International Journal for Quality Research 12(1) 227–252
ISSN 1800-6450

Ana Carolina Martins Rosa

Evandro Eduardo Broday [1]

Article info:
Received 22.11.2017
Accepted 24.01.2018

UDC – 005.6
DOI – 10.18421/IJQR12.01-13

COMPARATIVE ANALYSIS BETWEEN THE INDUSTRIAL AND SERVICE SECTORS: A LITERATURE REVIEW OF THE IMPROVEMENTS OBTAINED THROUGH THE APPLICATION OF LEAN SIX SIGMA

Abstract: *The present work is a review of literature, to identify the improvements acquired from the application of the Lean Six Sigma methodology in the industrial and service sectors in different countries. The PRISMA methodology was used to select relevant articles to the topic of work, and the bibliographic databases used for the research were the Google Scholar, SciELO, ScienceDirect, Taylor & Francis and Web of Science. The study counted on 27 articles to better exemplify these points, being 11 focused on the industrial sector and 16 on the services sector. It was evident that in both sectors the variability of the process and its waste were reduced, by eliminating non-value-added activities, improving process quality, productivity, efficiency, the service provided, increasing customer satisfaction, reducing costs and generating savings. It has been found that Lean Six Sigma is a versatile tool that can be adapted and applied in any segment, allowing potential opportunities for new research and applications.*

Keywords: *Total Quality Management, Continuous Quality Improvement, TQM. Customer Satisfaction, Lean Six Sigma*

1. Introduction

Global competition challenges organizations from different parts of the world and from all sectors. As an attempt to respond to the pressure created by this rivalry, companies have been adopting competitive and innovative methods that, in most cases, tend to emphasize quality and customer focus.

In this scenario, the use of quality methods is increasing. In addition to its focus on quality, product, service and process improvement, most of these approaches also focus on customer satisfaction.

TQM (Total Quality Management), a methodology that has its focus on continuous improvement, customer satisfaction and employee involvement, emerged in the mid 80's and until today is present as the current era of quality. Since it, several tools and methodologies have been developed, using the same sedate principles. One of them was Lean Six Sigma.

Lean Six Sigma is a blend of Lean Manufacturing and Six Sigma. It is an approach that seeks to continuously improve

[1] Corresponding author: Evandro Eduardo Broday
email: broday@utfpr.edu.br

quality, reduce variability and eliminate defects, resulting in customer satisfaction, reduced costs and consequently increased revenue (SNEE, 2010). This methodology is popular in the manufacturing sector, and has been conquering the service sector (Radnor and Boaden, 2008).

The benefits of Lean Six Sigma in the industrial and service sectors have been widely highlighted in the literature (Antony, 2005b) and include: ensuring that services and products meet customer needs, removing waste from processes, reducing the cost of poor quality, reducing the incidence of defective products or services, reducing cycle time, and delivering the correct product or service at the right time and place.

The present work carried out a bibliographical research in the following databases of scientific information: Google Scholar, SciELO, ScienceDirect, Taylor & Francis, Web of Science, along with the PRISMA methodology, with the combination of the following keywords: Total Quality Management, Continuous Quality Improvement, TQM, Customer Satisfaction, Lean Six Sigma, in order to delimit the articles pertinent to the theme and to be able to point out the purpose of using the methodology Lean Six Sigma in the industrial and service sectors when solving problems, also discuss the results found when applying the Lean Six Sigma methodology, and see if the theory presented by Lean Six Sigma matches with its practice in the case studies.

2. Methodology

The methodology used to build the work is based on the combination of keywords in several databases. As the research deals with the application of the Lean Six Sigma tool in the industrial and service sectors of different countries for the research criteria, the PRISMA methodology was used (Preferred Reporting Items for Systematic Reviews and Meta-Analyzes - Description of Preferential Items for Systematic Reviews and Meta-Analyzes).

