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Escola de Engenharia

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Appearance and evolution of Lean-Six-Sigma. Crucial tools in waste reduction and process variation

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Aparecimento e evolução de Lean-Six-Sigma. Principais ferramentas na redução de desperdício e variação do processo.

Resumo

Lean-six-sigma é atualmente uma das filosofias mais utilizadas em todo o mundo nas mais diversas áreas e responsabilidades. É originada a partir de duas outras filosofias, Lean manufacturing e Six-sigma.

A filosofia Lean manufacturing teve o seu início na indústria automóvel, sendo as suas origens associadas á produção Toyota. logo depois da II Guerra Mundial. Lean manufacturing é utilizado uma vez que melhora os processos produtivos, e é capaz de aumentar a satisfação dos operadores.

Six-sigma é por sua vez uma filosofia para melhoria do negócio, que foi desenvolvido mais tarde por Bill Smith nos anos de 1980 na Motorola. Esta filosofia tem como objetivo encontrar e eliminar as causas dos erros e defeitos no processo reduzindo para tal a variabilidade do mesmo, focando nos outputs que são importantes para os consumidores dos produtos.

O objetivo desta dissertação consiste em tentar perceber quando a filosofia Lean manufacturing e a filosofia Six-sigma, passaram a ser pensadas como uma filosofia apenas. A filosofia Lean-Six-Sigma. Verificar e identificar qual é o corrente desenvolvimento desta filosofia, e quais são as ferramentas mais reportadas utilizadas por esta. Para tal vai se recorrer a uma análise sistemática da literatura.

A filosofia Lean-six-sigma foi pela primeira vez mencionada por Michael L. George em 2002, e rapidamente foi espalhada por todo o mundo. É uma filosofia utilizada atualmente nas mais diversas áreas e ajuda as na melhoria da eficiência e redução de desperdícios nos mais diversos processos, com o objetivo de qualidade e eficiência na produção e qualidade de produtos e serviços entregues ao cliente. Para tal atualmente as ferramentas estatísticas são das mais utilizadas durante a implementação e utilização da filosofia Lean-six-sigma.

Apesar de ser uma filosofia reativa, a realidade é que esta filosofia, apresenta todas as características para continuar a ser uma filosofia bem-sucedida, visto que é capaz de colmatar as fraquezas que as duas filosofias individuais tinham, e uma das mais poderosas filosofias a identificar desperdícios e oportunidades de melhoria.

Palavras-chave

Lean-six-sigma; Lean manufacturing; Six-sigma;

Appearance and evolution of Lean-Six-Sigma. Crucial tools in waste reduction and process variation.

Abstract

Lean-six-sigma is currently one of the most used philosophies worldwide in diverse areas and responsibilities. It originates from two other philosophies, Lean manufacturing and Six-sigma.

The Lean manufacturing philosophy began in the automotive industry, and its origins are associated with Toyota production. Shortly after shortly War II. Lean manufacturing is used as it improves production processes and can increase operator satisfaction.

Six-sigma is, in turn, a philosophy for business improvement, which Bill Smith developed in the 1980s at Motorola. This philosophy aims to find and eliminate the causes of errors and defects in the process reducing its variability, focusing on the outputs that are important to the consumers of the products.

This dissertation aims to try to understand when Lean manufacturing and the Six-sigma philosophy began to be thought of as just one philosophy. The Lean-Six-Sigma philosophy. Check and identify what is the current development of this philosophy and what are the most reported tools used by it. To this end, it will use a systematic review of the literature.

Michael L. George first mentioned the Lean-six-sigma in 2002, and it quickly spread across the world. It is a philosophy currently used in the most diverse areas and responsibilities. It helps improve efficiency and reduce waste in the most diverse varieties, with the objective of quality and efficiency in the production and quality of products and services delivered to the customer. For this, currently, statistical tools are the most used during the implementation and use of the Lean-six-sigma philosophy.

Despite being a reactive philosophy, the reality is that this Lean-six-sigma philosophy has all the characteristics to continue to be successful since it can overcome the weaknesses of the two individual methods, Lean manufacturing and six-sigma. One of the most potent philosophies is to identify waste and improvement opportunities.

Keywords

Lean-six-sigma; Lean manufacturing; Six-sigma;

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1. Introduction

The present dissertation is an extensive review of the philosophy Lean-Six-Sigma realized within the scope of the curricular unit "Dissertation" from the master's degree in engineering and quality management. This chapter's goal is to introduce the theme through the framework and the objectives of this project. At least it also presented the dissertation structure.

1.1 Framework

The term Lean-six sigma is used in the current industrial context. This philosophy is the intersection of two other methodologies. When do these junctions happen? Where begin? Why begin? In what industries does this philosophy have more impact? What are the quality tools used in this philosophy? Some of the questions will try to answer in this thesis.

Henry Ford once said: "The customer can have anything they want, as long it is a black T Model".

This why? Because all the factories had to rebuild to change the product design. At that time, Ford's industries were well adapted to the technology and market conditions of the time, which allowed Ford's industries to dominate the market. However, they have incredibly inflexible manufacturing (Milgrom & Roberts, 1995).

Sometime later, Toyota's Manufacturing had a wholly different strategy in the other corner of the world. On each assembly line, Toyota's Manufacturing can produce thousands of different variants of essential products. Only made products that are for customers' orders and can quickly shift over these lines to create new models (Milgrom & Roberts, 1995).

One of the few similarities is that both manufacturers are capable of producing over three hundred and fifty variants of engine and transmission combinations on a daily, ongoing basis (Milgrom & Roberts, 1995).

Toyota's flexible manufacturing and a whole new characteristic was the architect of a new philosophy called Lean Manufacturing (LM). Its idealization began after World War II when the Japanese felt an enormous material shortage, financial difficulties, and a lack of human resources (Womack et al., 1990). Due to this shortage, the most prominent Japanese managers seem obligated to develop a new system-oriented process, principally more disciplined.

Lean manufacturing improves production processes and increases operators' satisfaction (Singh et al., 2010). It differs from traditional production as it focuses more on the organization's inventory, while Lean Manufacturing philosophy is opposed to these same inventories since it considers them a waste.

The LEAN philosophy focuses on cost reduction, eliminating activities that do not bring value to the product. For this, it is necessary to balance the various workstations and the connection between them so that the next workstation immediately consumes the product that leaves one workstation until the entire production line is completed (Meade et al., 2006). Several industries have been applying the LEAN philosophy, from the automotive industry to the consumer goods industry, including the food industry (Abdulmalek & Rajgopal, 2007) (Saurin et al., 2012).

By the years of 1980s, the philosophy Six-sigma start appearing in the world. At this time, the automotive industry in the United States of America is suffering and is almost destroyed. (Montgomery & Woodall, 2008)

So, by the year of 1980s, Bill Smith at Motorola developed a philosophy for business improvement, which is called Six-sigma (Snee, 2010). It also appears in the time that exists a profound growth in the use of diverse statistical methods to control and analyze quality parameters, production or business data all over the world (Montgomery & Woodall, 2008).

Six-sigma's name comes from the Greek letter Sigma, σ, which is used in statistics to measure the variability of any process (Pyzdek et al., 2010). So the name six-sigma suggests a goal of 3.4 defects per million opportunities (Costa et al., 2018). This philosophy aims to find and eliminate the causes of errors and weaknesses in the process, focusing on the crucial outputs to consumers (Snee, 2000).

Six-sigma is almost one response from the United States to the philosophy of Lean Manufacturing that began in Japan. Both methods in different times and countries help the developers to resurrect their production and improve the quality of the final product. The ultimate goal is "process excellence" for the improvement of companies (Snee, 2010).

Nevertheless, in history, manufacturing companies have begun to understand that both philosophies could be complementary.

So, by the year 2002, it appears for the first-time new philosophy, Lean-six-sigma, was first mentioned by Michael George in his book. Lean-six-sigma philosophy has quickly spread to the most diverse companies worldwide since 2002. Was and is used by the management leadership to improve the organization's performance more efficiently (Munteanu, 2017).

Lean-six-sigma is a result of the fusion of two other methodologies, Lean manufacturing and Six-sigma philosophy. Effects of the combination of the strong points of each method, the capability of Lean manufacturing to identify and eliminate waste and the capacity of the Six-sigma to control and analyze each process in detail. The main goal of Lean-six-sigma is process improvement. With this improvement, the aim is to reflect in the saving of the costs and increase the company's competitivity. All the improvements should be made focusing on the customer's necessities, desires and feedback (Munteanu, 2017).

The lean-six-sigma philosophy can achieve better results than the two philosophies that originate from Lean-six-sigma separately. This new philosophy also focuses on the commitment of the management and the company's collaborators, which is also a factor of success for Lean Six-sigma. This relies on the fact that Lean-six-sigma integrates the human element with the process improvements (Antony, 2011).

Twenty years later, this continues to be one of the most known methodologies. Not only applied to engineering processes but also other processes in the corporate world. The success of the implementation of this philosophy continues to rely on the capability of the implementation team to motivate and explain how this philosophy can bring benefits to all the intervenient in the process's company.

1.2 Objectives

This dissertation aims to try to understand when the Lean manufacturing philosophy and the Six-sigma philosophy started as just one philosophy. Hence, the Lean Six Sigma philosophy. First, check and identify the current development of this philosophy, Lean-Six-Sigma, and its most reported tools. For that, it will resort to a systematic review of the literature, using a PRISMA approach, to obtain the results (Moher et al., n.d.).

With the literature review, we will try to answer questions such as: When? Who? Which sectors of activity use the most? This philosophy? What type of problems do they solve? What are the most popular tools? These questions and keywords will be used to guide the bibliographic research for the literature review.

The expected results are a systematic and transparent review of the literature so that any other investigator trying to use the same temporal markers, keywords, or different types of features if using the same conjugations will find the same bibliographic results.

1.3 Dissertation Structure

The present dissertation is divided into five chapters.

The initial chapter presents the introduction to this dissertation project through the theme framework, the objectives for this dissertation and the presentation of the dissertation structure.

In the second chapter, the reader can have a resume of each philosophy's state of the art. The Lean manufacturing philosophy and six-sigma philosophy. Moreover, this dissertation focuses on the philosophy originated from the junction of these two methodologies, the Lean-six-sigma philosophy. All the philosophies are characterized by a brief framework of each philosophy, focusing on the history of the appearance and the principles. Finally, lean manufacturing and six-sigma philosophies are presented as the principal wastes and most used tools, considering only these philosophies separately.

The third chapter is described the research philosophy used to perform this dissertation.

The fourth chapter is presented all the results of the research performed. For example, it shows the principal industries that used the Lean-six-sigma philosophy and documents. It also suggests which problems are more familiar with this philosophy and the most used tools to solve them. The reader will also be able to verify the most cited outputs and results from implementing the Lean-six-sigma philosophy.

Lastly, the fifth chapter presents the conclusions of the research performed and the outcome obtained.

2. State of the art

Over time, the philosophies were studied and improved. Prove of this is the junction of two different methods.

This chapter is dedicated to showing the state of the art nowadays of the two philosophies that originated the philosophy "Lean-six-sigma", Lean and Six-sigma.

2.1 Lean Production

Lean was one of the most prominent philosophies in the industry. This sub-chapter’s aim is to categorize the philosophy: how it started, the philosophy principles, what the philosophy considers waste and which tools are primarily used in the philosophy.

The most common use of Lean is Lean production. Until today the use of Lean is more easily performed in the production area, being this way the most area on industrial fields that use this philosophy. For this reason will be more considered in this document, comparing with other Lean applications.

2.1.1. Lean history

In the last decades of the 20th century, the world witnessed another fundamental redefinition of the patterns of strategy, organization, and manufacturing firms (Milgrom & Roberts, 1995).

"The machine that changes the world" (Womack et al., 1990), the book published by Paul Womack, recognized the philosophy of Lean Manufacturing as a management philosophy and as world-class manufacturing. Since this publication, several other authors have focused their investigation on Lean Manufacturing (Henao et al., 2019).

Lean manufacturing was first implemented in the latest 1940 years in the Japanese automobile industry. Still, since the final decades of the 20th century, the philosophy has been spread internationally and to other sectors. The fundamental characteristics of this philosophy are flexibility, speed, economies of setting, and the development of core competencies (Milgrom &

Roberts, 1995). Furthermore, this philosophy focused on total quality, globalization, object-oriented, and process-oriented approaches (Rolstadås, 1995).

In the latest 1940 years, the Japanese are experiencing an enormous shortage of materials and people after the II World War. So, the automotive companies in Japan must overcome these difficulties. One example was the Toyota Motor Company, which originated the Toyota Production System (TPS), known as the Lean Manufacturing philosophy.

Toyota had to overcome challenges, like a ten-to-one production gap compared with American manufacturers, the smallest domestic market also the result of the II World War, the new trend from outside car manufacturers that were intending to establish an operation in Japan, and the intervention in labour disputes from the Americans (Womack et al., 1990). To overcome these challenges, Toyota started innovating its manufacturing methods. In 1946, Toyota modified its factory floor to allow its workers to operate various machines simultaneously. One year later, they accomplished that each worker worked on an average of two devices each (Gronning, 1997).

By 1951, they already had standardized work, created written procedures for each job, and promoted workers' capability to do different techniques (Gronning, 1997).

Toyota was invented at this point, and some of the essential concepts, like Just-in-Time (JIT) production, the Kanban "pull" supply systems (Sugimori et al., 1977), a Total Productive Maintenance (TPM), where they have an employee-involved method, to guarantee an improving machine performance (Suryaprakash et al., 2020). Moreover, the 5S process was created to allow a cleaner and more efficient workspace (Goswami et al., 2019).

