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FACULTY OF BUSINESS ECONOMICS
Master of Management

Master's thesis

Business Process Improvement through operational excellence methods
and techniques (Lean Manufacturing and Six Sigma)

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*Thesis presented in fulfillment of the requirements for the degree of Master of
Management*

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Master of Management: Management Information Systems

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Summary

This topic of the thesis is Business Process Improvement through operational excellence methods and techniques (Lean Manufacturing and Six Sigma). The core idea of this thesis is to show how business processes can be improved through different methods and strategies in order to achieve and sustain business performance and customer satisfaction by delivering speed and quality closed to perfection.

This master paper emphasizes a real life case of business process improvement methods and techniques, and consequently shows which ones suit the best with the given case. However conducting this research led me to new perspectives. The purpose of this research is to investigate how business processes can be improved through Lean Manufacturing and Six Sigma or a combination of these two methods and techniques. Focusing on Lean Philosophy which claims that a company can do more with less, the present investigation implies a filed case study bring into the forefront of the research the reducing of waste through New Edge Technology. Based on the theoretical aspect of Business Process Improvement methodology through Lean Six Sigma, the present study highlights how tools and methods of Lean and Six Sigma can be improved in order to reduce waste. The conclusions show how a business process can be improved by using the effective application of excellence operational technology.

This paper sheds light on the use of Business Process Improvement strategies mainly focused on the Lean and Six Sigma methods which I find suitable in building a case study within specific area. With the use of these strategies and methods it could be achieved partially, the target of the company reducing its manufacturing lead time production by over one third. Moreover, the focus of this thesis is to demonstrate how the combination of Lean Six Sigma can be used to improve the business processes. The master thesis is divided into four chapters in which different aspects of the topic are investigated. This summary provides an overview of the content of the thesis. The main research question addressed by the present paper is: *How to improve the business processes through using Lean Manufacturing, Six Sigma or a combination of these two methods and techniques?*

Chapter 1 provides an overview and the context of my research topic. Furthermore this chapter emphasizes the importance and methodologies adopted by BPI concept within the competitive business environment. It also underlines some theoretical aspects related to the competitive aspects of an organization on the market taking into discussion the production of high quality goods or services at lower costs satisfying in the same time the customer requirements. Within this chapter I show how I came up with the main research question and sub questions and the structure of the research methodology.

Chapter 2 provides the theoretical framework of how business can be competitive and successful using the philosophy of Lean and Six Sigma, taking into consideration the different authors and scholars. The Business Process Improvement methodology is based on the Lean concepts that go

hand in hand with Six Sigma which help business processes within many organizations to enhance excellence operational results reducing waste in such a way to maintain the quality, reduce lead time production and simplify business processes. Moreover, this chapter highlights the differences, but also the usefulness of these methods and techniques by using them together in order to simplify and improve the business processes.

Chapter 3 is dedicated to the case study. This chapter comprises the empirical research. More specifically it is dedicated to the analysis of the SABCA Limburg case study within aerospace industry. Focusing on Lean Philosophy which claims that a company can do more with less, the present investigation implies a case study that brings the reducing of waste into the forefront of the research through New Edge Technology.

Chapter 4 is meant to provide an overall conclusion and improvements. Likewise some recommendations are formulated for possible future research.

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CHAPTER 1

1.1. Introduction

Nowadays competitive business environment and technological advancements has challenged companies within many industries to come up with innovative strategies and process improvements (Antony, 2006). In order to remain competitive most companies have to reduce waste and increase quality through improving their business processes. By implementing such innovative strategies, companies ensure a speed up of their business processes, bringing their services or products more quickly on the market as well as a guarantee customer satisfaction maintaining simultaneously their market share (Antony, 2006). These innovative strategies are changing and evolving in such a way to make great strides in efficiency and effectiveness. Thus it can be said that not only competition fosters companies to find out innovative strategies, but also the pressure of customer's demands of having high quality products and services as well as the market pricing level which stimulates companies to reduce their costs (Antony, 2006).

The intention of this research is to focus on a set of methods and techniques which can support the implementation of Business Process Improvement (BPI) concept within different industries. During the last couple of years to better satisfy customers, the BPI has demonstrated to be one of the most efficient approaches to increase performance by improving efficiency of processes in production and services as well as by reducing time and costs (Cherry, 2012). As a consequence, the concept of BPI has been introduced and developed as a useful strategy. Moreover, it could be said that the core idea of BPI concept is to improve processes in order to achieve and sustain business performance, to convey employees and customer satisfaction as well as to increase the profits (Maleyeff, 2006). To this extent during the years both practitioners and academics highlighted several BPI techniques and methods, i.e. Continuous Process Improvement, Business Process Re-engineering, Business Process Benchmarking, Lean Manufacturing, Six Sigma, Agile Management, Design of Experiments, and Process Excellence as they are considered by Mark Gershon in his paper "Choosing Which Process Improvement Methodology to Implement" (2010).

For the last two decades, BPI concept has been widely practiced and developed in many industries including manufacturing, healthcare, industrial and financial sector and so forth (Hammer and Goding, 2001; Hoerl, 2004). In this way, the authors refers to BPI concept as an improvement methodology, adopted for improving a business process to achieve the goals through reducing time and cost as well as achieving customer satisfaction. Moreover, in the last couple of years, the concept of BPI has received greater attention and has been characterized by both scholars and researchers. For example, the concept of BPI was firstly defined by James Harrington (1991) as "a systematic methodology approach developed to help an organization make significant advances in the way its

business processes operate (pp. 20-21). Moreover, according to Harrington (1991) the BPI refers to making business more effective and efficient to meet customer requirements in products and services. And thus, as Griesberger et al. (2011) claim the effectiveness of BPI can be achieved by changing the state of elements of a business process. Consequently, in this context, the effectiveness relies on how the current business process achieves its goals; making the process more efficient means to minimize the resources involved within process such as raw materials, cycle time, costs from internal process operation.

Regarding to process operation three keys of BPI strategies have been identified from the literature. According to Lee and Chuah (2001) these aspects of BPI strategy have been adopted: Continuous Process Improvement, Business Process Re-engineering and Business Process Benchmarking. These three keys of BPI have different impact and effects within companies. According to Devenport and Short (1990), through Continuous Process Improvement the companies develop an aggressive approach to mitigate costs and lead-time in order to achieve the needs of the customers. Moreover, an important aspect within many industries is process innovation which often is seen as an alternative of Continuous Improvement approach. Further, the Business Process Reengineering is described by Hammer and Champy (1993) as "fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in critical contemporary measures of business performance such as cost, quality, services and speed" (as cited in Browne and O'Sullivan, 1995, p. 132). The last strategy of BPI is Process Benchmarking which means "the comparison of different levels of each process with others, especially with the competitors or the best practices in the same industry to determine performance gaps and improvements goals" (Garfamy, 2005). In other words, using these approaches of improving business processes enables companies to stay competitive, by increasing customer responsiveness, employee productivity and company's profitability (Page, 2010). To sum up, it could be said that BPI is one of the most efficient approaches used to increase efficiency, productivity and performance as well as to improve profitability, production and time mitigating in the same time the costs.

This thesis tries to shed light on the use of another BPI methods as well as their implementation in different industries. The role of BPI within companies has changed throughout history from the invention of machines and their improvements that had the role of speeding the production up to the use of empirically and statistically based methods to analyze and reduce variation in business (O'Rourke, 2005). The most of the BPI methods and techniques have been developed during the Manufacturing Era.

Throughout this research, the BPI methodologies are reviewed being mainly focused on the following concepts: The Lean Manufacturing concept and Six Sigma. The most BPI methods and techniques have been developed during the Manufacturing Era. In this perspective, Womack et al. (1990) claim that the methods of Lean Manufacturing are mainly directed toward the elimination of any kind of waste within the production processes. The Lean concept was mainly developed in order to replace the approach of old mass production. This new strategy focuses on changes on different

levels from the raw materials to production and customer satisfaction by adding value to the products, reducing the lead ó time costs and inventories (Marchwinski and Shook, 2004). According to Treville and Antonakis (2006) the Lean Manufacturing method pays attention to ÷whole process life cycle of production from raw material and production process to customer serviceö (pp.99-123). Nowadays many companies have been successfully adapted this concept of Lean manufacturing in their business processes.

In addition to Lean principles and practices most companies use also Six Sigma methods and tools in order to maximize quality, close to perfection (Pyzdek and Keller, 2010). To sum up, it could be said that Six Sigma methods are primarily concentrated on the process quality, while Lean methods put accent on time responsiveness. In this context, many studies show that companies which successfully implemented these techniques of Lean and Six Sigma have usually chosen a mix between them, namely Lean and Six Sigma (LSS) (Shere, 2003). Moreover, Shere defines LSS tools and methods as ÷an approach that synthesizes the use of established tools and methodsö (2003, p.9). In other words it can be affirmed that implementation of such techniques in many organizations are driven by the compatibility among these two methods. Thus, one could say that the results are achieved when both methods of Lean and Six Sigma are simultaneously combined. Furthermore, LSS can be seen as integrated method where Lean Manufacturing and Six Sigma strategies are coming together in order ÷to improve the quality of business processes through elimination of any non-value adding activities or wastesö (Meza and Jeong, 2013, p.402).

1.2. Research questions and sub-questions

The objective of this thesis research is to highlight how Lean Manufacturing and Six Sigma techniques can improve the business processes in order to increase performance levels at acceptable costs, profitability and high quality. Moreover, the paper aims to describe how these methods and techniques can be applied into the fieldwork within a specified industryø sector. By using a case study the present study takes into discussion the process improvement focusing on strategy related to the reduction of waste and production time. In the final part of this thesis is presented a set of conclusions and recommendations regarding BPI through LSS.

Hence, the research question addressed by the present paper is: *How to improve the business processes through using Lean Manufacturing, Six Sigma or a combination of the two methods and techniques?*

In order to answer to this research question, it is very useful to come up with the following sub questions:

1. What is exactly a business process?
2. What are Lean Manufacturing principles, tools and methods?
3. What are Six Sigma concept and principles as well as tools and methods?
4. What are the main differences between Lean Manufacturing and Six Sigma and how can they complement each other into LSS?

5. How can LSS be used by an industrial organization in order to achieve positive results of BPI?

1.3. Research methodology

This part of paper provides information on how the research is conducted emphasizing also the methods used to collect data in order to answer to the research questions.

This thesis employs different sources and documents, such as academics books, articles, scientific papers by accessing Universities' scientific databases and Google scholar. Moreover, Hasselt University provides a scientific database included EBooks, scholarly journals and articles. A very important source about Lean frame Manufacturing and Six Sigma were three books: 'The machine that change the world' (Womack et al, 1990), 'Lean thinking' (Womack et al, 1996) and 'The Lean Six Sigma Black Belt Handbook: Tools and methods for Process Acceleration' (Voehl et al., 2013). A set of documents and fieldwork research is employed for the investigation of a case study related to the research topic.

The methods engaged throughout this thesis makes reference to qualitative and quantitative research. According to Gray (2004) the qualitative method is a very contextual approach which can answer to questions like how and why. Citing from Snape and Spencer (2003) the qualitative research is defined throughout this thesis as:

[1] a situated activity that locates the observer in the world. It consists of a set of interpretive, material practices that makes the world visible [1] at this level qualitative research involves an interpretive, naturalistic approach to the world. This means that qualitative researchers study things in their natural settings, attempting to make sense of, or to interpret, phenomena in terms of the meanings people bring to them (pp.2-3).

In contrast the quantitative research is focused on primary and secondary data. In the research under discussion, this method makes reference to the company's data, such as: documents, statistical and fieldwork measurements. All these measurements are realized for a numerical and statistical point of view (British Library Business and IP Centre, 2015). For instance, this method can be easily used by a researcher to find out how many of the clients support planned changes for diverse products and services. Moreover, using a scale it can be measured how strongly the clients support the respective changes. Quantitative research can gather a large amount of data that can be easily organized and manipulated into reports for analysis. The definition of quantitative method engaged throughout this thesis is defined by Creswell (1994) as

an inquiry process [1] based on testing a theory composed of variables, measured with numbers, and analyzed with statistical procedures, in order to determine whether the predictive generalizations of the theory hold true (p.3).

All these research are situated within the particular context of the case study under discussion. The empirical part of the thesis aims to develop a case study based on the data collect from a Belgian company from the aircraft industry sector. The case study's definition used in this paper takes into consideration Yin (2003) description of a case study, as being:

[1] empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident [1]. It also copes with the technically distinctive situation in which there will be many more variables of interest than data points, and as one result relies on multiple courses of evidence, with data needing to converge in a triangulating fashion, and as another result benefits from the prior development of theoretical proposition to guide data collection and analysis (pp. 13-14).

Thus, the quantitative research is built on data provided by the company, and the qualitative research is based on the field work observation and knowledge obtained directly from the workplace. This allows the present paper to gain insight in the problem under investigation; in order to better describe and portray the process and the methods that have been chosen in order to improve the business processes.

I would like to mention the position I hold within the company as a worker employed under the economic concept of learning by doing allows me to observe and gather precise data which will contribute in building my empirical study. Moreover, as a direct observer I will describe and interpret what phenomena are occurring when applying BPI methods in the field under investigation.

1.4. Research outline

The thesis is divided into four chapters, as follows:

Chapter 1 provides an overview and the context of my research topic. Furthermore this chapter emphasizes the importance and methodologies adopted by BPI concept within the competitive business environment. It also underlines some theoretical aspects related to the competitive aspects of an organization on the market taking into discussion the production of high quality goods or services at lower costs satisfying in the same time the customer requirements. Within this chapter I show how I came up with the main research question and sub questions and the structure of the research methodology.

