are replaced next to the point of use. For this reason, the material only for the batch or product should be replaced. The company have to take care to not replace extra material to avoid extra intermediate stocks and disorganization.

More lean techniques such as Jidoka or structured changeovers can be influenced by these techniques like 5S or reduction of defects, because they will avoid some of the current mistakes, generating better performance.

After that, the bottling process will be quite optimized. The production could be more levelled reducing finished product stocks, less lead time, less intermediate buffers and less units in the inventories, better operator performance, less movements of the operators, better supplying relationship and faster. Afterwards, this same chapter analyses how reduce the defects and rejected bottles which will beneficiate with less overprocesing, waste of materials and better equipment efficiencies.

5.3.2. Analysis of defects and rejected bottles

Cause-effect diagram

The analysis of all the X’s (inputs) that can come into the processes also based on the SIPOC diagram is complemented now by the diagram cause-effect which is representing the causes that modify the answer Y, in this case the defects and rejected bottles (see below). All the inputs like materials, manpower, machine’s setting and speed. Everything influences the final result of the line.

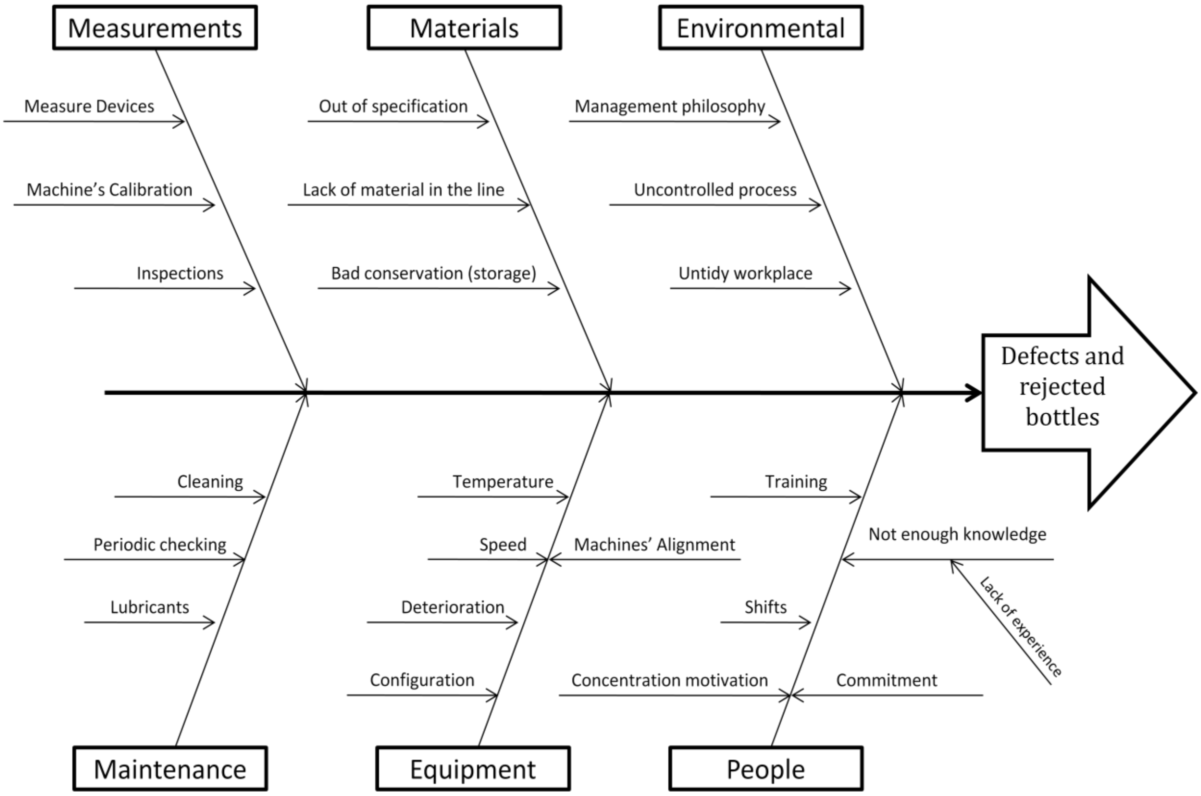


Fig. 5.7: Cause-effect diagram of defects and rejected bottles. Source: [Author].

The effect considered in the diagram is the second aim of the Lean Six Sigma project, the defects and rejected bottles, which are cause by many possible changes in all of the attributes represented in the diagram. It is divided into six categories; measurements, materials, environmental, maintenance, equipment and people. Inside the main branches, there are other influencing little causes that generate the defects on the bottles. All types of defects that appear on the previous *MEASURE* phase can be caused by the bad equipment fitting of the right values, performance and behaviour of the employees (people),

Afterwards, analyzing all the data obtained by the company, it is realized some scatter plot chart to study possible relationships between the variables of 'oxygen' and 'vacuum' that could be generating some pressure to the cork and generating bad bottles referring this defect.

Consequently, this supposition can be rejected becasue there is no relation based on the result of the charts (see annex 7.). The scatter plot of the oxygen is a typical chart showing that variation is higher where there is more concentration of samples. Anyway, the range of the values of 'extraction force' is not increasing, decreasing or any tendency (see ANNEX 7.1. and 7.2.). The right values for the oxygen should be the minimum as possible to not deteriorate the wine and for this reason the accumulation is at the left of the axis 'oxygen'. The same patron occurs with the relation between 'extraction force' and 'vacuum'. The range keeps similar for the different values of the axis vacuum besides the correlation values are very low to prove any dependence.

Then, these two attributes (oxygen and vacuum) are not going to be included in the cause-effect diagram because there is no significant evidence of relation to the Extraction Force. The important issues are going to be all the causes included in the cause-effect diagram. Most of them cannot be evaluated with a number, but reasonably, aspects like cleaning, motivation, bad row material properties to give some examples will affect to the product for sure.

Thanks to the cause-effect diagram, the company know now which main priorities to solve are and control to keep the number of defects low. For the moment, if the company would implement the project, these would be the points to focus first.

Capability analysis

This tool is one of the most important to know what Six Sigma level of the process is and how much number of products is produced per million out of specification. As it has been studied before, the three bottling line will be studies by themselves. The samples were collected from the beginning of the year during 7 months.

For the capability analysis it is necessary a subgroup size, where all the samples theoretically has no significant reasons to vary its value only for the variability of the process. Because of this, the size is always one. The samples methodology is to pick one bottle each batch. As a result, the subgroup is a single bottle and also the specific limits are between 20 kg (LSL) and 40 kg (USL) which is the unit of the collected data.

Extraction Force of the cork

According to the histogram of the Fig. 5.2., the 'Extraction Force' of the line A seems that the samples are centred quite well but has some prolongation to the upper limit. When the capability analysis is done, this problem appears in the results.

For the capability analysis of this data, it is necessary a Box-Cox transformation due to it has not enough normality on its distribution. The software Minitab finds out the best value for the transformation (see Annex 7.3.). The use of this tool needs the Introduction of the estimate Box-Cox value and the definition of a subgroup size which in this case is one because bottles are taken once each time. So, capability analysis result is the next:

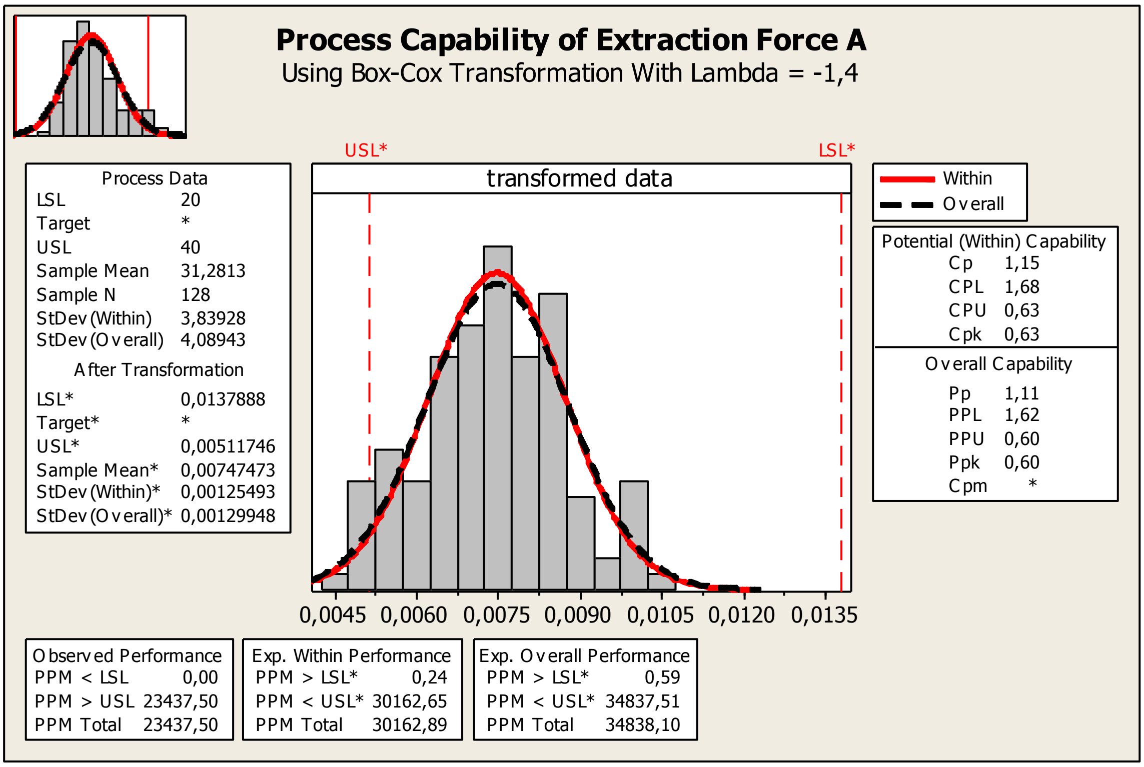


Fig. 5.8. Capability analysis line A. Source: [Author]

The line A process data is information without transformation of the values, but the interesting information for the company is the overall capability and observed results (calculated with the transformed data to get the normality in the distribution); *Overall Capability* which represents the coefficients of capability of the bottling process and the *Overall Performance* which is the expected number of unit per million out of the LSL and USL or the total number of defective bottles with the extraction force out of the interval. For knowing how the process is performing, there are the same formulas but are named in the charts as *Pp* instead of *Cp* (see 2.) and the same happens with the other parameters. It is because it refers to the distribution in long-term, where the spread of the distribution is wider (see Fig. 2.2.). Consequently, from now the results which always are referring to the capability of the process, refer to Pp, PPU, PPL and Ppk.

There is not bad capability (Pp) and excellent PPL. However, when the process will be better well-balanced the PPL will get worse coefficient but improving the PPU. The important values for the business of the winery are the expected products out of the limits. The Six Sigma capability is placed between 3σ and 4σ because the number of expected overall performance is 34.838,1 units per million. If one pay attention to the short-term normal distribution, the defects in the extraction force is the 3,4% of the bottles and all of them are being appearing on the upper limit, so, the company should pay attention to control all the causes that could affect the performance of the such as calibration, lubrication, configuration, maintenance of this machine and so on.

It has a problem with the higher specification. Actually, based on the current data there is a 2,34% of bottles with the extraction force higher than 40 kg but this data is not the entire quantity of bottles produced, for this reason the short-term will give to the company the expected number if they have analyzed all the bottles.

The line B of the winery is running better than the line A. It is also transformed to improve the normality of the distribution to get better expected results of number of defective bottles.

In the following chart Fig 5.9., the corking machine is working in a capable process only a bit shifted to the upper limit. The number of defects expected in overall performance is less than 1.324 bottles per million (0,13%) much better than the line A. Any value was registered in the data so, in the observed performance there is zero bottles out. The main issue is to control the well-balance process to keep in centre (30 kg) of force the corking machine. As one can see the sample mean is more than 32, so, this little shift of the total of the samples is generating some extra units outside the USL. The PP is not enough good with 1,14, so, as always they have to be carefully with the causes that generates variability to make the samples distribution narrower

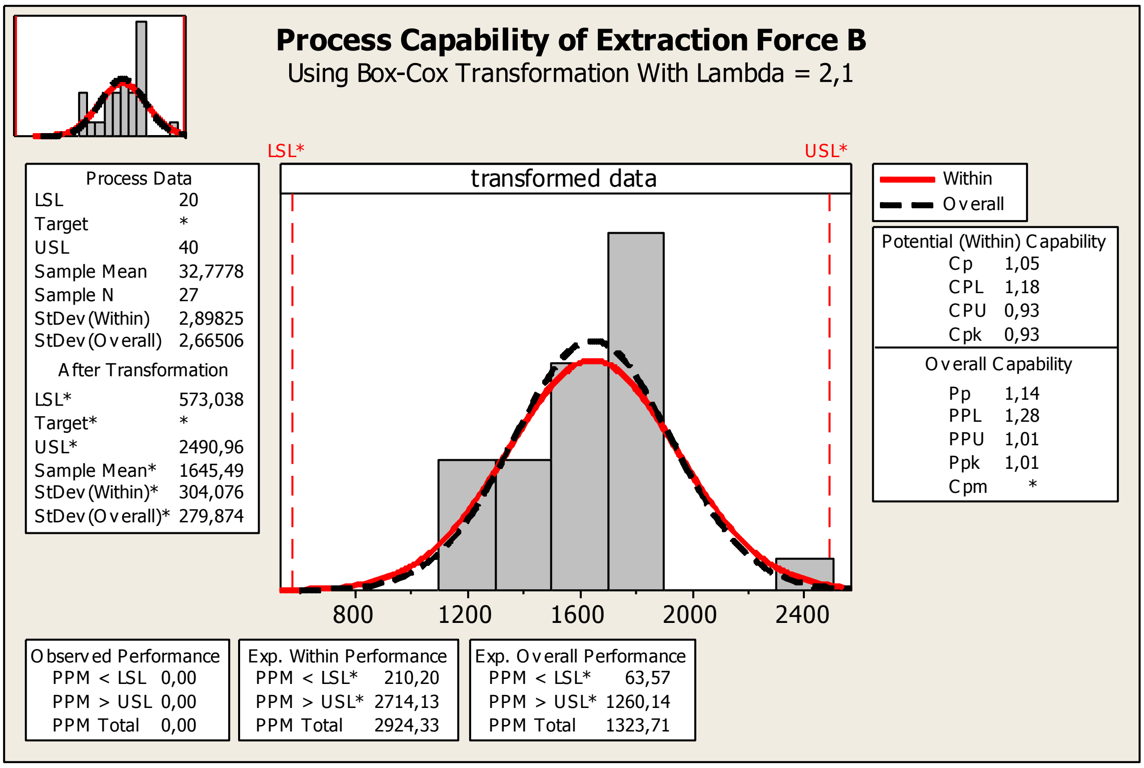
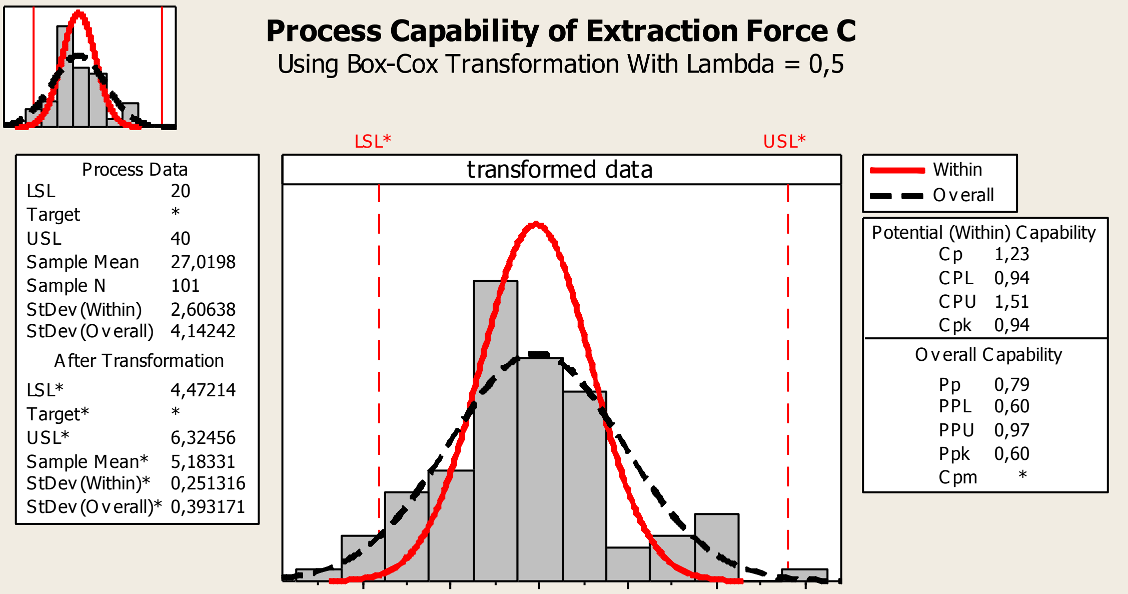


Fig. 5.9. Capability analysis line B. Source: [Author].

The last line C has been considered necessary to study from the April to the end of July. The whole data is not possible to transform into a normal distribution. So, analyzing the time series plot of the line C (see Fig. 5.5.) it can be appreciated that the company carried out on a bad configuration of the corking machine, because the range was from 15 to 30 kg producing defective bottles. From the index 132 of the chart, it can be appreciated a new amount of samples better centred. This difference in the range of the samples generates together a distribution which could not be a normal distribution because has two internal diverse distribution processes. With the lasts months of data the requirements are kept.

The recent mean is 27,02 kg (see below Fig. 5.10.), so, it is a little bit shifted to the left, the low limit and the capability is not correct. The Pp < 1 , so this line is not capable. Therefore, the expected results are 37.089 bottles out of specification. The company has to react to this fact because the 3,7% of the bottles are expected to be defective on the extraction force attribute.



Process Data	
LSL	20
Target	*
USL	40
Sample Mean	27,0198
Sample N	101
StDev (Within)	2,60638
StDev (Overall)	4,14242
After Transformation	
LSL*	4,47214
Target*	*
USL*	6,32456
Sample Mean*	5,18331
StDev (Within)*	0,251316
StDev (Overall)*	0,393171

Potential (Within) Capability	
Cp	1,23
CPL	0,94
CPU	1,51
Cpk	0,94
Overall Capability	
Pp	0,79
PPL	0,60
PPU	0,97
Ppk	0,60
Cpm	*

Observed Performance		Exp. Within Performance		Exp. Overall Performance	
PPM < LSL	9900,99	PPM < LSL*	2328,76	PPM < LSL*	35238,74
PPM > USL	9900,99	PPM > USL*	2,80	PPM > USL*	1850,04
PPM Total	19801,98	PPM Total	2331,56	PPM Total	37088,78

Fig. 5.10. Capability analysis line C. Source: [Author].

The importance of this is to keep control all the causes that could change the results. They have to be in mind always to try minimizing the variability to achieve a better capability on the process.

In the Fig. 5.10. the capability analysis explain that the number of defective bottles during these months of the data were almost 20.000 bottles per million. However, changing the parameters to produce bottle centred in 30kg the process will be able to improve a lot if all the causes are controlled. The expected potential capability is Cp 1,23, quite better comparing with the actual value.