Already in 1973, in the middle of the “1973 Oil Crisis”, the Japanese economy fell under the effects of a recession. However, Toyota was posting greater profits than other companies. (Ohno, 1988) So Toyota received more significant attention than all other automotive companies in Japan. In the latest 1970 years, Just-in-Time production was adopted by all Japanese automotive companies (Nakamura et al., 1998).

By 1980, Toyota and some other companies that adopted their philosophies had become so competitive using the method idealized by Toyota that they gained a 22,2% market share in US passenger car sales (Holweg, 2007).

Compared with American cars, Japanese companies presented vehicles in the United States at lower costs and higher quality. This difference is possible due to the production control systems that Japanese companies use (National Research Council, 1982).

After losing the market share, the American industry became more focused on which philosophy was using the Japanese automotive industry, trying to understand if this philosophy could be adopted in the United States. Lean manufacturing received enormous attention in the late 19th. In the occident, people are trying to understand what is making the Japanese superior in manufacturing and quality (Rolstadås, 1995).

Many companies try to implement this philosophy. However, not all were successful on the first try of implementation. For example, General Motors 1980 spent more than eighty billion dollars on robotics and other capital equipment, typically associated with the Lean Manufacturing philosophy. Unfortunately, it was unsuccessful in this implementation. Why? Because although the investment, they did not make any adjustments to the human resource policies or this basic manufacturing procedure, decision systems, and product development processes; without these changes was not possible to successfully implement the Lean philosophy. The result was a loss of those billion dollars. So, in the early 1990s, General Motors had assembly lines that should have been the most flexible in the world, producing only a single model (Milgrom & Roberts, 1995).

Companies must understand that Lean Manufacturing is only possible with efficient and lean-oriented management.

2.1.2. Lean principals

Several authors try to identify and describe the Lean principles.

Milgrom and Roberts, in 1995, at the beginning of the expansion of Lean Manufacturing, identified some principles for this philosophy. The codes are flexible machines, low set-up costs, low inventories, short production runs, recurrent product improvements, targeted markets, highly-skilled, cross-trained workers, cross-functional development teams, worker initiative, local information and self-regulation, horizontal communication, continuous improvement, enunciation on cost and quality, demand management, make to order, extensive contacts, long-term, trust-based relationships and reliance on the outside supplier (Milgrom & Roberts, 1995).

Rolstadås, in 1995, defended that the principal focus is the customer and that all the company activities must add value for the customer. Furthermore, the product delivery to the customer has to have high quality. However, the price has to be the minimum possible with the shortest delivery time (Rolstadås, 1995).

However, some principles implied in the Lean Manufacturing philosophy are the agreement between the companies, the suppliers, and the customers. Why? Because without that, some principles of the Lean methods are not possible. The suppliers must agree to supply smaller quantities more often. This agreement is possibly a reduction in the inventory. However, this demands constant communication between the supplier and the companies (Huson & Nanda, 1995).

So, all the principles of the Lean Manufacturing philosophy can be summarised as follows:

Value Identification – The product's value should always be defined from the customer's perspective once the customer represents the value of a product or a service (Thangarajoo & Smith, 2015).

Value stream definition – To create value is necessary to concentrate on the activities that bring value to the process, product, or service. Therefore, the idea is to define these activities and eliminate all the activities that are considered waste (Hines, Holweg, & Rich, 2004).

Production "Pull" Implementation – The production of one or various products has to be "pulled" by the customer. Only when the customer orders a product is this production started, the principle of the Just-in-time tool (Liker, 2004).

Continuous Flow – After the elimination of all the wastes existents in the value chain is obtained, a constant flow (Thangarajoo & Smith, 2015).

Pursuit of perfection – With all the four principles described before, the companies transformed their processes into more transparent, without waste, being the embodiment's aim (Thangarajoo & Smith, 2015).

2.1.3. Lean Types of waists

All the activities in the company should have value to the customer. Everything the customer is not paying the company is a waste; once, they represent a waste of resources.

Lean manufacturing philosophy determined seven types of waste that should be eliminated (J. Ben Naylor, Mohamed M Naim, 1999). These waists are excess inventory, waiting, defects, overproduction, unnecessary transportation, movement and material handling, and over-processing (Ohno, 1988).

One of the most know waste is the company's excess inventory. All the raw material or the final product that remains in the company's installations for too long does not create incoming. The raw material can never be used, and the final product can never be bought, and both situations make the companies lose money. For example, in an ice cream factory, if they make too much ice cream that they cannot sell in a short period, the company must invest in freezers, more space to put these freezers, and the electricity wasted will be increased (El-Namrouty & Abushaaban, 2013). All this spending does not bring value to the final product (Melton, 2005).

Over-production is a waist linked with excess inventory. As set before, one of the principles of Lean Manufacturing is the "pull" production, being this "pull" made by the customer. Over-production, on the other hand, does not wait for the customer's order and produces quantities superior to the charges when this is not necessary. Then the companies must exceed their inventory (Dailey, 2003).

The waiting time, the most common and more time expensive, is the set-up time. They are a waste that most companies try to reduce. Lean manufacturing promotes the same assembly line's capability to produce more than one product. In other words, the assembly line needs to make set-ups to change between products. This time between changes, Lean Manufacturing is considered waste and has to be reduced to the minimum. Making the set-ups more efficient or using other tools to minimize the need for set-ups is time-consuming and expensive, and it made the set-up on-site (Huson & Nanda, 1995). So it must be the aim of all the companies to reduce this time waist. To do that, Womack, from the begging, proposed that using technology was a better way to do it (Womack et al., 1990). The maintenance time due in the labour hours, making the operators have to stop what they are doing, is a waste of time.

Another waste is the transportation of materials. Again, some vehicle does not bring any value to the final product. For example, when the workstation is far apart, the materials must go between the workstations. This transportation is not paid for by the last customer and does not bring any value to the product. Some ways of minimizing or eliminating this waste are modifying the floor plan layout to get the workstation closer or evaluating the necessity of two workstations (El-Namrouty & Abushaaban, 2013).

Over-processing is another type of waste. This typically happens when the production is making a redundant effort. This effort can be over communication or output, which one more time does not bring any type of value to the product (Dailey, 2003). This type of waste can be visible when the companies use, for instance, quality control complexes when the process is very simples. Much of the time, the quality control could be more straightforward, the reflection of the process.

If everything was made well the first time, the defects do not happen. Furthermore, defects are another waste in Lean Manufacturing. It can appear from diverse sources that can be controlled or minimized for the error does not occur. Defects lead to costs. Immediately or in the long term, once require rework or more extreme offscourings of the products (Wahab, Mukhtar, & Sulaiman, 2013). For example, one source can lead to defects in equipment maintenance. Incorrect maintenance can lead to errors in the equipment that can cause either major or minor defects.

Movement and material handling express any movement of people that does not bring additional value to the product (Dailey, 2003). Similar to the type of waste transport, one of the principal causes of this type of waste is the layout of the plant floor, which brings unnecessary motion to the worker.

2.1.4. Lean Most used tools

The use of several tools permitted to achieve the leanest manufacturing possible. The use of several tools and several techniques allows for reduced inventory, enhanced quality, reduced lead times, and prevented waste.

Some techniques that can achieve these goals are using small batches in production, shorter lead times, reducing set-up times, and more frequent deliveries with smaller orders (Huson & Nanda, 1995).

So, several tools are used. The most used tools maintained in the current days are Kanban, 5S, Kaizen, Value Stream Mapping, and Just-in-time, which are some of the devices.

Kanban systems are one of the tools of Lean Manufacturing that can allow companies to achieve the minimum inventory possible. Using this tool, companies have many advantages in improving their operations and business. For example, it can be used in the production line to make strategic decisions about production, improve productivity, and minimize waste in the production line. In addition, this tool requires only producing something when there is a customer demand internally or externally (Rahman et al., 2013).

Another Lean tool is 5S. It is primarily used and mainly utilized in designing efficient facilities. Many applications can be used alone or with other Lean tools, for example, to decrease changeover times (Bevilacqua et al., 2015). The 5s stand for Sort (Organize), Set (Label), Shine (Clean), Standardise, and Sustain (Ramdass K., 2015).

Value Stream Mapping is a tool that uses paper and a pencil. It is used to improve the production system. For that, identify and eliminate all the activities that do not bring added value to a product family (Garza-Reyes et al., 2018). Value Stream Mapping is a tool used to determine the current state of a process using Lean philosophies to develop a process improvement for the future (Midilli & Elevli, 2020).

Another tool largest used in Lean Manufacturing is the Just-in-time tool. Huson e Nanda, 1995 studied the impact of this tool on the performance of some companies in the US. This tool will only improve the performance of companies if the savings in inventory costs and the growth in revenues outweigh the increased costs from direct manufacturing. However, it is a fact that using this tool allows companies to be leaner (Huson & Nanda, 1995). This consists of producing the product only when the customer orders and in the exact quantity that the customer orders.

Kaizen is a Japanese philosophy/tool that promotes minor improvements instead of bigger and expensive ones. These little improvements are made due to a continuing effort. Therefore, everyone in the organization must be involved, from the management to the operator on the plant floor. Moreover, by promoting these minor improvements, the kaizen tools ensure that the continuous improvement for these minor improvements allows for long-term and consistent progress. Also, minor improvements demand less money and less effort for the organization to achieve the improvement (Maarof & Mahmud, 2016).

2.2 Six-Sigma

Six-sigma appears years later in Lean manufacturing. Follow Lean manufacturing as one of the most prominent philosophies of the industry. This sub-chapter categorises the philosophy: how it started, the philosophy principles, what the philosophy considers waste and which tools are primarily used.

2.2.1. Six-Sigma history

Six-sigma is a statistics-based philosophy aiming to achieve nothing less than the perfect for every single process or product (Paul, 1999).

Six-sigma could be categorized as a disciplined philosophy that executes a collection of rigorous data and performs a robust statistical analysis to identify the principal sources of error and eliminate the errors or waste (Harry and Schroeder, 1999).

In the mid-1980s, engineer Bill Smith developed a new philosophy called Six-sigma at Motorola (Snee, 2010). They immediately had success, so their CEO, Bob Galvin, began applying Six-sigma to all Motorola organizations, concentrating on systems and manufacturing processes (Montgomery & Woodall, 2008).

The philosophy's success was so huge at Motorola that between 1987 and 1993, it was calculated that it exited a reduction of 94% in defects in semiconductor devices (Montgomery & Woodall, 2008).

In 1988, that Motorola won the Baldrige National Quality Award, an award recognizing their effort in reducing their defects and improving their quality. After that, an enormous push exists by Motorola CEOs to promote Six-sigma in the organization and outside of this. Six-sigma was primarily used in the industry and business strategy, not only in the USA but across the world (Snee, 2010).

Although the appearance of the six-sigma started in the mid of 1980, only in 1998 did the term six-sigma appear and was used by Johnson & Johnson.

Nowadays, Six-sigma has spread around the world. It is a philosophy that helps companies improve their quality, reduce costs and expand markets for products and services (Montgomery & Woodall, 2008).

The six-sigma goal is to reduce or eliminate the process's variability and remove the waste using statistical tools and various techniques. It is considered that if six Sigma is well implemented in a company, this will allow continuous improvement (Bañuelas and Antony, 2002).

They are reducing the variability of the process and ensuring that a reduction or maintenance of the process variability always ensures the customer the product's quality. For customers where the safety and quality of the products have to be higher, the exigence for their suppliers to have or implement some six-sigma philosophy is enormous.

Six Sigma can be defined as a program for quality improvement with the primary goal of reducing the number of defects to as low a point as 3.4 parts per million opportunities, the equivalent of 0.0003% of defects (Chakrabarty & Tan, 2007).

Six Sigma represents the amount of variation in a process, so Six Sigma has several levels that any company process or product can achieve. These levels represent the amount of variation in a circle or product that can originate errors (Chakrabarty & Tan, 2007). These levels can have several different interpretations or meanings (Henderson and Evans, 2000). Examples from these levels are, for instance, the stories of the defects for millions of opportunities. The statistical approach of six-sigma tries to reduce a process that stands in tree-level sigma, the equivalent of 66,800 defects per million opportunities, to the six-level Sigma, which is the equivalent of 4.0 defects per million opportunities (Bolze, 1998). Six levels exist in six-sigma, the six-level Sigma, which all companies should aim to achieve.

Some industries can also be a requirement for companies that want to be certified to have statistical control in their processes. With time, companies and the philosophy started growing, and the formation and knowledge of the person about the six-sigma divided into levels. There are five levels: white belt, yellow belt, green belt, black belt, and the last Master black belt.

One person with white belt knowledge understands the basic concepts of six-sigma, which allows participation in local problem-solving teams and supports the overall projects. However, in most companies, this level does not allow the person to participate in the Six-sigma project team.

The yellow belt is a superior level compared with the withe belt level. At this level, the person has a little more knowledge about Six-sigma, which allows the person to participate as a member of the project team Six-sigma project and is capable of reviewing the process improvements and supporting the project.

At the green belt level, the person can know green belt projects or teams, and this person has enough knowledge to help and assist in Black belt projects, thorough analyses, and data collection.

At a black belt level, the person can lead problem-solving projects, train another person in the six-sigma certification, and coach another project team.

The last level of certification in six-sigma is the Master Black belt. At this level, the person is capable of training and supporting black and green belts. In addition, this person can act like an internal consultant or an organization's six-sigma technician. This person can also develop critical metrics and new strategic direction.