Chapter 2 provides the theoretical framework of how business can be competitive and successful using the philosophy of Lean and Six Sigma, taking into consideration the different authors and scholars. The Business Process Improvement methodology is based on the Lean concepts that go hand in hand with Six Sigma which help business processes within many organizations to enhance excellence operational results reducing waste in such a way to maintain the quality, reduce lead time production and simplify business processes. Moreover, this chapter highlights the differences, but also the usefulness of these methods and techniques by using them together in order to simplify and improve the business processes.

Chapter 3 is dedicated to the case study. This chapter comprises the empirical research. More specifically it is dedicated to the analysis of the SABCA Limburg case study within aerospace industry. Focusing on Lean Philosophy which claims that a company can do more with less, the present investigation implies a case study that brings the reducing of waste into the forefront of the research through New Edge Technology.

Chapter 4 is meant to provide an overall conclusion and improvements. Likewise some recommendations are formulated for possible future research.

CHAPTER 2

2.1. Introduction

Within the present-day of economic world the market is characterized by a competitive environment, in which any business is looking forward to produce services and products by adding new value, but at the same time to satisfy customer requirements keeping very low costs and high quality level (Voehl et al., 2013). According to many scholars, such as Oakland and Tanner (2007), Voehl et al. (2013) and so forth the answer could be provided by the management system of Lean Manufacturing and Six Sigma. It could be said that the implementation of Lean and Six Sigma methodologies is permanently concerned with the continuous improvement of business flow, reduction and waste elimination as much as possible. Further, starting from the concept of BPI the paper explains techniques and tools related to Lean and Six Sigma concepts. Moreover, it is underlined the relationship between the principles of reducing waste in such a way to maintain the quality and the improvement of business processes. Usually waste is due to the operational processes within organization. Furthermore, eliminating waste is a continuous practice without an end point (Emiliani, 1998).

Before going into the theoretical discussion of lean topic itself, I would like to define waste. According to Ohno (1988) waste is defined as anything other than the minimum amount of equipment, material, parts and working time which is absolutely essential to add value to the product (as cited in Upadhye, Deshmukh and Garg, 2010, p.126). Authors like: Bicheno (2004) and Slack et al. (2007) stress that mitigation of waste is used by the companies in order to add value for the consumers. On the other hand, some authors like Ohno (1988) and Monden (1998) argue that mitigation of waste is used to reduce the costs. Likewise, George (2003) points out that waste represents anything that is not valuable for customers, for which is spent time, money and work (as cited in Rexhepi and Shrestha, 2011, p.3).

In this context, Voehl et al. (2013) states that any organizational activity can be classified into two types: value - added activities (VA) and non-value added activities (NVA) which can be also necessary, but they do not add value to activities. George (2003) defines VA as those activities that add value from customers perspective, for which they are willing to pay (as cited in Rexhepi and Shrestha, 2011, p.3). Thus, as Kollberg et al. (2006) point out all these VA activities can be named only by customers, but in the same time as Maleyeff (2006) argues these activities cannot be performed by customers themselves and moreover there is necessary to spend time and money (as cited in Rexhepi and Shrestha, 2011, p.3). Voehl et al. (2013) define NVA as activities that do not contribute to meeting external customers requirements and could be eliminated without degrading the product or service function or the business (p.102). This category of NVA can be interpreted as a necessary waste such as inspecting parts, checking the accuracy of reports, reworking a unit, rewriting a report (p.102).

According to Japanese philosophy of work, waste is divided in three main categories - Japanese

words, as followed:

- Mura or waste owed to the variation - Mura means irregularity; lack of uniformity; non-uniformity (Kenkyusha's New Japanese - English dictionary);
- Muri or waste owed to the overburdening or stressing related to people, equipment or system;
- Muda also known as the seven forms of waste.

Moreover, Taiichi Ohno (1988) classifies waste into seven major categories: overproduction, waiting, over processing, inventory, transportation, movement and defects product (as cited in Gao and Low, 2014, p.32).

1. *Overproduction* - this means making more of a product required by the next process or the end of the customer. This waste means to engage more materials without an order leading to a risk of more than is necessary to produce for customers.
2. *Waiting* - this is described as idle time occurred when information, parts, materials or people and equipment are not ready when it is required.
3. *Over processing* - this is described as any effort that adds non value to the product or service from the customer's view.
4. *Inventory* - this means to hold or purchase unnecessary materials or excess work within process. Too much inventory is not just an additional cost, but also guarantees that the processing is less organized.
5. *Transportation* - this is any activity that requires transporting parts and materials around facility.
6. *Movement* - this is occurred when there is any move of people or information that does not add value to the product.
7. *Defects product* - this means producing defective product that is scrapped or require re work which takes too much time.



Figure 2. 1 - The seven types of waste (Melton, 2005)

Later, scholars as Alukal and Manos (2006) and Voehl et al. (2013) added to these seven types of waste two more types of waste, taking into consideration the utilization of employees' capabilities. These wastes are related to employees' behavior as a result of human interactions and flows from

individual and collective belief systems: gossip, self-imposed barriers, deceptions and ego are a few of the many examples of personal waste (Voehl et al., 2013). This waste is also known as underutilized employees. It occurs when an organization does not recognize the people mental, creative, innovative and physical skills or abilities. It could be said that this type of wastes covers aspects such as: ignorance of innovative ideas developed by the people on the floor or responsibilities restriction of employees to take decisions (Voehl et al., 2013).

1. *Behavior* is any waste that result, from human interactions. It is present to some extent in all organizations. Behavior waste naturally flows from an individual's inherent beliefs. The concept of waste has not yet been effectively extended to the self-defeating behaviors of individuals and groups of people in the workplace (M.L. Emiliani (1998, pp. 615-631).
2. *Underutilized employees*: This is occurs when we fail to recognize and harness people's mental, creative, innovative, and physical skills or abilities (Voehl et al., 2013).

2.2. What is a business process?

A business process is a group of tasks or activities, such as planning and production that accomplishes a specific organizational goal. Davenport (1993) defines business process as "a specific ordering of work activities across time and place, with a beginning and clearly identified inputs and outputs: a structure for action". Moreover, Davenport states that a business process is composed by different, ordered activities (each business process has a start and an end, as well as specific inputs and outputs).



Figure 2.2 - Business Process
(adapted from Chesbrough and Rosenbloom, 2002, p.536)

Input represents what is put into a process or consumed in its operation to achieve a result or an output. Example of input can be material, man, machine or management. The output is the final product of the process, which is produced by the execution of a set of activities and it is destined to a specific customer.

VALUE - ADDED

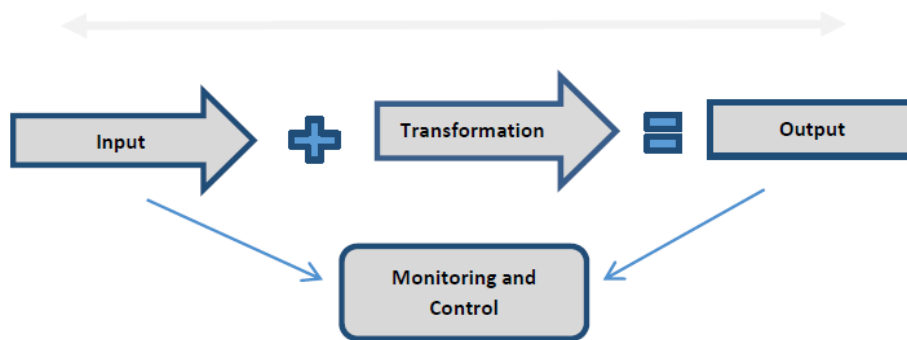


Figure 2.3 - Transformation process model (adapted from The Open University/ Leadership and Management courses)

In the figure above (fig.2.3) is presented an operation as a transformation process model which is characterized by a simple mechanism between the start and end of a product of the process, through which the input is transformed by adding value in such a way to obtain the required outcome. In other words it can be said that the process model described above sheds light to the flow of tasks during the process of production.

In 1997, Harrington, Esseling and van Nimwegen describe a business process as "a logical, related, sequential (connected) set of activities that takes an input from a supplier, adds value to it and produces an output to a customer" (p.18). In this context, Mentor (2010) describes a business process as a set of activities capable to create and add value to customers. Basically, this means that a series of events bring together people, technology and information in a way that create valuable outputs. However, a business process is not an accurate one. Thus, the improvement of the process is required in order to add value to the existing process as well as keeping up its standard. Even if this improvement of the process is used by the majority of business organizations, the reason behind its usefulness depends on the specificity of activities. Finally, all these actions are directed towards minimizing inefficiencies, while maximizing customer satisfaction and competitive advantage in the market. Therefore, there is a constant need towards improving a business process. It is the managers' responsibility to ensure that processes are waste free (Davis, 2009).

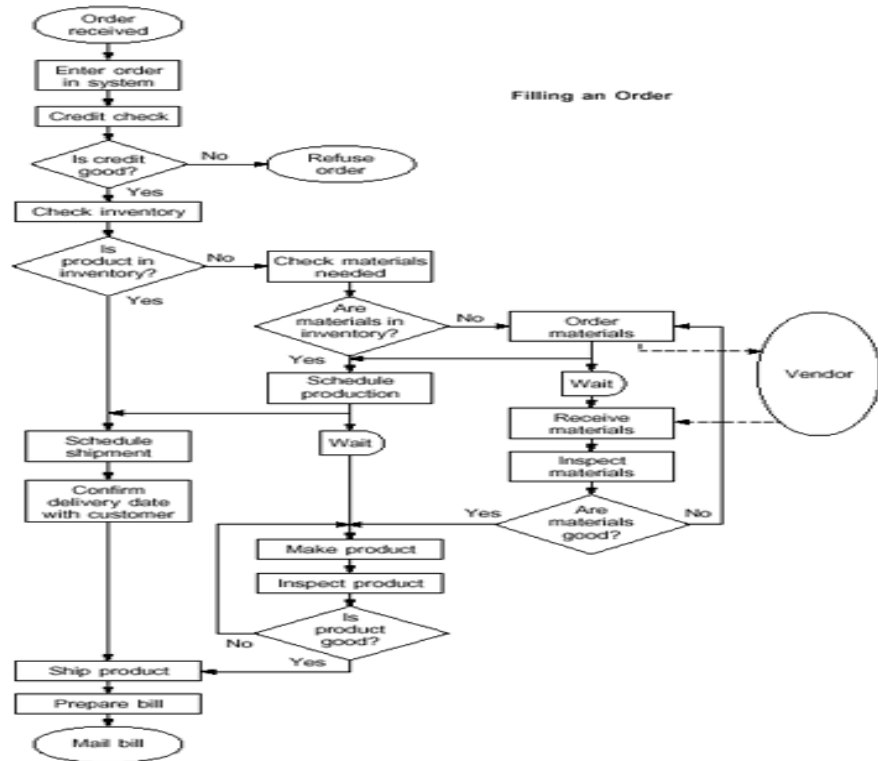


Figure 2.4 - An example of a process flow using a process flow chart (Tague, 2004, pp. 255–257)

To make it more clear, the figure 2.4 describes a business process flow that can eventually be improved. This process comprises several activities having various roles, which combined lead to a desired outcome. These activities can be switched, changed, eliminated or even added new ones in order to have a more efficient and fast flow. There are many factors that have an impact on the process flow. The activities are different depending by their type. There are: rectangles (representing tasks), arrows (representing flows), gateways (representing the decision taking in process) and circles (representing messages). This figure intends to make the transition to my case study which likewise tackles process flows (Tague, 2004).

2.3. Business Process Improvement

The concept of Business Process Improvement (BPI) has gained more attention these days. This can be due to the modern context of business environment in which competition plays an important role (Page, 2010). In addition, the increased emphasize on the quality of the products led to the re-evaluation of goals, procedures and structures of many businesses. According to Voehl et al. (2013) the reason for achieving these new challenges drives the businesses to develop a new approach of management defined as process improvement. In this context, it can be said that BPI can help industries to become more competitive on market demonstrating greater customer effectiveness and increasing employee productivity. In this context, improving business processes enables organizations to stay competitive on (Page, 2010). To sum up, it could be said that BPI is one of the most efficient approaches used to increase efficiency, productivity and performance, but also to improve profitability and time process.

As I already underlined in the first chapter in the first chapter the concept of BPI was firstly defined by James Harrington (1991) as "a systematic methodology approach developed to help an organization make significant advances in the way its business processes operate". BPI can be achieved by changing the state of elements of a business process (Griesberger et al., 2011). Overall, process improvement applies prevention methodologies to implement and improve business processes in order to achieve the process management objectives of effectiveness, efficiency and adaptability.

2.4. Lean Manufacturing

Lean manufacturing is one of the most popular advanced operational management which is based on a combination of advanced techniques of operational management (Schonberger, 2007). Lean manufacturing proposes the reduction of costs by creating a more efficient business; a business receptive to market requirements. This approach sets out to reduce all actions that do not add value to the production process, such as blocking of stock, repairing faulty products and needless movement of people and products around the business (Voehl et al., 2013).

In other words, it can be said that Lean Manufacturing could be seen as a philosophy of production, in which the main challenge is to reduce time between customer's requirements and process of production by eliminating waste.

In the following sub-chapters are described the principles, concepts, tools and methods of Lean. Before going deeply in the theoretical aspects of lean manufacturing, I would like to stress a brief history of the concept.

2.4.1. A brief history of Lean Manufacturing

Henry Ford, the founder of Ford Motor Company was one of the first people who took into discussions the ideas behind Lean Manufacturing. He used the term of "continuous flow" to create a model of assembly line production that simplified the process of car manufacturing from individual production to mass production (Hobbs, 2004). This resulted in minimizing waste such as time, resources, and space wasted in assembling cars in individual production.