The PRISMA methodology combines keywords and performs the research in several databases of scientific information, guaranteeing the non-exclusion of any study related to the topic, thus exhausting all the research possibilities. Therefore, a unique screening procedure proposed by the methodology can restrict the number of studies found, through specific selection criteria and defined for the research (Liberati et al., 2009).

The research was carried out including 5 bases of scientific information: Google Scholar, SciELO, ScienceDirect, Taylor & Francis, Web of Science, chosen for being the best known in the academic world.

The search for sources of scientific information was based on the use of keywords that were combined. The key words chosen for research were: Total Quality Management, Continuous Quality Improvement, TQM, Customer Satisfaction, Lean Six Sigma. Figure 1 shows the 4 combinations made with the keywords.

As can be seen from figure 1, the keywords were combined in this way, and searched in all of the aforementioned scientific information bases. The order in which keywords are searched does not change the direction of the search.

After the articles have been surveyed in all sources mentioned above, based on the same sets of keywords, the first screening of works relevant to the study in question is carried out. The selection was performed using the following rejection steps and criteria in the following order:

1) Ordering of articles in alphabetical order of author, in order to facilitate the removal of duplicates;
2) Removal of articles prior to 2007 (more than 10 years). Possible articles with more than 10 years are obtained from the bibliographic references of the articles found in the 1st selection; this step allows a

significant number of minor publications to be removed, thus shortening the search time;

3) Removal of articles that do not provide the complete basic information (Author, Title, Year of publication or Magazine of origin);
4) Removal of articles whose title does not show a relation with the subject;
5) Removal of articles that are not in the English language;
6) After the first selection, where the basic references of the articles (author, title, year of publication) are analyzed, the results will be analyzed:
7) Removal of articles whose objectives stated in the summary do not coincide with the objectives of the present study;
8) Removal of articles whose methodology is out of order or does not fit with the present study;
9) Removal of articles without full text available.

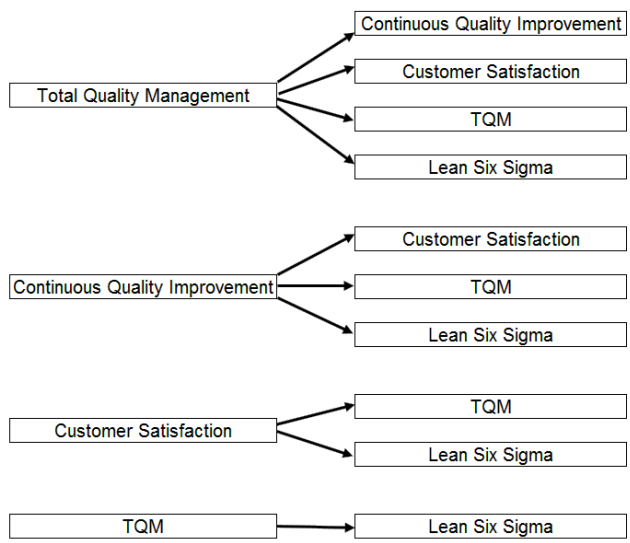

Figure 1. Keywords combination

The next step consists of a preliminary analysis of the selected articles with complete and accessible texts, accepting those that meet the following criteria:

- Case study articles using Lean Six Sigma;
- Articles that provide information on how Lean Six Sigma was applied in solving problems in the service and industrial sectors.

After obtaining the final list of selected articles, an analysis of the respective bibliographic references was made, in order to find other works relevant to the theme. Through this methodology it is possible to know the latest studies regarding Lean Six Sigma and the result of its application in the service and industrial sectors around the world.

The case studies chosen using the PRISMA methodology were analyzed as follows, as shown in figure 2.