2.2.2. Six-sigma principals

Six-sigma is a philosophy aiming to reduce waste, increase customer satisfaction, and improve processes or products, always with good measurable financial results. (Goh, 2002) So, six-sigma presents five central principles: customer focus, eliminating defects and outliers, involving stakeholders, accessing the value chain, finding the problem, and having a flexible and responsive system.

One of the essential principles of six-sigma is Customer focus. In this principle, the six-sigma tries to maximize the benefits that the customer can take from the product or service. To have a successful business, entrepreneurs must understand that the customer needs and desires a successful business. So is necessary, and six-sigma tries to achieve this by establishing quality standards according to the customer demands and the market.

Six-sigma is a statistical tool focusing on facts and data to achieve the best quality and productivity. Being a statistical tool, the six-sigma analyses all the processes, defining the goals for the data collection and identifying the purpose for each data collection. The statistical analysis of the collection date allows us to verify if the data collected is enough to assist in the purpose goals or if more information will be needed. Furthermore, with all the data, six-sigma allows for identifying the problems in the process and the root causes that leave the problems, defects, or outliers.

So, eliminating defects and the outlier of the process is another essential principle in six-sigma. After the process analyses, with the collected data is possible to modify the operation to eliminate defects. Usually, it begins with removing activities that do not bring any extra value to the customer. If the data collected cannot reveal the problem or root cause, several tools can be used to find out the problem of outliers in the process. The elimination of outliers or defects can remove the bottlenecks in the process.

In companies, the root causes of a problem or defect can sometimes be complex. Therefore, another principle of the six-sigma is involving stakeholders in problem resolution. This happens once the most challenging issue can necessitate the most complicated solution that, many times, only the stakeholders can allow. The solution problem teams must be competent in the applied philosophies and principles. Most of the time, these competencies must be patrocinated by the stakeholders once this specialized knowledge and training are required, even the minor problem or root causes.

The last principle of the flexible and responsive system determines that the companies must ensure that their employees understand and practice flexibility, allowing their design to be responsive to the implemented changes. Because only with these police and principles can the companies be efficient in implementing the changes in the processes. The persons involved in the projects should adapt quickly to the changes.

Companies that frequently invest in data collection and analyses to adapt their process can achieve higher compatibility.

2.2.3. Six-Sigma Types of waists

Six-sigma defines eight types of waists that should be eliminated: zero value processes, overproduction, movement, transport, inventory, defects, and unused employers' talent. This type of wait does not bring any value to the product or the customer, so it should be eliminated to reduce costs in the productive process in the companies.

Six-sigma is defined as a philosophy that only focuses on the processes that can bring value to the customer and the quality of the product. Everything else is a waste. This happens when a new step in the process does not bring any value to the product. These are the cases of quality tests that do not get any deal to the product, only ensure the producer that the product is without any defect. Six-sigma tries to eliminate these steps without affecting the quality of the product. To do that, use observation and analysis tools.

Production is another waste from a six-sigma perspective. This happens when the companies produce more products than what will be consumed by the market. The companies, in this case, are not only consuming resources as raw material but are also consuming time and effort to produce excess material. Without necessities in the market, this excess of products will cost the company unnecessary inventory. This will not bring any extra value to the quality product. Moreover, it can decrease the quality of production value.

Another type of waste is movement. Any step in the process which have any unwanted activity is undesirable. This is because the move will create a time lag due to the action of persons and can also bring the company transport charges. One example of movement is an employee that must move to another department or floor to access one tool that he needs daily and more than once daily.

Transport is another waste to six-sigma. Transport happens when the companies must transport a product without need. This is most of the time because the companies do not correctly plan the project or layout of the floor pant. One example of this happens when the floor plant's layout is inadequate; the employers must transport the product to continue the process.

Also, Lean six-sigma considers that inventory is a waste. This type of waste is primarily related to another waste, overproduction, or can be linked to an excess of raw material. When excess raw material that the company will not use in the nears time, the extra raw material leaves directly adds to the store and can also bring transportation expenses if the company must increase the warehouse or, in other cases, reallocate the warehouses.

Defects are also a waste. Products with defects will increase inventory waste. These defects can be repaired but will need extra resources to do so. This process does not bring any value to the customer, making it a waste to the customer and the company. More severe defects can lead to the need for scrap on the product and increase the scrap inventory. None of these scenarios is favourable to the companies. Six-sigma tries to ensure that the process is stable to guarantee that do not produce any products with defects and, if produce products with defects are immediately identified, stop and analyze the process.

Six-sigma promotes the continuous formation and flexibility of employers. So six-sigma is a waste if the employee's talent and appearance are not used correctly and at the correct time, and it can happen when the management does not facilitate the continuous formation of the employees or does not motivate them correctly.

2.2.4. Six-sigma Most used tools

All the tools or techniques used in the six-sigma philosophy are oriented to statistical calculation. Using many devices that allow statistical process control. (Ferrin et al., 2005)

The idea is to verify mathematically what waste is and try reducing or eliminating it through continuous improvement, which can be applied in different contexts. However, six-sigma is focused on the customer, supported by a well-defined philosophy with a group of tools that allows process improvement.

The principal focus of six-sigma is reducing the variability in the process. (Van Iwaarden et al., 2008)

Reducing the variability, six-sigma can assure the customer of the product's excellent quality and guarantee that the companies produce products between the established parameters.

Six-sigma have methodologies such as DMAIC and more recently, new methodologies such as Design for Six-sigma (DFSS), Identify Design Optimize and Verify (IDOV) have appeared.

These methodologies, appeal to some tools to achieve their results.

Six-sigma tools are flowcharts, Pareto diagrams, cause-effect diagrams, regression analysis, Defects per Million Opportunities (DPMO), Parts per Million Defective (PPM), control charts, and experiences design (Ferrin et al., 2005).

For six-sigma, the person or company will be able to use their methodologies according to their level of knowledge and certification. It will be essential to understand that, although six-sigma presents numerous tools, frequently, the simple tools are enough to reduce or even eliminate the defects of a complex manufacturing system in the initial stages (Raja, 2006).

One of the most known methodologies used in six-sigma is DMAIC. DMAIC stands to Define, Measure, Analyse, Improve, and Control. These are the five steps for this tool. This tool is utilized in existing processes/products. It is one of the most used techniques once these tools allow the companies to understand which approach they must follow to solve the problems and apply the right tool (Tjahjono et al., 2010).

DMAIC is a structured problem-solving method. Have 5 phases and have the goal of implementing long-term solutions to problems. In the define phase, the tools allow the team to define the situation succinctly and accurately. One this phase, the team must also identify the final customer and their requirements to determine the skills and areas that need to be worked on. In this phase, the team must be correctly formed, and the problem must be defined. In the measure phase, the team must recognize and document the process. The measurement systems are identified or can be developed if the process does not have any. If necessary, this system can be improved. After this phase starts analyzing, the team must identify the critical inputs with the data collected in the previous phase. With the results from this phase, the team can move forward to the next phase. In the improvement phase, the team has to determine which possible solutions they must improve the process. In this phase, the process must be optimized. The last phase is the control phase, and this phase starts when the process is optimized. In this phase, the team must define mistake-proof, long-term, and in the last case, reaction plans. To ensure that it moves forward process is continually optimized and improved. In this phase, the team has to create standard operating procedures and establishes process capability (Berardinelli, 2016).

Some tool that can be used in the six-sigma approach is flowcharts. A flowchart is a picture of all the steps for a process in sequential order. It is a standard tool that can be used for various purposes and functions. It is one of the most common process analysis tools. This process description can include actions, materials, or services (inputs or outputs). It can also be included in the flowchart, decision-making, people and time involved in each step, and process measurements.

Another tool is the Pareto diagram. This tool displays information about the relative importance of the factors for a persistent problem. This tool can identify the most critical factors, which must be analyzed first (Sokovic et al., 2005). A Pareto diagram is a bar chart of frequencies sorted by frequency. The most common design used in the Pareto diagram is the highest bars on the left and contains a line showing the scores produced by adding the heights from left to right. This diagram is primarily used in process analyses. Still, it can also be used in control process methodologies once this diagram identifies critical factors leading to failure or defects in a process (Wilkinson, 2006).

One of the most visual tools used in six-sigma is the cause-effect diagram. Another commons name for this tool is the fishbone or Ishikawa diagram. This tool is used to organize possible causes for a specific problem logically. This diagram can display the possible causes graphically and increase the detail in the chart, suggesting causal relationships between theories. This tool is used in the early stages of an improvement process. The team can fill out the diagram using brainstorming or an affinity process. The team is investigating the "Effect" and identifying possible causes that can lead to the "effect". The idea is the prioritization the issues and divides them into the six categories in the diagram. The 6 Ms in the chart are Methods, Machines, Materials, Measurements, Mother Nature, and Manpower (Liliana, 2016).

One of the most powerful statistical tools used in six-sigma is the tool regression analysis. This tool is essential for investigating the effect of explanatory variables on response variables. It is a statistical tool most used in almost all areas of knowledge that seek to fit the data in a mathematical model or an experimental data set (de Menezes et al., 2021). This tool estimates the relationships between a dependent variable and one or more of independent variables. With this tool, it is possible to establish the strength between the variables or model the future strength between the variables. The regression analyses include linear, nonlinear, and multiple linear variations. Linear and multiple linear are the most common models. Nonlinear regression is most used to fit the more complicated data sets.

Another tool primarily used in six-sigma is PPM or DPM calculation. This tool focuses on the process defects, making this tool one more accurate tool and a possibility for understanding the process and analyzing the current state of the process. The most common measurements are Defects per Million Opportunities (DPMO) and Parts per Million Defective (PPM). To implement this tool is essential correctly understand the difference between defect and defective. Defects are flaws in an operation or product where more than one defect can be found. Defective stands for a decision that is made that a product is unacceptable. This decision can appear based on an accumulation of multiple defects or only one defect that does not allow the use of the product's safety. DPMO is calculated by the ratio of the number of defects in one million opportunities. In other words, how many times has the company had a defect for every opportunity to have a mistake? For this calculation, the company must know the product very well to identify the opportunities and defects in the product. On the other side, PPM is the ratio between the number of defective units per 1 million units. To calculate PPM, the company should use the number of defective units divided by the total number of the sample size and, after multiplying by 1 million. This tool allows the company to calculate which sigma level the company stands at once; the result of this tool correlates with the sigma level.

Control charts are a graph used to examine how a process can change over time. It can be used as a tool to analyze the process and find out the problem, or it can be used as a control tool after implementing corrective measures. The data must be drawn in time order. Is it possible to find in this chart a central line that indicates the average that is the desire for the process in analysis? One is a chart for control. The chart has two more lines, an upper line for the only control limit and a lower line for the shorter control limit. These lines can be defined following the data collected before or for goals to a determined process. Resorting to the data in the chart is possible to analyze if the process variation is consistent or in control, if steaks are between the lines and close to the average, or if the process is out of control and has peaked out of the defined limits.

Experience design is a tool that is an approach to creating scenarios for an entire process. This tool, well used and defined, can be helpful to solve a problem, control behaviour or stimulate a positive and emotional response. It is a tool that can be applied in already implemented projects or new projects. The difficulty in well define the experience and implementing this tool in black belt projects.

The methodology Design for six-sigma (DFSS) is a similar tool to DMAIC. However, the tools that this philosophy uses different tools to achieve its goals. For Instance, DFSS employs the Identity, Design, Optimize and Verify (IDOV) tool, achieving better results in designing or even redesigning processes or products (Antony and Banuelas, 2002). In addition, these tools typically include innovation tools, such a case of creative problem-solving and evident design. Usually does not happen when companies employ the DMAIC philosophy. (Chakrabarty & Tan, 2007)

2.3 Lean-six-sigma

Lean-six-sigma appeared years later after the needy of the industry to mitigate the faults that both philosophies that originated present. This sub-chapter aims to categorize the new conjunct philosophy: how it started and the philosophy principles.

2.3.1 Lean-six-sigma appearance

Two of the most known philosophies for process and product improvement cross their ways and combinate their knowledge to be one of the most influential and effective waste elimination and process improvement techniques (Spector, 2006). It is the start of Lean six-sigma. Lean Six Sigma is a well-structured philosophy that increases performance and expands effective leadership and customer satisfaction (Snee, 2010).

Since then, that Lean-six-sigma has been a much-used philosophy in business Improvement. This philosophy Works well for process-based problems whose root cause is not recognized. This philosophy is a practical toolkit to improve the quality of products and or services through the reduction of waste and the variability of the process (Lee, McFadden, and Gowen 2018; Sunder and Antony 2018).

Lean-six-sigma was first mentioned by Michael L. George, in 2002, in his book "Lean-six-sigma: Combining Six sigma quality with Lean Speed" (Munteanu, 2017). Quickly this new philosophy spread worldwide.

The fast dissemination occurs due to combining the best elements and qualities of lean (continuous improvement theories) and six-sigma (scientific management). Although both philosophies have produced good results, the truth is that both philosophies have limitations and weaknesses (Snee, 2010).

So, in the early 2000s, companies start to join both philosophies (Snee, 2010). This is because several companies recognized quality products and services due to the use of the six-sigma philosophy but stated to verify that some factors, such as cost and productivity, are increasing with this philosophy (Besseris, 2014). For cost reduction, the Lean philosophy allows the elimination of waste. This is possible once; the Lean philosophy permits the remotion of the on-added behaviour. An essential addition to the six-sigma philosophy, which focuses on the reduction and elimination of defects due the scientific management (Antony et al., 2005). This is why these philosophies are so robust together. They complemented each other. Lean philosophies focus on the information flow and waste reduction in the processes and between two or more processes, while six-sigma is the focus in each process (Singh & Rathi, 2019).