Even if, other manufacturers began to use Ford's ideas, they quickly realized that the inflexibility of the system itself represented a problem. Meanwhile, in Japan, the Toyota Company was founded at a time when American automobile companies such as Ford and General Motors dominated the automobile field. Moreover, during and after the World War II a disturbance in the Toyota's production has been arisen. There was a post war hardship: stock of unsold cars was greater than before. Lean is based on Toyota Production System (TPS), the most tools and techniques being developed within Toyota Motor Company (Ohno, 1988).

According to Toyota Motor Company, TPS system is based on two concepts: automation with human touch, namely Jidoka in Japanese language and Just in Time (JIT) concept. Jidoka means that when a problem occurs, the machine or process stop immediately, preventing defective products from being produced (Toyota, 2010). The next concept, JIT means that every process produces only what is

needed by the next process in a continuous flow (Toyota, 2010).

The Japanese specialist Ohno, the manager of Toyota Motors Company claims that Toyota Production System (TPS) can be easily described as a process of analyzing and looking at the time line, from the moment the customer place the order to the point when the cash is collected. The time line has to be reduced by removing the non-value-adding waste (Ohno, 1988). It could be said that at the heart of TPS is the idea of eliminating waste or *muda*. According to the Toyota philosophy *muda* does not add value to the product from the client's perspective.

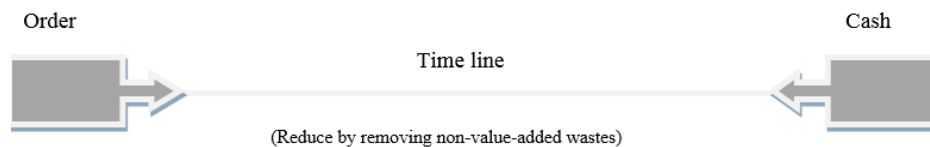


Figure 2.5 -Time line of Toyota Production System (Ohno, 1988)

Figure 2.5 emphasizes the time line of TPS according to Ohno (1988). This consists in a set of activities based on demand. The TPS fulfils customer demand efficiently and promptly by linking production activities to real time market demand. To this extend Toyota embraces JIT concept. Taiichi Ohno (1988) explains the goal of TPS as simply to shrink the timeline from order to cash by removing non-value added waste, *muda* (p.9) . Moreover, Womack and Jones (1996) claim that Toyota used this process successfully and, as a result, emerged as one the most profitable manufacturing companies in the world. This method sets out to reduce all actions that do not add value to the production process, such as blocking of stock, repairing faulty product and needless movement of people and product around the enterprise (Voehl et al., 2013).

2.4.2. Definition of Lean

The Lean concept comprises a set of measures like: mitigating the waste, stability of processes, constant improvement processes and coping with change. Furthermore, there are several techniques and methods which used accordingly can enhance the personnel resources efficiency. Consequently, all these methods and techniques help companies become Lean.

The term *Lean* is defined by Womack et al (1996) as a system that uses less in respect of all inputs to create the same outputs as those created by traditional system, while contributing increased varieties for the end customer (as cited in Chahal ,Sharma, Chauhan, 2013, p.698). Voehl et al. (2013) argues that Lean is an operational philosophy with a focus on identifying and eliminating all waste within an organization. The methodology is applied to production, service application and support. Lean focuses on eliminating waste from processes and increasing process speed by focusing on what customers consider quality, and backwards from that. Thus, Lean can be seen as a manufacturing philosophy which is based on the principles of reducing the time between the customer

order manufacturing and the delivery of the requested product by eliminating losses (Todorut and Cirnu, 2011, pp.153-155). Moreover, it could be said that Lean focuses on the strategy to produce products as it is needed or as it customers demanded it.

Some specialists as Voehl, Harrington, Charron, and Melton have a particular interpretation of Lean arguing that Lean is a phenomenon of production that seeks to maximize the effectiveness of labor number one resources of the company: people. Hence, Lean is a way of thinking, of adapting to changes, of eliminating losses and continuous improvement (N ft n il , 2010). There are many tools and techniques which, used together, maximize the efficiency of human resource and with which a company may appear as Lean (N ft n il , 2010). Lean strategy looks as a culture in which all employees continuously look for ways to improve business processes (Todorut and Cirnu, 2011).

To be more focused it can be said that Lean focuses on delivering high quality products at acceptable price and proper time, eliminating in the same time waste or non-value added (NVA) activities (Womack and Jones, 1996). These activities represent ðworkø activities that do not add value to the customers and for which they are not willing to pay; therefore, should be eliminatedð (George, 2003, p. 28). Additionally, these activities exist because of the current structure of the system within organizations, and they are considered wasteful (Maleyeff, 2006).

Adopting lean significantly reduced lead time that allows practicing make-to-order production with on time delivery of production, although when make-to-stock approach is applied. One of the most important benefits of reducing lead time is helping organizations in lowering inventories through the supply chain (TQM Magazine, 2005).

2.4.3. Lean Manufacturing principles

Lean manufacturing is underpinned by 5 principles: *Value, Value Stream, Flow, Pull and Perfection*.

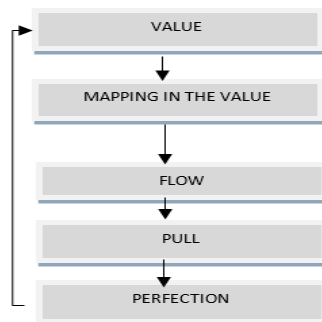


Figure 2.6 - Lean Manufacturing principles (Mertins, Heisig and Vorbeck, 2001)

According to Womack and Jones (1996):

- *Value* is defined as a ðcapability provided to customer at the exact time and at a right price, as established in each case by the customer. Value is critical starting for lean thinking, and can only be defined by the ultimate end customerð (p.16).
- *Value stream mapping* is defined as the set of all the ðspecific activities required to design,

order, and provide a specific product, from concept to launch, order raw delivery, and raw materials into the hands of the customer (p.19). In value stream is described what happens with a product in every step of its production. The value stream contains everything that goes into creating an effective product or service for which customer is willing to pay.

- *Flow* is defined as “capability provided to customer at the exact time and at a right price, as established in each case by the customer. Value is critical starting for lean thinking, and can only be defined by the ultimate end customer” (p.21).
- *Pull Systems* means that “no one upstream should produce a good or service until the customer downstream asks for it” (p.67).
- *Perfection* is defined as “organizations begin to accurately specify value, identify the entire value stream, make the value-creating steps for specific product flow continually, and let customers pull value from the enterprise, something very odd begins to happen [] suddenly perfection [] doesn’t seem like a crazy idea” (p.25).

In this context, Westwood et al. (2007) bring into discussion the example of healthcare system in which Lean principles are applied in order to show the steps followed by an organization.

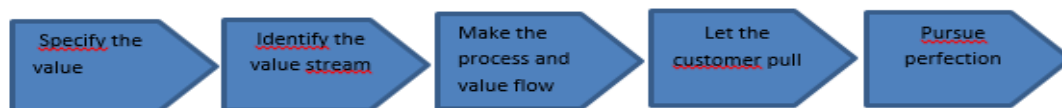


Figure 2.7- Lean manufacturing principles adapted for healthcare (Westwood et al., 2007, p. 4)

Likewise, figure 2.7 shows those five principles of Lean adapted for healthcare industry. As it can be seen the second principle - *Value stream mapping* (VSM) - is the most important one. It is oriented towards identification of the process that creates value for customer and which can be achieved through the value stream in manufacturing and patient journey in healthcare.

2.4.4. Tools and methods in Lean Manufacturing

Lean has a very extensive collection of tools and methods. These are essential components of Lean transformation process. The main Lean Production tools and methods are: 5S Workplace Organization and Standardization, Single-Minute Exchange of Die (SMED) Just - in -Time (JIT), Kanban Pull System, Value Stream Mapping (VSM), Kaizen (Continuous Improvement) and, Visual Management, Cellular Manufacturing.

The tools described in this chapter, are the ones considered to be the most essential in explaining Lean concept. Moreover, some of these tools are applied in the case study under discussion. Some of the methods and techniques mentioned above are assessed and highlighted using the practical data collected for the SABCA Limburg case.

Further on, some methods and tools of Lean used throughout this research are described below in order to have a better understanding of them, but also for a better analysis of the case study under discussion.

I. Workplace Organization and Standardization (5S)

This is a method which comes from TPS and it used to organize basic activities such as the workplace ordered, cleaned and safe and standardize materials, machinery, manpower used in value-adding activities reducing process difficultness. 5S is a list of five Japanese words: Seiri, Seiton, Seiso, Seiketsu and Shitsuke (Voehl et al., 2013).

The concept of 5S was described by Hiroyuki Hirano and Melanie Rubin (1996) as following:

Japanese terms	English terms	How does it helps?
Seiri	Sort	Wasting time looking for a tool – Purpose: Eliminating waste that result from a poorly organized work area
Seiton	Set in order	Having all the necessary things in the workplace, the workers having quick access to any materials and tools, in this way the workers become more productive
Seiso	Shine	The workplace has to be cleaned and inspected maintain a high performance in work environment
Seiketsu	Standardization	Maintaining and applying new standards of the above mentioned to ensure that every task is performed in the best practice
Shitsuke	Sustain	Regularly applying and maintaining the standards

Table 2.1 - The 5S Method (adapted from Hirano and Rubin, 1996)

According to Voehl et al. (2013) the purpose of 5S is òto arrive at a safe, neat, orderly workplace where everything required to perform for your customers is readily accessible by your employees. Implementing 5S result in a common sense work area with an organized sequence of activities required in your value - added processö. In other words, 5S is an important tool which supports the behavior of each step optimizing the processes within the organization, sustaining a workplace through disciplines and making work easier and safe by eliminating waste.

II. Single-Minute Exchange of Die (SMED)

The main goal of SMED is to mitigate the output and quality losses because of the changeovers. Quick changeover is a technique which has as the main scope to reduce the resources needed for equipment

setup including exchange of tools and dies (Voehl et al., 2013). It could be said that SMED is a method focused on reducing changeover times (Marchwinski and Shook, 2004). According to Bicheno and Holweg (2009) argue that change overtime is the time it takes between the last manufactured parts in the first series till the first part approved part in the second series.

III. Just-in-Time (JIT)

JIT is an organizational philosophy and it is based on the idea that production activity must be designed and calculated with high precision so that inventories are minimized (Stan and M r scu - Klein, 2012). The definition of JIT can be found in many scholarly studies. For example, Bozarth and Handfield (2008) define JIT as: "a philosophy of manufacturing based on planned elimination of all waste and on continuous improvement of productivity." It could be said that daily schedule could be realized and the production sequence plan is operated from a JIT perspective. As a consequence, excessive or insufficient production capacity could be avoided and also the waste of production resources or loss of orders could be eliminated.

The goal of JIT is to strength the production efficiency and performance. JIT is a philosophy that is used [] to describe the just-in-time delivery of all services or materials to the next process in VA process. The objective of JIT is to make sure that we minimize the amount of materials that we have in our possession at any point in time (Voehl et al., 2013). It can be said citing Ryan Grabosky (1993) that JIT is concerned with having "the right material, at the right time, at the right place, and in the exact amount."

IV. Kanban Pull System: the system that pulls the production

The traditional production system is characterized by products that are pushed to production levels and which are determined by planning and forecasting often inaccurate. These levels often exceed demand, resulting in unnecessary quantities of stocks getting finished.

Kanban means "signal" and it is one of the most famous tools of Lean Manufacturing. According to Ohno (1988) Kanban "is the heart of the pull system and it was the operating method of the Toyota System. Kanban in fact is a tool to achieve JIT production establishing flow in a process." Furthermore, Kanban is a tool which consists in obtaining materials or required products "just in time" for their use within the process. In simple words, this tool is a continuous supply system components of the workstations, so that the workers to have what they need, where and when they need. Kanban's method is simple: the storage of unused inventory is a waste of resources. Organizations must follow new methods to manage the change. The ideas of working come from many different disciplines including statistics, industrial engineering, production management, and behavioral science (Schonberger, 1982).

According to Voehl et al. (2013) the purpose of using Kanban in the production process is "to regulate the flow of information and materials between employees by connecting sequential value added process steps. Kanban systems allow you to define the exact quantities of products that are

required to meet your customer demand. The benefit of this system is that you produce only what the customer requested, therefore eliminating any tendency for overproduction, one of the nine wastes. That is to say the pull of the product during the production process comes from customer demand.

A Kanban control system contains a signaling device to regulate the flow. When the production system has an inventory, it uses a card which acts as a signal to indicate what amount is required. Kanban consists in using cards to control the material along the process. A Kanban card comprises product name, requesting department, quantity required, and photos and could be printed, written or in an electronic way that contains barcode and other electronic technology.