In this case it is important to comment the fact that the overall capability is quite different of the potential capability and this means that there are other causes different from the intrinsic variability that makes the process to have a wider distribution. This makes the range of samples being bigger. Therefore, if this machine is controlled more often it could avoid any shift on the corking machine and reduce external causes that change the variablility. It means that in samples taken consecutively, the potential (within) capability it could be achieved. This potential capability refers to the short-term where any external influence affects the distribution of the samples. It would be the case of a group of consecutive samples. However, it also should be necessary focus on the reduction of the variability of this process to be sure that it is going to be capable always despite of the natural changes on the process.

Analysis of Volume of wine

The same methodology as the variable 'Extraction Force' is applied but now for the other variable 'volume of wine'. However, the objective for this step has to be a little bit different as the last because the data information is collected at the end of the process line. For this reason, the volume of wine theoretically is not going to be out of the limits of the automatic control of the filling.

As it was explained in the chapter 4.2. and Fig. 4.3., this automatic machine refuses the bad filled bottles, so, at the end of the process they should not arrive bad filled bottles. The interesting concept to study is to know how the capability of the process is because the bottles rejected in the process should be related with the bottle out of specifications in the expected overall performance.

An important concept to know is that in this data are included only the bottles which are good filled. This means that this *Expected Overall Performance* number is going to represent all bottles which are rejected because causes that belong to the normal expected distribution where it is only included the intrinsic variability produced by the process of filling. The bottles not filled or middle filled are not included in this number of bottles per million due to they belong to this intrinsic variation.

The study of the line A (see Fig. 5.11.) shows expected bottles out of the limits because just one sample appears in the data with less than 741ml. Therefore, the proportion in a million of bottles is a significant number. It generates this equivalence to bottles per million and probably it was a mistake in the control machine or the bottle had more width and it let this bottle pass the control. Anyway, the most relevant information is that the capability of the process should be better trying to achieve the Pp>1,33 or even Pp>1,50 if it is possible. If the company reaches this performance the overall performance will be improved and it will reduce the number of rejected bottles in the line, which is expected for this defect of bad filling to be 0,028%. As the table 5.1 showed about the line A during the day of the visit appeared a 0,17% of bottles rejected for filling reasons. So, assuming the supposition that this 0,17% is the percentage mean of the process, a difference of 0,142% were mistakes of failing fillings such as middle filled or not filled because were another type of defects in the filling machine, . So, the 0,028% are mistakes of the normal variability of the process. The process also needs to be centred the mean 1ml to the right, because it is now in 749,1ml, avoiding fillings with less than 741ml and balancing both capabilities side, PPU and PPL.

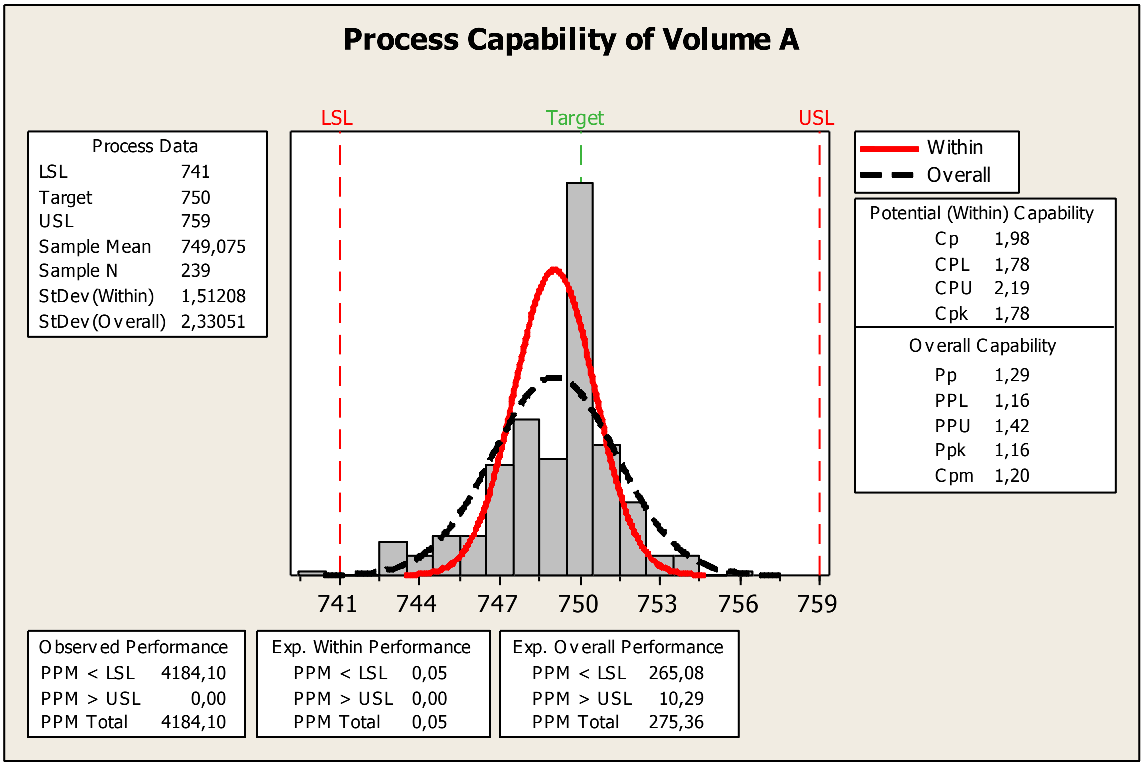


Fig. 5.11: Capability analysis volume line A. Source: [Author].

For the company would be great if they can avoid all the rejected bottles caused by filling and at least trying to fill all the bottles inside the limits. In this case, in a batch production of 40.000 bottles the rejected bottles by this variability would be around 25 bottles, so this number will accumulate more number of bottles along the weeks.

In the next image (Fig. 5.12.) the filling of the line B is presented that this samples are quite well-balanced with capability around Pp=1,15. The process need to improve its capability to reduce the number of fillings out of the control limits. This line is rejecting more bottles for intrinsic variability on the filling than the other two.

The rejected bottles by filling in the line B collected during the visits was a 0,23%. If one see the time series plot of volume (see ANNEX 6.2.) the line seems to work under less variation. The line can be working better reducing the number of bad filling because the expected overall performance based on the data from 7 months is 616 bottles per million.

As a result, the line is filling with less than a 5σ level. For improving, the company needs to control the parameters such as speed, fitting of the neck of the bottle and the wine system feeding to reduce the spread of the real distribution and reduced the rejected bottles.

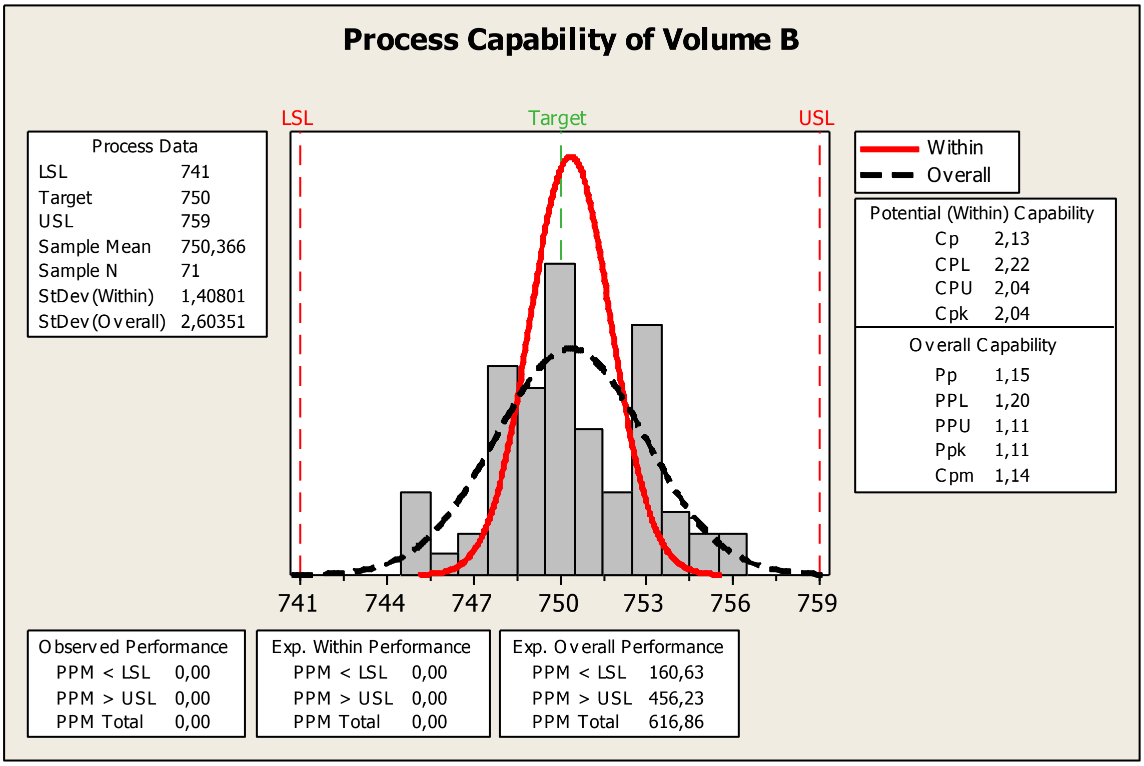


Fig. 5.12. Capability analysis volume line B. Source: [Author]

The last analysis is the third line (see Fig 5.13.). The line C has the best results, with only 60 bottles out per million, and perfectly centred in the target 750ml. All the capability parameters are more or equal of Pp, PPU, PPL ≥ 1,33. This line is working near of the 6σ excellence, and reaching the 5σ level in this line.

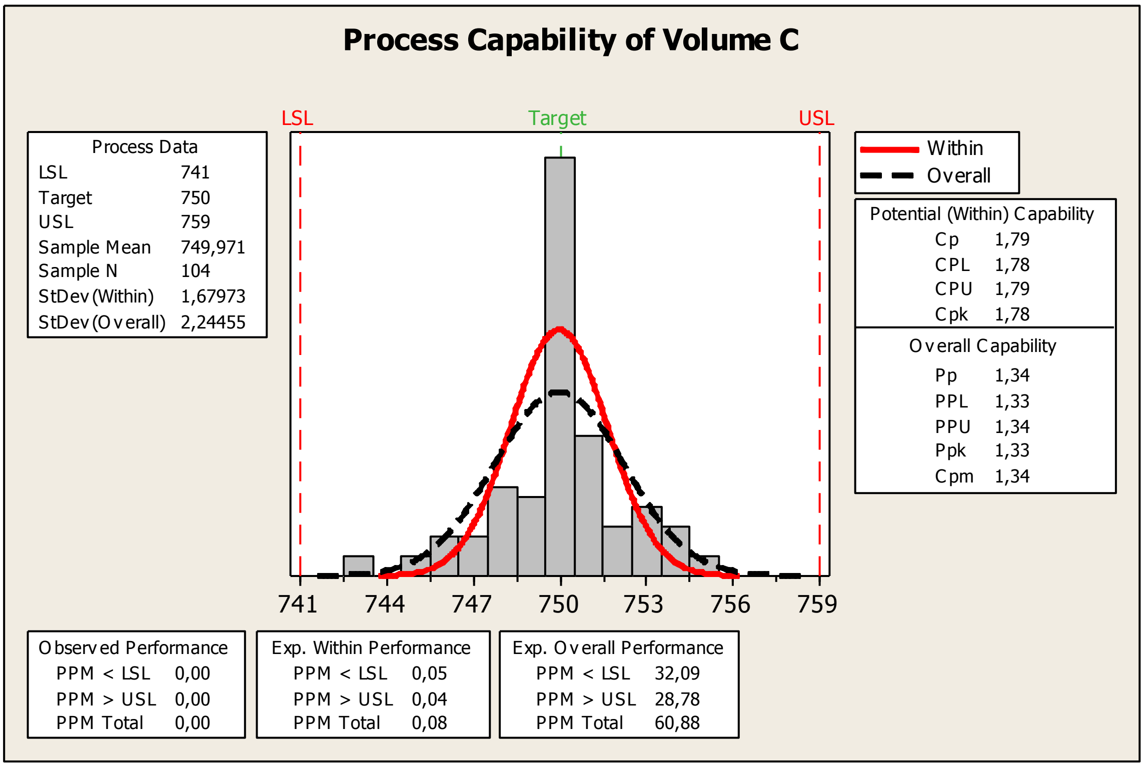


Fig. 5.13.. Capability analysis volume line C. Source: [Author]

As conclusion about the filling machines of each line, one can see that the line C is filling with a really good capability and well-balanced.

Line A and B need to control the parameters such as speed, fitting of the neck of the bottle to not loose wine, the wine system feeding and other causes could get to the process a better performance avoiding most of the bottles out of specification.

The next step can be the reduction of the limits of specification once the processes are completely capable to perform better process quality for the product with always the same quantity of volume.

5.4. Phase 4: IMPROVE

5.4.1. Lean improvement proposal

The expected results of the future VSM proposal are explained in the last chapter 5.3.1. Then, the improvements in the processes are represented with the changes between the current and the future VSM. Thanks to the changes the lead time can reduced a 56,6%, optimizing the queues and inventories in the processes with more value added time percentage to 65%. Then, the reduction of buffers needs a good alignment of the machine's speed of the line to work in a continuous piece flow without stops.

It is important to agree with the suppliers the new philosophy for a more frequent replacement, until not more than 2 weeks of stock. So, the stock could be reduced at least 50%, allowing a better physical space and equipment organization in the winery. The belts between processes can get shorter to work in a more compact layout, but without cellular layout because the machinery and the wine tanks are too big for this layout.

Meanwhile the winery tries to change for the new ways in the bottling line management, in the same plant; there is the possibility of implementing new techniques such as Standardization and 5S, which can be applied on every type of business.

For the deployment it would be necessary the creation of improvement teams, where operators of the line, managers with knowledge in continual improvement, and top managers. It is necessary employees from each level of the organization to have an optimal overview. For instance, the improvements of defects of one machine of a process, it would be required its responsible, the plant responsible, and managers. All the information must be known to find always the root of the causes involving all the related employees with the area of improvement and then assign the tasks, monitor and measure the improvement. These teams have to check that all the improvement routines or changes are being followed by the employees always. They must be constant to achieve the better results until these changes become good habits on their performance.

Standardization

The standardization will be one of the objectives of this improvement teams. This technique avoids some of the future possible mistakes, errors, defects in all the activities that the machines and personnel. Most causes that generate the effect of the rejection of bottles are related with the way of the operators perform such as maintenance, cleaning, sort, communication between operators and mangers and communication within the shift. Many standardized activities will increase the efficiency of the line because the standardization find the optimal schedule, movements, order of sequence activities working the improvement teams on it.

This technique may increase the efficiency of each process, changeovers (SMED), maintenance, saving of material, the rejection and defective bottles.

5S

For a Lean implementation, the 5S implementation is considered the first aim to develop in the bottling line. It is applicable to every area of the company, so, there is no problem to implement on all the processes of the line.

The way to apply this technique it will be introducing visual colours as it is shown in the Fig 5.14. These colours will show the shape of the pieces that must fit in that its specific place and the operators can remember better, recognize and perform faster each time they use them.

The tools can be ordered by order of use, and paint a line on the floor pointing out the way to the use of that piece. The operators should make some changes on the label machine each time, so, it is one of the places that would enjoy these benefits.

During the visit the author took that picture, where it can be seen the tools and pieces not placed in the tools wall, maybe because these pieces have no specific place or because they are not placed in the right place. They are at the bottom of the picture put together. According to this technique, each tool must have a place for it. At the right of the photo there are pieces on the wall on its place, but anyway, the benefit of including colour shapes on the wall will help to all these issues.

1. Recognize easier the right place avoiding possible mistakes, untidy workplace, and finding faster the part.
2. Reduction of time every use the operator need the tool.
3. The possibility of groping tools by colours, differentiating for each activity and facilitating the standardization of activities ordering colours depending on the order of use.
4. Help to other operators from another area the possibility to sort them without knowledge only fitting the pieces on the places. An operator can be developing multitask, using the same tools, just helping other worker or doing cleaning and organizing tasks.
5. Help to new employees in that workplace to learn and perform faster through the colours.
6. Reduction on the changeover times and maintenance tasks times when they need to use the pieces or other product. Promoting faster changeover, reducing downtime between product shifts, faster performance and avoiding errors with the products for the preventive maintenance.

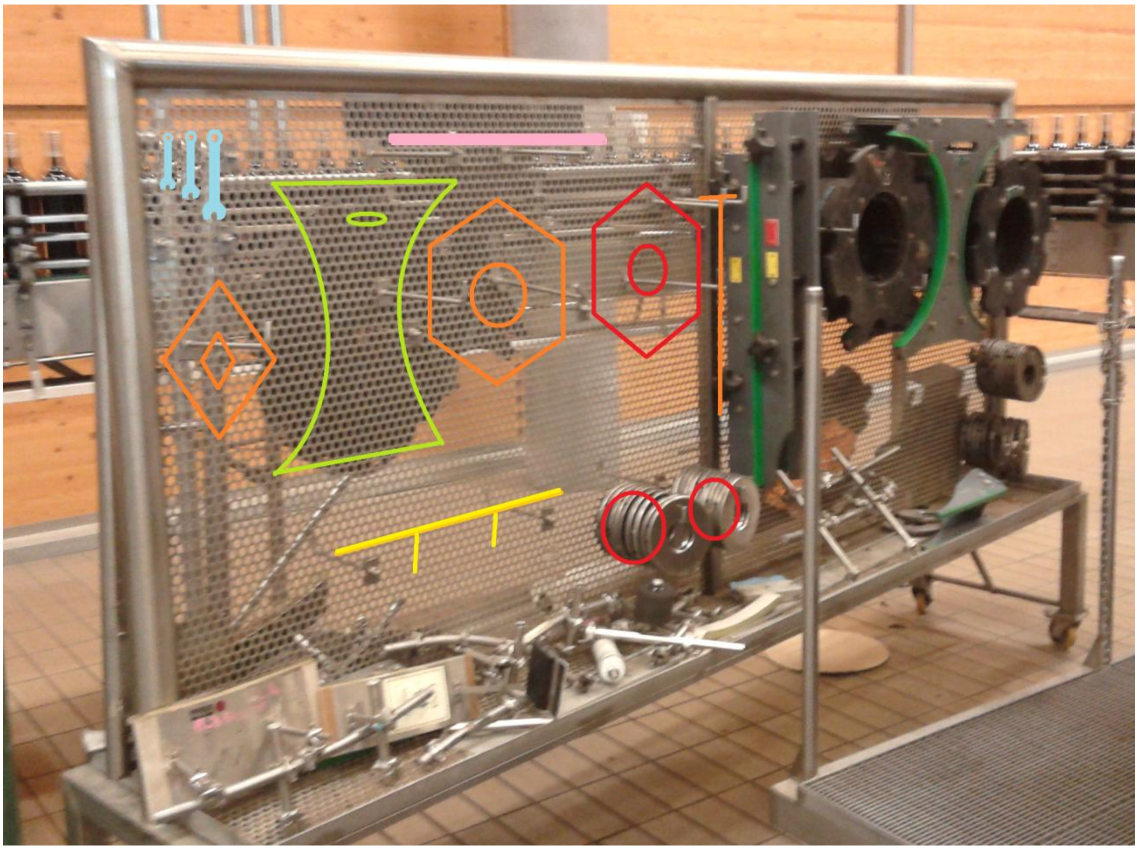


Fig. 5.14. 5S technique proposal on a tools and pieces place.