Lean-six-sigma is a philosophy from a business perspective that allows industries to successfully understand their customer desires, reducing or eliminating the variability within the production and trying to eliminate or reduce all non-value-added processes or activities (Singh & Rathi, 2019).

2.3.2. Lean-six-sigma principals

The fusion between the two methodologies, Lean Manufacturing and Six-sigma, originated the philosophy Lean-six-sigma. A new philosophy that combinate all the principles of the two separated philosophies create nine new principles. The principles are managing professionals, analyzing processes and results, managing and controlling processes and results, managing resources, improving processes and results, managing projects, managing information, managing suppliers and long-term planning (Juliani et al., 2019).

The professionals in a company are an essential part of that and crucial for all success that the company can achieve. However, for the professionals to have an active role in the company is crucial that the professionals are managed through training and commitment of all the collaborators, managers, and employers. The training can be planned and systematic to modify or develop the collaborators' knowledge, skills, and attitudes. Everything through learning experiences improves the collaborator's performance in various activities (Shokri et al., 2016). One of the best practices is introducing the Lean-six-sigma philosophy to all the collaborators, managers, and leaders once the training allows everyone to focus on issues such as leadership and resistance to change. Alternatively, even learned how to prioritize a project, communicate better and motivate others or even focus on team building (Antony et al., 2018). It is crucial that the training be continuous and that the organizations be capable of allocating the resources for this continuous training.

With continuous training being realized, the performance and effectiveness must be tracked to verify this and improve if necessary. The tracking also allows an understanding of the effectiveness and the whole range of the improvement on the projects to understand if the project produces accurate positive financial results (Snee, 2010). Also, for good training and practice, during the exercise, the participants should be encouraged to participate and engage in open discussions, with the goal that the members of the Lean-six-sigma improvement team feel comfortable contributing to the discussion (Chakravorty and Shah, 2012). The training and the active practice of the Lean-six-sigma allow organizations to incorporate a culture of continuous improvement in all sectors. This culture results in cost savings, the improvement of the processes, and consequent results (Andersson et al.2009).

The principle of managing and controlling processes and results is one of the essential principles of the Lean-six-sigma philosophy. With the implementation of the new projects, which aim to improve the process and raise the financial incomings, it is important to have teams capable of managing and controlling all the processes involved. Good operations planning can define responsibilities for their collaborators and deadlines and define a plan for how the activities should be performed. This group of characteristics allows constant monitoring of all the factors and the control of how the materials and people move through the process in terms of time, operations and layout (Deithorn and Kovach2018). When well performed, this principle leads to standard procedures, so in the long term, constant verification will not be needed once these practices are based on the organizational culture, guidelines, and prediction procedures (Chakravorty and Shah2012). Is to expect that the standardization of these procedures is made through evidence, which can help the necessary changes for Lean-six-sigma implementation. The evidence can also provide a better knowledge of the procedures due to the evidence's transparency and a better understanding of the company's collaborators (Kieran et al., 2017). All standardized processes can be improved, and standardization is crucial for that, once allowed to identify necessary operations, waste time, and allow the management of the process and the control of the same (Guo et al., 2018). A correct monitorization of the process will reflect improved efficiency of the company's operations, reducing the variability of their process, ensuring the quality of their products or services and eliminating waste in the process (Thomas, Barton, and Chuke-Okafor 2009). This monitorization must be made with pre-established metrics, which must be pondered and crucial for the process once it influences the decisions. These decisions are made by the Lean-six-sigma team, the top managers and the stakeholders, with the monitorization made by a quantitative approach using statistical techniques and lean-six-sigma tools. These decisions must be sustainable decisions that will improve the process performance (Thomas et al., 2016). It is expected that the organization will have the initiative to benchmark other companies in their sector of activity to understand what is made in the market and compare their performance statistically with the results they should be achieving (Improta et al., 2018).

Analyzing processes and results is one of the essential principles in Lean-six-sigma. This principle focus is identifying the root causes of inefficiencies and creating solutions for them. To do that, the companies should create a multidisciplinary team to facilitate the identification of a problem solution (Walker and Davies 2011; Antony et al.2012; Stonemetz et al.2011). These multidisciplinary teams should be formed by people with skills and formations that allow these members to be project facilitators in implementing Lean-six-sigma techniques and the most diverse Lean-six-sigma tools (Delgado, Ferreira, and Branco2010; Gayed et al.2013). The process analysis should always be done in the real work of the process. Only this way, it possibly eliminates some misunderstandings with other processes (Lee et al., 2014). Utilizing the value stream mapping in a multidisciplinary configuration, the team can ensure that they can give correct information and a better understanding of the analyzed process and its objectives. They realize the value of the process and their products from a customer perspective, more efficiently identifying the waste and the variation in the process (Antony et al.2012; Lee et al.2014). After that, the teams can correlate the identified root causes and validate them using some Lean-six-sigma techniques. The Lean-six-sigma techniques well implemented also allow for stimulating improvements, the appearance of new ideas and a more engaged and dedicated workforce (Kieran al.2017).

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In an organization, two types of essential resources exist human and financial. The managing of these resources is another of the Lean-six-sigma principles. The management of human resources is vital for the organization to implement the Lean-six-sigma philosophy (Timans et al., 2012). Furthermore, this is only possible if the organization has adequate human resources that have the goal to implement a spirit of positivity and allows the formation of their team leaders in Lean-six-sigma, relationship, and knowledge transmission, which allow them to be a facilitator for the Lean-six-sigma implementation (Antony et al., 2012). It is essential, however, that all the teams can be efficient, and it is required for the company assure that exists an exemplary environment in the company to try to reduce the dissolution of the team's previous format to implement Lean-six-sigma projects. The changes in the team are difficult to avoid and eliminate; however, they can be reduced (Lameijer, Does, and De Mast2016). Financial resources have an enormous impact on human resources. Once the organization cannot financially able to afford the Lean-six-sigma projects, by not capable of hiring qualified professionals or even giving formation to its employers (Kalashnikov et al.2017). The financial resources also impact the quality of their products or services. Some processes can be costly, so the organization must find opportunities for improvement to reduce the process cost (Cherrafi et al.2017). These improvements can be made by resourcing to Lean-six-sigma techniques that can identify and eliminate waste in the process, for example. Being able to improve the financial part of the process (Trzeciak et al., 2018). It is also crucial that the managers of the companies understand that they must invest financial resources in the Lean-six-sigma projects implementation to achieve more profit in the future. Only with some financial resources is it possible fully implement Lean-six-sigma (Fletcher2018).

Improving processes and results is one of the principal principles in Lean -six-sigma. All techniques and tools used in this philosophy aim for results and process improvement. While implementing this philosophy, companies must implement and use tools that can cover all functions in the project. Does the goal of the implementation team define where and when the tools should be applied in the project (Antony et al., 2012). The implementation team and the companies should be aware that during the projects, it will be necessary to change the techniques and tools associated with the Lean-six-sigma philosophy once the project complexity increases. The initial tools may be incapable of being sufficient to allow a continuous improvement of the projects, so the necessity to adapt the tools and techniques to ones that allow good decision-making and a continuous improvement of the processes and results, with the aim also of operational excellence (Duarte et al., 2012). To improve all the processes and, consequently, the outcome of these results, all techniques and tools chosen by the teams should be capable of allowing the team and the management to obtain measurements from the processes and performance analysis. Only this way will they be capable of making decisions that permit an improvement in the process from operational and economic perspectives (Costa et al., 2018).

After the first improvements, the tools that allow the measurement and the reduction of the process variability will be crucial to ensure the companies that they process are capable of producing products or services with quality. The measurement of the variability also allows the companies to have an idea of the deterioration of the process, allowing the company to act accordingly before the cost of the deterioration and the consequences continuous rising. Nowadays, the competition is enormous, and any extra costs or deterioration of the quality of the products or processes can be crucial to any company once the competition obligates companies always to exceed efficiency and always aims to increase customer satisfaction with their products or services (Timans et al., 2014). This variability measurement will only be effective if the inputs or outputs variables are well defined, giving the team and the management the capability of a good read of the process. The reduction of the variability will also allow the reduction of the process's wastes. It is another aim of the lean-six-sigma philosophy.

Much of the time, defective products or inefficient processes are the result of the waste existing in the processes. This defectives products or processes can cause the company enormous costs (Gayed et al., 2013). Usually, the waste in the companies is associated with overprocessing, overproduction, excessive inventory or raw-material or finished products, movements, transportation, defects or even the wrong use of the capacity of their collaborators (Panat et al., 2014). It will be crucial for the company to focus its strategy on the needs and expectations of its customers. So will be essential to adapt tools or techniques capable of obtaining customer feedback during the process analysis to allow the companies to adapt their processes to customer satisfaction (Drohomeretski et al.2014). Only this way, with tools capable of "listening" to the customer's opinion, the companies will be capable of identifying which processes and products are critical to customer satisfaction (Thomas et al., 2017).

One of the companies' most common uses of the Lean-six-sigma is in projects. This philosophy allows the companies to improve their operational efficiency and effectiveness by using a project-by-project structure highlighting those most strategically pertinent (Koning et al.2010; Lameijer, Does, and De Mast2016). The companies need to identify the most strategic projects using this project. The Lean-six-sigma philosophy allows them to demonstrate the philosophy more effectually to the stakeholders and the collaborators once this type of project has more visibility than the previous one. Several criteria exist that allow for determining what produces high value in the organization's objectives, such as giving more importance to the projects that elevate the educational aspects of the companies and long-term return investment. On the other side exist the projects that are only associated with return on investment that do not should be prioritized (Snee 2010). The top management must agree on the right prioritized project. Once, they must allow and guarantee that the team have all the necessary resources and tools to implement Lean-six-sigma in a determined project (Thomas et al., 2017). In addition to the top management agreeing with the priority projects, it is also essential to identify and integrate the stakeholders of the prioritized project. Once only that is facilitated, the process of developing organizational improvement strategies (Dowellet al.2017). Good communication and understanding between all the stakeholders, top management and collaborators are crucial only this way; all contributors will be aware of all needs for implementing a successful Lean-six-sigma implementation philosophy and the role of this philosophy in achieving the achievement of the previous goals defined by the top management (Bakow et al., 2017). Communication is crucial because not all professionals and managers will favour the Lean-six-sigma implementation and the consequent changes. So leadership has been recognized as the critical factor for implementing Lean-six-sigma, which is necessary for the leaders of the company to supervise the selection and execution of the philosophy, to find any resistance that can happen and try to solve this resistance to changes

(Antony et al., 2012). The leaders will also be influential in adapting the company to the changes and directing the company toward the primary goal of customer satisfaction through customer needs. Furthermore, allocate resources to achieve this primary goal- The leaders must guarantee that all these changes and motivations are made at institutional and department levels. (Antony et al., 2012) On the other side, the relationship between the organization and their suppliers should also be analyzed once it is crucial to identify and prioritize the suppliers that have more impact on the company's success and the success of the projects where the company are involved in the Lean-six-sigma philosophy (Kieran et al., 2017).

The principle of managing information focus mainly on communication in the organization. Usually, the companies try to make a communication plan that ensures that all the collaborators in the company receive all the information and adequate information and can handle the changes in the process with this report (Andersson et al.2014). This communication should be regular, and all the collaborators must have exceptional attention to this communication that should be updated with the meetings that happen throughout the stages of the Lean-six-sigma implementation and practice (Nicoletti2013). The communication plan has to present to all the collaborators their roles and responsibilities in the organization and, above all, inform the collaborators how the Lean-six-sigma works and which benefits the organization and their collaborators can get from it (Antony al.2012).

In general, all the principles of Lean-six-sigma could be more successful and efficient when the flow of information is known to everyone. This happens because all the processes are more evident, where the process can be improved, and where to exist waste. This is more effective if a view of all the process sequences exists (Timans et al., 2012). Also is essential that all the process owners participate in the process mapping. They will be essential in determining waste related to their processes and people (Lee et al., 2014). The efficiency of the information flow is directly related to the more effective tracking of the Lean-six-sigma projects (Schmidt al.2017). All the data should be available in real-time, and if well used, this can be a competitive advantage for the organization once the professionals can carry out statistical analysis for the projects and deadlines almost in real-time. The professionals can also overview the project capacity and improve their resources and real-time allocation (Schmidt al.2017).

Managing suppliers is one of the principles of the Lean-six-sigma that goes beyond the organization. This is crucial for the organization's strategy because it is essential to know and understand the supplier's capacity. This is because insecurities in the products or services provided by the suppliers in quality perspective or delivery schedule can affect the process and planning of the organization (Thomas and Barton2011). In all businesses and markets, the companies must compare the suppliers' proposals and rank them, considering some characteristics of the proposal that will most satisfy the company. The requirements can be the quality of the product or service, the on-time delivery, or even the payment time (Delgado, Ferreira, and Branco2010). It is expected that the supplier should continuously improve their product, intending to present a better product or even solve some quality issues detected in the customer, or present a more competitive product in terms of costs and delivery time (Kumar et al.2016). One of the essential things in the relationships between the organization and their supplier is the organization's knowledge of the supplier’s capacity. This capacity is an enormous impact on the production planning of the organization. So the organization must ensure the right ways to communicate with their suppliers and send a clear message that is required for the suppliers. The suppliers, on the other side, must always ensure that they have the tools to ensure their capacity (Duarte et al., 2012).