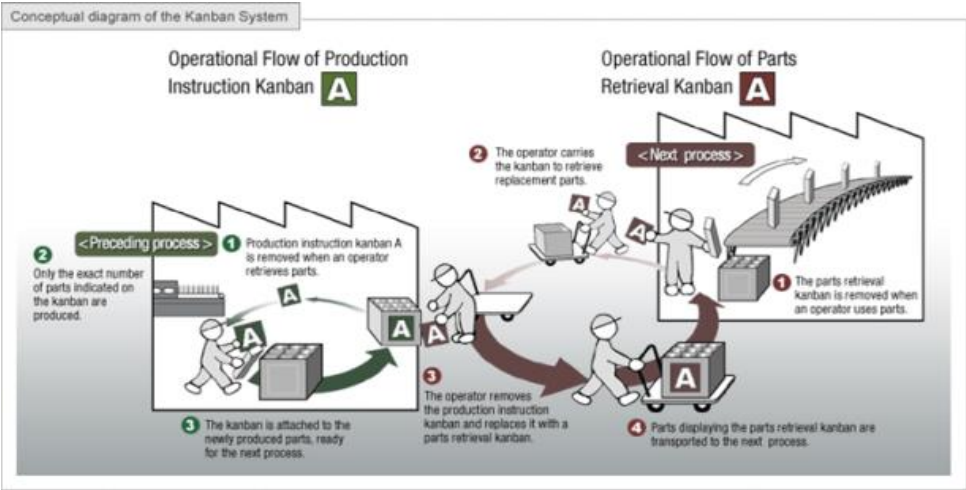


Figure 2.8 - Conceptual diagram of Kanban Production System at Toyota (<http://www.toyota-global.com>)

Production Instruction Kanban	Parts Retrieval Kanban
Step1. Production Instruction Kanban is removed when an operator retrieves the parts	Step1. The parts retrieval Kanban is removed when the operator used the parts
Step2. Only the exact number of parts indicated on the Kanban are produced	Step2. The operator carries the Kanban to retrieve replacement parts
Step.3 The Kanban is attached only to the newly produced parts, ready for the new process	Step.3 The operator removes the production instruction Kanban and replaces it with parts retrieval Kanban
	Step.4 Parts replaying the parts retrieval Kanban are transporting to the next process

Table 2.2 - Production Instruction Kanban and Parts retrieval Kanban (<http://www.toyota-global.com>)

The figure and the table above show how Kanban method works in assembling process at Toyota. As it is indicated in figure 2.8 and table 2.2 there are two types of Kanban, which are used for managing parts at Toyota: Production Instruction Kanban and Parts retrieval Kanban. Moreover, it can be said that Kanban has an overwhelming role used to establish a 'continuous improvement' aiming to reduce inventory through applying the concept of JIT (Voehl et al., 2013).

In order to better understand Kanban Pull System method I use a helpful example. Suppose an organization produces a product from one material called Y, at the initial point of production there is

on bin of Y at the floor, one bin of Y at the inventory department of the factory where the production staff obtains raw materials and one bin of Y at the supplier who has been selected to deliver the materials. Each bin of Y has card holding information about the material, this card is called Kanban card. During the process, the factory uses the materials and once the floor is empty a flag of demand is raised (trigger), the empty bin is returned to the inventory department with its card. The inventory department replaced the empty bin with a full bin obtained from the supplier. In turn, the inventory department sends the empty bin to the supplier for replenishment of materials. The supplier provides the inventory with the desired material with the exact description on the card. Again this process will be repeated with the exact amount needed each time to reduce the inventory cost. The number of Kanban cards depends upon the actual number of the items required during each stage of the process. The control during the assembly is achieved by identifying every Kanban card needed to complete the assembly or production.

V. Kaizen

Kaizen is a philosophy of management that focuses both on process and results. According to Masaaki Imai (1986) who introduced the Kaizen concept all over the world with his well-known book *Kaizen: The Key to Japan's Competitive Success*, Kaizen is ðan umbrella conceptö for the majority of Japanese organizations. Kai means ðchangeö, while Zen means ðfor the betterö. Another translation would be ðchangeö plus ðimproveö. Kaizen or continuous improvement is a method where employees work together to achieve regular improvements within the manufacturing process.

Core Principles	Management improvement concepts	Practical outcomes
Process orientation	Process control through process support and evaluation	Training the workforce in simple methods and use existing skills and experience Effort are emphasized and encouraged while results are rewarded
Small step improvement	Extensive use of standards (SOPs) as the base for improvement Separate the task of improving and the tasks of maintaining standards	Discipline required to maintain standards Focus on improving own work standards using common problem-solving format- PDCA
People orientation	Active management support and Involvement "mandatory volunteerism", i.e. management policy to join but contributions based on volunteerism	Board participation using permanent or temporary groups for problem solving in parallel structures (QCCs and teams) Individual suggestion systems for training and motivation

Table 2.3 - Kaizen Principles (Berger, 1997)

This method comprises a set of firmø particularities and talents the collective talents, which together contribute to the creation of a system that sustain waste elimination from manufacturing processes.

Applying Kaizen in Gemba (employees), significant improvements are made at acceptable cost within

production and business processes. According to Berger (1997), there are three principles of kaizen: process orientation, improving and maintaining standards, and people orientation. In simple words, Kaizen is improving environment through process improvement that is accomplished by standards and people involvement. Within the kaizen philosophy, the focus is therefore on communication, motivation and reward.

In my opinion, the most important differences between the classic style of management and kaizen philosophy lies in the solution's flow. In the case of classical management solutions come from top to bottom, for example from the manager to maid or security guard. In the case of kaizen philosophy the solution's flow is exactly opposite; the solutions come from the bottom to the top (from employees to manager). Thus, the role of employees is pivotal within the organization. The point is that each employee could find solutions to improve the labor process. In other words it can be said that kaizen concept does not only make the employees aware by their important role within the organization, but also makes them more accountable and disciplined in order to improve the labor process.

VI. Value Stream Mapping (VSM)

Womack and Jones (1996) argue that VSM is "the set of all the specific actions required to bring a specific product through the three critical management tasks of any business: [1] problem solving, information management, physical transformation". VSM is one of the most popular tools that help to minimize waste. It is used to analyze the flow of materials and information currently required to bring a product or service to a customer. Likewise, Kollberg et al. (2006) and Manos et al. (2006) defined VSM as a tool that helps to map all the actions in process by analyzing the flow in order to identify and reduce NVA. In other words it could be said that VSM aims to reduce or eliminate non-value added work, in order to achieve the lean manufacturing.

For example, at Toyota, where the technique originated, VSM is known as Material and Information Flow Mapping and it proved to be an effective tool because of its example of flow through operational or manufacturing cycle, identifying both those losses and value creating activities (Woehrle and Abou-Shady, 2010). This tool is used to understand the process flow within the whole organization. To develop a final product or service, information and material will be required. By understating this process flow in detail, it will help to identify the waste that occurs within the process. To get the best results and accurate value stream map, organizations should develop it by involving people who are responsible for those activities (Morrow and Main, 2008).

According to Fillingham (2007) VSM is an important tool, which involves frontline staff in the process of problem identification and coming up with solutions. For example, in a hospital, it involves mapping all activities by analyzing the whole process from the moment a patient checks in until end of treatment (Kollberg et al., 2006). Moreover, Fillingham (2007) stresses out that in trauma service in the case of Boston hospital, they created a team of doctors, nurses, therapists, managers and patients,

who were responsible to map a patient's journey in detail. By identifying the non-value-added activities and errors, they became aware of the poor service provided. It took nine months to make all improvements through different projects, by ensuring senior leadership support, standardizing the work, setting equipment and information in their place, reducing the length of patient's stay by 33% and reducing paperwork by 42% (Fillingham, 2007).

In figure 2.9 a briefly example of Wirral hospital is explained. It is a useful example to understand VSM in the hospital setting. Using VSM, the hospital was able to see that for 100 minutes of treatment, patients spend 610 minutes of their time and hospital spend 330 minutes of time. This case highlights the amount of waste produced within the hospital as a consequence of complex processes (Jones and Mitchell, 2006). Thus, in a hospital setting, value stream is helpful tool to streamline the processes that are NVA.

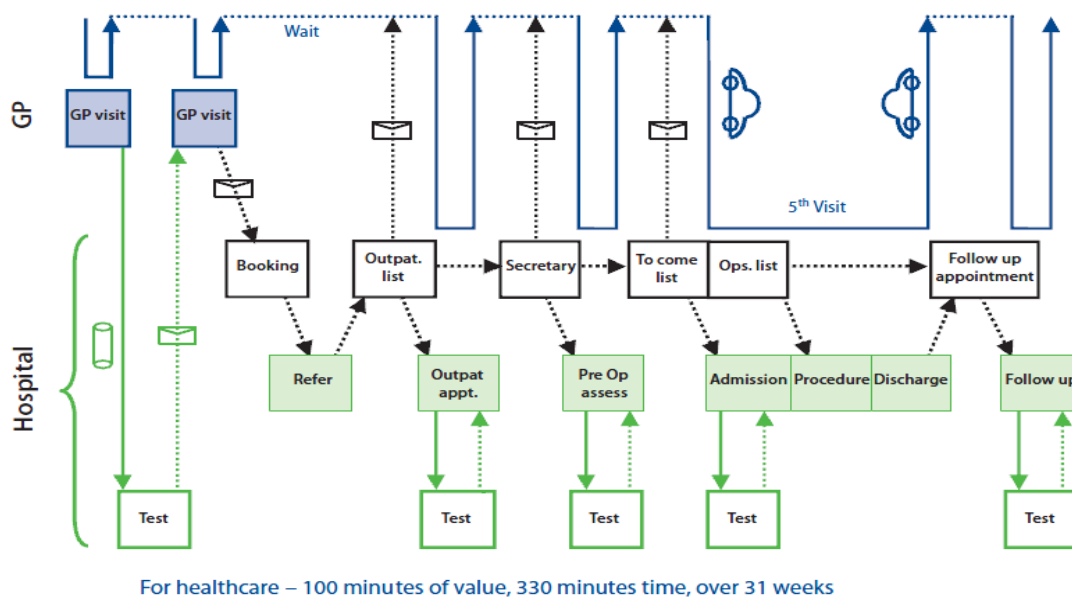


Figure 2.9 - Value Stream Mapping example from Wirral Hospital (Jones and Mitchell, 2006)

As the figure shows above VSM is a technique that is used to develop a visual representation of all the activities required to add value for the customer, in this case the patient. VSM is done in two steps. According to Voehl et. al. (2013) the first step is to build a current state map in which it can be reviewed every single activity that is currently being conducted in order to provide the product or service for the customers. The current state map gives accurate information and a description of what the organization currently does for the customer. In this way it can be understood the weaknesses of the current process to identify what is needed to be improved to get better performance for the customers. Once a current state map has been completed and identified all possible wastes, the second VSM step can be completed, preparing a future state map. The future state map defines a visual representation of how the organization can perform at some point in the future. As the figure 2.9 shows a couple of symbols are used to draw value stream mappings different software packages as eVSM and iGrafx (Manos et al., 2006).

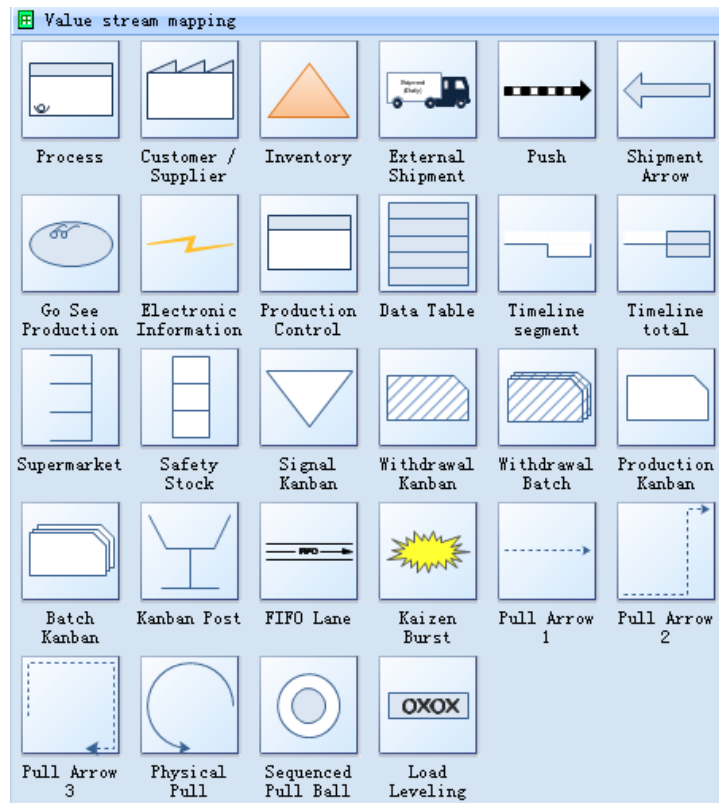


Figure 2.10 - Typical VSM symbols (Edraw Soft, 2012)

To sum up, VSM is a significant lean tool which helps organizations to analyze the process flow of materials from the beginning of the process to delivery to the customer. Moreover, this tool takes into consideration not only the items, but also the management and information system that support the basic items. From my own fieldwork experience VSM is a very useful tool in working with cycle time reduction procedure and is mostly used in Lean toolkit.

2.5. Six Sigma

Six Sigma is nowadays most well-known system for improving the processes quality. The concept of Six Sigma was introduced and developed by Bill Smith in 1986 at Motorola. It is based on improving the quality of process outputs by identifying and elimination of defects by using various statistical, data - based tools and techniques (Voehl et al., 2013).

Six Sigma is a method of process management and aims to improve customer satisfaction, speed cycle time and reduce defects in manufacturing (Pyzdek and Keller, 2010). Moreover, Six Sigma is a technical method of management which has as the main objective the improvement of business processes in order to create and supply perfect products and services.

Six Sigma can be defined in many ways. For example, Pande and Holpp (2002) argue that Six Sigma can be defined through three main strategies: improving processes, redesigning ones that are outmoded, and the ongoing management of the processes (pp. 6-14). Moreover, Six Sigma can be seen from two perspectives. One is the statistical perspective and another is the business perspective. From the first one perspective, Six Sigma is achieved if a process does not have more than 3.4 defects

per million opportunities (Pande and Holpp, 2002).