Moreover, the operators should recognize the pieces or tools that are damaged or are useless. The 5S lean technique associates with red tags these devices which are not necessary to keep the workplace tidy. In this red tag you can inform for instance, the date of removal and in which container should be put after that date helping for a faster removal.

Thanks to this easy implementation and the use of red tags for useless pieces, the 5S can be included in the philosophy of the company. The employees have good routines of cleaning, so, they will apply this technique without problems and following the 5S, maintaining along the time.

Regarding other lean techniques, some Heijunka concepts are applied through the levelling of the production and continuous flow, which they already use these. The benefit is to coordinate the production with the expected sales, and enjoy the maximum number of changes to not overproduce more bottles of some models of wine. In the *ANALYZE* phase, it is explained that the production should reach 3 changes, so, it means that the production can bottle 4 different products during a day. Then also, thanks to the introduction of data collecting (see 5.4.2.), more parameters could be registered to control efficiency rates like the parameters explained in TPM (see 1.5.7.)

5.4.2. Improvement strategy for defects and rejected bottles reduction

First of all, the specific improvement strategy on the reduction of the defects is focused on the introduction of new ways for collecting data. The benefit of recording data will give them the opportunity to study how the behaviour of the rejected bottles is. As the author did during the visits, the bottling line has detectors to decide which bottles pass the control and which do not. It is considered the first step due to the process improvement by Six Sigma needs data.

For this collection data, a template place has been designed to place next to every automatic control (see below). The proposal for this improvement is formed by a simply way to collect the information and measure the number of rejected bottles in each control.

Control/Controllo	Day/Giorno	Product/Prodotto	
	Defect/Difetto 1	Defect/Difetto 2	Other/Altro
Start time/Ora di inizio Total Bottles/Bottiglie			
1			
2			
3			

Fig. 5.15. Table for defects collection. Source: [Author]

The benefits of this new way of collecting data is that the company will be able to analyze the data as it has been done with the two attributes that the winery collect data; Extraction force and Volume .

This table is an easy way for the personnel to register all the defective bottles which are rejected on all the automatic controls (see Fig. 4.2.); *filling-corking, capsule, label, package weight* and even other problems that could appear on the *belt* such as broken bottles in due to bad alignment because they fall or other reasons. It will not disturb the habitual tasks of the operator, so, it will not make them more extra movements for this data collection. The tasks of the line operators is also to check the rejected bottles because sometimes the sensors could fail as it happened during the visit in the capsule machine rejecting some bottles that were correct. Consequently, the operator's methodology will be to write down the number of rejected bottles on the paper each time the operator goes to check and pick the bottles to reprocess again depending on their defects (see Fig. 5.1.)

It is considered necessary to follow a study for every product to know more details about the run-up, run-down of the process. It is just enough to fill out the information of what control, day, product, and the main defects in this control are. Then, every hour control and write the time and during the hour write down the defects each time the operator goes to the control to do their task of checking. Also it is necessary the number of bottles produced in that hour, it would be easy to write the total number of bottles produced until that moment because all the controls show the bottles produced on the display (see example ANNEX 8.2.).

Thanks to this new information for the winery, they will have the chance of enjoying the next benefits:

- Know exactly what processes have more rejected bottles to reduce the overprocessing and waste material to invest first on the most effective process.
- Find possible patrons along the time because each product is collected separately. Know how number of defects varies depending on the starting of the production or after periodic maintenance.
- Implementation of SPC. Run charts about the number of defects, time series plots to realize about variation along the time on the number of rejected bottles.
- Find out the optimal time for a general maintenance and overhaul of the equipment (Realizing if the defects have tendency of increasing from a specific time).
- Focus to optimize the worst machines to be more effective.
- Improve the calibrations, configurations, based on the knowledge about when the equipment is put out of order and realize it faster.
- Study what is the most efficient production speed where the rejected bottles are minor. Scatter plot (Number rejected bottles-speed) or DOE (Design of Experiments).
- More effective strategy of production comparing the three lines.
- Grouping data by shifts, model of cork, bottle, label, and others.

Extraction Force

The ideal option for improving the analysis of the ‘extraction force’ would be increasing the number of samples. Up to now, the capability analysis was done with subgroups of just one unit because it is the way the winery takes samples at the end of the process. The change in this way and making subgroups of 2, 3 or 4 will provide better information about the intrinsic variability and the variability for external causes. This change can help to realize more reliable analysis to be able of reducing all other disturbing parameters which alter the corking machine and the extraction force. The point will be to check after the corking machine and then put the wine again into the filling pipe and rewash the bottle to continue with the normal activity to waste less material. This samples methodology could change when the process become more capable and well-balanced, but the data should continue to be registered instead of 4 bottles each time, 2, to have a subgroup size and to get better expected results.

After that, during the Analyze phase, it was mentioned the problems that each line have. From this moment after analyze how the processes are. The objective is to adjust to correct the shifted lines controlling all the parameters that change the result. It is very possible that others attributes like the materials conditions of the cork and bottles influence on the extraction force, so, everything has to be controlled the find the root of the causes.

In the first *Extraction Force Line A*, the variability has to be studied to reduce it and to get better capability levels because it is not enough capable to keep high Six Sigma levels so, many bottles are produced out the limits.

The winery needs to fix the calibration because the historical data is 31,3 kg for this reason the naturalness of the samples are producing all of the defective bottles upper 40 kg.

When the process become better centred then, the second step will be reduction of the variability to make it capable good more than $Cp>1{,}33$.

In the *Extraction Force Line B*, the methodology applied will be the same as line A. The process has to shift to the left side to reduce the force up to 30 kg because most of the bottles are out of the USL (Upper Specification Limit) of 40 kg. Then, it is necessary to have the control of all the causes that generate this variability. The movement of the samples distribution can generate a better placement of the spread of the attribute product distribution to reach higher capability results.

Finally, the *Extraction Force Line C* is not capable. Moreover, it is not centred properly, so, it needs to improve both mistakes because it is not centred and it is shifted. 3kg from the expected mean around 30kg.

As a result, this line needs to solve these two problems at the same time because the shift is very considerable and the incapable cannot be allowed if the objective is the reduction of defective bottles.

Volume of wine

For the volume of filling, it is considered the same first solution as the extraction force. The increase of samples followed. Thanks to that the intern variability of the filling machine will not be affected by others because the 2, 3 or 4 samples followed can be considered that work under the same conditions because there is no time for shifts.

For the volume of filling, it is considered the same first solution as the extraction force. The increase of samples followed. Thanks to that the intern variability of the filling machine will not be affected by others because the 2, 3 or 4 samples followed can be considered that work under the same conditions because there is no time for shifts, or changes on the machine's calibration, etc. Therefore, the expected bottles out of the specification will be very accurately.

This methodology could be implemented taking 4 following bottles every day, every hour, during a week and afterwards return the wine to the filling pipe to not waste material. With this information the process can be studies perfectly and find all the causes to understand every external cause that makes the process vary more than its natural variability.

For the moment, based on the analysis of the filling of wine process, the *Volume Line A* has a shift of 1ml to the low side. On the other hand, the *Volume Line B* should improve their capability and shift a bit the process to the left side (Low level) the configuration of the volume B because is filling more than the target.

The *Volume Line C* process is capable and centred. It does not need any specific change.

What is interesting for the process is the improvement of the capability. If the company finds out the relationship between the causes to know if it is more related with material, operators, configuration and setting, speed of the line or others, they could increase the capability and achieve a minimum number of bottles rejected. After achieving that, the next step will be the reduction of the control limits, step by step, to achieve a product with less variation and more units closer to the target.

As a conclusion, the methodology that should be implemented is the next:

- Control better the parameters to reduce the variability and standardizing the activities, for increasing the capability.
- If the process is shifted, readjust the configuration of the related attributes to centre processes.

- When the capability is improved up to levels of Pp>1,5, reduce the limits (LSL and USL) and then continue controlling again the process.

5.5. Phase 5: CONTROL

Up to now, the project has worked with all the data collected. All this information has been analyzed to get the solution for improving the processes in the bottling line of the winery. When one arrives to this phase, the methodology is to make the statistical process control of the variables which want to be controlled because the new improvements are running, so, this control will realize about the positive or negative changes. Besides, the improvement teams who worked for improve the new ways in the company should be encouraged to continue putting special emphasis on the routine activities to ensure that are still doing things good, without come back to the typical errors made before.

From the statistical point of view, the author’s study cannot continue implementing the phase (CONTROL) for the rejected bottles problem because the information collected from the visits (see 4.3.2.) is not enough due to the lack of time to study. There is no enough data to analyze under statistical proves. On the other hand, the data registered by the laboratory of Extraction Force (see 4.3.3.) is controlled in this phase by the analysis of charts that explain how the process can be controlled.

The methodology followed is going to be developed with the data provided by Mezzacorona. Nevertheless, the theoretical control should be carried out with the future data that would be collected after the implementation of the improvements from the *IMPROVE* phase. Anyway, the methodology used in the study would be the same with the future data. So, the control is studied with the data of the laboratory from January to July.

In this phase it is only studied the *Extraction Force* because the control of the other variable *Volume of wine* is not going to be studied with control charts. This fact it is because of the data was registered by the laboratory, but only the bottles that arrive to the end of the line. As a result, the bottles that do not pass the automatic control after the filing are rejected and reprocessed. This means that the I-MR chart will not show bottles outside the limits. For an appropriate control the bottles could be picked to analyze just after the filling as it is explained in the IMPROVE phase, so, without any filter of bottles to know all the data.

Controlling Extraction Force

The tools used for this control is the I-MR chart (see 2.1.3). Thanks to this chart is possible to study the different stages during the year. The same properties of the chart alerts about unusual values, and for these control they have been selected all. For this control there is a difference between the control limits (UCL and LCL, Upper and Lower control limit) that are used here and the specification limits (USL and LSL) which are the limits for the company or customer quality. The control limits are dependent on the experimental data results, and the specification limits are based on the customer desire or product functionality limits decided by the company.

The first line, *Extraction Force Line A* is controlled from the beginning of the year (see Fig. 5.16.). The range of the limits is indicating the *individual value* with 3 times the standard deviations in on each side, every month. It is because the objective is to have the process under control without any samples outside and any alert. The limit of the *moving range* indicates the difference between the last and the current sample, alerting if there is too much variation in two consecutive samples.

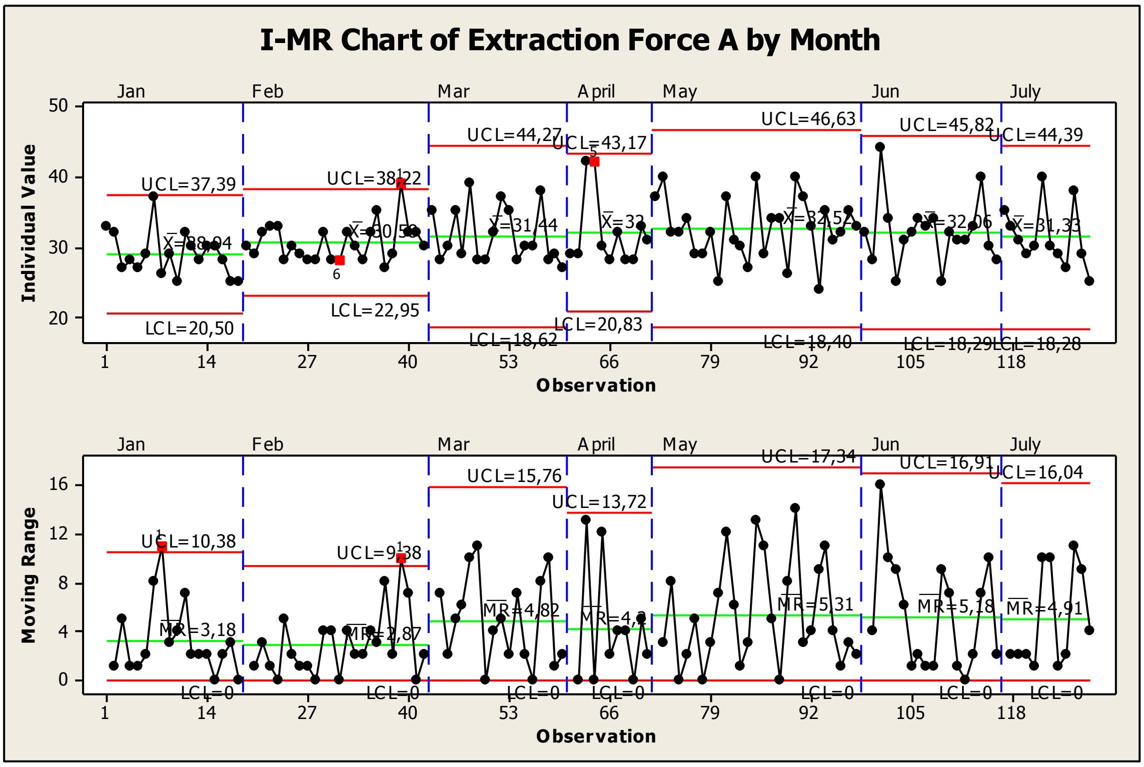


Fig. 5.16. I-MR chart of Extraction Force A. Source [Author]

According to the Fig. 5.16., the first impression is that the process is gaining variation, if one looks at the first two months in comparison with the last months. The month of March some cause is affecting this variability on the line A. This fact is appreciated in the moving range as well, increasing the moving range of standard deviation from 9,38 to 15,76kg.

The problem of this new variability is that the limits are bigger than the desired from the winery. As it happen in the ANALIZE phase, the limits are between 20 and 40. Both limits, upper and lower are out of specification generating more defective bottles than the desired.

Regarding the alerts, the most important is the alert of April, because there are two consecutive samples was with the same product and the same day, so, it is important to analyze why it was corking bad and producing defective bottles.

As a result, there is the possibility of analyze better the last 25 samples. Now, the limits are selected by the author according to the desired values and more recently, there is no any alert in the process (see below).

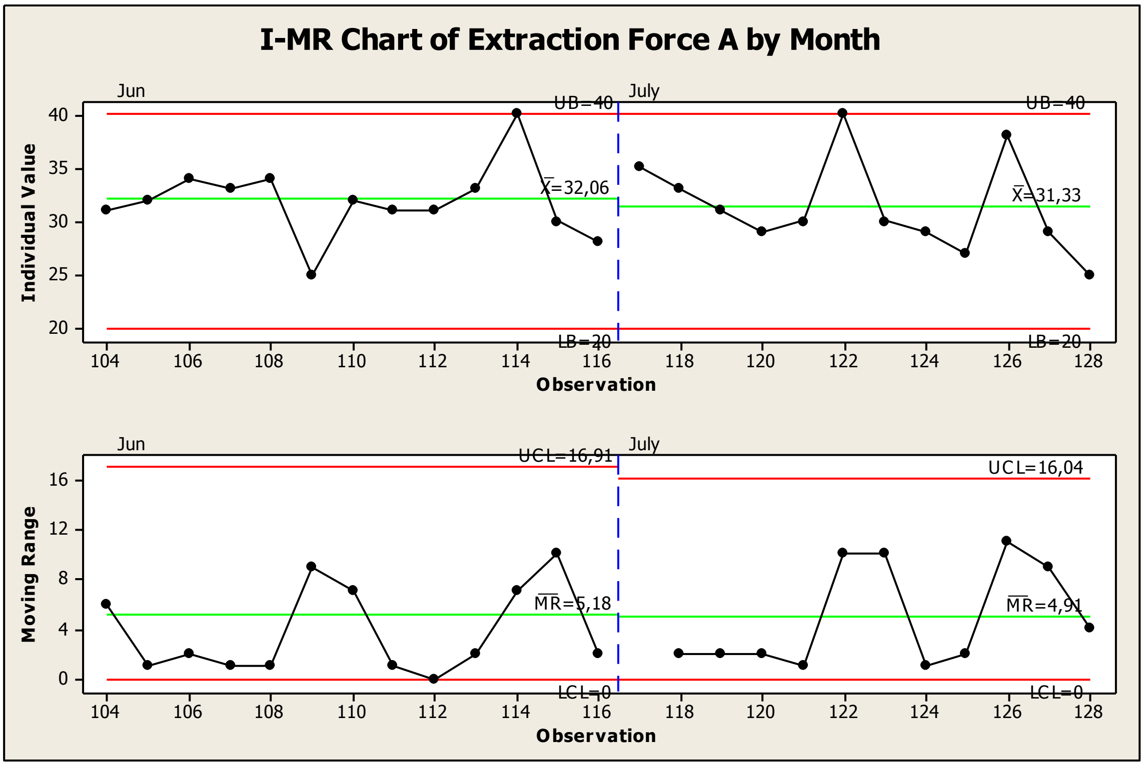


Fig. 5.17. I-MR chart of Extraction Force A last 25 samples. Source [Author]

Also one of the benefits of enjoying a process under control is that the variability is under control, so, when in the ANALIZE phase the capability analysis was realized, the author noticed that the process should improve its capability and this control complement the methodology for achieving the reduction of the defects.

Regarding *the Extraction Force of the Line B*, the process is under control. Any alert and any strange behaviour appears during the year (see Fig. 5.17.).

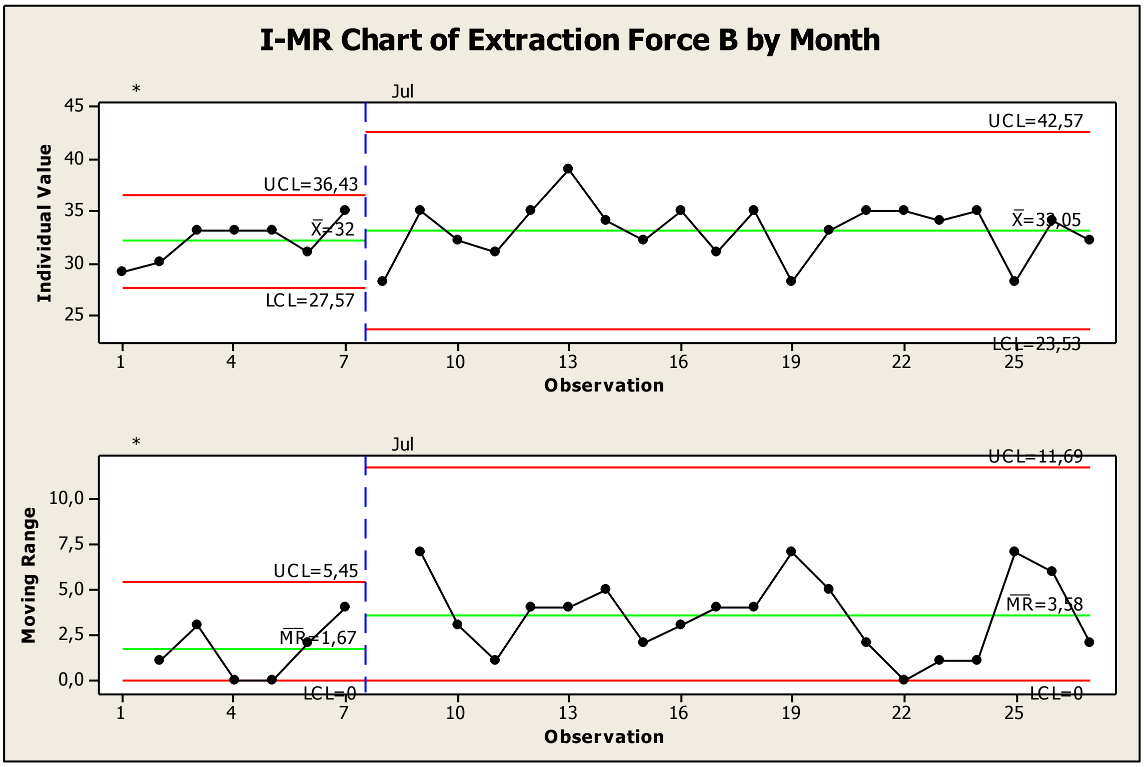


Fig. 5.18. I-MR chart of Extraction Force B. Source [Author].