Long-term planning is one of the most structural principles in Lean-six-sigma implementation and long-term management. This is because the Lean-six-sigma philosophy only can be successful in a company if this company compromise on the long-term use of the philosophy and implementation. The company culture must change, and the structure and processes will be modified. Furthermore, these are improvements and changes that do not happen effectively in a short period. The cultural changes in all organizations and collaborators should occur progressively. It should also create a workplace climate that successfully allows long-term implementation. Once a fast implementation was already proven to lead to an aggressive reaction for the collaborators and drastically reduced motivation to implement Lean-six-sigma techniques (Delgado, Ferreira, and Branco2010). Once again, this principle is also based on the adequate professionals for the implementation, with the proper education and knowledge and support from the top management of the company, that more than any other collaborator, wants the success of the implementation and the company. The support of the top management is significant because they will be crucial in combatting the changes resistance and allowing the transformation of the organ-insertional culture from reactive to proactive thinking (Shokri, Waring, and Nabhani2016). The long-term success of the Lean-six-sigma implementation in a company can also be measured by how well the practitioners can achieve their goals and objectives previously established in a strategic plan (Antony et al., 2018). Both these factors can create a positive impact on operational performance. Nevertheless, to do so, the top management must present to their collaborators a well-defined and clear strategic plan that can assist the development of a productive work environment and improve the organization's flexibility between their collaborators and practitioners (Antony et al., 2012). In the long term, Lean-six-sigma can offer continuous operational improvement, techniques, and processes to ensure that the new changes are maintained (Kumar et al.2006). This change was performed to meet the requirements and expectations of the stakeholders.

3. Research Philosophy

Twenty years later, of the first citation of the Lean-six-sigma philosophy, this bibliographic revision focuses on understanding the Lean-six-sigma philosophy that results from a fusion of two methodologies.

This philosophy is one of the most cited and reported philosophies in diverse areas.

For a better understanding, this bibliographic review starts to give the reader a review of the two different philosophies that originated the Lean-six-sigma philosophy.

After that, a resume of the Lean-six-sigma review exists so that the readers can establish the historical overview and principles of the new Lean-six-sigma philosophy.

Two decades later, and with resources to the PRISMA approach, the Lean-six-sigma philosophy's continuous improvement and current status will be answered in the next chapter (Moher et al., 2009.).

PRISMA means Preferred Reporting Items for Systematic Reviews and Meta-Analyses, and it is an evolution of the previous approach QUOROM (Quality of Reporting of Meta-analyses) (Moher et al., 2009.).

It is a systematic review; this means that it is a review where the question or chosen words are well defined, that the authors use to select and, in a critical way, evaluate what is relevant for the research, that way, collect and analyze only the data that are important for the systematic review. The authors can choose to use a meta-analysis review or not to analyze and resume all the results that the authors found (Moher et al., 2009.).

To facilitate the review, the PRISMA approach gives the authors 27-item to check when they are performing the review. Table 1 shows the 27 items. This table is an adaptation of Table 1 of the article "Preferred Reporting Items for a Systematic Reviews and Meta-Analyses: The PRISMA Statement", elaborated by Moher et al. in 2009 (Moher et al., 2009.).

Table 1 – Checklist of the 27 items to include when performing a systematic review using the PRISMA approach. SOURCE ARTICLE: "Preferred Reporting Items for a Systematic Reviews and Meta-Analyses: The PRISMA Statement" by Moher et al., 2009.

Section	Topic
Title	Title
Abstract	Structured summary
Introduction	Rationale
	Objectives
Methods	Protocol and registration
	Eligibility criteria
	Information sources
	Search
	Study selection
	Data collection process
	Data Items
	Risk of bias in individual studies
	Summary measures
	Synthesis of results
	Risk of bias across studies
	Additional analyses
Results	Study selection
	Study characteristics
	Risk of bias within studies
	Results of individual studies
	Synthesis of results
	Risk of bias across studies
	Additional analysis
Discussion	Summary of evidence
	Limitations
	Conclusions
Funding	Funding

The authors also give a four-phase flow diagram. Figure 1 shows the 4 phases of the PRISMA approach. This figure is an adaptation of figure 1 of the article "Preferred Reporting Items for a Systematic Reviews and Meta-Analyses: The PRISMA Statement", elaborated by Moher et al. in 2009. (Moher et al., 2009.)

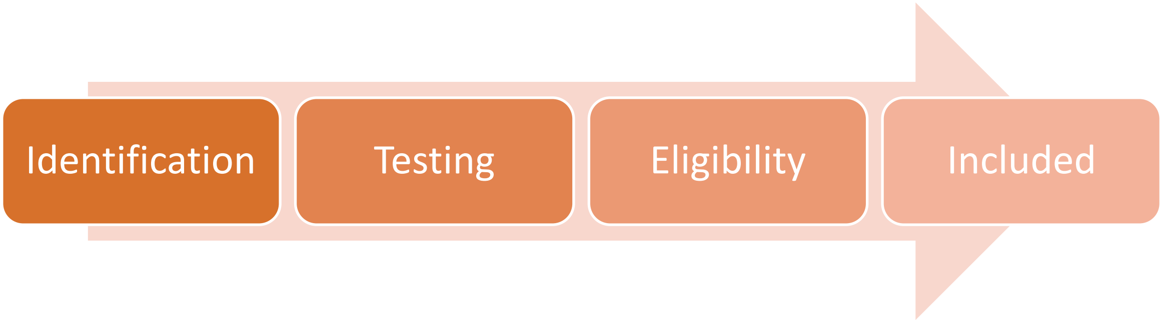

Figure 1 – Flow of the different phases of the PRISMA approach, Adaptation of Figure 1 1 of the article "Preferred Reporting Items for a Systematic Reviews and Meta-Analyses: The PRISMA Statement" elaborated by Moher et al. in 2009. (Moher et al., 2009.)

This systematic approach will be used in 3 different databases. So are Elsevier, Scopus, and Web of science. However, only used articles accessible by Minho University or public access will be used. The research data for the articles are from 2002 to August 2022, and the research words for this review are "Lean-six-sigma".

For each database, was obtain the following command to search:

ELSEVIER - <title> & quot; Lean-six-sigma & quot;-Search | ScienceDirect.com</title>

SCOPUS - TITLE-ABS-KEY("Lean-Six-Sigma")

Web of Science - "Lean-six-sigma" (Topic)

4. Results and Discussion

For doing this research was used three different databases. All databases have other entries for other authors allowing in this way that a more significant number of authors be able to publish their results.

The database "ELSEVIER" has 1250 articles on the research data.

Although the Lean-six-sigma was first mentioned in 2002. (Munteanu, 2017) In the database "ELSEVIER", only in the early years of the 2010s, this philosophy starts to have a more significant number of entries in the database. In 2019 and 2021, the database "ELSEVIER" had the most important entries, articles, or references to the Lean-six-sigma philosophy.

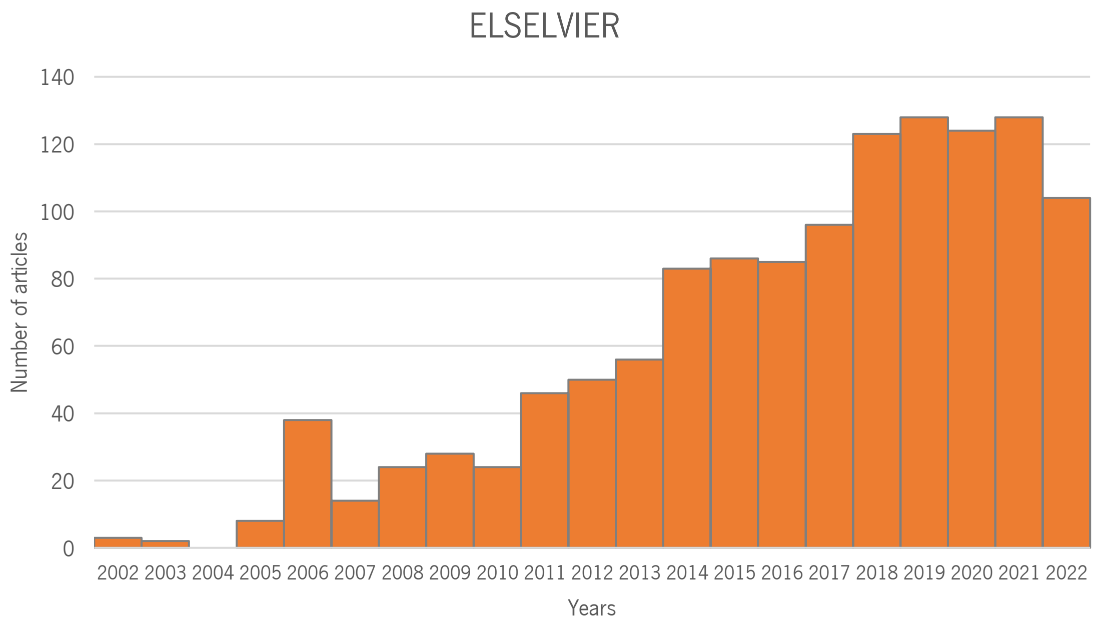

Figure 2 – Graphic representation of the number of entries in the database "ELSEVIER" by year. The keywords used to perform this analysis were "Lean-six-sigma".

As illustrated in Figure 2, in the last five years, 2022 included, this topic saw an increase of articles in the database, with at least 120 mentions per year in these five years. Representing this way, half of all mentions since 2002.

In 2004, the database "ELSEVIER" did not mention the philosophy "Lean-six-sigma". Therefore, it was not possible to find out any explication for this.

This year, Lean-six-sigma was already mentioned 104 times until August.

Of all 1250 mentions on "ELSEVIER", nine are repetitions, totalling 1241 citations.

On the database "SCOPUS", the philosophy "Lean-six-sigma" was mentioned in 2043 times final publications, since 2003, that was the first appearance of a mention of this philosophy.

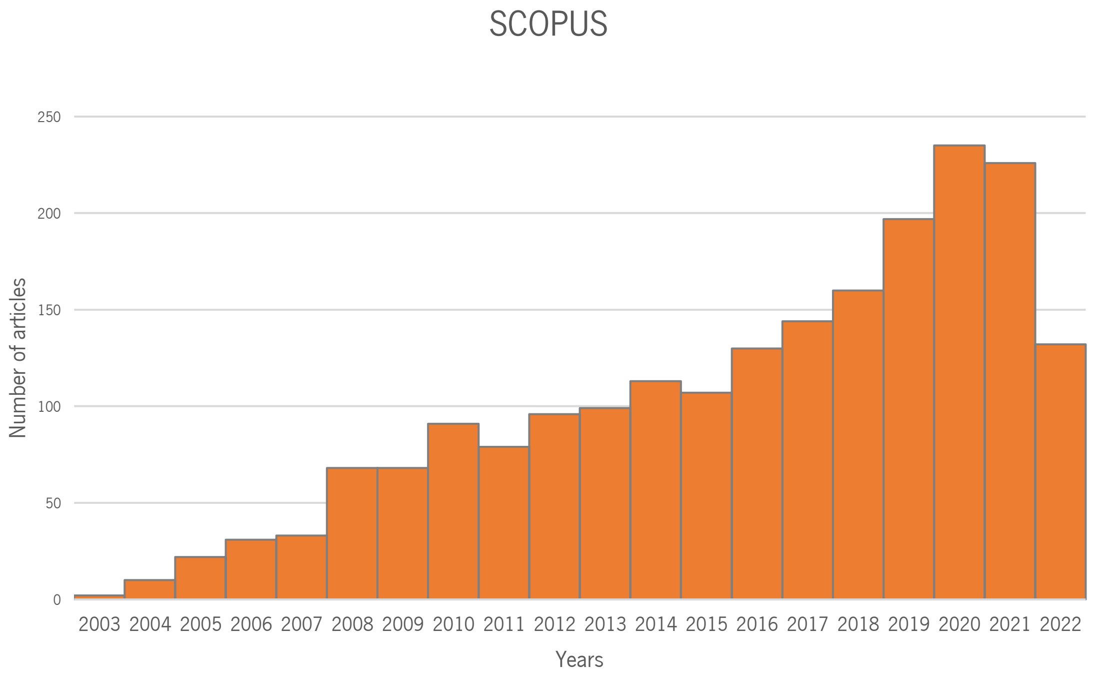

Figure 3 – Graphic representation of the number of entries in the database "SCOPUS" by year. The keywords used to perform this analysis were "Lean-six-sigma".

On the database "SCOPUS, over the years, the number of articles that mentioned the philosophy "Lean-six-sigma" is increasing, as seen in figure 3. Being the year 2021 the year that most publications have where was mentioned the philosophy "Lean-six-sigma". Until now, in 2022, it has already been published 133 articles.

Similar to what happened in the database "ELSEVIER" and "SCOPUS", the last four years, excluding 2022, were the years where more articles were published. In these years was published at least 150 documents mentioned the philosophy "Lean-six-sigma".

Until this date, it is impossible to assure that in the database "SCOPUS", the year 2022 will have the same tendencies as the previous four years. However, with the publication that has not finished its process, the database "SCOPUS" have in 2022 168 mentions of the philosophy "Lean-six-sigma". Therefore, if all the authors could be approved in the year 2022, this database will follow the same tendency as the previous years and have at least 150 publications mentioned as "Lean-six-sigma".

The last five years in the "SCOPUS" represent almost half of the publications in this database that mention the philosophy "Lean-six-sigma".