From business point of view, according to Antony and Banuelas (2001) Six Sigma is defined as a business strategy used to improve business profitability, to improve the effectiveness and efficiency of all operations to meet or exceed customers' needs and expectations (as cited in Kwak and Anbari, p.709, 2006). Six Sigma has been defined since its birth with different definitions and it has many popular definitions. For instance, Snee (2004) defines Six Sigma as:

a business improvement approach that seeks to find and eliminate causes of mistakes or defects in business processes by focusing on process outputs that are of critical importance to customers (as cited in Desai and Shrivastava, p. 1, 2008)

Another definition has been developed by General Electric (GE) which claims that Six Sigma is

a highly disciplined process that helps us focus on developing and delivering near-perfect products and services. The central idea behind Six Sigma is that you can measure how many defects you have in a process, you can systematically figure out how to eliminate them and get as close to zero defects as possible. Six Sigma has changed the DNA at General Electric it is the way we work - in everything we do in every product we design (p.1, 1999).

To sum up, one can say that Six Sigma focuses on reducing variations through monitoring and measurement tools. It is based on a philosophy that holds that every process can and should be repeatedly evaluated and significantly improved, with a focus on time required, resources, quality and cost (Voehl et al., 2013).

2.5.1 Principle of Six Sigma - Define, Measure, Analyze, Improve and Control (DMAIC)

The most important principle engaged by Six Sigma is DMAIC. This principle is a very rigorous methodology of Six Sigma being characterized by *define – measure – analyze – improve - control* processes and it works equally well on variation, cycle time, yield, design, and others. According to Watson (2004) it can be said that DMAIC is a rigorous, step-by-step, logical discipline for defining the most critical business improvement issues, converting them into statistical problems, and then resolving them as standardized daily work practices (pp.93-98). This project illustrates a very rigorous methodology that aims essentially increasing the capability and also the reduction of defects identified in a products or processes within a company. It is required the following steps:

1. *Define* - This step is to determine the objective and purpose of the project, gathering information regarding to process and define the problem
2. *Measure* - It means understanding the process performance focusing maxim effort to improve the current situation
3. *Analyze* ó This step is to find the root causes to problem and verify found causes. It usually involves dealing with data.
4. *Improve* ó After the root causes have been determined, this step aims at identifying solutions to reduce and tackle them.
5. *Control* ó The purpose of this stage is to ensure long-term success attained after implementation. The project results are to be supervised and corrected if necessary.

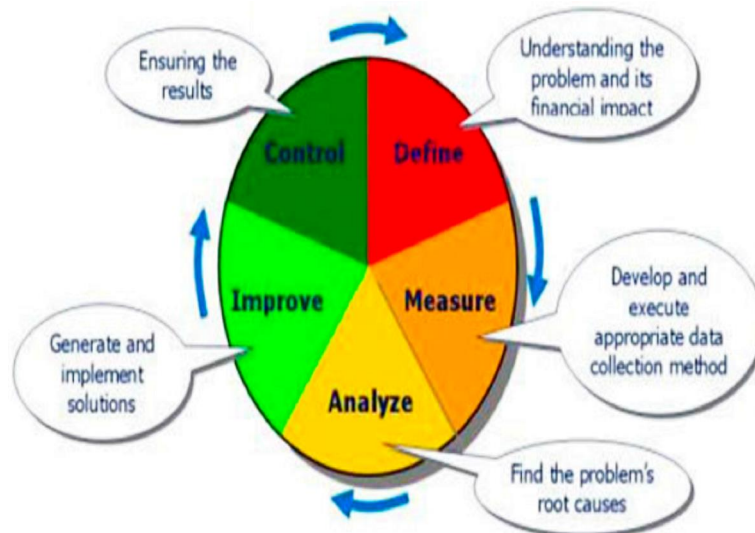


Figure 2.11 - The 5 phases of DMAIC (Glen Barton, 2014)

Figure 2.11 shows the important deliverables and tools used in each step of DMAIC. This approach uses different Six Sigma tools to create ideas, collect information and measure regarding data, analyze the results and come up with improvement methods to improve the processes. Called by General Electric as DMAIC, this methodology is in essence a structured way of solving problems in an existing process based on analysis of real process data (Cronemyr, 2013, p.441). It can be said that Six Sigma is referred to a statistical method or a quantitative method, because decisions are made on the basis of statistical analysis of quantitative data. On the other hand it has to be taken in consideration, the qualitative methods, because without this, Six Sigma does not work.

The alternate use of quantitative and qualitative methods in the DMAIC process is described further. The Define phase and the beginning of the Measure phase are mostly qualitative. Further, a problem to be solved needs to be formulated from people's experiences. Sometimes quantitative data from process evaluations are used. The rest of the Measure phase and the beginning of the Analyze phase are mostly quantitative. It is here where the statistical analysis takes place, but the statistical analysis does not by itself reveal the underlying root causes. It rather indicates where to look deeper into the problem. If a correlation between two variables has been found, the Six Sigma team still needs to discuss, by using an Ishikawa diagram, what the possible underlying root causes may be, and how these could be avoided. Hence, the rest of the Analyze phase and the Improve phase are mostly qualitative, even though causation is not only correlation is should always be quantitatively verified before starting improvements. Finally, the Control phase is mostly quantitative since the improved process is measured and monitored.

2.5.2. Tools of Six Sigma

A Six Sigma process can utilize as a tool of analysis Statistical Process Control (SPC). Voehl et al. (2013) has stated that SPC methods is useful in identifying and solving tools which leads in achieving

process stability by reduction of variability and defects within business processes. SPC occurs because always will be variations in the characteristics of people, materials, services and information. There are some basic tools of SPC which can be used in improving the business process (Oakland, 2003). These are: cause and effects diagrams (an analysis of what causes the problems within processes), flowcharts which mean verifying and controlling the variation over time, Pareto analysis to place activities that cause of defects prioritizing the importance of the defects, Scatter diagrams which examine the relationship between two causes and factors to see if they are related.

The tools selected in this sub-chapter, are the ones considered to be the most essential, moreover some of them they are applied in paper's case study:

- A.) Cause-and-Effect Diagram and
- B.) Process Flowchart and Process Mapping.

A.) Cause-and-effect diagram. The diagram is also known as the Ishikawa diagram or fishbone diagram. It is defined as a fishbone because of its structural outlook and appearance. It is a visual and analysis tool as part of a problem-solving process that provides a systematic way of looking at effects and the causes that create or contribute to those effects. This diagram helps to organize the causes that contribute to a certain problem during an event or process. A fishbone diagram is useful trigger ideas and promotes a balanced approach in group brainstorming sessions where individuals list the perceived causes with respect to effect (Park, 2003).

As it is shown in the figure below (fig.2.12) the effect is written in a rectangle on the right-hand side, and the causes are listed on the left hand side. They are connected with arrows to show the cause and-effect relationship.

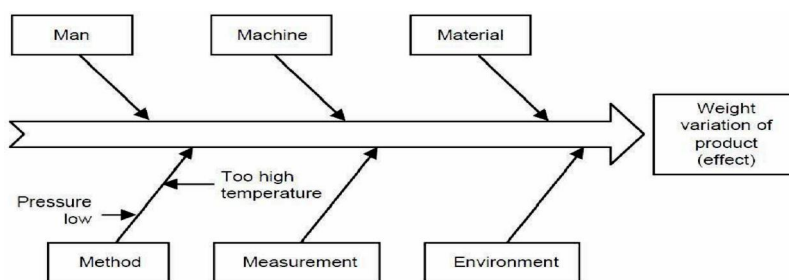


Figure 2.12 - Cause-and-effect diagram (Voehl et al., 2013)

How this diagram works is described below:

1. The first step is to find the effect.
2. The second step sets up the goals which should be stated in terms of measurement related to the problem within business process. This step is important to the people involved because they have the possibility to know that their efforts are achieving good results.
3. Build the diagram structure: in this step, the major categories are listed to identify the sources of causes.
4. Programs for activities.

5. People, staff or management.

B.) Process Flowchart and Process Mapping. For quality systems it is useful to represent system structure and relationships using flowcharts. A flowchart provides a picture of steps of work that are required to understand a process. The Process Flow chart provides a graphical representation of the steps in a process for a better understanding (Voehl et al, 2013). Flow charts are also referred to the Process Mapping or Flow Diagrams. In this context, Breyfogle, III et al. (2001) argue that:

„[] creating process Flow Charts as a team is a great way to display an accurate pictures of the process and to gain insight into opportunities for improvement. [] the flow chart can be used for maintaining contingency of process application and subsequent improvement / establishment of standard operation procedures“ (p.158).

Constructing a flow chart is often one of the first activities of a process improvement, because of the following benefits:

- There is always a straightforward perception of the process;
- It facilitates to recognize NVA operations;
- It helps communication and team work;
- It helps that everyone in the organization is on the same page.

2. 6. Lean Six Sigma (LSS)

According to Cirnu and Todorut (2011) the mixture between Lean and Six Sigma can lead to improvements related to cost, quality and time by focusing on the process performance. Six Sigma is a method focused on reducing variation and improving the efficiency of the process by following a problem-solving approach using statistical tools. Lean is an approach based on eliminating waste and improving the flow by following the Lean principles (Cirnu and Todorut, 2011).

Furthermore, an important role in Lean approach is played by the other methods and strategies to improve quality: Kaizen, 5S and value chain. It can be said that LSS is a mixture of the two methods, an analysis, practically a business process that allows companies to increase profitability by designing and monitoring the business activities, in such a way that mitigate waste (Cirnu and Todorut, 2011).

According to Deac, Badea and Dobrin (2010) when Lean is integrated with Six Sigma, on the background of a Kaizen continuous improvement, it can be said that this is the secure way to excellence. The interference between Lean and Six Sigma has as results the following aspects:

- Fluent production without Six Sigma implies quick production but poor quality;
- Six Sigma without fluent production implies quality production but without added value;
- Fluent production with Six Sigma implies quality production at acceptable cost.

CHAPTER 3

CASE STUDY - SABCA Limburg N.V. MOV3L COMP for A350 XWB within Cleanroom 1

3.1. Presentation of SABCA

Société Anonyme Belge de Constructions Aéronautiques (SABCA) is one of the main aerospace companies in Belgium. It was founded in 1920 and nowadays the company employs around 1000 highly trained persons. SABCA is specialized in designing, manufacturing and marketing avionic systems and structures for the civil, military, and aerospace sectors. The group's products are mainly fuselages, acceleration and braking systems, tanks, control systems, and dashboard components. SABCA also offers airplane and helicopter maintenance services. Net sales break down by market into civil aviation (40%), aerospace (31%) and defense (29%) (Euronext, 2015).

3.1.1. SABCA short history

After the war, SABCA became a major partner in most Belgian military aircraft production and upgrade programs like the Hunter, F-84, F-104G, Dassault Mirage 5, Lockheed F-16, Agusta 109 Helicopter. A new plant was opened in 1955 on the Charleroi airport for that purpose. In a move towards diversification in the field of high technologies, SABCA was among the early participants in the European space programs and has since more than 40 years designed and manufactured major elements of the European Spacelab and large parts of the Ariane and Vega launchers (SABCA, 2015). On the civil aircraft side, SABCA had a slow start with the production of the outer wings of the Fokker 27/50 family, the flaps of the Dassault Mercure, the flaps again for the VFW-614 and other more or less successful projects. However, the civil aircraft activity really took a boost in 1989 when a first risk-sharing contract was signed with Airbus. Since that day, SABCA has been selected as a partner for all new Airbus programs, including the giant A380, the A400M and the new A350 XWB. SABCA also designs and produces metallic and composite subassemblies for the Dassault (900/2000/7X and SMS) and Gulfstream business jets programs (SABCA, 2015).

Nowadays SABCA is engaged in aircraft industry in the pre-design, design, development, production, testing for huge companies like Airbus, Dassault and Gulfstream, as well as in space programs (Ariane, Vega). Thanks to the technical and financial support of the Walloon Region, the Brussels-Capital Region and the Federal authorities, SABCA pursues active research in alternative production processes for composite structures and the group's R&D investment policy stresses global prospecting to identify opportunities and define the characteristics of products that will be demanded tomorrow. Furthermore, in the defense market, SABCA is active in the maintenance, repair and upgrade of military aircrafts and helicopters (F16, Mirage F1, Alpha jet, helicopters) (SABCA, 2013). With an extensive and varied know-how built in the last 90 years, SABCA has two subsidiaries SABCA Limburg and ASM Aero. In Belgium the company has three main plants placed strategically in Brussels, Charleroi and Lummen. Recently (2012) SABCA Group has become the major partner of

ASM Aero in Morocco (SABCA, 2015).

3.1.2 Brief overview of SABCA Limburg

SABCA Group comprises the mother company SABCA and a fully-owned subsidiary SABCA Limburg. SABCA is listed on the Brussels Euronext stock market.

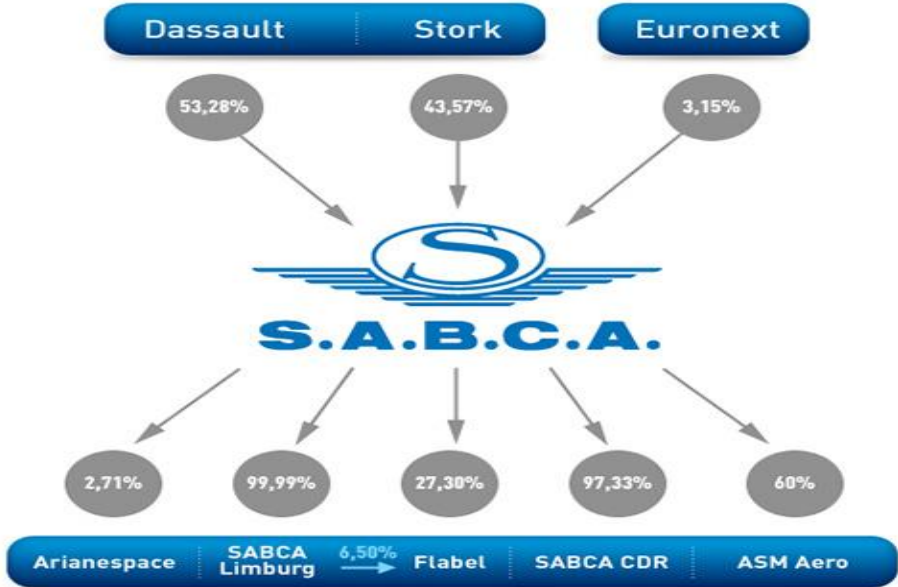


Figure 3.1 - SABCA Group (SABCA 2015)

As can be seen in the figure above, a vast majority of the 2.400.000 shares belong since 1968 to two important players in the aerospace world : the French Dassault Group (53,28%) on one side and the Dutch Stork Group (45,57%) on the other side. SABCA is the owner at 99,99 % of SABCA Limburg NV, its subsidiary dedicated to the development and production of advanced composite elements for aircraft and launchers. SABCA is a majority partner (60%) in ASM Aero, a brand-new assembly plant located in Casablanca, Morocco. ASM Aero will provide low-cost solutions in a very competitive market. The company also possesses, directly or indirectly, minority interests in holdings or joint ventures linked to its industrial activities (SABCA, 2015).