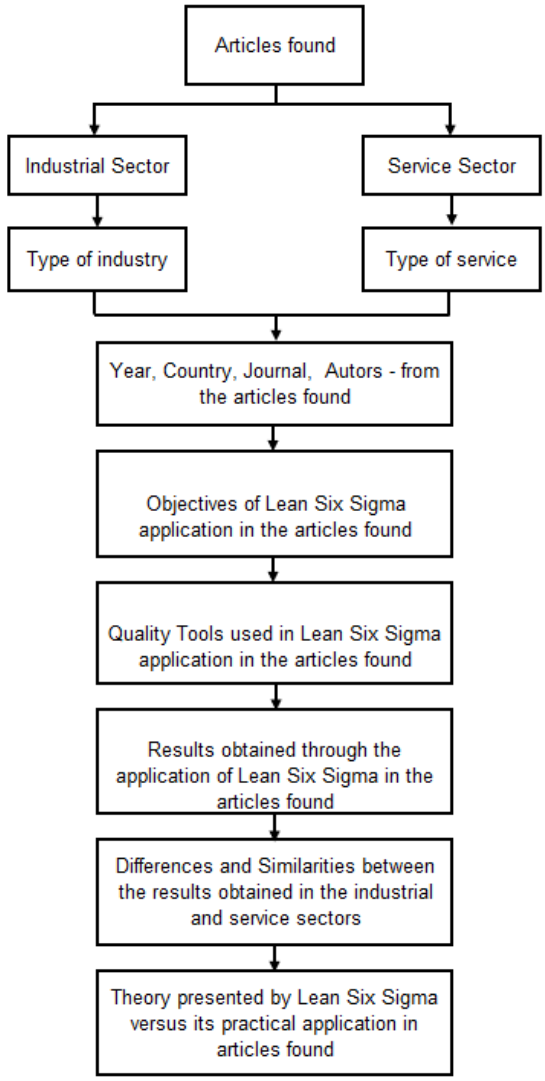

Figure 2. Methodology to analyze the articles

So, the analysis will go through the following steps:

- Separation of case studies according to industry, industry or services;
- The analysis of the sectors will be done separately, considering the following items:
- Type of sector that was applied;
- Purpose of the case studies;
- Tools used in the implementation of Lean Six Sigma;
- Percentage of use of tools;
- Results obtained after the practice of Lean Six Sigma;
- Difficulties encountered with the implementation of Lean Six Sigma.
- Comparison between differences and similarities between the two sectors.

- Confronting what is said in theory by Furterer (2002) versus the practice of implementing Lean Six Sigma.

To better exemplify the analysis of the results obtained, the work will have graphs, tables and tables, thus facilitating the understanding of the data.

3. Analysis and results

Using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyzes), this research had a universe of 5,277 articles, of which 27 articles were selected for the study, according to figure 3.

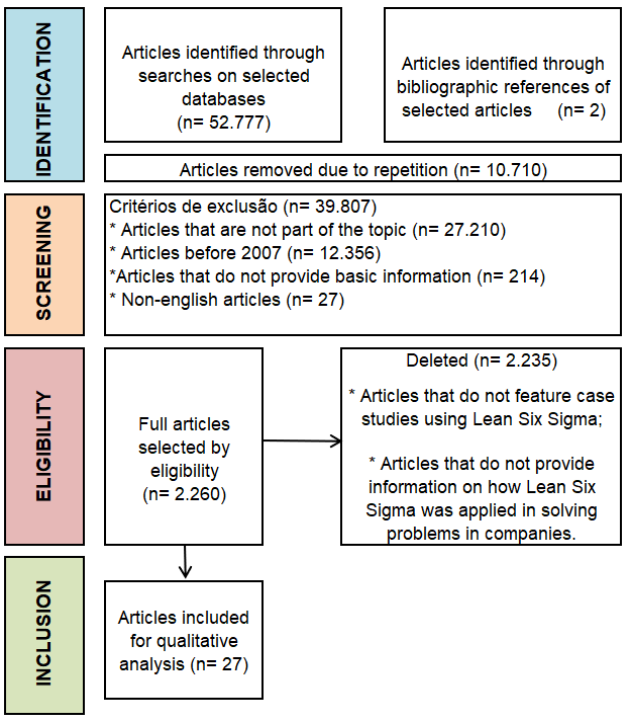

Figure 3. The PRISMA results

In a first screening were eliminated articles that were repeated between the databases, articles prior to 2007, articles that are not part of the topic, articles that did not provide basic information such as the author's name and the date of publication, and articles who were not in the English language.