This year, Lean-six-sigma was already mentioned 132 times until August.

Of all the 2043 results on the database "SCOPUS", at least 26 results are duplications.

On the database "Web of Science", the philosophy "Lean-six-sigma" was mentioned 1051 times since 2004. However, once this historical philosophy was first mentioned in 2002, the result of 1999 was removed from these results.

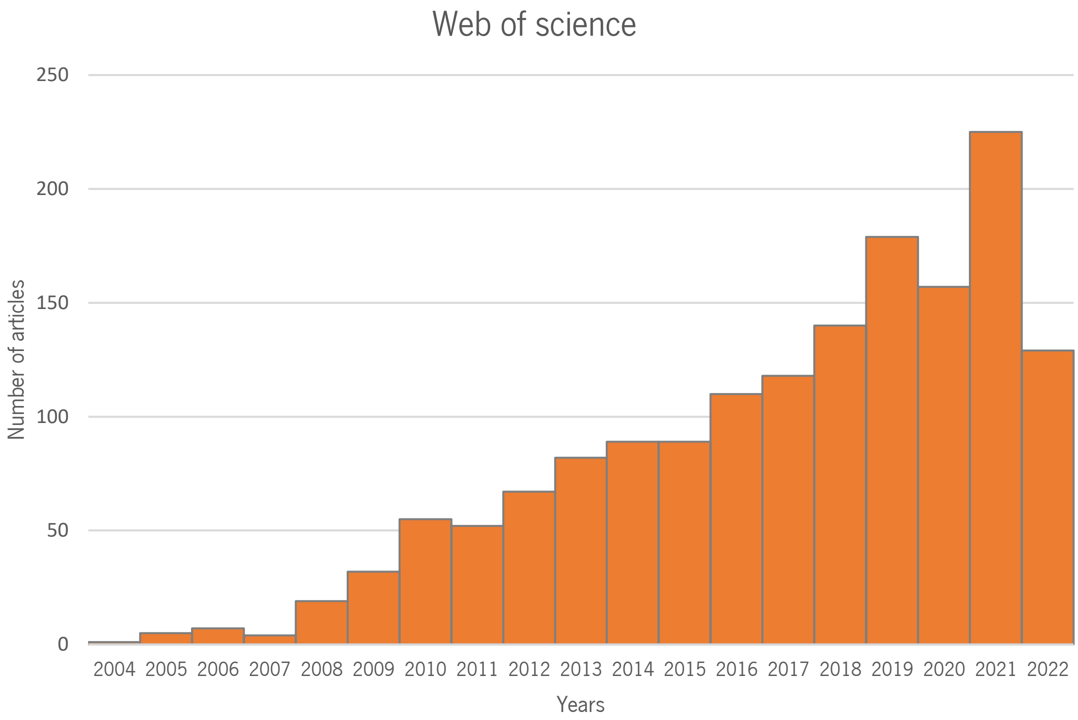

Figure 4 – Graphic representation of the number of entries in the database "Web of Science" by year. The keywords used to perform this analysis were "Lean-six-sigma".

It is possible to visualize in figure 4 that also on the database "Web of Science", over the years, the number of citations of the philosophy "Lean-six-sigma" was increasing, being the year 2021, the year when more publishing with the citation of "Lean-six-sigma" occurred, with a total of 225 publications.

In 2020, the number of publications decreased 2019, contradicting the increase in the number of citations. This reduced number could be related to the pandemic, which has the begging of 2020 and can influence the number of studies. In 2021, the number of citations appeared to restore growth.

Once again, on the database "Web of Science", the last five years, 2022 included, represent fifty per cent of all the citations of "Lean-six-sigma" in the database. Again, these results are similar to what happened to the databases "ELSEVIER" and "SCOPUS".

On the database "Web of Science", it is not possible to assure that the number of citations this year, 2022, the citations of the philosophy "Lean-six-sigma” will be superior to the previous year. Until August, exit 129 citations. The year 2021 can also be an outlier in the number of citations, 2020 was a year with a reduced number of citations, and due to the pandemic, some publications could be delayed to 2021.

Of all the 1560 citations, only one was a duplication.

The differences found in the number of publications between the databases occur due to the criteria of which database and author. The requirements for the acceptance and publication of an article are also different, so the number of articles found in these three databases is expected to be different. It is possible to find these differences in the previous results where the number of citations in the same time range differs in the three databases.

The principal area of interest of the database is also related to the number and type of publications made on the database.

"SCOPUS" is the database with a more significant number of publications, while the other two, "ELSEVIER" and "Web of Science", have an equal number of publications that cite the philosophy "Lean-six-sigma".

Figure 5 – Graphic representation of the number of publications made by the type of publication by a database.

Once each database also has the criteria to categorize the articles, only was considered elaborate figure 5 the three principal types of publications: Review articles, research articles and Conference abstracts.

Considering the type of publication made on these three databases, the primary type of publications that cited the philosophy "Lean-six-sigma" was research articles, on all the databases, for a big difference considering the other two categories considered to elaborate figure 5.

The database "ELSEVIER" and "Web of Science" have a similar number of publications of several review articles and conference abstracts. However, on Scopus is possible to find a more significant number of conference abstracts compared with the other two databases.

These results can be explained with the criteria for each database to accept the publication of some determinate article.

4.1 Principal industries

Lean manufacturing and Six-sigma were developed by the car Industry and telecommunications industry, respectively. In the begging of these methodologies, these industries had an enormous booster and became more competitive and presented products with more quality. The appearance of the combined method “Lean-six-sigma” came to mitigate the faults that both philosophies had separately.

Being a philosophy that originated in manufacturing, it is not a surprise that one of the areas that cite the philosophy "Lean-six-sigma" nowadays is engineering.

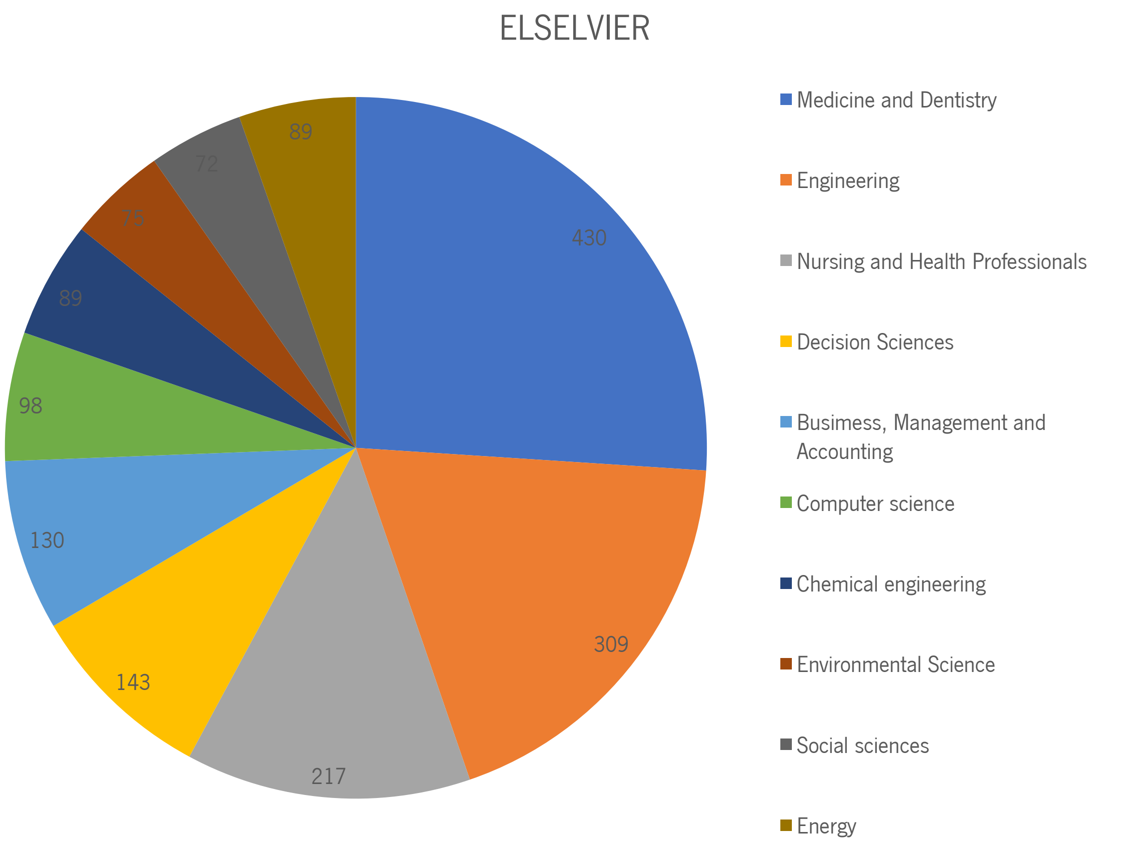

Figure 6 – Graphic representation of the number of entries in the database "ELSEVIER" by study field. The keywords used to perform this analysis were "Lean-six-sigma".

However, as visualized in figure 6, medicine and dentistry are the areas where the philosophy "Lean-six-sigma" are more cited on the database "ELSEVIER", with at least more than 120 results than engineering. Medicine and Dentistry had mentioned "Lean-six-sigma" 430 times, while engineering had only mentioned this philosophy 309 times. The top 3 areas that mentioned "Lean-six-sigma" on the database "ELSEVIER" are the area of Nursing and Health Professionals.

These demonstrate that, although "Lean-six-sigma" as they developed in manufacturing, the truth is that the principles and tools can be implemented in all the working areas, pushing all the areas for development and continuous improvement. Prove that is the most diverse area where this philosophy was cited. These are the areas mentioned above and the areas of decision sciences, business management and accounting, computer science, chemical engineering, environmental science, social sciences, and energy.

The database "SCOPUS" divide the areas into more fields than "ELSEVIER", which, due to a significant range, divides the articles/documents into these areas.

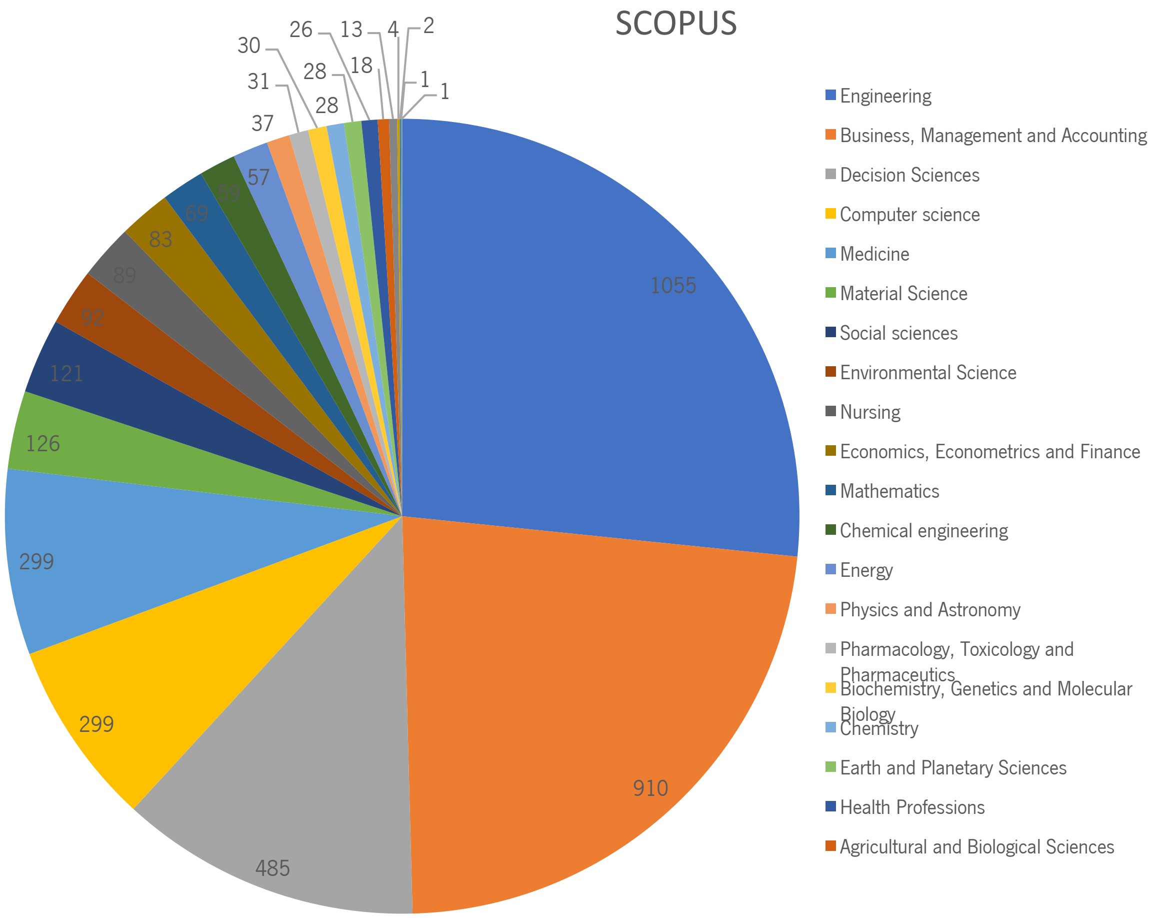

Figure 7 – Graphic representation of the number of entries in the database "SCOPUS" by study field. The keywords used to perform this analysis were "Lean-six-sigma".