The subsidiary SABCA Limburg was established in 1992. SABCA Limburg is specialized in the manufacturing of high-tech composite assemblies for aircraft. Two automatic tape-layers (ATL) and very large autoclaves, coupled with an increasing know-how, allow the production of integrated skins for flaps and stabilizers. In cooperation with the Engineering office in Brussels, SABCA Limburg is also responsible for the flap track fairings of several aircraft. Space is also present in this plant with the final system integration of Ariane 5 assemblies. Around 100 persons are employed at SABCA Limburg (SABCA, 2015).

SABCA Limburg has the plant located in Lummen, Belgium.



Figure 3.2 - SABCA Limburg plant

According to the Annual Report of SABCA (2013), since its formation SABCA Limburg has made many significant steps to enhance its capabilities and competitiveness in the aerospace industry covering most aspects of a modern manufacturer of advanced composite materials, such as: serial production, customer support, researching and developing new manufacturing methods and processes and optimizing existing ones, design of complex structural components, tool design and manufacturing, testing qualification and manufacture of high-value composite aero structures.

3.2. Organizational culture within SABCA Limburg

3.2.1. SABCA Limburg - Mission and Vision

As a major world player in the design and manufacturing of composite structural parts for the aeronautic and space industries, the company is committed to serve clients and ensure the highest level of quality and responsiveness, at acceptable prices (SABCA, 2014). Its commitment to offer quality at a reasonable price lead SABCA Limburg to use state-of-the art management techniques designated to the improvement of customer satisfaction and company profitability (SABCA 2011).

Mission: Why SABCA Limburg exists?

According to SABCA Limburg the company stands for composite aircraft products and services with the Lowest Total Cost of Ownership (TCO). In other words it can be said that the company mission is to offer high-quality aircraft components and services (SABCA, 2014).

Vision: What is SABCA Limburg goal?

The key goal of the company is to achieve the reputation of a World Class manufacturing company which delivers high quality complex and optimal aircraft systems and services.

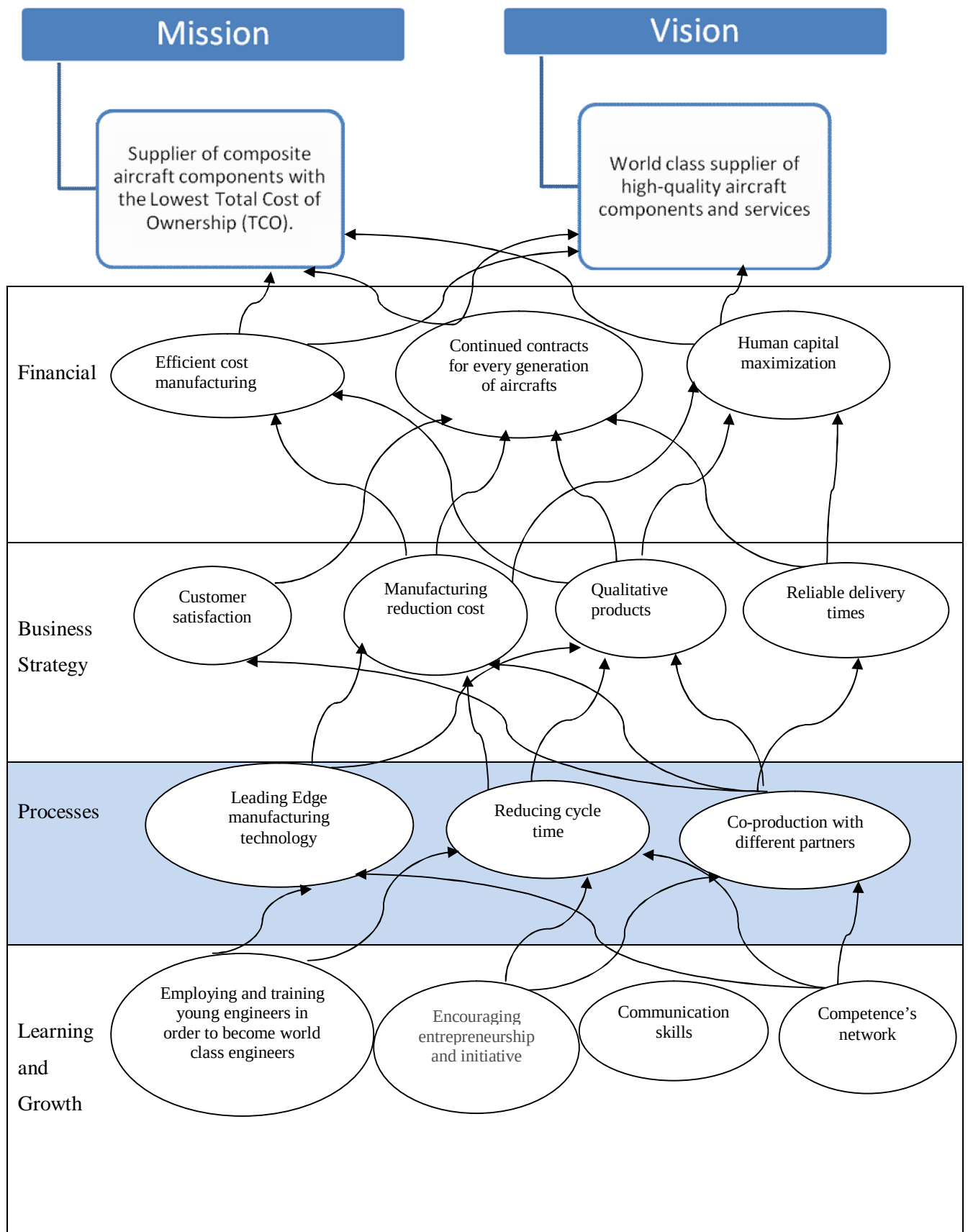


Figure 3.3 - Mission and Vision within SABCA Limburg (adapted from SABCA Limburg documents)

The figure 3.3 describes how the mission and vision of SABCA Limburg is accomplished in respect of four main components: financial, business strategy, processes and learning and growth. As I already mentioned at the beginning of this chapter, the present study case focuses only on the aspects of process manufacturing. In order to produce composite aircraft components at TCO, but also to become a world class supplier of high-quality aircraft components and services the policy of SABCA Limburg is to continually improve technologies, co-production of work, as well as the allocated production times.

By using leading edge manufacturing technology the company intends to reduce the manufacturing costs keeping and improving the quality of their products and services. This attempt of engaging leading edge technology is only possible through a permanent training of the employees and network of competencies.

Furthermore, the reducing of cycle-time has to be achieved without impairing customer satisfaction, products quality and manufacturing costs. Another important aspect related to the manufacturing processes is according to SABCA Limburg the coproduction of work. Making up the co-production of work is an essential step in achievement of company mission and vision. This factor lays the foundation for improving not only customer satisfaction, products quality and manufacturing costs, but also delivery time. As a conclusion it can be sad that the organizational structure spins around the core work process of an organization.

3.2.2. Lean Transformation Techniques within SABCA Limburg

Since one the objectives of SABCA Limburg within the manufacturing processes is to reduce cycle time, and implicitly the improvement of processes efficiency it follows that the future actions and measure has to be chosen in such a way without affecting the customer satisfaction, products quality and manufacturing costs. In order to achieve these goals SABCA Limburg engaged for the improvement of manufacturing processes some lean techniques. As techniques of lean transformation SABCA Limburg has proposed the following tools: 1) 5S, 2) Value Stream Mapping (VSM) and Single Minute Exchange of Die (SMED) and 3) Innovation.

The detailed procedure can be described through the following figure.

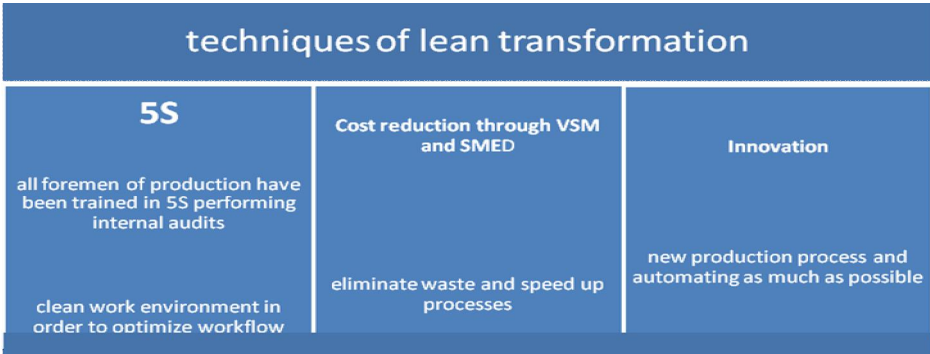


Figure 3.4 - Techniques of lean transformation (adapted from SABCA Limburg documents)

According to SABCA Limburg, 5S project has been introduced in 2010 for all departments on the shop floor. All foremen of production have been trained in 5S and a follow up is performed through internal audits. Major purpose is to create a clean work environment and free up shop floor space for optimum work flow and optimize the available work space for existing and new programs. Continuous improvement is organized on all major programs. VSM and SMED are standard techniques which are applied to reduce cost. Existing programs have been reviewed through specific projects to eliminate waste. For new programs, the lean idea is introduced when the concept of the work flow is set-out. New technologies such as laser projection and improved cutting tools are introduced to speed-up processes. This is the responsibility of the production engineers. SABCA LIMBURG strongly adheres to new production processes and participates in SABCA Group research programs to continuously seek added value for its products. Major axes today are reducing weight in the actual concepts and automating where ever possible.

Having a preliminary discussion with an employer from SABCA staff, about the manufacturing process it was revealed that within Cleanroom1 is an unsolved important problem in regard to the production cycle time for CFRP (carbon fibre-epoxy prepreg and core material) preparation of flap structure fairings components for A350 XWB. The term component shall be interpreted as assembly of elementary parts. Figure 3.5 shows the list of components which have to be manufactured within Cleanroom1:

		FSF components		
Aircraft	RH Wing	Track 4	Fixed fairing	Moveable fairing
		Track 3	Fixed fairing	Moveable fairing
		Track 2	Fixed fairing	Moveable fairing
		Track 1		
	LH Wing	Track 1		
		Track 2	Fixed fairing	Moveable fairing
		Track 3	Fixed fairing	Moveable fairing
		Track 4	Fixed fairing	Moveable fairing

Figure 3.5 - FSF Components (adapted from SABCA Limburg documents)

The fairings will be manufactured by manual lay-up of CFRP in cure tools within Cleanroom1. These cure tools are customized according the shape of each CFRP parts. The milling will be done on trim tools with a standard frame and removable blocks for each CFRP part.

As a new temporary employer of SABCA Limburg and in the same time as student at a master in the field of Management Information Systems, together with the staff of SABCA Limburg, I decided to investigate the cycle time problem of manufacturing process in regard to CFRP composite of movable 3L (it can be seen in the figure above - fig. 3.5), shortly named MOV3Lcomp process for A350 XWB within Cleanroom1.