There are not as samples as the other lines, but the in the month of July the chart does not show unstable points. Only it is considered to check the well-balance of the line because the process is corking bad because the extraction force is more than 30 kg. The adjustment will keep the limits between the specific limits for the winery between 20 and 40.

In the line C, the *Extraction Force* (see Fig. 5.19) can be appreciated that during the last months increases the mean due to it was not centred. Along the first months of the year, the process was totally out of specification. It is true that the process was performing quite good but shifted from the required target near 30, only 2 samples are alerted by being far from the mean.

In March there is an alert of 6 points increasing the moving range consecutive. It is an alert because it is not common in a process under control. It may inform the winery that some maintenance it could be necessary because is increasing in moving range every sample more.

It is interesting to study what happened during May because the process achieves excellent variation levels reducing around 33% its standard deviation. After that, the process started to get the right way to shift the mean of the extraction force closer to 30.

At the end of the month of June the process is out of order because it changes and increase around 10 kg more and remains there for 12 samples but then, the results are placed under the mean, so the winery should control to avoid that the extraction force comes back to be shifted below the correct well-balance. It can be appreciated better in the Fig. 5.20. both amount of samples out of control.

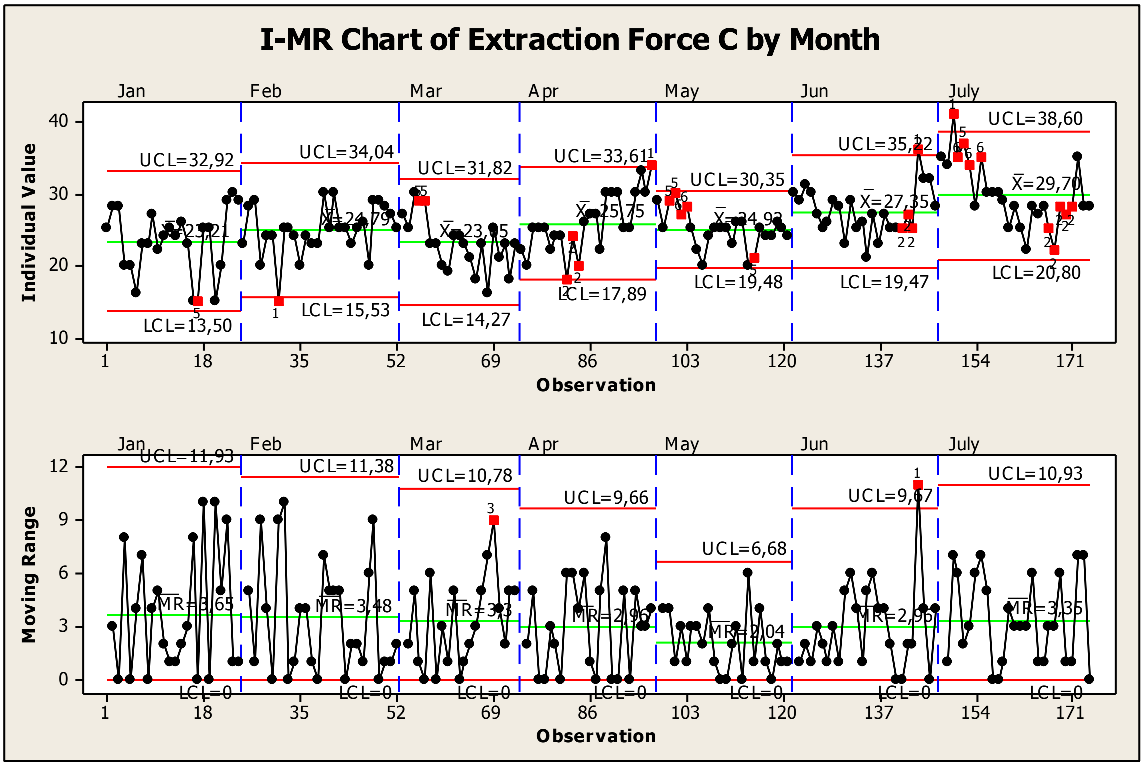


Fig. 5.19. I-MR chart of Extraction Force C. Source [Author]

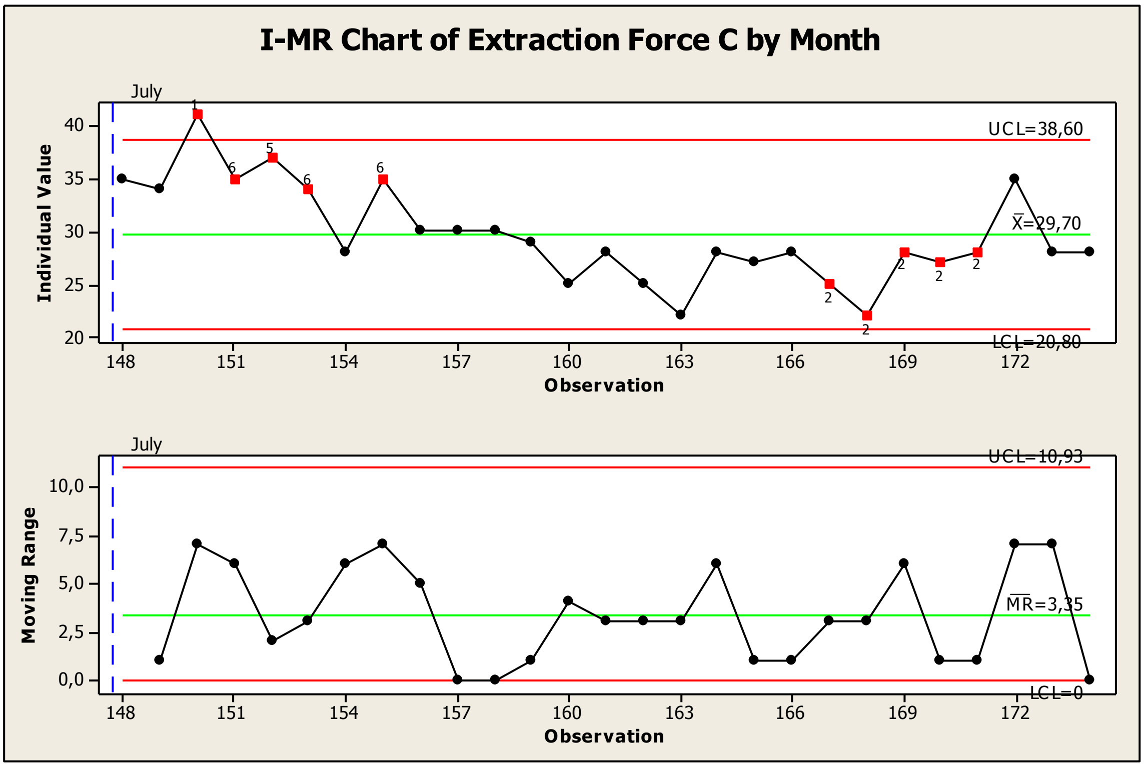


Fig. 5.20. I-MR chart of Extraction Force C last month. Source [Author]

Conclusions

Lean Six Sigma philosophy has always been introduced as a methodology that can be implemented in all business areas. In this case, the work implements the methodology in the bottling line of the winery Mezzacorona.

The first notion is that the winery does not specifically apply any of the two management techniques, Lean manufacturing or Six Sigma. Therefore, the bottling line and all the involved activities might be optimized by the Lean Six Sigma thinking. Due to this fact, the principal issue that appears at the beginning of the implementation is the lack of data from the bottling processes, which is essential for the improvement. There is a lack of information of processes times, efficiencies, number of rejected bottles and defects occurred. As a result, the bottling lines are not as optimized as they could because the main efforts are focused on the previous phases related with the creation of the wine.

The bottling production apparently runs good, but from the Lean Six Sigma view wastes are hidden that should be reduced. In the real processes there are wastes related with extra waiting times in the buffers, big raw materials inventories, overproduction, reprocessing and defects in bottles as a main problems. Then, thanks to the information that could be collected by the author and the laboratory information, the three objectives are defined in the *DEFINE* phase of the DMAIC cycle. So, after the comprehension of all processes involved, in the proposal implementation, the buffers would be reduced between processes, the replacement would be modified involving the suppliers more often, sequencing the maximum number of products by day according to the takt time of July and bottleneck process. In that case (July), it was 4 products per day, reducing the batch size.

These changes could improve the lead time in 56,6%, reduce the final stock and raw material inventories and optimize the resources. Moreover, it is proposed a 5S methodology to reduce waste in operators' time in the activities avoiding some of the future mistakes or confusions in their tasks in all processes. The technique would focalize on the facilitation of the operators recognition and sorting of the tools used for their activities. All of this would develop the Lean thinking, and at the end, finding the proper standardization based on improvement teams.

The study of the Lean improvements is realized with the information of the Line B of the winery, but, the changes and improvements could be totally adapted to the other lines. Also, as a future application if were desired, more techniques would be more developed in a real implementation like the standardization of tasks, changeovers (to apply SMED), 5S implementation in all areas, but the problem in this work was the available time of research, because each development would be improvement projects by themselves.

According to the variables of study the variation of the process is fundamental. By controlling these variables it is possible to have the control in order to avoid excessive products out of specifications. Consequently, the first conclusion is that the winery do not analyse data by statistical tools, so, they do not know the behaviours of the processes, variables, and it is quite impossible to find accurately why the processes are having accidental variability, and not only the natural variation.

A new methodology to collect data is based on the control of the number of rejected bottles and defects. Thanks to that, it would be possible to develop in a future implementation. A Lean Six Sigma project could be developed working with enough information to do more statistical studies along the time to find out some possible patrons in the behaviour. Then, according to the author's data collected about defects, the line A is having more rejected bottles, in particular the *Filling* process. Apparently, it could be the bottle or the speed of the line, for this reason a detailed collection of rejected bottles might help the winery find out the reasons. In the line B, *Corking* and *Capsule* processes generate more rejected bottles.

In the case of the variables of *Extraction Force* of the Cork and *Volume of wine*, the winery collects data of many attributes, but only one sample each time. This fact makes more difficult the study of the variability because there are not consecutive samples in which the variation in the values must be just the natural variation of the process. In this case, there is no time to be affected by external variation such as all the causes considered in the *Cause-effect diagram* (Fig 5.7.). Therefore, in a future implementation, it is necessary to change where they control these variables and collect them in the same process by groups, at least 2, but recommended 4 samples until the external causes that affect the variability would be recognized.

Regarding the data provided by the laboratory of the winery, the conclusions that can be deducted from the Extraction Force is that the three bottling lines are having more variation than the desired if they want to get a low number of defects for this reason. In a first solution, they have to pay attention because the processes are not within a good capability; even the line C is not capable. Because not all the bottles can be checked, the analysis of capability expects in the line A a 3,4% and line C 3,7% of bottles out of specifications because, the line A is shifted to the upper side expecting most of the defects over 40 kg and the line C the opposite, is shifted to the lower side, with most of the defects under 20 kg.

This variable is studied by control charts in the last phase of DMAIC cycle. In a future implementation, the control of the variables has to be done always, during the whole year. Consequently, when the winery makes some changes to improve the process, in the control chart the results could be seen, if they are effective or not.

In this work, the control chart were realized with all the data provided by the winery, so, the control cannot be made with the proposal improvements because of the winery has the decision to decide if it would like to apply the new changes. The control is divided by month whereas in a future control, it could be divided by periods of new changes expecting improvements or by periodic checking of the machinery, shifts, etc. The benefit of knowing about data is that it would give the opportunity to find out the main reasons about when the process is not under control due to some external causes.

Regarding the second variable studied, the *Volume of wine* filled in the bottles, and the three lines are capable. However, the line A and B are not over the optimal capability value. The company, when achieves the adequate values of capability, afterwards, the next point would be the reduction of the interval limits to increase its quality and fill always with less variation. It can be studied more accurately the bottles in which the process do not perform properly. The assumption that the author's data made of the line A, it is that a significant percentage of bottles would be bad performed. It is because most of the defects in that machine are middle filled or without filling.

As improvements, the line A shows a deviation of 1 ml in the filling which should be controlled to avoid rejected bottles because the process is not centred. In the line B the main problem is the spread of the distribution although there are more expected bottles out by the upper limit.

The defective bottles in the filling process do not continue in the line. They are reprocessed again carrying out their tasks and putting the bottle again at the beginning of the stage. Anyway, the reduction of these defective fillings reduce waste of material, operator time, efficiency because of the reprocessing and because they delay the final production batch time. But the fact that there are not defective bottles in the data is because of the samples are taken at the end of the line, so, the bottles of the data have passed the automatic control after the Filling-Corking machine.

As the Extraction Force, the methodology of collection of samples should change for a better statistical analysis, collecting bottles just after the filling to not have limited the data to good filled bottles. Then the rule is to apply the same methodology with a group of samples consecutive.

Besides all the deductions and proposed solutions, this works could help other researches and future studies in the wine-making sector. Lean Six Sigma is related with other phases of the wine such as the growing and laboratory work before bottling and also transporting of the wine. It is based on some other case studies and companies which are already applying Lean Six Sigma projects in their wineries.

Regarding the bottling phase and the study realized in this work, the Lean Six Sigma methodology proposed is a first proposal implementation. It is focused on the application of the DMAIC improvement methodology cycle. The DMAIC cycle is a continuous improvement philosophy, so, once the improvement would be developed, implemented and controlled, if the processes reach the right values, it will mean that the causes are detected and are well implemented. To detect these causes and control them, the process must be capable. Then, it must achieve a reduction on the variation to be under control. As a result, the specification limits should be reduced to increase the quality in the variables and to continue with the cycle again. It could be that the processes change to worse or different scenarios. In all cases, the cycle will start again, defining the new situation. After that, the new objectives will be proposed to implement the cycle again using the adequate techniques and statistical tools for continuing the improvement, always looking for the business excellence, with the best savings, less waste and highest quality.

In conclusion, for the best successful implementation it is necessary a cultural change. It is mentioned the importance to encourage all the employees when the new changes are implemented. All of them need to put their efforts on the aims of the company in order to reduce defects, time or mistakes, and so on. The spirit of continual improvement has to be promoted by the company and top managers to persuade the whole organization. It will get the greatest saving costs when the improving changes would be assimilated and applied properly and continue the cycle again to not lose the improvement spirit.

References

Abdul Wahab, A N, Mukhtar, M and Sulaiman, R. 2013. *A Conceptual Model of Lean Manufacturing Dimensions.* s.l. : Procedia Technology 11, 2013. pp. 1292-1298.

Akpolat, H. 2004. *Six Sigma in Transactional ans Service Enviroments.* s.l. : Gower Publishing Company, 2004.

Alarcon, L. 1997. *Tools for the identification and reduction of waste in construction projects.* s.l. : Alarcon (Ed.), Lean Construction, A.A. Balkema, Rotterdam, The Netherlands (1994), 1997.

Arnhneiter, E. D. and Maleyeff, J. 2005. *The integration of Lean management and Six Sigma.* s.l. : The TQM Magazine 17 (1), 2005. pp. 5-18.

Benjafaar, S, Heragu, S and Irani, S. 2002. *Next generation factory layouts: research chal-lenges and recent progress.* s.l. : Interfaces 32 (6), 2002. pp. 58-76.

Bessant, J, Caffyn, S and Gallagher, M. 2001. *An evolutionary model of continuous improvement behavior.* s.l. : Technovation 21, 2001. pp. 67-77.

Bettini, R., et al. 2010. *The Lean Six Sigma Approach for Process Improvement: A Case Study in a High Quality Tuscany Winery.* s.l. : Journal of Agricultural Engineering (4), 2010. pp. 1-7.

Birkmann, S and Deuse, J. 2007. *Using a Group Technology Approach to Level a Low Volume and High Mix Production.* s.l. : Proceedings on the 12th Annual International Conference on Industrial Engineering, 2007. pp. 265-270.

Black, J. T. 1991. *The Design of the Factory with a Future.* s.l. : McGraw-Hill, New York, 1991.

Bohnen, F, Maschek, T and Deuse, J. 2011. *Leveling of low volume and high mix production based on a Group Technology approach.* s.l. : CIRP Journal of Manufacturing Science and Technology (4), 2011. pp. 247-251.

Brady, J. E. and Allen, T. T. 2006. *Six Sigma literature: a review and agenda for future research.* s.l. : Quality and Reliability Engineering International, 2006. pp. 335-367.

Breyfogle III, F W. 1999. *Implementing Six Sigma: Smarter Solutions Using Statistical Methods.* s.l. : Wiley, New York, 1999.

Breyfogle III, F. W. 1999. *Implementing Six Sigma: Smarter Solutions Using Statistical Methods.* s.l. : Wiley, New York, 1999.

Brun, A. 2011. *Critical success factors of Six Sigma implementations in Italian companies.* s.l. : Int. J. Production Economics 131, 2011. pp. 158-164.

Buch, R and Rivers, D. 2001. *TQM: the role of the lidership and culture.* Leadership & Organizational Development Journal 22 (8) : s.n., 2001. pp. 365-371.

Chan, F. T. S., et al. 2005. *Implementation of total productive maintenance:A case study.* s.l. : Int. J. Production Economics 95, 2005. pp. 71-94.

Coleman, B. J. and Vaghefi, M. R. 1994. *Heijunka: A key to the Toyota prodcution system.* s.l. : Prodution and Inventory Management Journal, 1994. pp. 31-35.

De Koning, H and De Mast, J. 2006. *A rational reconstruction of Six Sigma's Breakthrough Cookbook.* International Journal of Quality and reliability Management 23 (7) : s.n., 2006. pp. 766-787.

De Vries, H. 1999. *A Business Approach to the Role of National Standardization Organizations.* s.l. : Kluwer Academic Publishers, Dordrecht, The Netherlands 1999, 1999.

De Vries, H. and Jakobs, K. 2005. *Advanced Topics in Information Technology Standards and Standardization Research.* s.l. : Idea Group Publishing, Hershey, USA, 2005. pp. 11-36.

Dean, H W and Bowen, D E. 1994. *Management theory and totoal quality improving research and practice through theory development.* s.l. : The Academiy of Management Review 19 (3), 1994. pp. 392-418.

Devane, T. 2004. *Integrating Lean Six Sigma and High-Performance Organizations: Leading the Charge Toward Dramatic, Rapid, and Sustainable Improvement.* s.l. : Pfeiffer, 2004.

Dow Chemical Company. 2014. Dow Services. [En línea] 2014. http://www.dow.com/dowservices/consulting/partners/sixsigma.htm.

E.& J. Gallo Winery. 2014. E.&J. Gallo Winery. [Online] 2014. http://gallo.com/.