On the database "SCOPUS", the principal area that mentioned "Leas-six-sigma" was engineering, with a total of 1055 mentions of this philosophy. Opposite what happens in the database "ELSEVIER", where the area that most cited this philosophy is "Medicine and Dentistry". On the database "SCOPUS", the area of "Medicine" appears in fourth place, and even if it was joined to this area, the results of the area of "Dentistry", these two areas do not will change the position on the table. Once the area of "Medicine" cited "Lean-six-sigma" 299 times, and "Dentistry" had only one publication where they mentioned "Lean-six-sigma".

The second area on the database "SCOPUS" that cited "Lean-six-sigma" was "Business, Management and Accounting", which cited the philosophy "Lean-six-sigma" 910 times. This number of citations is seven times the superior of the citations on "ELSEVIER" for the same area.

To close the top three, of the areas that cited "Lean-six-sigma" on the database "SCOPUS" is the area of "Decision Sciences", with a total of 485 citations. Compared with the previous database "ELSEVIER", this study area also appears in a good position.

As is possible to see in figure 7, the database "SCOPUS" divide their fields of study into more areas compared with the database "ELSEVIER". The database "SCOPUS" divided their fields of study into twenty-five fields, which are Engineering, Business, Management and Accounting, Decision Sciences, Computer science, Medicine, Material Science, Social sciences, Environmental Science, Nursing, Economics, Econometrics and Finance, Mathematics, Chemical engineering, Energy, Physics and Astronomy, Pharmacology, Toxicology and Pharmaceutics, Biochemistry, Genetics and Molecular Biology, Chemistry, Earth and Planetary Sciences, Health Professions, Agricultural and Biological Sciences, Multidisciplinary, Arts and Humanities, Psychology, Dentistry, and Immunology and Microbiology. All the areas are described sequentially by a decrescent number of citations.

It is also possible to prove on this database that although this philosophy has the begging in the industry, the truth is that nowadays, all the fields of study can use and improve by implementing the "Lean-six-sigma". Indeed, of the top ten of the database "SCOPUS", only two areas of the study are directly linked with the industry and the improvement of the industry.

Considering the last two databases, the database "Web of Science" divide the areas into more field studies. For example, the database "Web of Science" divided all the publications that mentioned the philosophy "Lean-six-sigma" into 120 fields of study.

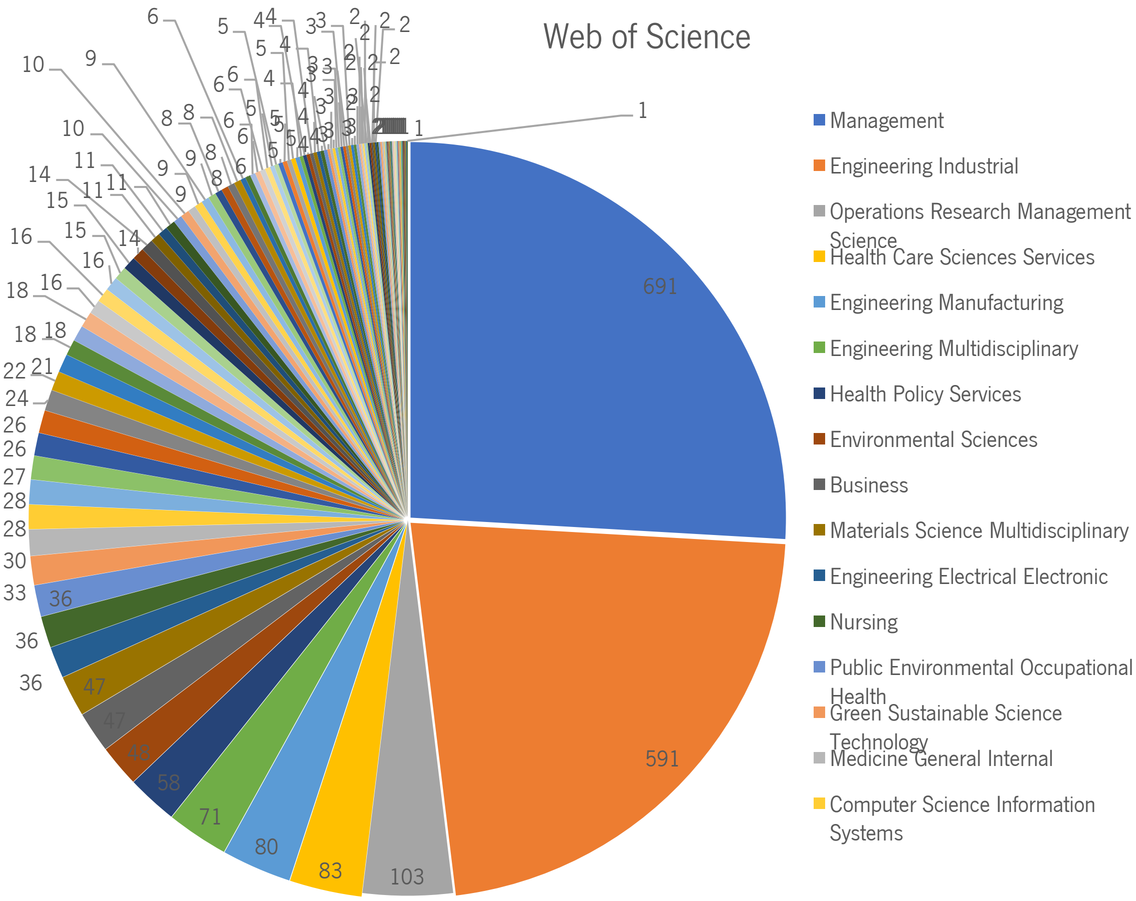

Figure 8 - Graphic representation of the number of entries in the database "Web of Science" by study field. The keywords used to perform this analysis were "Lean-six-sigma".

On the database "Web of Science", the principal area mentioned the philosophy is "Lean-six-sigma, with a total of 691 mentions. Compared with the previous two databases, the principle of the database "Web of Science" does not is the same. Compared with the database "SCOPUS", they are of management raise one position. While comparing with the database "ELSEVIER", this raises four positions.

Engineering Industrial is the second area mentioned in the philosophy "Leas-six-sigma" on the database "Web of Science". Although the two primary databases do not exist in this specific area on the other database, the most similar field in the previous databases is Engineering. Furthermore, the database "ELSEVIER" is in the same position, with fewer mentions of the database "ELSEVIER". On the database " Web of Science", the philosophy was mentioned in the Engineering Industrial field 591 times.

To close the top three of the areas that cited "Lean-six-sigma" on the database "Web of Science" is the area of "Operations Research Management Science", with a total of 103 citations. This area does not appear on the other two databases.

As is seen in figure 8, the database "Web of Science" divides its fields of study into more areas than the previous two databases. The database "Web of Science" divided their fields of study into 120 fields, which are beyond the top three the Health Care Sciences Services, Engineering Manufacturing, Engineering Multidisciplinary, Health Policy Services, Environmental Sciences, Business, Materials Science Multidisciplinary, Engineering Electrical Electronic, Nursing, Public Environmental Occupational Health, Green Sustainable Science Technology, Medicine General Internal, Computer Science Information Systems, Education Educational Research, Engineering Mechanical, Computer Science Interdisciplinary Applications, Surgery, Haematology, Statistics Probability, Computer Science Theory Methods, Economics, Engineering Environmental, Radiology Nuclear Medicine Medical Imaging, Multidisciplinary Sciences, Oncology, Pharmacology Pharmacy, Medical Informatics, Medical Laboratory Technology, Automation Control Systems, Environmental Studies, Business Finance, Computer Science Artificial Intelligence, Pathology, Social Sciences Interdisciplinary, Telecommunications, Chemistry Analytical, Computer Science Software Engineering, Education Scientific Disciplines, Mechanics, Anaesthesiology, Critical Care Medicine, Engineering Chemical, Physics Applied, Cardiac Cardiovascular Systems, Clinical Neurology, Metallurgy Metallurgical Engineering, Obstetrics Genecology, Pediatrics, Transplantation, Biochemistry Molecular Biology, Chemistry Multidisciplinary, Engineering Biomedical, Information Science Library Science, Materials Science Textiles, Mathematics Applied, Rheumatology, Biochemical Research Methods, Food Science Technology, Mathematics Interdisciplinary Applications, Medicine Research Experimental, Ophthalmology, Regional Urban Planning, Transportation Science Technology, Urology Nephrology, Communication, Construction Building Technology, Energy Fuels, Engineering Petroleum, Geriatrics Gerontology, Instruments Instrumentation, Nanoscience Nanotechnology, Orthopaedics, Psychology Applied, Rehabilitation, Respiratory System, Robotics, Agriculture Multidisciplinary, Biotechnology Applied Microbiology, Chemistry Applied, Computer Science Cybernetics, Engineering Aerospace, Gastroenterology Hepatology, Hospitality Leisure Sport Tourism, Imaging Science Photographic Technology, Immunology, Industrial Relations Labour, Mining Mineral Processing, Otorhinolaryngology, Public Administration, Veterinary Sciences, Agricultural Engineering, Area Studies, Behavioural Sciences, Biology, Cell Biology, Chemistry Medicinal, Chemistry Organic, Computer Science Hardware Architecture, Criminology Penology, Dentistry Oral Surgery Medicine, Development Studies, Emergency Medicine, Endocrinology Metabolism, Engineering Civil, Geosciences Multidisciplinary, Law, Mathematical Computational Biology, Mathematics, Meteorology Atmospheric Sciences, Microbiology, Neuroimaging, Neurosciences, Peripheral Vascular Disease, Physics Condensed Matter, Physics Multidisciplinary, Transportation and Zoology.

The database “Web of Science” appears to be more judicious about their fields and the categorization of their publications. This is possible to conclude due to the enormous differentiation that exists in the areas of study. Also, three different databases that have discriminated their fields of study differently prove that the three databases have different requirements for publication on their databases and that they have different interests in the type of publication that they want to do. this

With the analysis of these three databases is possible to verify that the philosophy "Lean-six-sigma" is mainly used in engineering and management. However, it is increasingly in other fields and gained more and more importance in improvement in other areas that were not the base of this philosophy creation. It also influences the number of publications made on the databases. For instance, the database "ELSEVIER" have more interest in medical or science theme publications once the top three for this database are distant from the other two databases. With this data, it is not possible to conclude what is the preference of the other two databases once it is impossible to be sure that the significant publications on engineering or management were not linked to the principal use of the philosophy "Lean-six-sigma" in this field or the preference of this fields by the database "SCOPUS" or "Web of Science". More database analyses will have to be made, which will not be done for this dissertation.

This proves that the philosophy "Lean-six-sigma" is capable of adaption to diverse fields and used to improve processes in the organizations where it is implemented.

4.2 Main types of Problems addressed

More than 300 studies/articles were read, verifying that some common problems were addressed in the principal's areas.

In the health field, was verified that the principal’s worries were:

- reducing the time waiting for patients.
- reducing redundant procedures.
- improve cleaning and disinfection processes.

Therefore, the principal aim is to improve the efficiency and quality of patient services.

Being capable of reducing redundant procedures is possible to obtain the result as reducing the time waiting for patients in the most diverse health areas and improving at the same time the procedures that allow for better cleaning and disinfecting room, which allows a better rate of hospital infections. This way may have some assurance in a state that all the problems in the health area are interconnected.

For instance, one of the uses of Lean-six-sigma in the health field was to improve the cleaning of the patient rooms in the hospital, better communication with the different teams and the knowledge of waste improves the room preparation time and the infection diseases due to the non-efficient cleaning.

Lean-six-sigma in health is also primarily used to improve cleaning or disinfection processes. This is important because better and faster cleaning or disinfection processes allow the patients to respond faster to services and decrease the infection rate.

On the other side, in the industrial field, where this philosophy had its beginnings, the supply chain was one of the biggest preoccupations.

The two principals' problems addressed in the industry were:

- elimination of waste.

- reduce lead time in the supply chain.

The elimination of waste is and always has been an enormous preoccupation in the industry. The elimination of waste allows the improvement of lead times and processes and can bring value to products or affected services.

It is happening in the organisations' internal and external supply chains. The most difficult to achieve better results usually are the external ones due to the demand for agreement between the parties. The supply chain is constantly changing, which allows and promotes continuous improvement.

Another significant and essential concern in the industrial field is the companies' sustainability. With the crescent preoccupation with the ambient and the collapse of the natural resources, it is of the most crucial importance that the organizations give more and more time and knowledge to improve their sustainability side. Therefore, more and more are giving value to companies where their green side is more evident and efficient. Also, due to the lack of materials, the companies must be able to adapt and improve their processes to decrease their climatic footprint. On the other side, the increase in the costs of materials and human resources and the continuous pressure from the markets to improve the race quality-price of their products and services encourages the companies to continuous improvements to reduce more and more costs and the lead-times more.

On the management level, the principal problems addressed to solve with Lean-six-sigma are:

- failures on their plant floor.
- availability of the machines
- the waste that happens due to the failures in production.

Indeed, waste can also appear due to the lack of availability of machines that are impossibly continuous in production. Furthermore, machines poorly parameterized produce defective products. This is also a big waste due to the unusable raw material and final product.

Common to all the fields of study is that Lean-six-sigma promotes innovation in the most diverse areas. Over the years, this aspect has been significant due to the higher competition between the organizations to present the best product at the lowest price and as faster as possible. In recent years, with the increase in the prices of raw materials and services, it is imperative that diverse organisations that want to continue to be competitive and have a profit be capable of enhancing their process to reduce waste and use better resources to remain competitive.

4.3 Most used tools

For each problem addressed were several philosophies capable of helping the solution. However, being Lean-six-sigma, a philosophy to eliminate waste and reduce process variation and defects, the most used tools used are the statistical tools and their variances.