3.2.3. Industrial process flow chart

The industrial process flow represents a very useful source in order to understand the manufacturing organization as processes and sub-processes. As it can be seen in the picture below the industrial process is divided in three main parts: logistic, manufacturing and inspection. For the case study under discussion the research is focused on manufacturing process of MOV3Lcomp within Cleanroom1

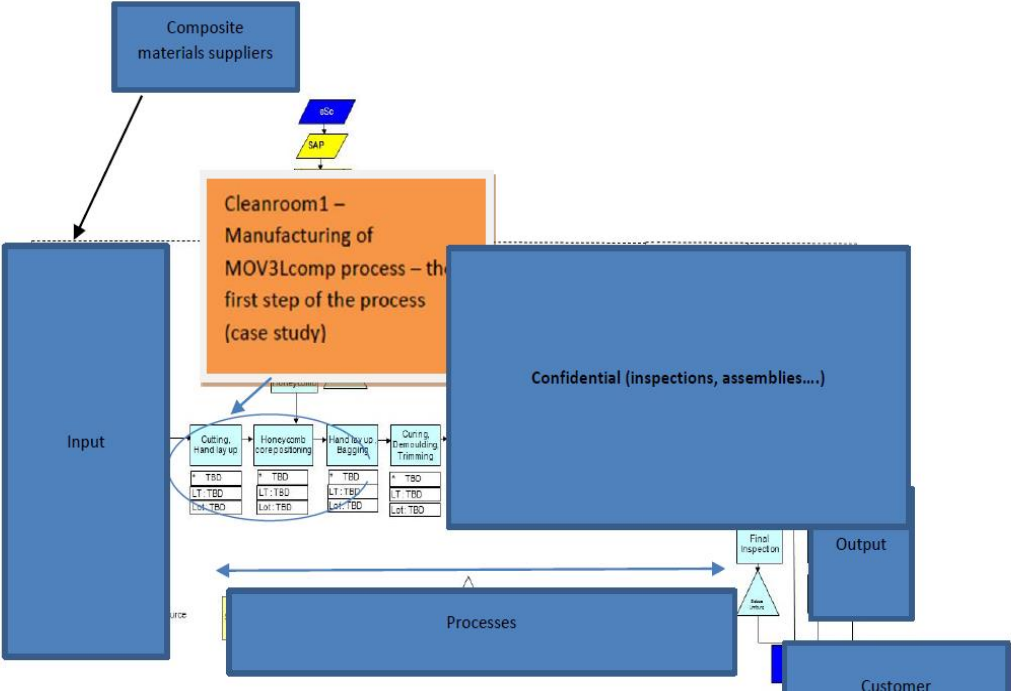


Figure 3.6 - Industrial process flow chart (adapted from SABCA Limburg documents)

The fig. 3.6 shows the separate steps of the process in a sequential order. MOV3Lcomp manufacturing process within Cleanroom1 is a sequential connected set of operations composed by the following activities: cutting, hand lay-up, honeycomb positioning, hand lay-up and bagging. It is manufactured by manual lay-up of carbon fibre - epoxy prepreg and core material in Invar cure tools. All these operations are integrated into two sub- processes: 1) cutting and 2) lamination&bagging. Due to my field work experience and observations of the activities well as after the discussions with some staff employers I came to the conclusion that the material flow is a straightforward operation which usually does not encounter problems which could affect the production process within Cleanroom 1. Focusing on the investigation and application of different lean techniques within Cleanroom 1 the paper further describes the flow process and the value creation and manufacturing cycle time analysis of MOV3Lcomp within Cleanroom 1.

3.2.4. Mapping the process flow within Cleanroom 1 In order to complete MOV3Lcomp within Cleanroom 1 various processes and sub-processes has taken place.

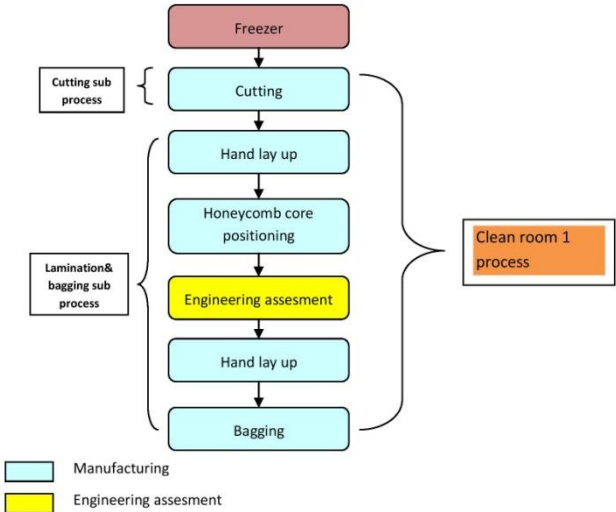


Figure 3.7 - Process flow of MOV3Lcomp engage within Cleanroom1 (Adapted from SABCA Limburg documents)

The manufacturing process performed within Cleanroom1 begins from removing the materials from freezer until the composite part is pushed to autoclave. After removing the materials from freezer starts the cutting sub - process. Before cutting the materials is very important to thaw the role material in conditions of controlled temperature and time until the polythene bag is open. Hereby I can come with an example from my own fieldwork experience. The time for thawing 40 linear meters material is between 4-6 hours, transferring the material from - 18°C storage in a room with 21°C. If the material is not used immediately it has to be stored in the freezer. When the rest of the materials are placed for storage in the freezer, it must be resealed in a polythene bag containing a desiccant pack to prevent ingress of moisture.

The first step after removing the materials from freezer is cutting. The materials are cutted with the Gerber machine. The cutting machine consists of a table and a 2D CNC cutting tool. The GERBER is used to cut and identify layers. All materials except for the Tedlar material will be cut on the GERBER. SABCA Limburg has the capacities in-house to program the cutting table.

The next step is the hand lay-up operation. This is a technique which is used for fabricating composite components. This technique consists of placing successive layers on cure tool. After each autoclave cycle, the cure tool has to be cleaned before starting to place the layers. The workers are guide in ply placement by a set of templates, ply - book and record sheet. The plies have to be laid in the correct order respecting the steps from Ply Book in the correct order and in the correct direction. The plies have to be stacked in the proper sequence with the material oriented in the right direction. After all plies have been laid up the parts are bagged and sealed before being cured in the autoclave. The third step is positioning honeycomb. This operation is done manually and requires time and attention. After each placement of honeycomb an engineering assessment is necessary. When the

assessment is accordingly another operation of hand lay-up is occurring.

The last step is represented by the operation of the last bagging. This process can be the subject of errors if the measurements are not realized correctly. The last bagging involves placing different materials such as release fabric, breather, caul plates and plastic.

3.3. The Six Sigma methodology - a DMAIC approach

When embracing the Six Sigma methodology, DMAIC approach stands as the backbone of implementing it. The five steps presented bellow (fig. 3.8) offers SABCA Limburg an adequate path to improve the problem at hand. It is however necessary that both human and materials resources are properly attributed and are complementary in order to accomplish the DMAIC path.

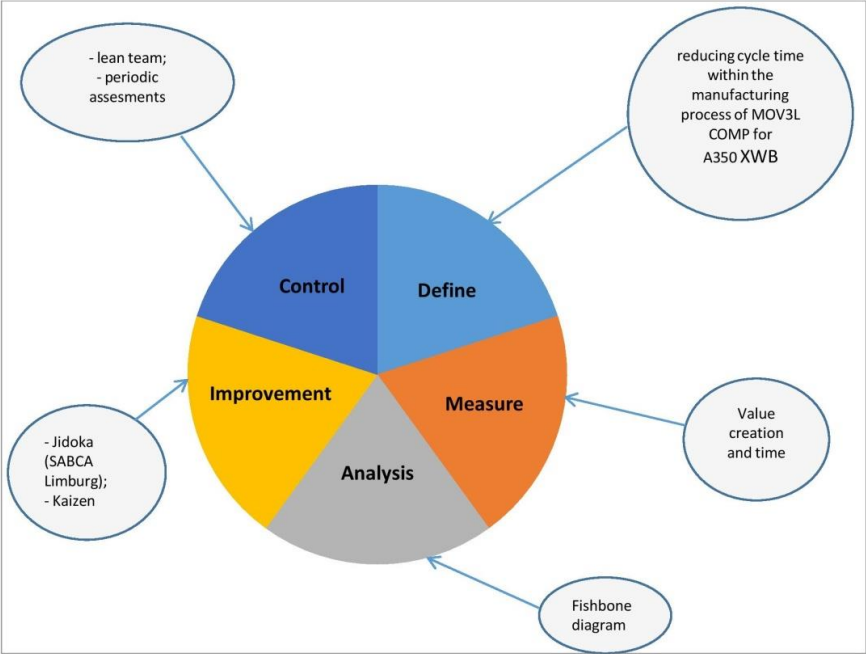


Figure 3.8 - DMAIC method within MOV3L COMP

3.3.1. Definition of the problem

The subsidiary selected for the present case study is SABCA Limburg N.V. The company was selected due to my own work experience within. The overview of the case study research will cover background information and substantive investigative issues related to reducing cycle time within the manufacturing process of process MOV3Lcomp for A350 XWB. The research of the case study was conducted in the Cleanroom1 where the composites are hand lay-up, for which SABCA is developing the flap support fairings (FSF) of Airbus A350 XWB. The issue investigated is oriented toward the production process within Cleanroom1 in order to reduce cycle time manufacturing by removing the non - value adding waste. Research was conducted in such a way to determine if the process within Cleanroom1 by implementing lean techniques could continuous improve the production by achieving

in the same time the goals of the company.

To sum up, the present research will shed lights on a set of value-added and non-value added activities specifically designated to the manufacturing process of MOV3Lcomp for A350 XWB within Cleanroom 1 in order to simplify the process, to increase production and to improve timing without impairing customer satisfaction, products quality and manufacturing costs.

3.3.2. Data collection through value creation and time matrix

In the table below is presented the process under consideration decomposed into a series of individual/group operations. This calculation is based on my own field work experiences as a worker as well as a result of almost 1 month of observation within Cleanroom1. The identification of opportunities for the improvement of manufacturing MOV3Lcomp process within Cleanroom 1 are strongly linked with operational timing of certain operations of it.

In order to identify the NVA activities were used the seven wastes of Lean Manufacturing as the base of the analysis. The time matrix analysis based on cycle time includes: set-up time, processing time, moving time, waiting time, inspection time, error and rework time and human behavioral within the workplace.

Name of operation of MOV3Lcomp process	Time/operation (min)	VA/NVA activities	Operators
Cutting sub-process			
Cutting with Gerber machine	Confidential	VA	1
Sorting the layers on each sequence by human operator(one sequence has more layers), packaging and transferring the materials to freezer in order to be thawed	Confidential	NVA	1
Subtotal	Confidential		
Lamination&bagging sub-process			
Meeting group workers with team leaders planning the daily actions separately for each shift	Confidential	NVA	Group
Bringing the templates from storage	Confidential	NVA	1
Inspection Ply location	Confidential	NVA	1
Preparing the cure tool, preparing the bagging (sealant, release, breather) and vacuum during the intermediates stages of successive sequences of plies according to record sheet	Confidential	VA	2
Applying the templates, mark the position of the plies with a pencil according to the ply-book and record sheet; the plies are also positioning using reference holes in the tool which correspond with reference holes cut out by the 2D cutting machine in the scrap part of the plies; removing the templates from tool	Confidential	NVA	2
Inspection and rework/special cases	Confidential	NVA	1
Layer 1	Confidential	VA	2
Layer 2	Confidential	VA	2
Layer 3	Confidential	VA	2
Layer 4	Confidential	VA	2
Material core positioning	Confidential	VA	4 - positioning 2 - hand lay up
Inspection	Confidential	NVA	
Layer 5	Confidential	VA	2
Layer 6	Confidential	VA	2
Layer 7	Confidential	VA	2
Layer 8	Confidential	VA	2
Vacuum	Confidential	VA	2
Measurements	Confidential	VA	2
Store the templates	Confidential	NVA	1
Subtotal	Confidential		

Table 3.1 - Time matrix and value creation for each process

Taking into consideration the claims of George (2003) and Maleyeff (2006), in the case under discussion value added (VA) is represented by any part of the production process that can improve the final product for the customer and for which they are willing to pay. At the heart of the VA and NVA analysis was the concern to identify and finally to eliminate the waste occurred in the manufacturing process of MOV3Lcomp process within Cleanroom 1. By breaking down every process into VA and NVA steps, it was possible to identify the waste in the manufacturing process under discussion. After all the approach of VA and NVA lead to the changes in existing manufacturing process due to the need of reduction and elimination of some problematic operations within Cleanroom1.

The time matrix analysis was obtained according to operational time of each operation separately. As it can be seen in the table above the operations identified within Cleanroom1 is divided in two categories, namely: cutting and lamination&bagging. The operations which added value to the product are expressed in minutes.

Within cutting sub-process, the total time of the production cycle which adds value to the final product is around 1 hour. NVA activities are representing by the operation related to the sorting of layers for Gerber machine. These activities performed by a human operator gather around 2 hours and can be actually regarded as loss (*muda* in Japanese). According to Toyota 3M model in order to eliminate the waste the first step is to get the root of the problem. In the case of MOV3Lcomp process within Cleanroom 1 the unnecessary movement of the human operator to sort the layers on each sequence takes time and makes the process of work more difficult.

Within the sub-process of lamination bagging the operations which add value represents a cycle time of 12 hours. As it can be seen in the table above NVA activities are represented by the handling and visual actions such as: meeting group workers with team leaders planning the daily actions separately for each shift, bringing the templates and storage the templates, applying the templates, mark the position of the plies with a pencil according to the ply-book and record sheet and removing the templates from tool, inspection ply location and honeycomb and sometime inspection and rework in case of errors and defects. In the total of NVA, the highest waste within the manufacturing process is represented by the following operations: bringing and storage the templates, applying the templates, mark the position of the plies with a pencil according to the ply-book and record sheet and removing the templates from tool. More exactly, these operations represent 31.16% from the total of activities involved in this sub-process.

3.3.3. Analysis - Fishbone diagram of MOV3L manufacturing process

Since the NVA activities were identified, the analysis is directed towards the identification of the causes and the effects. This analysis is requested in order to solve the problems involved within manufacturing process of MOV3L comp within Cleanroom1. Thus, using the Fishbone diagram I am trying to visually display the cause - effect analysis.

Having as the base of the analysis, the theoretical aspects presented in chapter 2 I frame the problem in the form of the question: Why the cycle time of manufacturing MOV3L within Cleanroom 1 is so high? The categories considered in the cause and effect diagram were taken in consideration: (1) people involved within process (those who perform the operations within process); (2) management (3) technology (machine, equipment and tools) required to accomplish the tasks; (4) materials used during the process; (5) measures used in the process and used later to evaluate the quality; (6) environment (the conditions, such as location, time, temperature, and culture) in which the process operates.