After this screening, 2260 articles remained as potential candidates for the study. The inclusion criteria were then applied. They searched for articles that presented case studies using the Lean Six Sigma methodology, and also provided information on how Lean Six Sigma had been applied in solving organizational problems, showing their results. After this step, 2235 articles were deleted, remaining 25 case studies consistent with the inclusion criteria and objectives of the present study.

After obtaining the 25 articles selected, an analysis of the respective bibliographic references was performed in these 25 articles, to find other possible case studies relevant to the subject. In this analysis, it was searched the articles described in the bibliographic references of the articles already selected. By the reading of their abstracts, it was able to evaluate if these

would be pertinent to the work. This analysis resulted in another 2 articles fitting the idea of the work in question.

The combination of the 25 articles selected through the exclusion and inclusion criteria, plus the 2 articles found among the bibliographic references of the already selected ones, resulted in a total of 27 appropriate articles for the purpose of the study.

The 27 articles selected for analysis deal exclusively with the use of the Lean Six Sigma methodology, through case studies of companies in the service and industrial sectors around the world. Table 1 summarizes the year of publication, the country in which the study was applied, the publication journal, the authors and the application sectors, divided into services and industry.

Table 1. Main characteristics of the selected articles

Year	Country	Journal	Author	Sector
2007	India	Production Planning and Control	M. Kumar, Antony J., Singh R., Tiwari M., Perry, D.	Industrial
2008	England	Journal of Manufacturing Technology Management	A. Thomas, R. Barton, C. Okafor-Chuke	Industrial
2010	England	International Journal of Productivity and Performance Management	Anthony A., et al.	Services
2010	Portugal	Journal of Manufacturing Technology Management	C. Delgado, M. Ferreira, M. White	Services
2011	India	Production Planning and Control	Vinodh S., Gautham S., A. Ramiya	Industrial
2011	India	International Journal of Lean Six Sigma	Ray S., John B.	Services
2012	Jordan	Jordan Journal of Mechanical and Industrial Engineering	Mandahawi N. Fouad A., S. Obeidat	Industrial
2012	Thailand	Total Quality Management and Business Excellence	C. Cheng Chang Q.	Services
2012	England	International Journal of Productivity and Performance Management	Krishan J., et al.	Services
2012	Italy	Leadership in Health Services	Chiarini A.	Services
2013	USA	International Journal of Lean Six Sigma	M. Franchetti, P. Barnala	Industrial
2013	USA	International Journal of Pediatrics and Adolescence Medicine	Lighter D.	Services
2013	Ireland	Leadership in Health Services	Laureani A., Brady M., Antony J.	Services
2013	Italy	Public Money and Management	A. Chiarini, Bracci E.	Services
2014	Sweden	Industrial Management and Data Systems	R. Andersson, P. Hilletofth, Manfredsson P. O. Hilmola	Industrial
2014	USA	Quality Engineering	N. Anderson, J. Kovach	Services
2015	Indonesia	Industrial Engineering and Service Science	Indrawati S., M. Ridwansyah	Industrial

Table 1. Main characteristics of the selected articles (continued)

Year	Country	Journal	Author	Sector
2015	Portugal	International Journal of Management Science and Engineering Mngt	Goat M., Domingues J., J. Requeijo	Industrial
2015	Brazil	Proceeded Computer Science	Filardi F. Berti D., Moreno V	Industrial
2015	USA	Revascularization Cardiovascular Medicine	S. Agarwal, J. Gallo, Parashar A. K. Agarwal, S. Ellis, U. Khot, R. Spooner, E. Tuzcu, S. Kapadia	Services
2015	USA	Journal of Facilities Management	M. Isa, M. Usmen	Services
2016	Oman	Production Planning and Control	J. Garza-Reyes, M. Al-Balushi, Antony J., V. Kumar	Industrial
2016	Australia	International Journal of Lean Six Sigma	Leopoldo Gutierrez-Gutierrez Sander	Services
2016	Brazil	Perioperative Care and Operating Room Management	P. Ramos, E. Bonfá Goulart P., Medeiros M., Cruz, N., P. Puceh dandelion, Feiner B.	Services
2016	India	Production Planning and Control	Vijaya M. Sunder	Services
2017	USA	Journal of Pediatric Surgery	Tagge E., J. Lenart, A. Thirumoorthi, Garberoglio C., Mitchell K.	Services
2017	Brazil	Quality Engineering	Milk D., R. Montesco Sakuraba C.	Services