Edwards, J N. 1993. *Inside a smoother running engine: An American giant transforms itself, Target.* s.l. : The Periodical of the Association forManufacturing Excellence 9 (3), 1993. pp. 5-11.

Eti, M. C., Ogaji, S.O.T. and Probert, S.D. 2004. *Implementing total productive maintenance in Nigerian manufacturing industries.* s.l. : Applied Energy 79, 2004. pp. 385-401.

Flynn, B B, Schroeder, R G and Sakakibara, S. 1994. *A framework for quality management research and associated measurement intrument.* s.l. : Journal of Operations Management 11 (4), 1994. pp. 339-366.

—. 1995. *The impact of quality management practices on performance and competitive advantage.* s.l. : Decision Sciences 26 (5), 1995. pp. 659-692.

—. 1995. *The impact of quality management practices on performance and competitive advantage.* s.l. : Decision Sciences 26 (5), 1995. pp. 659-692.

Formoso, C, et al. 1999. *Method of Waste Control in the Building Industry.* s.l. : Proceeding ICLG-7, University of California, Berkeley, CA. USA, 1999. pp. 325-334.

Galsworth, G. D. 2005. *Visual Workplace/Visual Thinking: Creating Enterprise Excellence through the Technologies of the Visual Workplace.* s.l. : Visual Lean Enterprise Press, 2005.

George, M. L. 2002. *Lean Six Sigma: Combining six sigma quality with lean speed.* s.l. : McGraw-Hill, 2002.

George, M. 2003. *Lean Six Sigma for Services.* s.l. : New York. McGraw-Hill, 2003.

Gest, G, et al. 1995. *Review of fast tool change systems.* s.l. : Computer Integrated Manufacturing Systems 8, 1995. pp. 205-210.

Goodson, R E. 2002. *Read a Plant-Fast.* s.l. : Harvard Business Review 80, 2002. pp. 105-113.

Graves, R, Konopka, J M and Milne, R J. 1995. *Literature review of material flow control mechanisms.* s.l. : Production Planning and Control 6 (5), 1995. pp. 395-403.

Guzmán Ferradás, P and Salonitis, K. 2013. *Improving changeover time: a tailored SMED approach for welding cells.* s.l. : Procedia CIRP 7, 2013. pp. 598 – 603.

Helo, P., et al. 2014. *Toward a cloud-based manufacturing execution system for distributed.* s.l. : Computers in Industry 65, 2014. pp. 646-656.

Hollnagel, E. 2004. *Barrier analysis and accident prevention.* s.l. : Ashgate, 2004.

Hoop, W J and Spearman, M L. 2004. *To Pull or Not to Pull: What Is the Question?* s.l. : Manufacturing & Services Operations Management (6), 2004. pp. 133-148.

Hyer, N L, Brown, K A and Zimmerman, S. 1999. *A socio-technical systems approach to cell design: case study and analysis.* s.l. : Journal of Operations Management 17, 1999. pp. 179-203.

Imai, M. 1986. *The Key to Japan's Competitive Success.* s.l. : McGraw-Hill, New York, 1986.

Information Technology Industry Council. 2014. Information Technology Industry Council. [Online] 2014. http://www.itic.org/.

iSixSigma. 2002. iSixSigma.com. [Online] 2002. http://www.isixsigma.com/implementation/financial-analysis/six-sigma-costs-and-savings/.

iSixSigma Magazine. 2009. isixsigma-magazine.com. [Online] July/August 2009.

Jones, E. C. 2014. *Quality management for organizations using lean Six Sigma techniques.* s.l. : Boca Raton, FL : CRC Press, 2014.

Lage Junior, M y Godinho Filho, M. 2010. *Variations of the kanban system: Literature review and classification.* s.l. : Int. J. Production Economics 125, 2010. págs. 13-21.

Lawer III, E E. 1996. *From the ground Up: Six principles for building the new logic Corporations.* s.l. : Jossey-Bass, San Francisco, CA, 1996.

Lee, K.-C. and Choi, B. 2012. *Six Sigma Management Activities and Corporate Competitiveness.* s.l. : Total Quality Management 17 (1), 2012. pp. 893-911.

Li, J and Blumenfeld, D. 2006. *Implementing an Andon.* s.l. : Industrial Engineer: IE 38 (10), 2006. pp. 52-53.

Liker, J K and Meier, D. 2006. *The Toyota Way Fieldbook - A Practical Guide for Implementing Toyota's 4Ps.* s.l. : New York: The McGraw-Hill Companies, Inc. New York, NY, USA., 2006.

Liker, J. K. 2004. *The Toyota Way.* s.l. : McGraw-Hill, New York, 2004.

Lin, ChiaJou, et al. 2013. *Continuous improvement of knowledge management systems using Six Sigma methodology.* s.l. : Robotics and Computer-Integrated Manufacturing 29 (3), 2013. pp. 95-103.

Linderman, K, et al. 2003. *Six Sigma:a goal-theoretical perspective.* s.l. : Journals of Operations Management 21, 2003. pp. 193-203.

Lungberg, O. 1998. *Measurement of overall equipment effectiveness as a basic for TPM activities.* s.l. : International Journal of Operations and Production Management 18 (5), 1998. pp. 495-507.

MacInnes, R L. 2002. *The Lean Enterprise Memory Jogger.* s.l. : 1st Edition Salem, NH, 2002.

McIntosh, R. I., et al. 2001. *Improving changeover performance. A strategy for Becoming a Lean Responsible Manufacturer.* s.l. : Elservier, Ltd, 2001.

McKone, K. E., Schroeder, R. G. and Cua, K. O. 1999. *Total productive maintenance: a contextual view.* s.l. : Journal of Operations Management 17, 1999. pp. 123-144.

McLachlin, R. 1997. *Management iniciatives and just-in-time manufacturing.* s.l. : Journal of Operations Management 15, 1997. pp. 271-292.

Metternich, J., Bechtloff, S. and Seifermann, S. 2013. *Efficiency and Economic Evaluation of Cellular Manufacturing to enable Lean Machining.* s.l. : Procedia CIRP 7, 2013. pp. 592-597.

Miltenburg, John. 2001. *U-shaped production lines: A review of theory and practice.* s.l. : Int. J. Production Economics 70, 2001. pp. 201-214.

Mondem, Y. 1981. *Adaptable kanban system helps Toyota maintain jist-in-time production.* s.l. : Industrial Engineering 13 (5), 1981. págs. 29-46.

—. 1993. *Toyota Production System: an integrated approach to just-in-time.* s.l. : Industrial Engineering and Management Press, 1993.

—. 1983. *Toyota Production System: practical approach to production management.* s.l. : Industrial Engineering and Management Press, Institute of Industrial Engineers, 1983.

Nakajima, S. 1988. *Introduction to Total Productive Maintenance (TPM).* s.l. : Productivity Press, Cambridge, 1988.

Ohno, T. 1982. *The origin of Toyota prodcution system and kanban system.* s.l. : Prodcedings of the Interntional Conference on Productivity and Quality Improvement. Tokyo, 1982.

—. 1988. *Toyota Production System: Beyohnd Large Scale Production.* s.l. : Productivity Press, Cambridge, MA, 1988.

Osono, E, et al. 2008. *Extreme Toyota: Radical contradictions that drive success at the world's best manufacturer.* s.l. : Hoboken, NJ: Wiley, 2008.

Pamfiliea, R., Petcu, A. J. and Draghici, M. 2012. *The importance of leadership in driving a strategic Lean Six Sigma management.* s.l. : Procedia - Social and Behavioral Sciences 58, 2012. pp. 187-196.

Rinehart, J, Huxley, C and Robertson, D. 1997. *Just Another Car Factory?* s.l. : Cornell University Press, Ithaca, NY, 1997.

Rivard, D. 2009. *The Ultimate Fruit Winemaker's Guide.* s.l. : Bacchus Enterprices Ltd. 2nd Edition, 2009.

Robert, J. 2002. *Total productive maintenance (TPM).* s.l. : Available from: JackRobert@TAMU_Commerce.edu, 2002.

Rother, M and Shook, J. 2003. *Learning to see.* s.l. : Cambridge, Massachustts: Lean Enterprise Institute., 2003.

Schoroeder, Roger G, et al. 2008. *Six Sigma: Definition and underlying theory.* s.l. : Journal of Operations Management 26, 2008. pp. 536-554.

Schroeder, R G, Linderman, K and Zhang, D. 2005. *Evolution of quality: first fifty issues of production and operations management.* s.l. : Production & Operations Management 14 (4), 2005. pp. 468-481.

Seth, D. and Tripathi, D. 2006. *A critical study of TQM and TPM approaches on business performance of Indian manufacturing industry.* s.l. : Total Quality Management, 17(7), 2006. pp. 37-41.

Shafer, S M and Moeller, S B. 2012. *The effects of Six Sigma on corporate performance: An empirical investigation.* s.l. : Journal of Operations Management 30, 2012.

Shafer, Scott M and Moeller, Sara B. 2012. *The effects of Six Sigma on corporate performance. An empirical investigation.* s.l. : Journal of Operations Management 30, 2012. pp. 521-532.

Shah, R and Ward, P T. 2007. *Defining and developing measures of lean production.* s.l. : Journal of Operations Management 25, 2007. pp. 785-805.

—. 2003. *Lean Manufacturing: context, practice bundles, and performance.* s.l. : Journal of Operations Management 21 (2), 2003. pp. 129-149.

Shingo, S. 1985. *A revolution in Manufacturing. The SMED System Productivity.* s.l. : Productivity Press University Park II, 1985.

—. 1988. *Zero quality control: source inspection and the poka-yoke system.* s.l. : Productivity Press, 1988.

Silva, S. P., et al. 2005. *Cork: properties, capabilities and applications.* s.l. : International Material Review 50, 2005. pp. 345-365.

Singh, N, Shek, Kwok Hung and Meloche, D. 1990. *The Development of a Kanban System: A Case Study.* s.l. : International Journal of Operations & Production Management 10 (7), 1990. pp. 28-36.

Sinha, K K and Van de Ven, A H. 2005. *Designing work within and between organizations.* s.l. : Organization Science 16 (4), 2005. pp. 389-408.

Stevenson, W J. 2005. *Operations Management 8th Edition.* s.l. : New York, N.Y McGraw-Hill, 2005.

Sui Pheng, L and Ha Dung, L. *Learning from Manufacturing: JIT and MRP in Built Environment Education.* s.l. : Built Enviromental Education.

Surendra, M G, Yousef, A Y and Ronal, F P. 1999. *Flexible Kanban system.* s.l. : International Journal of Operations and Production Management. Vol 19, No 10, 1999. pp. 1065-1093.

Suzuki, T. 1992. *New directions for TPM.* s.l. : Productivity Press, Cambridge, MA, 1992.

Taghizadegan, S. 2006. *Essentials of Lean Six Sigma.* s.l. : Butterworth Heinemann, 2006.

Teece, D. T., Pisano, G. and Shuen, A. 1997. *Dynamic capabilities and strategic management.* s.l. : Strategic Management Journal 18, 1997. pp. 509-533.

Tenera, Alexandra and Carniero Pinto, Luis. 2014. *A Lean Six Sigma (LSS) project management improvement model.* s.l. : Procedia - Social and Behavioral Sciences 119, 2014. pp. 912-920.

Toyota Motor Corporation. 2014. Toyota Global. [Online] 2014. http://www.toyota-global.com/company/vision_philosophy/toyota_production_system/just-in-time.html.

Treichler, David, et al. 2002. *Design for Six Sigma: 15 Lessons Learned.* s.l. : Quality Progress 35 (1), 2002. pp. 33-42.

Tsuchiya, S. 1992. *Quality Maintenance:Zero Defects Through Equipment Management.* s.l. : Productivity Press, Cambridge, MA, 1992.

Van Goubergen, D and Van Landeghem, D. 2002. *Rules for integrating fast changeover capabilities into new equipment design.* s.l. : Robotics and Computer Integrated Manufacturing 18, 2002. pp. 205-214.

Van Scyoc, K. 2008. *Process safety improvement—Quality and target zero.* s.l. : Journal of Hazardous Materials 159, 2008. pp. 42-48.

Veža, I., Gjeldum, N. and Celent, L. 2011. *Lean Manufacturing Implementation Problems in Beverage Production Systems.* s.l. : International Journal of Industrial Engineering and Management (IJIEM) (2) 1, 2011. pp. 21-26.

Villa, A and Taurino, T. 2009. *From New-Taylorism to human sustainability - Extending management concepts outside industrial sector.* s.l. : The Journal of Japan Industrial Management Association 60, 3E, 2009.

Waeyenbergh, G. and Pintelon, L. 2002. *A framework for maintenance concept development.* s.l. : International Journal of Production Economics 77 (3), 2002. Vols. 299-313.

Walker, G., et al. 2007. *A review of Sociotechnical Systems Theory: Classic Concept for New Command and Control Paradigms.* s.l. : Human Factors Integration Defence Technology Centre 2007, 2007.

Welch, J. 2005, March. *Six sigma leaders. Ex-ceo of ge believes six sigma goes beyond quality.* s.l. : Quality Magazine, 2005, March. http://www.qualitymag.com/articles/84016-view-from-the-top-six-sigma-leaders.

Wemmerlov, U and Hyer, N L. 1986. *Procedures for the part family/machine group identification problem in cellular manufacturing.* s.l. : Journal of Operations Management (6), 1986. pp. 125-147.

Wemmerlov, U and Johnson, D J. 1997. *Cellular manufacturing at 46 user plants: Implementation experiences and performance improvements.* s.l. : International Journal of Production Research (35), 1997. pp. 29-49.

Womack, J P and Jones, D T. 1996. *Lean Thinking: Banish Waste and Create Wealth in your Corporation.* s.l. : Simon & Schuster, New York, 1996.

Womack, J. P, Jones, D. T and Roos, D. 1990. *The Machine that Changed the World: The Story of the Lean Production.* s.l. : Harper Perennial Ed. New York, 1990.

Xingxing, Zu, Lawrence, D Fredendall and Douglas, Thomas J. 2008. *The evolving theory of quality management: The role Six Sigma.* s.l. : Journal of Operations Management 26, 2008. pp. 630-650.

Xingxing, Zu, Robbins, T. L and Frendendall, Lawrence D. 2010. *Mapping the critical links between organizational culture and TQM/Sig Sigma practices.* s.l. : Int. J. Production Economics 123, 2010. pp. 86-106.

Zarbo, R J and D'Angelo, R. 2006. *Transforming to a Quality Culture: The Henry Ford Production System.* s.l. : American Journal of Clinical Pathology Practice Patterns, 2006.

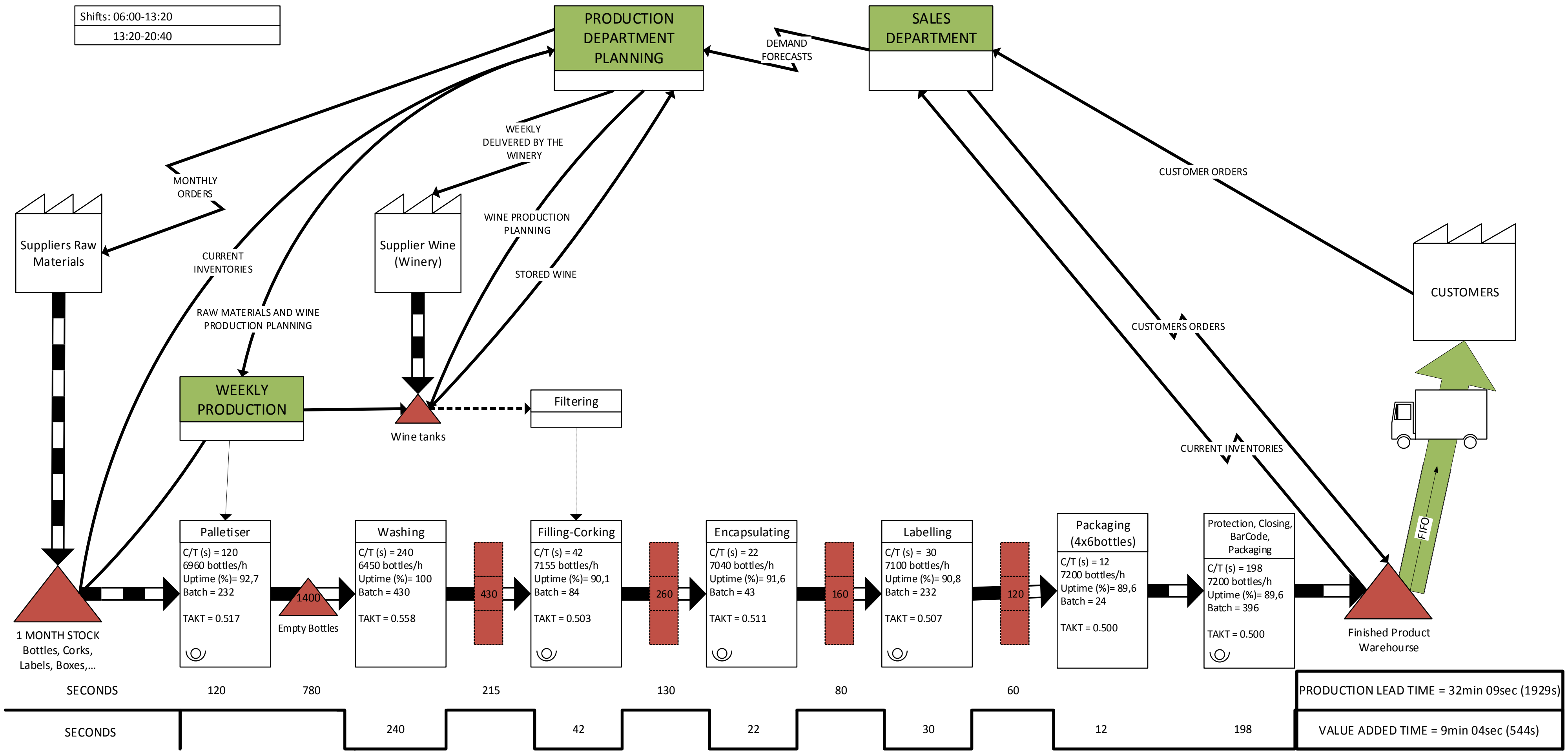
Annex

ANNEX 1. SIPOC diagram

S (Supplier)	I (Input)	P (Process)	O (Output)	C (Customer)
Winery (Tanks of stored wine) Raw materials, Complement and Chemical suppliers. Machinery equipment	Filtered wine *Raw materials*: Bottles, Corks, Capsules, Label Bovines, Boxes. *Complement material*; Laser Ink, Adhesive tape. *Chemicals*; Soda, Sulfur, Nitrogen Manpower *Machine settings*: Speed (bottles/h), Internal configurations (ml of filling, cork, label and capsule position). Belt speed	- Product settings - Bottles Palletiser - Washing - Filling-Corking - Encapsulating - Labelling - Packing - Protecting, Closing, BarCode - Packaging, Storing.	Wine bottles in package of 6 bottles.	Shops Supermarkets Wholesalers Distributors