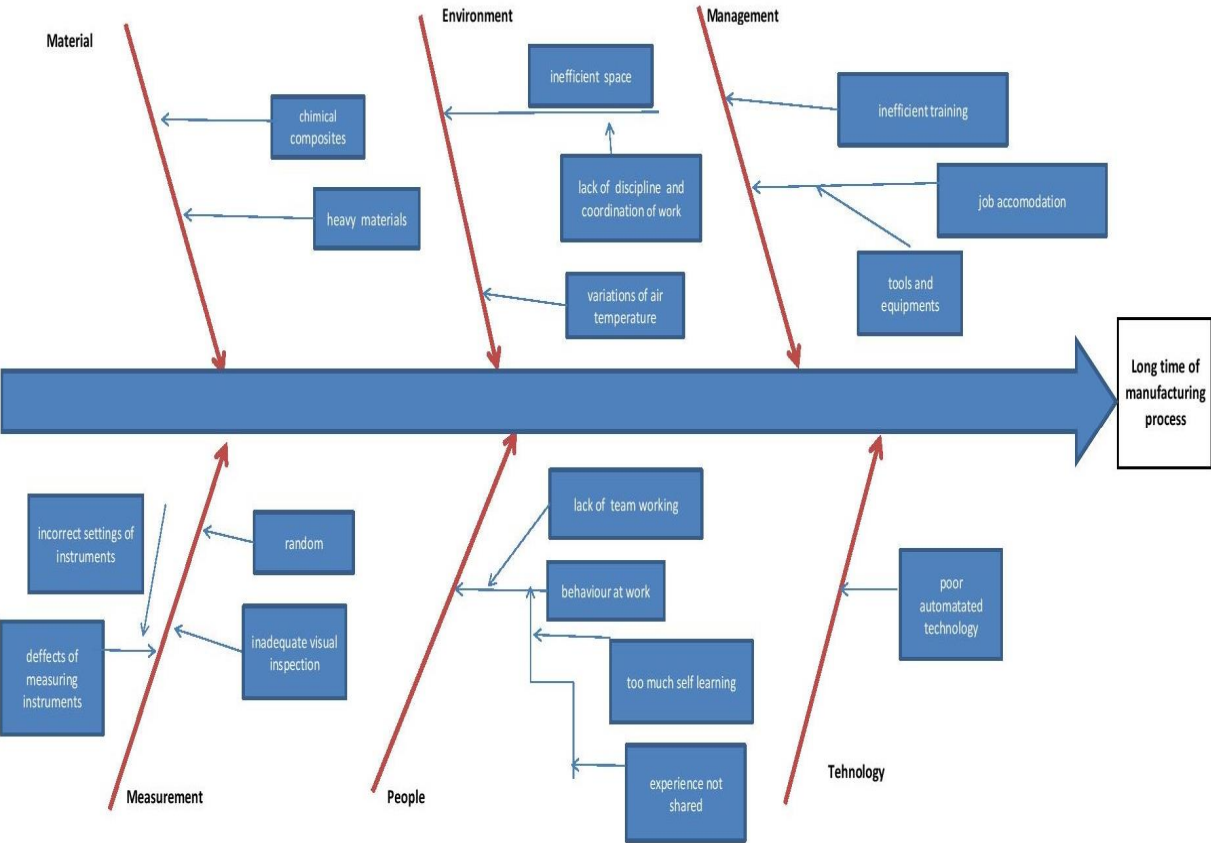


Figure 3.9 - Fishbone diagram within MOV3L COMP

According to the figure 3.9, the problem itself can be described by classifying the main roots of the causes in two subcategories: lack of new edge technologies and organizational behavior within the process of manufacturing MOV3Lcomp within Cleanroom1. As I already explained throughout this thesis, the data presented above is based on direct observation of the process flow, fieldwork documentation and measurement of cycle time as well as the identification of VA /NVA within the manufacturing process of MOV3Lcomp.

The attempt of SABCA Limburg to reduce the time within the process of manufacturing MOV3L within Cleanroom1 is based on the implementation of New Edge Technology. As I already

explained at the beginning of this chapter one of the measure taken by SABCA Limburg in order to speed up the process is based on innovation (laser projection system and improved cutting tools). Furthermore, according to the documents analyzed and my own fieldwork research in order to accomplish this measure SABCA Limburg uses ðLeanö philosophy (VSM, SMED) as standard techniques when the concept of the work flow is set-out, as well as when innovation is taking into discussion.

One of the *New Edge Technology* nowadays is the laser projection system. The system can be the catalyst towards creating a ðLeanö process flow. This helps removing tools, setup, and drawing interpretation errors while speeding up activities and improving product quality. Compared to the traditional method for composite hand lay - up this process eliminates essentially all of the NVA activities regarding to: time to bring and storage the templates, time with position tooling templates, mark the position of the plies and removing the templates from tool, time to inspect and analyze the ply location and honeycomb, time to draw in case of nonconformities, time to read and understand the work instructions from the ply-book and record sheet. Furthermore, in order to eliminate NVA regarding to cutting sub process, JTI method helps reducing time through automation, perhaps a robot designed to place the layers from the cutting table to the lay-up area, and eliminate the need to bag up the kits by storing them in the freezer until needed for the next lay-up process.

CHAPTER 4

4. Conclusions, improvements and recommendations

4.1. Conclusions

This chapter concludes the findings of the empirical research and finally presents a few improvements and recommendations.

The main goal of this paper is to highlight how different methods and techniques can be used to achieve the improvement of business processes through LSS operational excellence strategies. Based on the theory, empirical research and my own fieldwork experience I am able to draw a conclusion that provides an answer to the research question, and sub questions likewise, from the first chapter.

As it can be seen in the first part of my work, I approached a set of tools and methods of BPI, that I selected from a wide range, and which I considered the most interesting to have under investigation. Throughout this research, the business process methodology was taken into consideration according to the concepts of the Lean manufacturing and Six Sigma. As it is mentioned in the theory these two methods gained a greater appreciation for the impact they had on business process improvement. Moreover both principles are very popular within the quality and performance operational management field.

This paper has shown each other's particular aspects as well as the main differences between the two above mentioned methods, and how they complement each other when combined into Lean Six Sigma. To sum up, lean manufacturing is a managerial strategy approach which aims to eliminate any kind of waste within processes having as scope to improve the businesses performance, reduce lead time, and inventory by applying the just in time (JIT) approach, but at the same time to cut costs and create new profit opportunities. In order to achieve the previously mentioned targets through Lean manufacturing it is crucial to use the following tools: 5S and SMED, Kanban which leads in mitigating the inventory by applying the concept of JIT, Kaizen which implies the engagement of the people through the process of defining and proposing different solutions having as scope the elimination of waste related the process for improvement. Another tool which is very useful in BPI is VSM strategy which helps in working with cycle-time reduction.

Complementary with the lean concept the Six Sigma method which implies achieving maximum quality levels close to perfection. This strategy makes use of statistical tools and quality standard methods for business process performance and improvement. More specifically, the outcome of the combination of the two methods is: streamlining operations, adding value and boosting profits. One of the biggest benefits that I found for LSS is to focus on employee's involvement in process improvement, stimulating their contribution and better value delivery to the customers. Involving employees in implementing those improvement strategies provides them with great self-esteem and more goals oriented attitude.

This paper emphasizes a real life case of BPI methods and techniques, and consequently to decide which ones suit the best with the given case. However conducting this research led me to new perspectives; as stated in the theory there are several methods and techniques which can support BPI implementation. I however believe that in order to support the BPI implementation it is better to create a combination of methods and techniques that work in synergy and help to faster achieve the desired goals.

Tracking back to the research sub question: *How can be LSS used by an industrial organization in order to achieve positive results of BPI?* This thesis illustrates a case where a process has to be improved through the use of Lean and Six Sigma. This paper concludes that there is a need of simultaneously enforcing of those two methods in order to successfully improve the process and keep control over it. The main aspect of this thesis was to extract data in order to identify where the problem stands and which part of the process has to be depicted and improved.

Almost every organization can implement process improvement methods, however in the case of SABCA Limburg a particular combination of practices had to be addressed in order to obtain the desired outcome. I strongly believe that not only improvements in the production line, but also the human factors have to be trained and adapted in a manner that supports the principles of LSS. Furthermore, it is unwise to opt only for only bringing in new technologies, and drift away focus from all employees within the company. Regarding to this context SABCA Limburg claims that this is the responsibility of the production engineers. In other words it can be said that this group of production engineers represents the basic design elements of technology underlying the work of the organization and has the knowledge of how that technology has to be utilized (Schein, 2010, p.60). In my own experience within the company I found some dysfunctional interactions among engineers and workers, but also among workers themselves. This can be characterized by the longtime of waiting for the inspections, measurements or in finding solutions to the placement of layers. On the other hand I observed a particular culture amongst workers that does not cope with Kaizen's principles. According to Schein (2010) this type of culture is based on human interaction (p.59). More specifically, this interactions amongst workers should be improved and also focus more on trainees.

As an intermediate conclusion and the fact that NVA activities during the process collected around 360 minutes (31.16%) from the total of operations involved in this sub-process lamination&bagging only I would say without denying the importance of VSM and SMED that the actual situation requires in addition an evaluation of organizational behavior within the workplace. Based on my personal fieldwork research within the manufacturing process of MOV3Lcomp within Cleanroom1, the organizational behavior crisis is rooted in a difficult interpersonal relationship, unsatisfactory team working and communication barriers, commitment as well as insufficient personnel training in performing the tasks. Moreover, authors like Höök and Stehn (2008) highlight the successful implementation of Lean tools along with a change in the organizational behavior. Thus, it can be said that the process improvement could be fully accomplished through the implementation of Kaizen method. As Berger (1997) argues, Kaizen has proven already its efficiency in improving

organizational mechanism by supporting the development of employees and organizational communication.

4.2. Improvement of the manufacturing process by using Kaizen method

As it is already mentioned in the theory chapter, one of three Kaizen principles is people orientation. Hence, Kaizen refers to the link between the individual worker and the whole organization. Along with the people factor, Kaizen at the same time reduces cost due to production waste and improves product or service quality by reducing NVA activities. Moreover, Kaizen has an impact on the total cycle time of the entire production process (Voehl et al., 2013). By using Kaizen approach the focus is on the continuous improvement of production flow and efficiency, by involving and developing all employees not only the engineers. From my worker perspective Kaizen helps employees to improve organizational behavior through planning, communication and innovation. Implementing all these strategies, Kaizen positively supports employees by engaging them in the process improvement. In addition to this Kaizen ensures that employees develop the confidence and necessary capabilities in order for SABCA Limburg to become the most valuable assets.

Kaizen		
Planning and preparation	Implementation	Tools
<ul style="list-style-type: none"> ● Problem: the organizational behavior (difficult interpersonal relationship, unsatisfactory team working and communication barriers, commitment as well as insufficient personnel training in performing the tasks); ● Solutions: <ol style="list-style-type: none"> 1) supporting the development of employees in order to work effectively in small groups, solving problems, documenting and improving processes, collecting and analyzing data, and self-managing within a peer group, 2) involving all employees in the process improvement by achieving consensus, 3) lean training and set up of lean team. 	<ul style="list-style-type: none"> ● practical approaches and daily small scale changes; ● pushes the decision making down to the employees responsible for the task or process and requires open discussion and a group consensus before implementing any decisions; ● seek out and investigate innovative consistent with the philosophy of continuous improvement. 	<ol style="list-style-type: none"> 1. Standardized work sheet; 2. Time observation sheet; 3. Cycle time; 4. Standardized work combination sheet; 5. Capacity sheet; 6. Kaizen sheet.

Figure 4.1 - Kaizen method

Figure 4.1 shows a set of actions divided into three main steps. The first step Planning and Preparation is based on problem identification. As it can be seen in the table the problem in case under discussion is related to the organizational behavior. In order to eliminate the waste I propose a set of solutions which have to be implemented on a daily process. Further, the Implementation step has to be directed towards continuous improvement by placing the people and their needs as one of the priorities for SABCA Limburg.

As a long term solution in order to speed up the manufacturing process of MOV3L COMP within Cleanroom1 it is recommended to use a Kaizen strategy. First of all in actual settings in Cleanroom1 individual actions within the process have to be eliminated thus the set-up of a lean team should be charged with practice Kaizen activities. Therefore, a team should be established in Cleanroom1 and they should practice Kaizen activities as a team.

In order to calculate and measure the results of implementation a set of tools presented in the table above is required. If the following three questions can be answered YES: *Is the data statistically different from BEFORE and AFTER? Are the reasons for the change understood and favorable? Is the AFTER behavior expected to represent the future performance in the longer term?* (Six-Sigma-Material - SSM, 2015). Then these limits of the process can be used in the Control Plan for future monitoring. If you cannot answer YES to all of the above criteria then the Process Owner should have a guide in the Control Plan that identifies corrective action and ideas for the special causes. The process is probably not mature or in enough control to use recalculated control limits. Process control should be done before assessing final process capability (SSM, 2015).

Moreover, according to the working Japanese philosophy Kaizen is a daily process whose aim goes behind the simple improvement of productivity. In this context I would say that the accomplishment of Kaizen within Cleanroom 1 imposes practical approaches and small scale changes with regard to a continuous process. By using Kaizen SABCA Limburg can be able to accomplish big change. However, the people not always agree with the philosophy of Kaizen considering this strategy difficult and hard to achieve it. Thus, the use of numbers and pictures to explain Kaizen could be a practical way to understand it.

At the end of the improvements within the process it may be necessary to calculate new process control limits in order to make these limits the triggers for corrective and preventive action. Once the solution has resolved the problem, the improvements must be standardized and sustained over time. The standard-operating-procedures may require revision, and a control plan should be put in place to monitor ongoing performance. The team transitions the standardized improvements and sustaining control plan to the process players and closes out the project (SSM, 2015).

4.3. Recommendations

The present research work relied on the analysis of primary and secondary sources I believe however, that further analysis focusing on testing LSS methods and tools analyzing the organizational culture within different organizations taking in consideration more aspects of employees behavior is necessary. The further examination of LSS methods across organizational culture will help for a successful implementation and overall business success.

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