It can be seen in Table 1 that the journal Production Planning and Control had the biggest number of articles related to the theme of the work, 4 articles, followed by the International Journal of Lean Six Sigma, with 3 articles on the subject of work. The country which was most prominent in the application of Lean Six Sigma, according to the survey of articles, was the United States of America, totaling 6 articles, followed by India, with 4 articles. In the industrial sector, 11 articles were analyzed on the subject of the work and 16 in the service sector.

3.1. Analysis of Lean Six Sigma in the industrial sector

Lean Six Sigma (LSS), a methodology that has emerged to improve the production and quality of the industry, has gained increasing popularity in the industrial sector. The approach, which aims to help companies create simpler manufacturing operations and increase product quality, delivered significant improvements and cost savings in companies as diverse as General Electric Co., Dell Inc., Xerox Corp., and Johnson & Johnson (Garraia et al., 2008).

According to the articles selected for this work, the eleven articles related to the industrial sector are found in Table 2, as well as the type of industry that used the Lean Six Sigma methodology.

Note that Lean Six Sigma methodology can be applied in any industrial sector. And, among the selected articles, the iron ore industry, stood out as it presented two case studies in different countries.

A summary of the Lean Six Sigma implementation of the objectives in the articles analyzed are shown in Table 3.

Table 2. Lean Six Sigma application in industry

Country	Type of industry
England	Automobile and aerospace parts
Sweden	Telecommunications equipment
England	Aerospace structures
India	Castings for machinery
Oman	Iron ore
Indonesia	Iron ore
Jordan	Paper
Portugal	Bolts
India	Automobile parts
Brazil	Petroleum
U.S.A.	Recycling

Table 3. Application goal of Lean Six Sigma in the manufacturing sector

Author	Year	Type of industry	Lean Six Sigma implementation of the objective in Article studied
A. Thomas, R. Barton, C. Okafor-Chuke	2008	Automobile and aerospace parts	The objective of this study was to develop and implement an integrated model of Six Sigma (LSS) for the manufacturing industry.
R. Andersson, P. Hilletofth, Manfredsson P. O. Hilmola	2014	Telecommunications equipment	Improve flexibility, strength and agility of a telecommunications equipment company.
A. Thomas, Francis M., R. Fisher, P. Byard	2016	Aerospace structures	Achieve greater production efficiency at the same time ensuring the reduction of variation and the critical issues are eradicated from the production process.
M. Kumar, Antony J., Singh R., Tiwari M., Perry, D.	2007	Casting parts	Reduce the defect occurred in the final product (automotive accessories) manufactured by a casting process.
J. Garza-Reyes, M. Al-Balushi, Antony J., V. Kumar	2016	Iron ore	The LSS proposed framework was tested in a single business unit of an iron ore producer and focused on addressing a specific problem (reduce ships load time).
Indrawati S., M. Ridwansyah	2015	Iron ore	Improve the capacity of the manufacturing process.
Mandahawi N. Fouad A., S. Obeidat	2012	Paper	Lean Six Sigma application in order to optimize the production process, increase productivity and improve the performance of cutting machines and printing
Goat M., Domingues J., J. Requeijo	2015	Bolts	Lean Six Sigma application to reduce production costs

Table 3. Application goal of Lean Six Sigma in the manufacturing sector (continued)