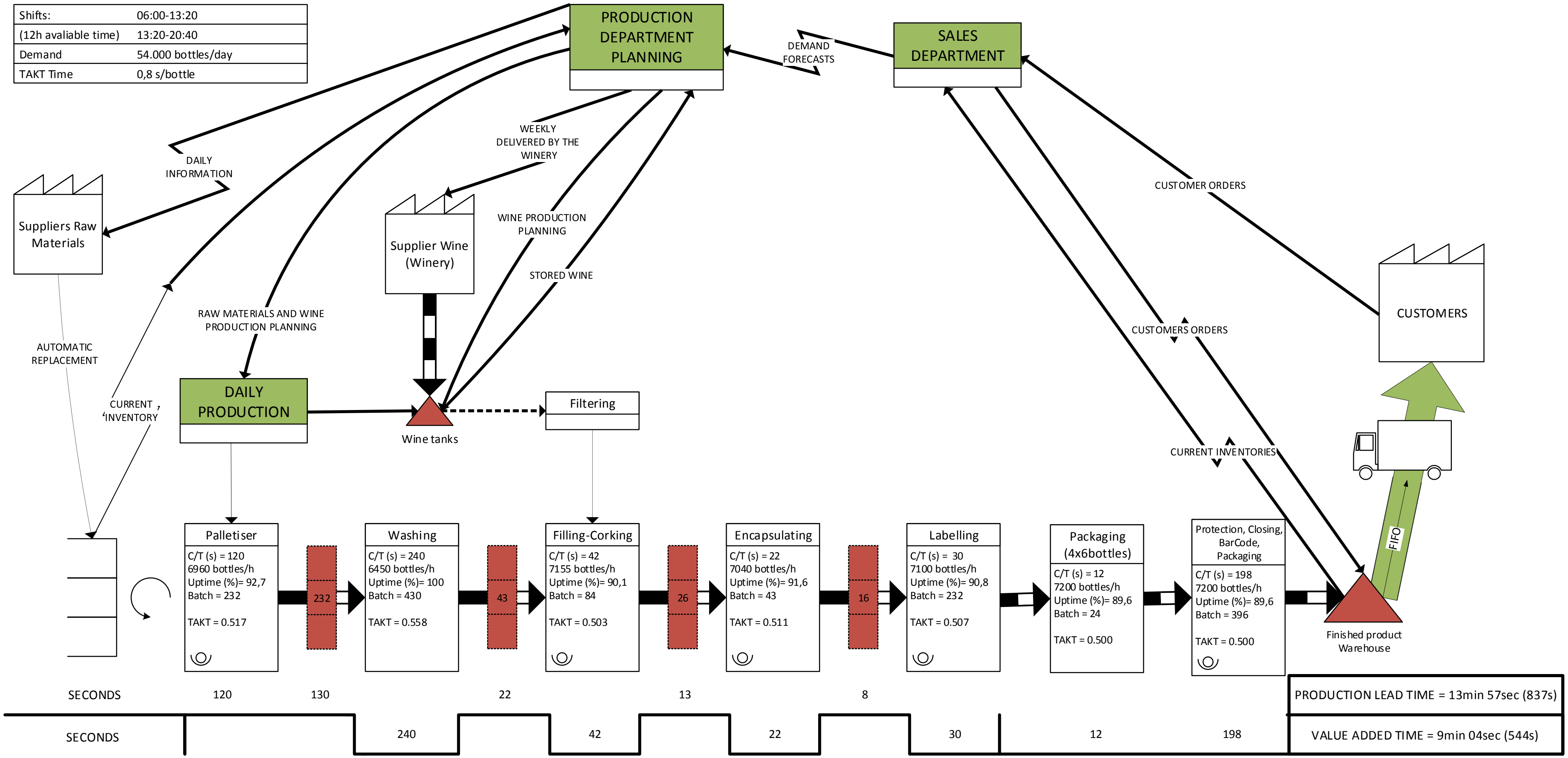
Source: [Author]

ANNEX 2. Actual VSM (Value Stream Mapping)



Source: [Author]

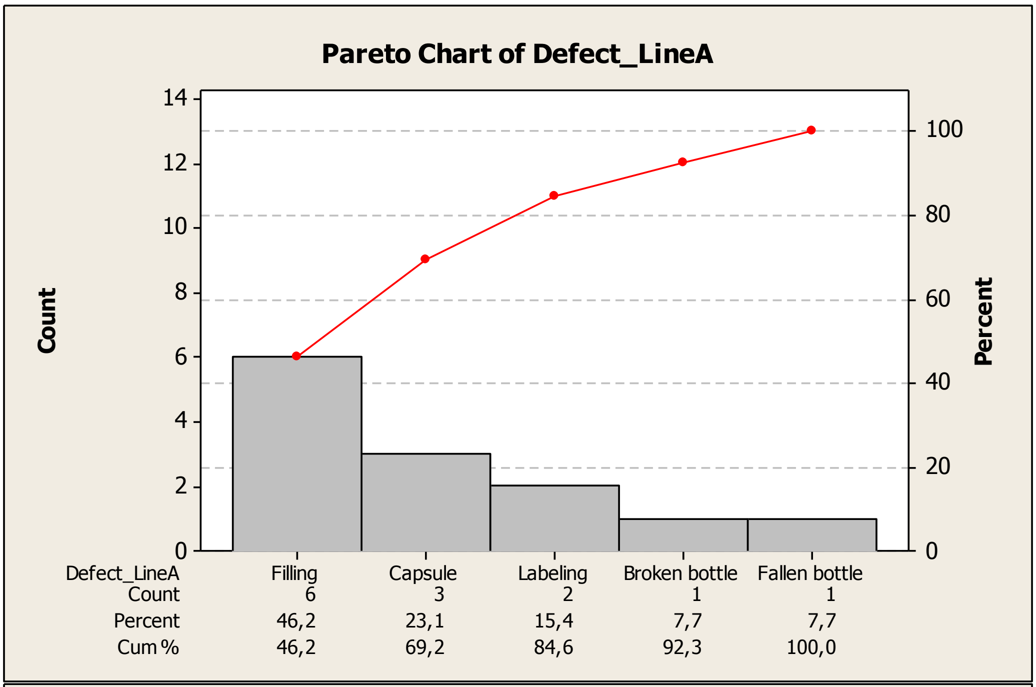
ANNEX 3. Future VSM (Value Stream Mapping)

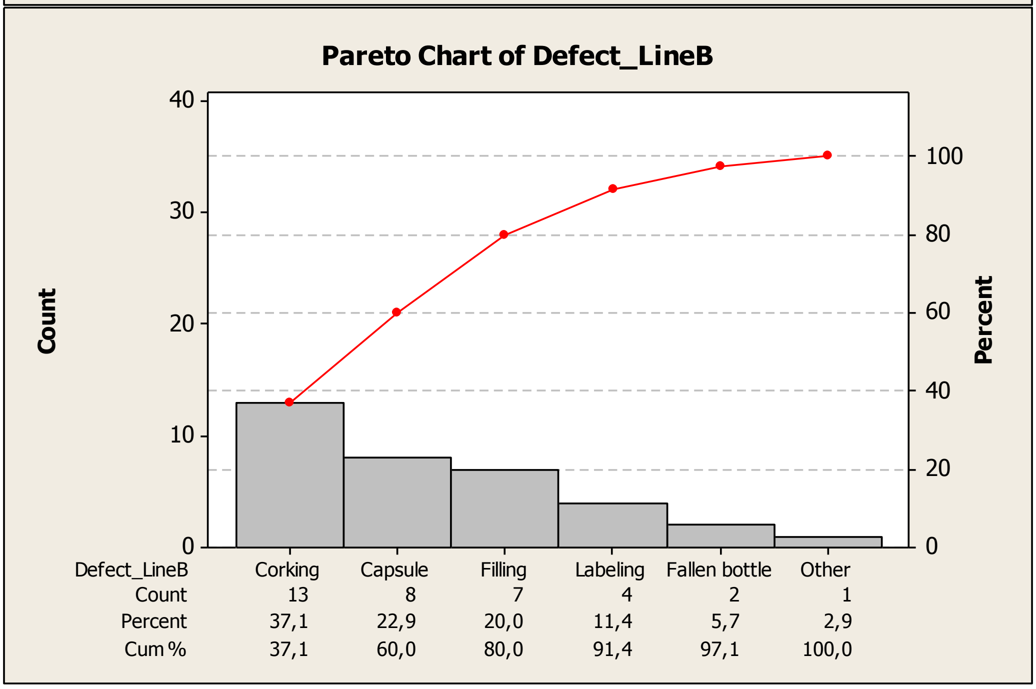


Source: [Author]

ANNEX 4. Pareto Charts

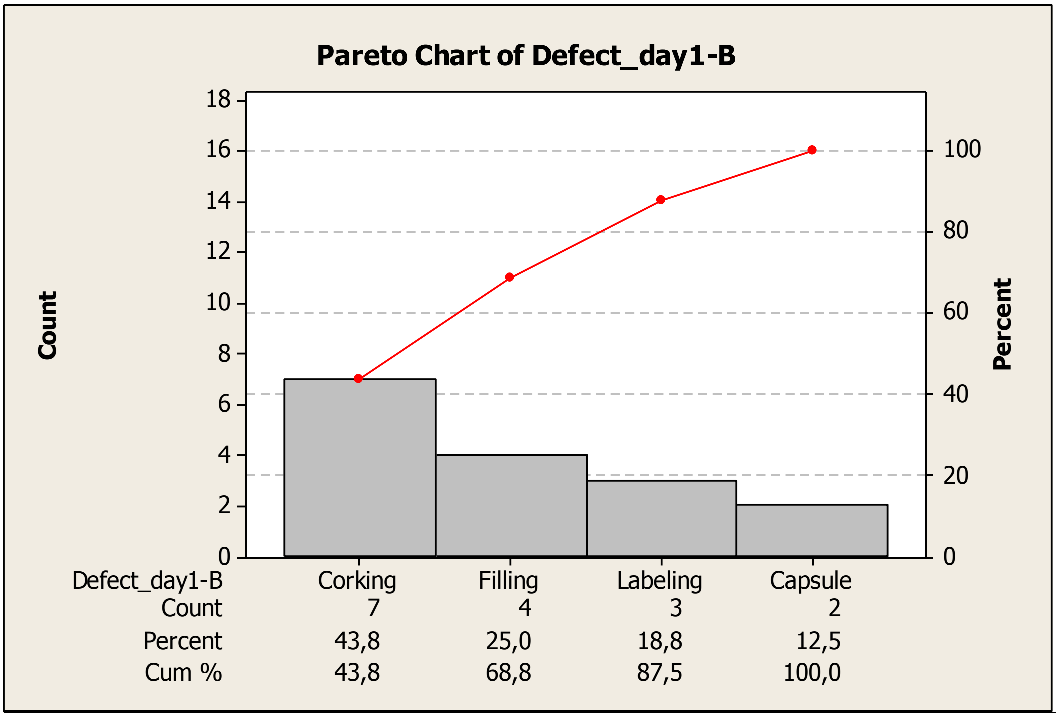
ANNEX 4.1. Pareto chart of Line A (1 day) and Line B (2days)

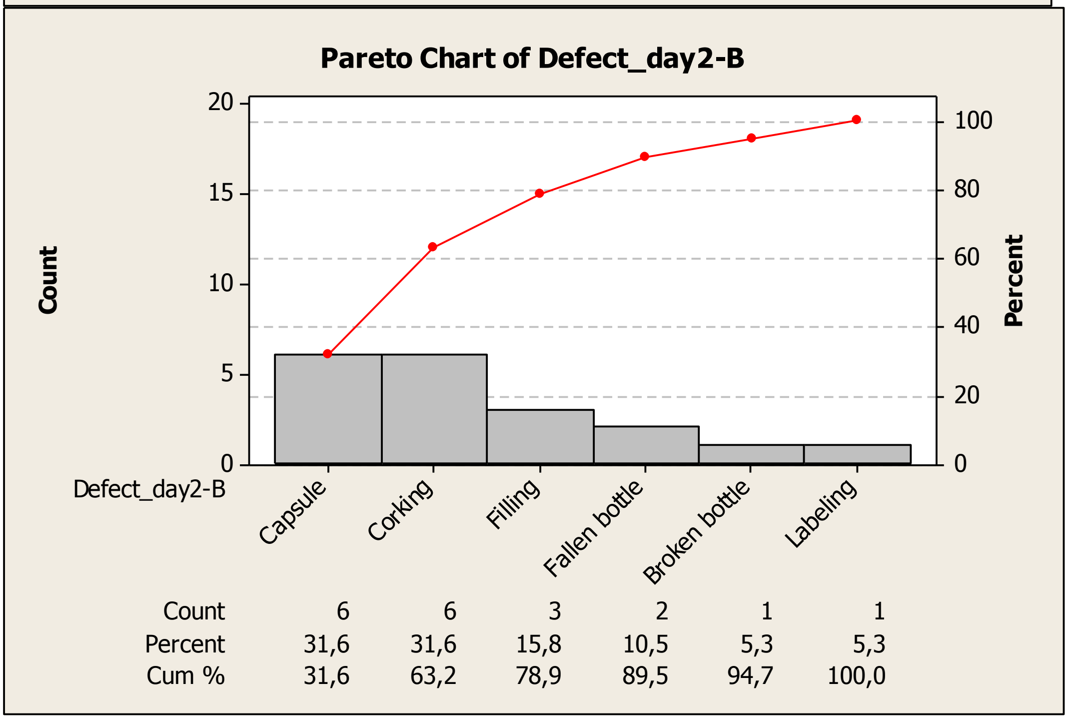




Source: [Author]

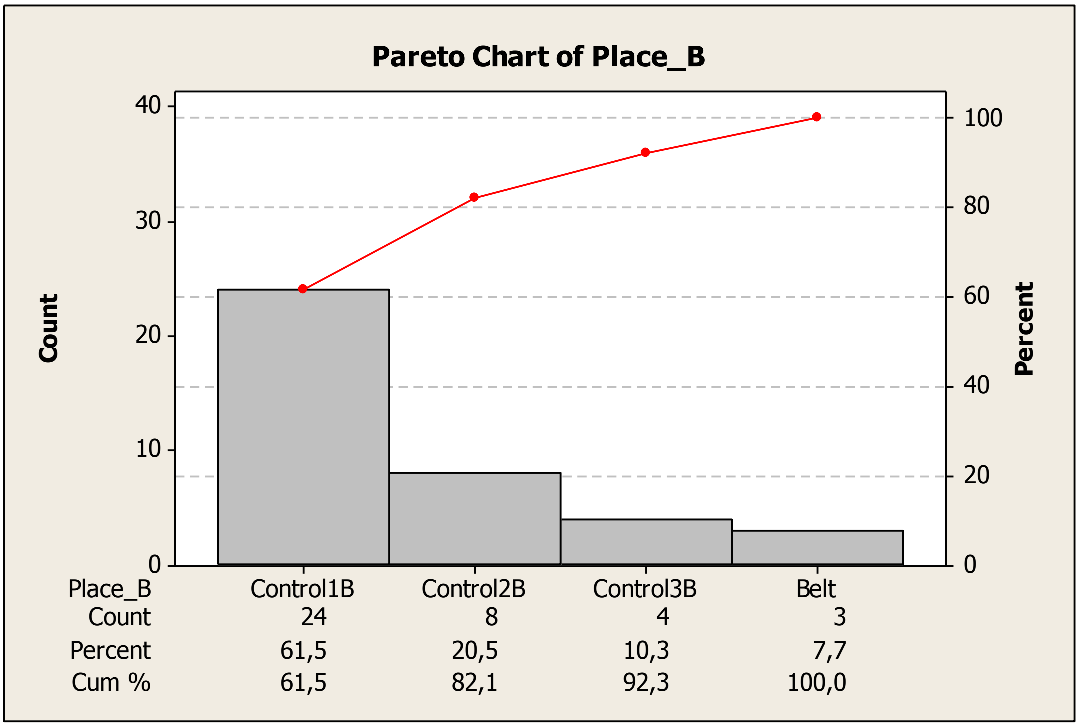
ANNEX 4.2. Pareto chart within 2 days of samples in the Line B





Source: [Author]

ANNEX 4.3. Pareto Chart of rejected bottles depending on the control place of the line B.



Source: [Author]

ANNEX 5. Extraction Force charts and data

ANNEX 5.1. Extraction force basic statistics by Line

Descriptive Statistics: Extraction Force

Variable	Line	N	N*	Mean	SE Mean	StDev	Minimum	Q1
Extraction Force	A	128	0	31,281	0,361	4,089	24,000	28,000
	B	27	0	32,778	0,513	2,665	28,000	31,000
	C	174	0	25,655	0,330	4,359	15,000	23,000

Variable	Line	Median	Q3	Maximum
Extraction Force	A	30,000	33,000	44,000
	B	33,000	35,000	39,000
	C	25,000	28,000	41,000

ANNEX 5.2. Extraction Force basic statistics by Type of Cork

Descriptive Statistics: Extraction Force

Variable	Cork Type	N	N*	Mean	SE Mean	StDev	Minimum	Q1
Extraction Force	CORTO (37)	41	0	28,512	0,886	5,671	15,000	25,000
	LUNGO (43)	288	0	28,417	0,295	5,009	15,000	25,000

Variable	Cork Type	Median	Q3	Maximum
Extraction Force	CORTO (37)	29,000	30,500	41,000
	LUNGO (43)	28,000	32,000	44,000

ANNEX 5.3. Analysis-of-variance ANOVA of Extraction Force by Type of Cork

One-way ANOVA: Extraction Force versus Cork Type

Source	DF	SS	MS	F	P
Cork Type	1	0,3	0,3	0,01	0,911
Error	327	8486,2	26,0		
Total	328	8486,6			

S = 5,094   R-Sq = 0,00%   R-Sq(adj) = 0,00%

```
                                 Individual 95% CIs For Mean Based on
                                 Pooled StDev
Level        N    Mean  StDev  ---+---------+---------+---------+------
CORTO (37)   41  28,512  5,671  (-------------------*-------------------)
LUNGO (43)  288  28,417  5,009             (------*-------)
                               ---+---------+---------+---------+------
                               27,20     28,00     28,80     29,60

Pooled StDev = 5,094
```

Source: [Author]