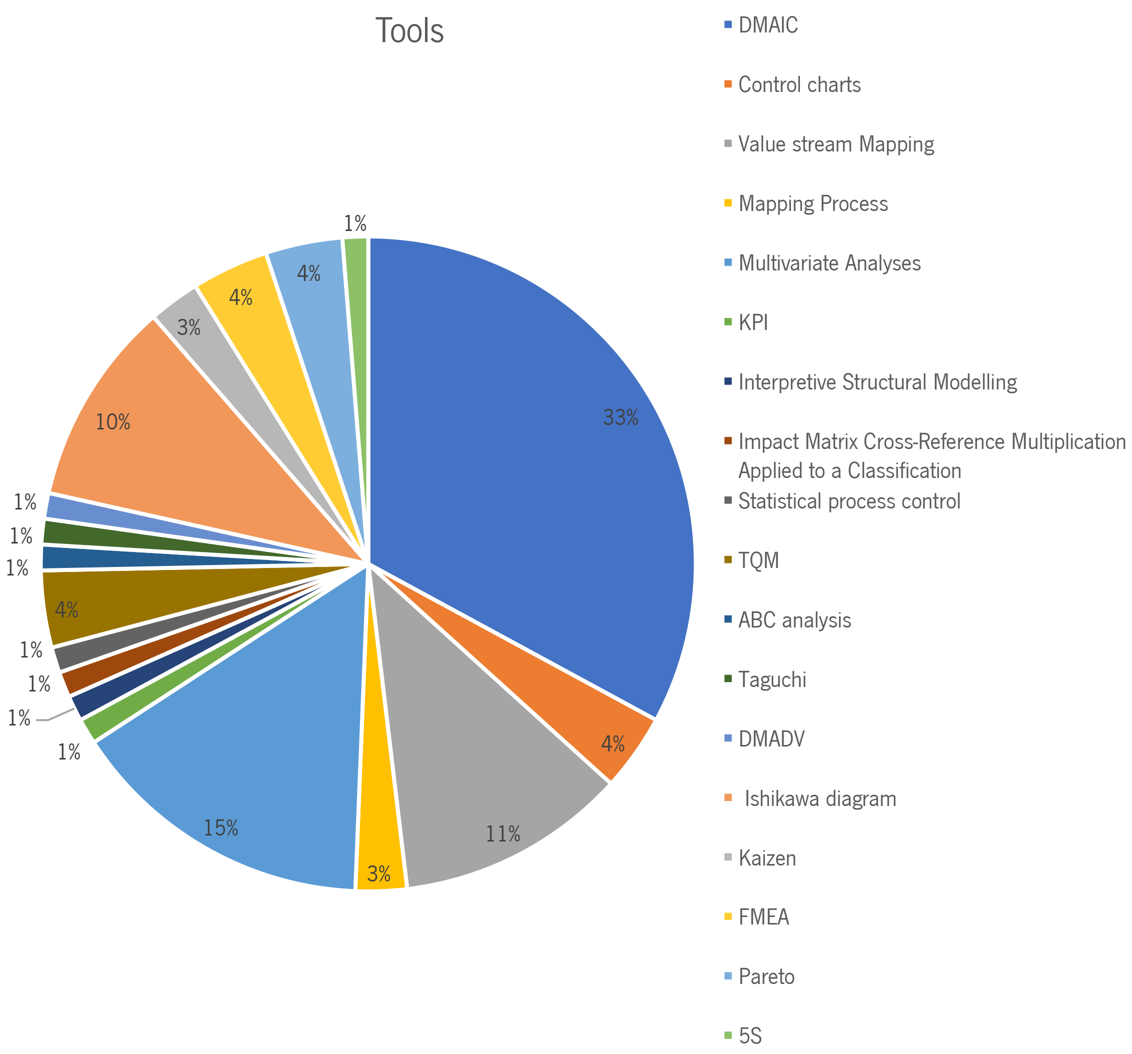

Figure 9 – Graphic representation of philosophies used during Lean-six-sigma implementation

Although other tools can be used in parallels, such as control charts and kaizen, DMAIC and multivariate analyses were the most used tools. Both tools together represent 48% of all the tools used during Lean-six-sigma implementation. However, DMAIC is used more than double the multivariate analyses.

Using statistical tools allows companies to understand and control their processes. For example, these tools can measure the time waste or produced defects. So, it is no surprise that these statistical tools were the most used, once one of the principal aim of the philosophy Lean-six-sigma is to reduce the process variance and defects.

In third place appears Value stream mapping followed by the Ishikawa diagram. Both philosophies can be used alone, however, in an enormous numerous studies, these two tools are used in some phases of the DMAIC tool. These two tools represent 11% and 10% of all the tools used.

Examples of other used tools are Control charts, Mapping Processes, Key Performance indicator (KPI), Interpretive Structural Modelling, Impact Matrix Cross-Reference Multiplication Applied to a Classification, Statistical process control, Total Quality Management (TQM), ABC analysis, Taguchi method, Define Measure Analyse Design Verify (DMADV), Kaizen, Failure Modes Effects Analysis (FMEA), Pareto diagram and 5S, among many others.

The less-used tools are also widely used. However, they are used in more specific situations and can be used to control or defined the process, among other things. Also, as normally the improvements made for these tools are not so evident, the reference of these tools in the published bibliography can be less than others.

Control charts or FMEA are used to control and define the process. Both can be used to improve the process, but this is not the principal aim of these tools, so the reference to using these tools is not evident.

Kaizen tools are also a tool that is primarily used. However, it was not cited mainly in the bibliographic once this tool aims to make minor improvements that can lead to a more considerable improvement. However, this improvement is slower but more consistent.

It is possible to predict, that due to the continuous necessity to have a statistical control process and a high reduction of the costs due to the strategic costs of the wastes, the statistical tools will remain the principal used tools. Due to the continuous necessity to have a statistical control process and a high reduction of costs, statistical tools will remain the principal used tools.

4.4 Most cited output/results

One of the most cited outputs and results is better communication between multidisciplinary teams. Lean-six-sigma promotes better knowledge among all. Communication allows the teams to understand what everyone does and eliminate redundant procedures that both diverse teams are doing.

Allowing, for instance, other results to be possible. Results such as more efficiency in the delivery of services and products.

The three principals' outputs addressed in the health were:

- reducing the time waiting for patients.

- reduce the rate of hospital infections.

- Increase availability of equipment.

In healthcare, the use of multidisciplinary teams of Lean-six-sigma allows the time that the patients must wait for some service or product to decrease. For instance, receiving an electrocardiogram in less than 10 minutes increases by 40% after the teams' intervention.

The elimination of redundant procedures and the improvement of some processes allows a reduction of the time that patients must wait and the increased availability of equipment that much of time can save lives.

Another more considerable preoccupation in healthcare, and one of the most cited results and outputs, is cleaning improvement. Improvement in cleaning allows, for instance, the number of infections in the hospital due to poor cleaning and disinfection to decrease. It is a topic important in the healthcare field, and various improvements in several hospitals/clinics allow the reduction in the number of hospital infections and consequently promote a faster patient recovery that does not have consequences of hospitaller infections.

The three principals' outputs addressed in the industry were:

- Reduce the lead times.

- Reduce costs.

- Increase the value.

In industry, the most crucial aims still are waste reduction in a productive area. With all the waste reduction is possible to reduce the lead time of the delivery of products and services to the consumer. The elimination of processes and activities that do not bring any value to the product or service, and do not influence the quality, brings more value to the products and services of the organization.

The reduction of the lead time and elimination of waste brings a reduction in the costs of production. One of the higher costs in production still is the time that one product takes time to produce and the human resources necessary to produce the product. A time reduction and human resources reduction brings a cost reduction.

The variation decrease in the process allows a guarantee that the product and services are delivered to the customer with a good certain of quality. With this guarantee, it is possible to increase the product value or service. Consequently, allows the organization the capability to remove processes or activities that are necessary to assure the quality of the products or services.

All these activities or processes used to assure the quality of products or services are considered waste.

For instance, in one automotive organization, the improvement of the processes and the layouts allows the organization a reduction the cycle time from 548 minutes to 452 minutes, which results in an 18% improvement in process cycle time.

The two principals' outputs addressed at the management level were:

- availability of the machines.

- Increase productivity and efficiency.

In management departments, the Lean-six-sigma can help these departments increase productivity and efficiency in all sectors while decreasing the production costs in maintaining lead optimization processes and workflows.

A better understanding of the maintenance needs will allow the availability of the machines and equipment to be increased due to better maintenance. Also, a better understanding of production demands and improved planning will permit better use of the machines and equipment, and consequently will be more available for new productions or increase of the existing productions.

All this permits the productivity and efficiency on the plant floor to increase. More productivity and efficiency allow the management to consider new projects or increase the existing projects with some guarantee of capacity.

For instance, a study in small and medium companies shows that is possible to improve the delay in orders by a reduction of 66% on the delay. The improvement in the delay permits more production efficiency. The time delay starts with a 42% of a time delay to a 14 % of time delay.

Overall, pulling out some exceptions even in different areas most of the outputs are the same. The increased efficiency and the reduction of waste can generate the consequences of the increase in the quality of products and services provide to the customer. The final aim in all areas is to be more competitive in a world increasingly competitive.

5. Conclusions

Two philosophies originated a new philosophy, a more robust philosophy named Lean-six-sigma. As stated before by Joseph De Feo, "The Lean-six-sigma focus on the need to improve process flow, speed, and the quality of products by working hand-by-hand to meet business and customer requirements" (FEO, 2005).

Lean-six-sigma could use the best of the two philosophies and mitigate the weakness of the boot methodologies. Using Leas-six-sigma, companies can improve the quality of their products and services, reduce the waste of resources and time, minimize the time for producing or designing, and minimize the time to deliver a product or service to their customer. The companies or organizations can also eliminate factors that can inflate lead times, costs or even inventory (FEO, 2005).

Being a powerful tool, this philosophy left the walls of the industrial field and was used to help improve other fields. With this philosophy, several businesses were accomplished to achieve innovation ratings capable of giving these companies a higher performance on the market and better competitivity.

It was not one of the most addressed problems to solve with the philosophy of Lean-six-sigma. However, the significant due problem should always be mentioned. Also, this philosophy could be implemented and help in the most diverse areas. In 2021, lean-six-sigma was used to solve the problem of food waste and loss in the Nigerian food supply chain (Kolawole et al., 2021). In this study, they use the tool DMAIC to understand the supply chain's problems better and achieve a way to reduce them (Kolawole et al., 2021).

Lean-six-sigma is a philosophy used to automatic diagnostic the problems and their root causes and perform problem-solving for these same issues, and address solutions capable of solving them. This way is secure to state that the philosophy of Lean-six-sigma is reactive, focusing on quality issues and continuous improvement.

Although the philosophy Lean-six-sigma is used in the most diverse areas and responsibilities is possible to conclude that most of the problems addressed in all areas, used tools and outputs are very similar, and the aim is very similar.

The reduction of lead time for the delivery of the services or products to the consumers, the elimination of redundant processes and the exact time reduction costs were the most problems ad outputs found in all areas.

The most used tools were also common to all areas: statistical tools capable of process measure and control.

Must be also considered that in the industrial field, there is a more considerable preoccupation with the environment and the reduction of the ecological footprint. Nowadays, this is a more significant concern with the reduction of the raw materials that, until now, we know and the industry's impact on the environment. Therefore, green Lean-six-sigma is appearing, and it is possible to believe that some industries, as we know, will be changed to more clean and ecological production.

The lean-six-sigma philosophy is constantly promoting product and process innovation, so we this philosophy the companies will focus on continuous improvement and problem-solving. The success of this philosophy can be fast however, the organizations will gain much more if achieve a change in the organizational culture in long term.

Twenty years later, the Lean-six-sigma philosophy is primarily used, and although all the areas should have proactive thinking and work to prevent the problem, the reality is that some problems and wastes can only be identified after an extensive analysis that is only possible after "production" start. Furthermore, a meticulous statical and multivariate analysis is sometimes necessary for suitable waste identification. So is this why Lean-six-sigma continues to be used mainly in the more diverse areas. Nevertheless, as once said by Peter Drucker, "You cannot improve what you do not measure".

5.1 Limitations and perspectives for future work

For the elaboration of this dissertation was found some limitations. Limitations, such as some articles are not accessible or open access to all, and some of the found articles do not have enough clarity about the tools used for improvement. Or clarity on the obtained results.

The limitations above do not allow all the data clouds to be analysed. However, it is possible to state that the results with all the data, will not be so different compared with the presented results in this dissertation.

In the future, it will be interesting to understand the limitations that the companies found during the philosophy of Lean-six-sigma implementation, to try to mitigate these difficulties. One difficulty, in this case, will be finding enough information or data to achieve significant conclusions about the subject.

Considering the Lean-six-sigma philosophy, it will be interesting to try to facilitate the implementation of Lean-six-sigma for small and medium enterprises. Knowing this, for these companies the difficulty increases for a correct philosophy implementation due to the lack of specialized personnel and money.

After this work, it will be appealing to understand the impact of the Lean-six-sigma philosophy in industry 4.0.

Other possibility, with the recourse of a survey form, it will be possible to understand the small and medium enterprises' knowledge about the Lean-six-sigma philosophy and its impact on the companies.

For last, it should be explored the path of evolving Lean-Six-Sigma philosophy from reactive to preventive. This would be more advantageous to new companies or projects.

6. References

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