ANNEX 6. Volume of Wine data

ANNEX 6.1. Volume of Wine basic statistics by Line

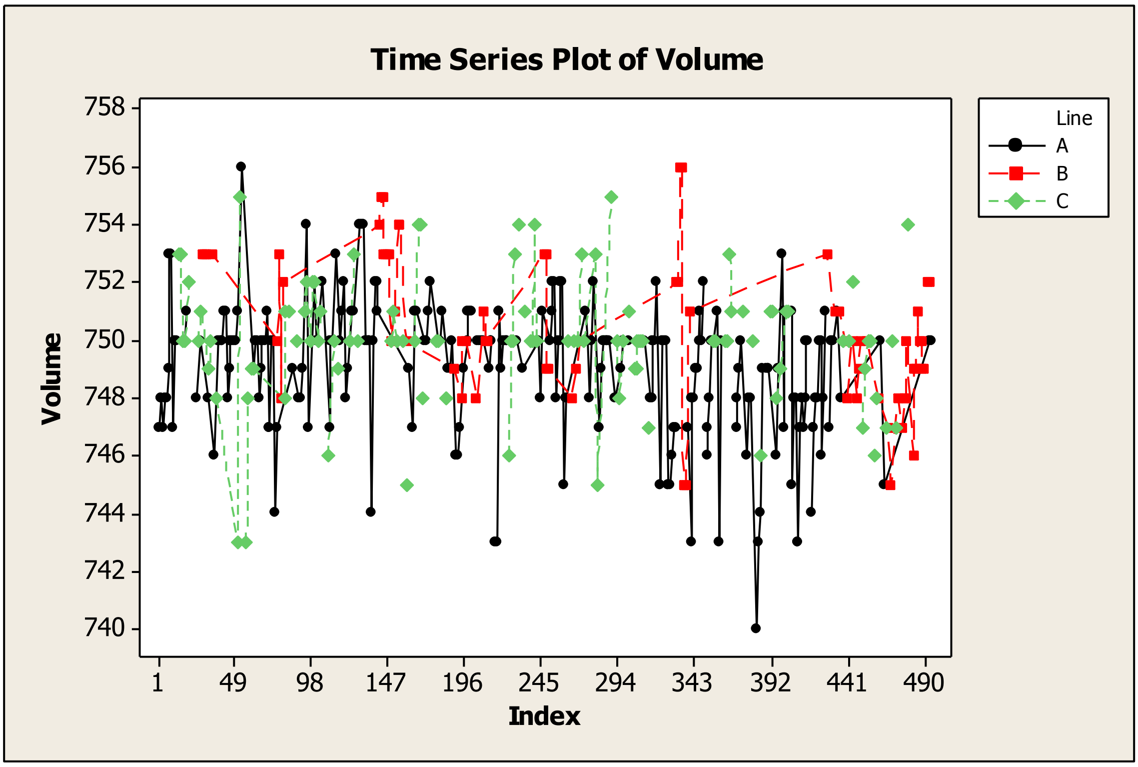
Descriptive Statistics: Volume

Variable	Line	N	N*	Mean	SE Mean	StDev	Minimum	Q1	Median
Volume	A	239	8	749,08	0,151	2,33	740,00	748,00	750,00
	B	72	2	750,39	0,306	2,59	745,00	749,00	750,00
	C	104	70	749,97	0,220	2,24	743,00	749,00	750,00

Variable	Line	Q3	Maximum
Volume	A	750,00	756,00
	B	753,00	756,00
	C	751,00	755,00

Source: [Author]

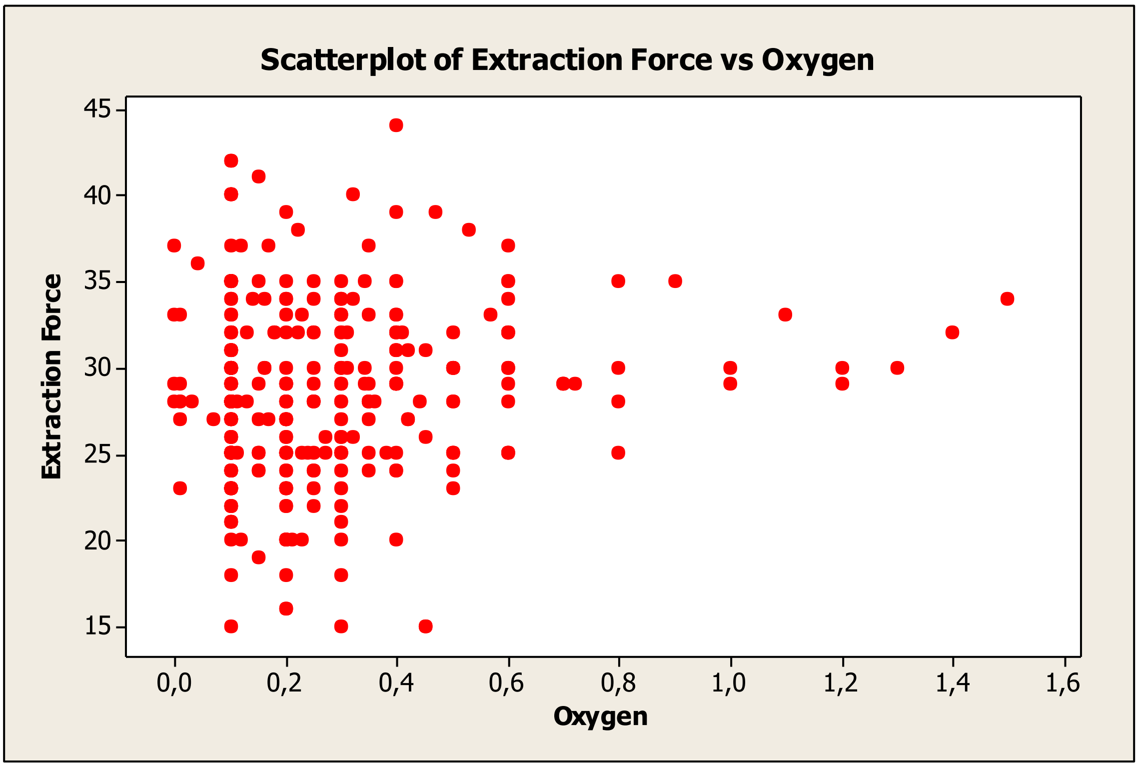
ANNEX 6.2. Time Series Plot of Volume of Wine by Line

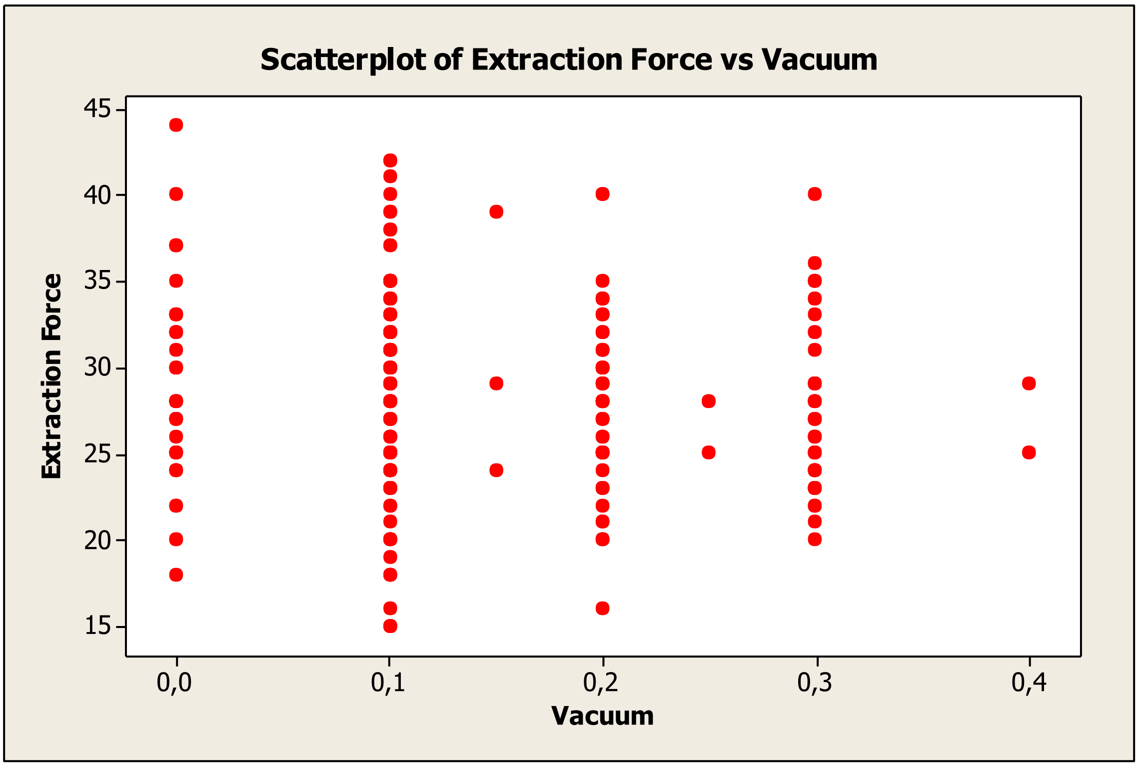


Source: [Author]

ANNEX 7. Analysis of Variables

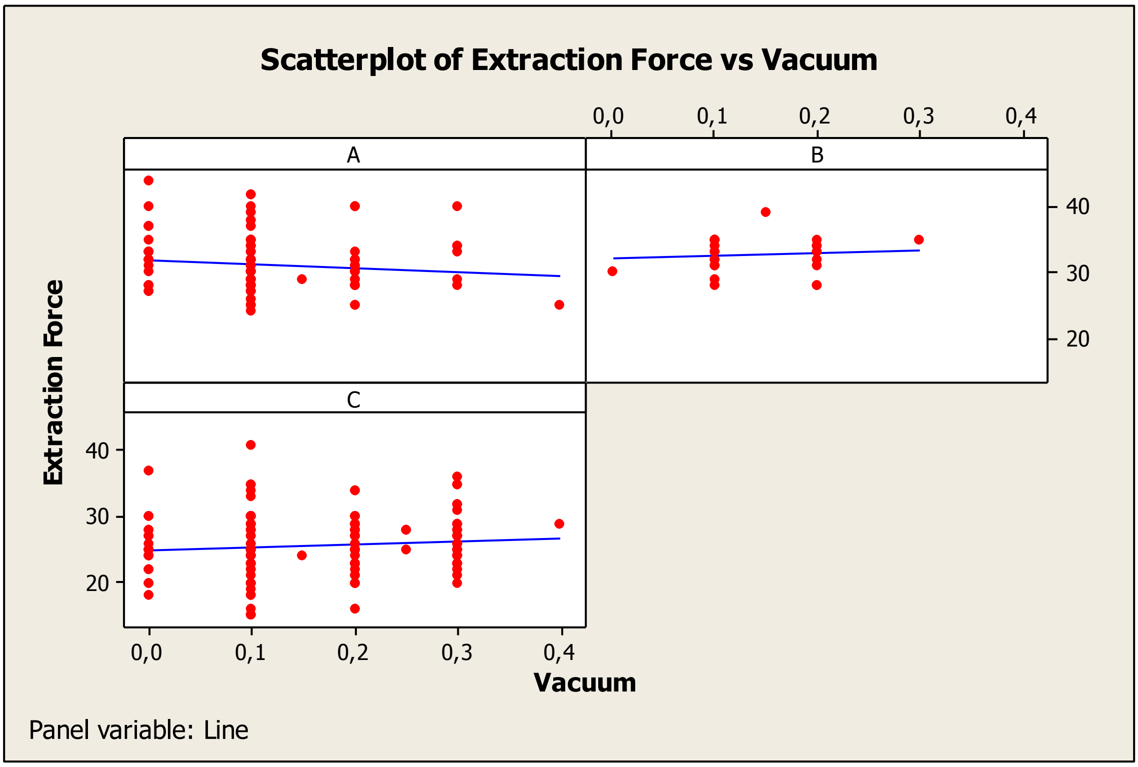
ANNEX 7.1. Scatterplot Extraction Force vs Oxygen and Vacuum

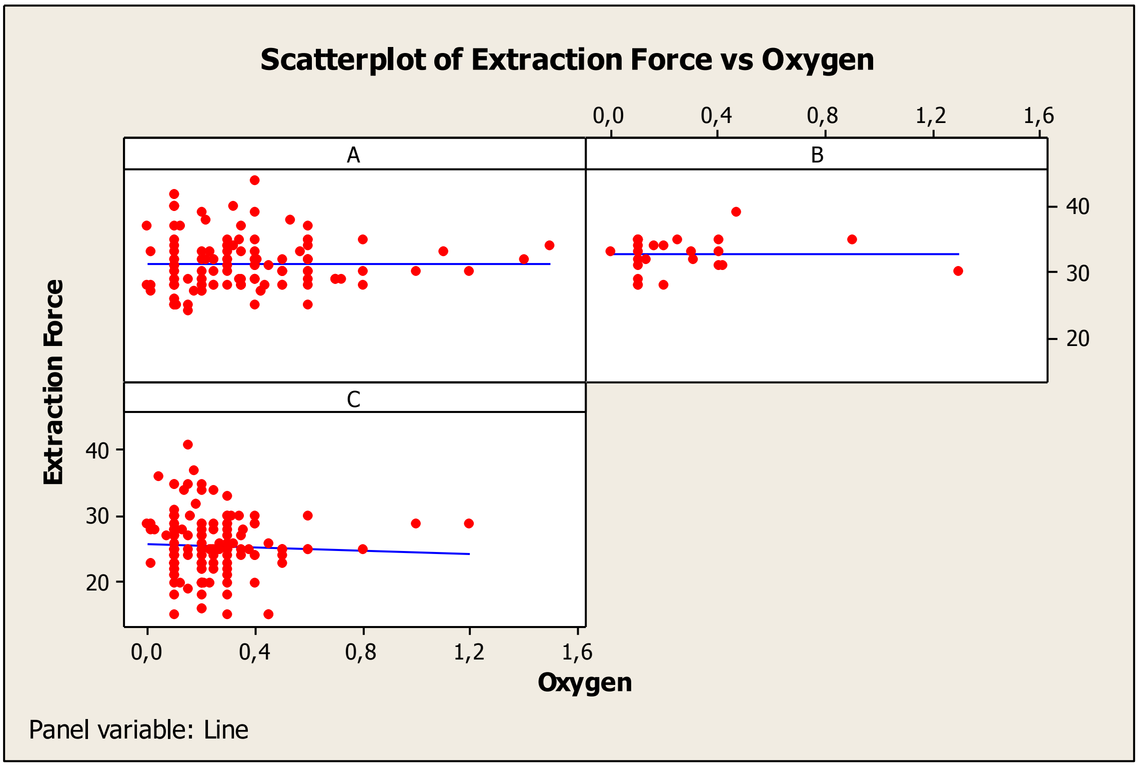




Source: [Author]

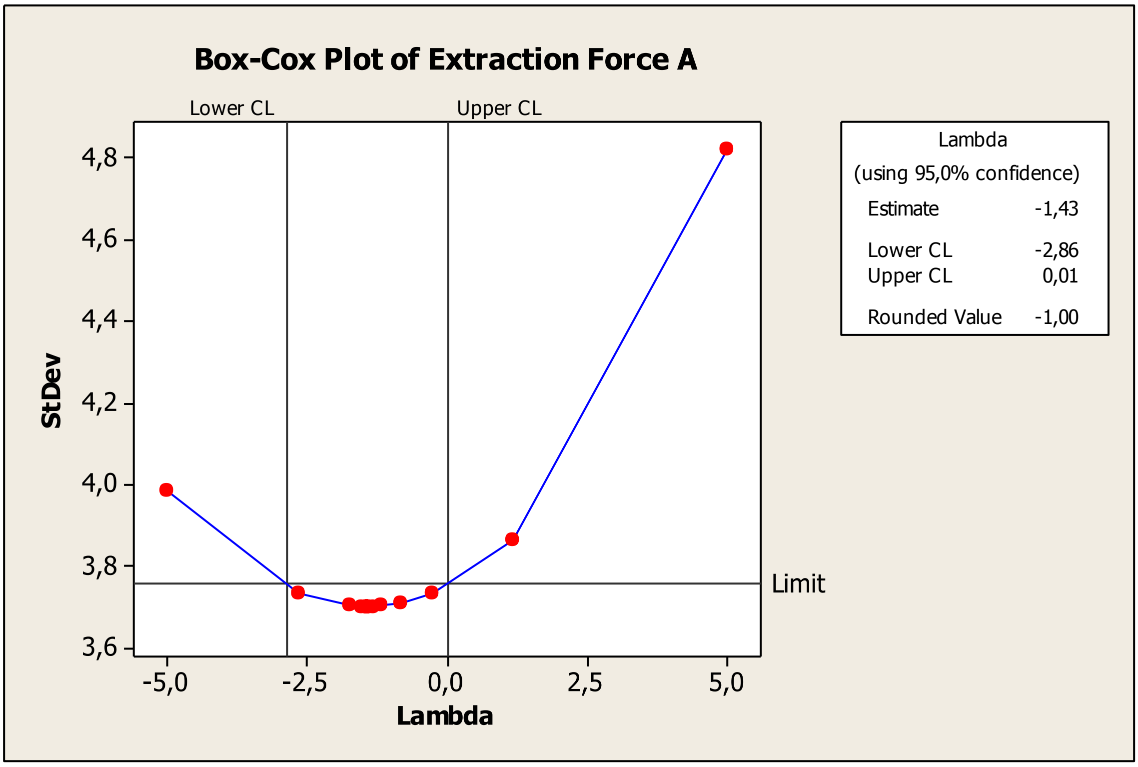
ANNEX 7.2. Scatterplot Extraction Force vs Oxygen or Vacuum by lines





Source: [Author]

ANNEX 7.3. Box-Cox transformation of Extaction Force A



Source: [Author]

ANNEX 8. Measurement of Defects

ANNEX 8.1. Collecting Table of Defects

Control/Controllo	Day/Giorno	Product/Prodotto	
	Defect/Difetto 1	Defect/Difetto 2	Other/Altro
Start time/Ora di inizio Total Bottles/Bottiglie			
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			

Source: [Author]

ANNEX 8.2. EXAMPLE Collecting Table of Defects (4hours)

Control/Controllo	Day/Giorno	Product/Prodotto	
Filling-Corking Machine	02/09/2014	MEZZACORONA CLASSICA EU CHARDONNAY	
LINE B		750 2013	
	Defect/Difetto 1	Defect/Difetto 2	Other/Altro
Start time/Ora di inizio Total Bottles/Bottiglie	Bad Filling	Without Cork	
7.35h 6226 **1**	1111	11111 11	
8.35h 12567 **2**	11111 1	11111	Position cork: 1
9.35h 18882 **3**	1111	11111 1	
10.35h 24751 **4**	111	1111	
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			

Source: [Author]

ANNEX 9. Control chart information

I-MR Chart of Extraction Force A by Month

Test Results for I Chart of Extraction Force A by Month

```
TEST 1. One point more than 3,00 standard deviations from center line.
Test Failed at points:  39

TEST 5. 2 out of 3 points more than 2 standard deviations from center line (on
     one side of CL).
Test Failed at points:  64

TEST 6. 4 out of 5 points more than 1 standard deviation from center line (on
     one side of CL).
Test Failed at points:  31
```

Test Results for MR Chart of Extraction Force A by Month

```
TEST 1. One point more than 3,00 standard deviations from center line.
Test Failed at points:  8; 39

* WARNING * If graph is updated with new data, the results above may no
          * longer be correct.
```

I-MR Chart of Extraction Force C by Month

Test Results for I Chart of Extraction Force C by Month

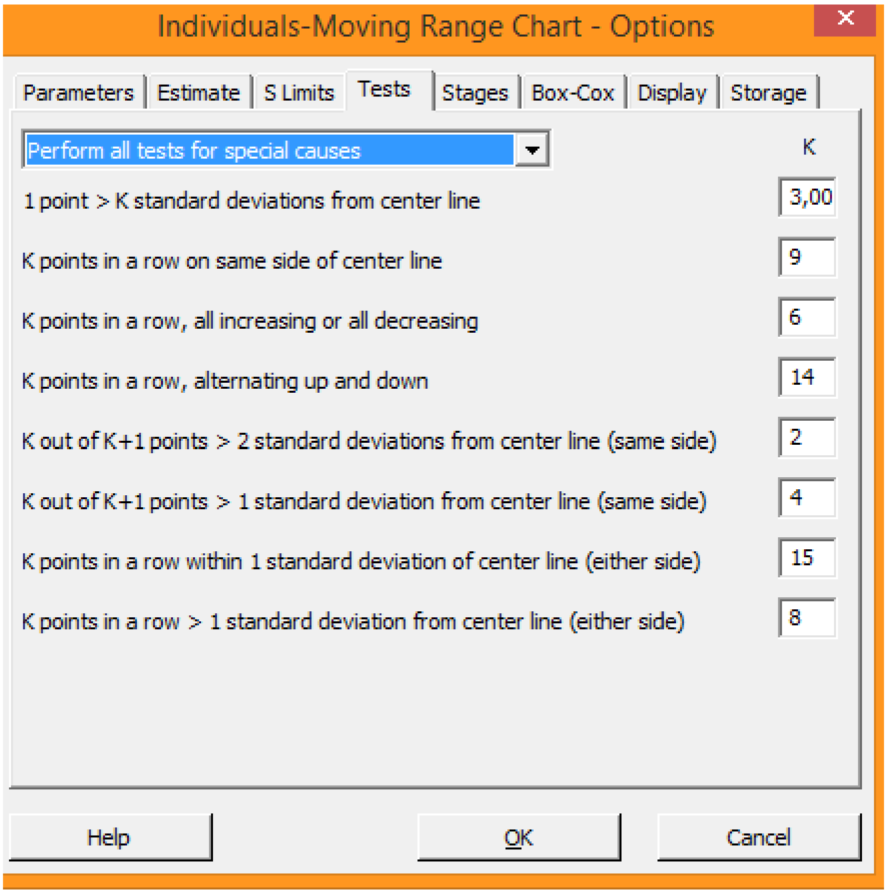
```
TEST 1. One point more than 3,00 standard deviations from center line.
Test Failed at points:  31; 97; 144; 150

TEST 2. 9 points in a row on same side of center line.
Test Failed at points:  82; 83; 84; 141; 142; 143; 167; 168; 169; 170; 171

TEST 5. 2 out of 3 points more than 2 standard deviations from center line (on
     one side of CL).
Test Failed at points:  17; 56; 57; 84; 97; 100; 101; 115; 152

TEST 6. 4 out of 5 points more than 1 standard deviation from center line (on
     one side of CL).
Test Failed at points:  57; 97; 102; 103; 151; 152; 153; 155
```

Test Results for MR Chart of Extraction Force C by Month

```
TEST 1. One point more than 3,00 standard deviations from center line.
Test Failed at points:  144
```

Source: [Author]

ANNEX 9.1 I-MR Alerts of special causes



Source: [MINITAB]

ANNEX 10. Questionnaire

General information about the methodology

1. Does the winery implement Lean manufacturing or Six Sigma procedures?

   a. Lean b. Six Sigma c. Both **d. None** e. Other

   1.1. Do the mangers have notions about Lean or Six Sigma?

   a. Yes b. No

   1.2. Do the operators have notions about Lean or Six Sigma?

   a. Yes b. No

2. Does the winery use some continual improvement techniques?

   a. Yes b. No

   2.1. Which one? **In the growing and wine making, taking samples and analyzing attributes values.**

   During the bottling process there are electronic devices to control without data register and some values are registered like the opening force of the cork, temperature, oxygen, vacuum, liquid, but all of these only in some taken samples.

3. Does the winery have some waste reduction plan in the processes?

   a. Yes b. No

   3.1 In which areas or processes? **All areas.**

4. Which of these waste do you consider there are in the winery? Sort them.

   a. Overproduction (1) b. Waiting

   c. Transportation routes **d. Overprocessing (3)**

   e. Inventory (1) **f. Operators Movement (2)**

   g. Defects **h. Underutilized people (2)**

5. Does the winery implement defect reduction strategy?

   a. Yes b. No Which one? **After every stage there is devices to check if the process what done correctly, but the company does not register number and information about the defects. Only register data from temperature of the wine and the opening force of the cork to check if it is between the specification limits.**

6. Does the winery implement variability reduction strategy?

   a. Yes **b. No** Which one?

7. Has the winery implemented some quality projects in the past?

   a. Yes b. No Which one? **Increasing of number of controls.**

8. What is approximately the demand (bottles) from all products per year?

   45.000.000 bottles (2.000.000 Sparkling wine)

9. Who are the customers?

   a. Shops **b. Supermarkets**

   c. Distributors **d. Wholesaler**

10. How is this demand curve?

    a. Regular b. Random **c. Seasonal (Christmas)**

    d. Unknown e. Other

    10.1. How is the predictable demand from each client?

    Similar

11. What is the batch size of bottles?

    40.000 bottles

12. How many kilos of grapes received every year?

    50.000.000 kg

13. What percentage is profitable of the grapes received?

    100%

14. Is this production adjusted to the forecast demand?

    a. Yes **b. No**

15. What does the winery do if the grapes produced are more than the required for the demand wine?

    a. Produce wine anyway b. Frozen the grapes c. Sell the grapes

    d. Other: _______

16. What is the quantity they received in once time? From the harvest?

    3.000 kg

17. How many months is the wine bottling?

    a. The whole year b. Some months : ___ c. Days: ______

<u>Communication, Involvement and employee's skills</u>

18. How is the communication?

    a. From top to down

    b. Some departments two-way communication

    c. Open, two-way with feedback

    d. Other: ___________

19. Is there a method to collect suggestion from the employees?

    a. Yes b. No

20. Does the employee suggest improvements for its workplace and job?

    a. Yes b. No Suggestions/month: **Every day**

21. Do the employees know about the managerial objectives of the company?

    a. Yes b. No

22. Do employees of the operation line know about the number of bottles needed to produce?

    a. Yes b. No

    7.1 Do they know about the takt time?

    a. Yes **b. No**

23. Are the employees encouraged with the objectives of the winery?

    a. Yes b. No

24. Do they know about improvement strategies of the process?

    a. Yes b. No

25. Do you consider the employees are ready for a change in the working way?

    a. Yes b. No

26. Is there communication and exchange of information between shifts?

    a. Yes b. No

27. Do the employees know about the preventive maintenance of their equipments?

    a. Yes b. No

28. Who is the responsible of the maintenance of the machinery?

    a. Employee user b. Maintenance people

    c. A maintenance service company d. Other:___________

<u>Jidoka, devides, standardization</u>

29. Do the operation line employees have the skills to fix a problem in the operation line at the same moment?

    a. Yes b. No

30. Do the equipment have some devices to detect when the bottle is in the process or when is not? Example: To not fill a place without bottle.

    a. Yes b. No

31. Do the bottling line machines have devices to detect abnormities during the same process?

    a. Yes b. No

31.1. Do these abnormalities arrive to the end of the line?

a. Yes **b. No**

32. Do the employees have the power to be able to stop the whole bottling line process? Example: Because it is putting the labels wrong, or it is filling less quantity.

a. Yes b. No

33. Is there a line stop system in the bottling line?

a. Yes b. No

34. Who has the responsibility for problem solving?

a. Individual manager **b. Manager teams**

c. Small employee teams d. All employees are asked

e. Others: ___________

35. Can the operators usually solve the problem, detect and refuse bottles when they realize about a bad bottle?

a. Yes b. No

36. Are the maintenance processes standardized?

a. Yes **b. No**

37. Are the operators activities standardized to not create differences in times, quality or efficiency between shifts and people?

a. Yes b. No

38. Are there visual devices implemented?

a. Displays in the machines configuration (Andon)

b. Boards of visual promotion of information (training, safety, quality,…)

c. Others: _____________

Voice of the Customer VOC, CTQ's

39. Does the winery received feedback from the customers?

a. Yes b. No

39.1. What is the way?

a. Telephonic **b. Personally**

c. Complaints depart. **d. Others: e-mail**

40. I have seen on the website some award-recognition of the products. Does the product have some attributes that the customer does not valuate or spending much time and cost for the customer recognition?

a. Yes b. No

40.1. Are the sales related with the number of award of the products?

a. Yes b. No

Maybe the customer is looking for another flavor different than the committee of the wine competitions.

41. Are these attributes that the customer appreciates more? Sort hem

a. Visual (Design Bottle, label, packing) b. Smell c. Color

d. Taste **e. Aromas**

f. Others: ______________________________________

42. What is the opinion about the products from the customers?

Very high quality/price

43. What is the customer opinion about the reliability of the products?

From 1 to 10 (top): **9**

44. What is the customer satisfaction?

a. < 80% b. 80-90% **c. 91-95%** d. 96-100%

45. Could you sort these purchase factors based on importance? 1st, 2nd, ... by Company's Opinion

a. Delivery on time (1) **b. % of the order completed (2)**

c. Price (1) **d. Time of especial deliveries (2)**

e. Relationship (3) **f. Development of new product (3)**

g. Brand image (4) **h. Products discounts (4)**

i. Proximity with the client (4) j. Others: _________________

46. Could you sort these purchase factors based on importance? 1st, 2nd, ... by Customer's Opinion

a. Delivery on time (1) **b. % of the order completed (3)**

c. Price (1) **d. Time of especial deliveries (3)**

e. Relationship (2) f. Development of new product

g. Brand image **h. Products discounts (2)**

i. Proximity with the client (3) j. Others: _________________

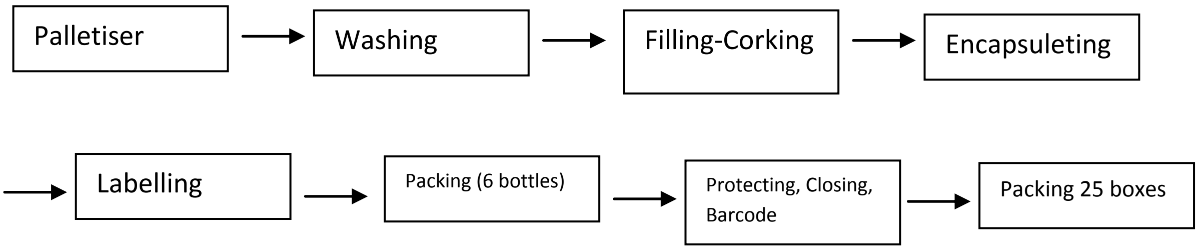
46.1. Are there some factors to measure the last factors?

a. Yes b. No Which one? **Sales reports**

<u>Bottling Process</u>

47. How is the bottling line processes?

Product/ type of wine:



48. Is there a continuous flow inside the bottling?

    a. Yes b. No

49. Is there continuous flow with the input and output (after the previous stage, with the distributor or client)?

    a. Yes **b. No**

50. Is filtering done just before comes into the bottling line?

    a. There is a previous storage stage

    b. It is the filtering include in the bottling line process.

    c. It is between the tanks and the bottling process

51. What is the bottleneck in the process?

    a. Washing b. Filling c. Corking d. Labelling

    e. Encapsulating f. Other: __**Depends on the configuration**_________

52. Does the bottling line have "buffers" inside the production line?

    a. Yes b. No

<u>SPC (Statistical Process Control) from the harvest to the bottle (Quality Control)</u>

53. Does the winery implement SPC for controlling the processes?

    a. Yes **b. No** Where? **In the growing stage and wine-making production and in some steps of the bottling line, they control if the variables are inside the specification limits without a SPC. After the bottling, they control a sample everything in the laboratory with the same methodology.**

54. What percentage of the processes is with SPC?

    a. 0-10% b. 11-30% c. 31-70% d. 71- 90% e. 91-100%

55. Does the company have recordkeeping data of the processes?

    a. Collecting and Harvest b. Fermenting c. Bottling

    d. Clarifying **e. Others: All**

56. What is the information that they keep in the Bottling process?

    a. Values of variables b. Efficiency, performance, machinery

    c. Number of defect from each one d. Takt time

e. Speed machinery **f. Bottleneck process**

g. Other: __________

57. Does the company register time about the bottling process?

a. Cycle times b. Changeover times

c. Operators times d. Breakdowns times

e. Takt time **f. Others: Not registration times**

58. Do they take samples to control the final quality of the products?

a. Yes b. No

59. Do they take samples to control of the intermediate quality of the products?

a. Yes b. No **(Opening force of the cork and temperature of the wine)**

60. How is the procedure of the samples taking?

a. One sample each time

b. Two or more following samples each time

c. Two or more not following samples each time

d. Other: Temperature (1), Opening cork force (12 in one type of cap because there are 12 machines and one from each corker in the other two lines), at the end of the process (1) checking everything.

61. How is the samples time procedure?

a. Always at the same time **b. Every specific time** c. Random time d. Other _______________

62. What are the quality controls of the wine?

Temperature and cork

62.1. Before Bottling? **All the process of the grape and wine**

62.2. After Bottling line? **One bottle every hour at the end of the packing machine.**

63. Are the inspections carried out at the source of the problem?

a. Yes b. No

64. What are the specific limits of the attributes/levels of the final bottle regarding the winery processes?

a. Liquid volume (3mm)

b. Label Position

c. Alcohol percentage

d. Liquid leaks e. Others:__________

65. Does the company works with descriptive statistics (mean, standard deviation, data distribution)?

a. Yes **b. No**

66. How is their procedure when the samples of a batch are not achieving the specifications?

a. Check every bottle b. Reject the bottles

c. Check some random bottles more d. Other: _______________

67. Which topic do you consider are important in the process to control them?

a. Losses of wine during processes

b. Changeover times (runup, rundown, set up)

c. Breakdowns

d. Productivity of the operators

e. Efficiency of the machinery

f. Others: ________

Defects, Six Sigma

68. What are the common defects/mistakes in the bottling production line?

a. Broken bottles **b. Placement of the labels**

c. Quantity of liquid filled d. Bad cleaning of the bottles

e. Bad fitting of the cork f. Operator's mistakes

g. Others: __________ **c and e; operators reprocess the bottle.**

69. Does the company use the Pareto chart defects?

a. Yes **b. No**

70. What is the defect rate in the bottling process line?

a. +10% b. 5-9%

c. 1-4% d. 0.622-1%

e. 0.0233-0.621% (4sigma) f. 0.00034-0.0233% (5sigma)

g. 6Sigma or more

71. Do you compare and take advantage from past data?

a. Yes b. No

71.1. What kind of comparison is useful for them?

a. Benefits b. Performance machinery

c. Performance's operator d. Number of rejected bottles/lots

e. Quantity of defects f. Others: ___________

72. Are they planning improvements in the wine-making?

a. Yes b. No **New software for the production**

Stock, Materials

73. Do they have stock of bottles, corks, input materials?

    a. Yes b. No

74. How is the replacement of these materials?

    a. Always the same quantity

    b. Depending on the necessary units (from the production plan based on forecast)

    c. When there is no material

    d. When the operator consider it necessary

    e. Other: _________

75. Values of these stocks and quantity replace it? (It is necessary to plan how much has to be produced to avoid inventories in process and overproduction (important waste))

    a. Expected bottles produced per period + stock security

    b. All the quantity possible in the inventories

    c. Unknown number

    d. Other: :__________

76. Are the raw material delivered directly at the point of use?

    a. Yes **b. No**

Suppliers

77. How many materials are suppliers of the winery for the bottling process of raw material?

    a. Corks b. Bottles c. Capsules

    d. Chemicals (sulfur, nitrogen) e. Adhesive tapes f. Boxes

    g. All

78. How is the winery demand to these suppliers?

    a. By security stock point b. Every time (month, 60 days, other)

    c. Other : ________

79. When does the company decide to bottle the wine?

    a. Under customer's order b. Predictable demand

    c. When the wine is ready to bottle d. Other: _________________

80. Do they produce stock of wine in tanks or other place before send to the bottling?

    a. Yes b. No

Stock, Final product, JIT

81. Is the winery producing the wine and moving to the last bottling when they receive the order?

    a. Yes **b. No**

82. Does this wine stored in tanks have a maximum time to be there?

    a. Yes b. No What time? **From 2 months to 5 months if the tank is full.**

83. Is the production of a finished bottle stored in the winery waiting for the customer's order?

    a. **Yes** b. No

84. Does the final bottle deteriorate the quality if it is stored?

    a. Yes **b. No**

    84.1. How much time is a maximum for the storage?

    a. 1 Year b. Other: **More than one year, a lot of time.**

85. Do they sell under FIFO order?

    a. Yes b. No

86. What percentage of the good deliveries is on time?

    a. 0-50% b. 51-70% c. 71-90% **d. 91-100%**

87. In the sparkling wine with fermentation in bottle, is the first bottling step produced in the same bottling production line as the final bottling where the bottle is corked?

    a. Yes **b. No**

<u>OEE, Efficiency</u>

88. How much time is the equipment actually used? (loading time)

    - **2/3 (66.6%) bottling line in use.**

89. How much of this equipment time is value added?

    They do not know. They know that approximately the bottling process from bottle to packing is 30 minutes.

90. What are the parameters to calculate the output performance?

    a. Bottles/h b. OEE c. Other: __________

91. What is the OEE of the bottling line machines?

    a. <65% b. 66-75% c. 76%-85%

    d. >85% **e. Other: They do not work under efficiency parameters.**

92. Where are the most common breakdowns in the bottling line?

    a. Washing b. Filling c. Corking d. Labeling

    e. Encapsulating **f. Other: Palletiser before the washing**

93. What are the causes of the breakdowns?

    a. Operator do not follow the manual operations

    b. Improper maintenance

    c. Electrical connections

    d. Overrunning machine’s capability

    e. Problems between belt and machine alignment

    f. Ignoring warning signal

    g. **Untrained workers (not all)** h. Others:_____________

94. And the causes for stoppages?

    When there are many problems.

95. Is the machinery working at the designed speed?

    a. Yes **b. No, lower (buffer inventory)** c. No, higher

    d. Other:

<u>5S</u>

96. Do the employees or company review unnecessary items or potentially removal items? Sort

    a. Yes **b. No**

97. Do the tools have a designed localization?

    a. Yes **b. No**

98. Do the same workers clean their workstations as a routine and continuously?

    a. Yes b. No, cleaning service c. No, not regularly d. Other

99. Are in all procedures habitual the continuous 3S first?

    a. Yes **b. No, not all** c. No

100. Are the processes standardized and reviewed?

    a. Yes **b. No** c. Not reviewed often

<u>VSM</u>

101. What is the lead time from the beginning (grapes to final bottle)?

    Depending the model, from 2 months to 6 years.

102. What is the lead time in the bottling line?

    Aprox. 30 min

103. What are the cycle times of the machines? (If it is possible to take data)

    They do not check times.

104. What is the number of operators in the bottling line?

    7

105. How many shifts are during a day?

2

105.1. How many hours the shifts?

6:00-13:20-20:40 **Continuous.**

Sequence

106. How much number of different wines are they bottling in the bottling line?

More than 400 models

107. Is the bottling line process sequencing the different types of wine in the production plan when they have different wines ready to bottle?

a. Yes b. No

Changeovers, Standardization

108. How much time does the equipment require to set up and change the configuration to bottle another type of wine?

a. t<1min b. t<10min **c. t>10min**

Time: 1h

109. Do the employees follow a structured order for each changeover between products?

a. Yes b. No

110. Are the movements of the employees optimized? (Reducing Movement waste)

a. Yes b. No

111. Does the operator have a performance schedule for the repeatedly activities?

a. Yes **b. No**

112. Is the winery standardizing the procedures of the employees in the bottling line to reduce waste of time?

a. Yes **b. No**

113. Can the employees work in other job place to replace the absent of someone?

a. Yes b. No **c. Some of them**

114. Do they use universal tooling and systems for faster changeover?

a. Main areas have standard tooling

b. All areas have standard tooling and systems are standard

c. No

115. Are the bottling line structures as a manufacturing cell?

a. Yes **b. No**