Author	Year	Type of industry	Lean Six Sigma implementation of the objective in Article studied
Vinodh S., Gautham S., A. Ramiya	2011	Automobile parts	The objective was to implement Lean Six Sigma and track your results.
Filardi F. Berti D., Moreno V	2015	Petroleum	The objective of the research was to analyze the results of the Lean Sigma implementation process in the information technology sector as a tool to improve the cost allocation process and time in a large oil industry company in Brazil, under the internal perspective of employees.
M. Franchetti, P. Barnala	2015	Recycling	The objectives of the project were to improve processes and increase capacity through the implementation of Lean Six Sigma tool.

Note that the main objectives are summarized in increasing production capacity, improving productivity and thereby reducing costs. Only two case studies distinguished from the others about the objectives, not applying the methodology in the production process itself, but in other departments. These were the iron ore industry, in Oman, which used the methodology Lean Six Sigma to improve loading their ships with iron ore, and oil industry in Brazil, which applied the methodology during the administrative sector of company, seeking to improve the internal relationships of the employees.

The Lean Six Sigma allows the use of various quality tools in its implementation. The selected items from the industrial sector, the main tools used in the Lean Six Sigma methodology, is shown in Table 4.

Table 4. Application goal of Lean Six Sigma in the manufacturing sector

	Principais ferramentas utilizadas													
Tipo de Industria	DMAIC	VSM	5S	Cause Effect	TPM	FMEA	SIPOC	VoC	SWOT	7 Wastes	NAV/AV	Kanban	Control charts	Pareto
Automobile and Aerospace parts	✓	✓	✓	✓	✓									
Telecommunications equipment	✓						✓	✓	✓					
Aerospace structures	✓	✓									✓	✓	✓	
Casting for machinery	✓	✓	✓		✓									
Iron ore	✓	✓		✓			✓	✓						
Iron ore	✓					✓				✓	✓			
Paper	✓		✓							✓				
Screws	✓	✓				✓		✓				✓		
Automobile parts	✓	✓	✓	✓								✓		
Petroleum	✓													✓
Recycling	✓			✓						✓	✓		✓	✓

It is observed some standard tools being used in the case studies, as shown in figure 4, the percentage of using these tools.

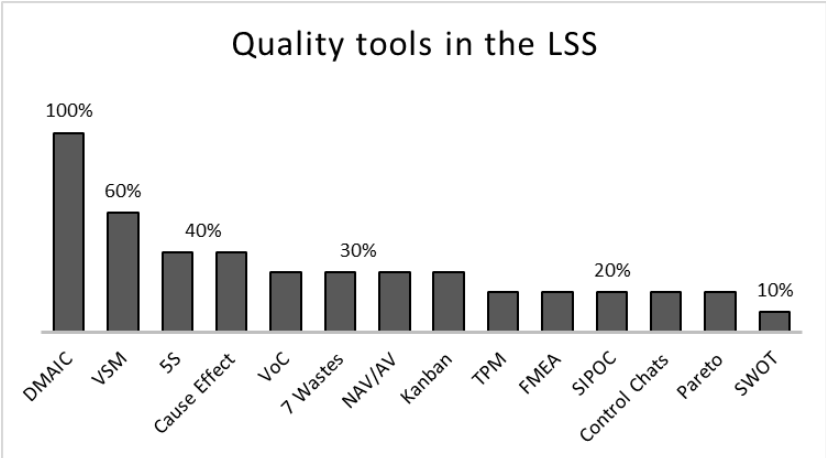

Figure 4. Percentage of use of the tools in LSS in the industrial sector

Traditional models and applications of Lean Six Sigma follow predominantly a focus on Six Sigma, using the DMAIC tool for the development of the study. As expected, all the case studies analyzed in this study show the use of DMAIC cycle.

It was observed that the tools used among the stages of tool DMAIC (Define, Measure, Analyze, Improve, Control) were distributed as follows:

sets: VoC, SIPOC, SWOT.
Measure: VSM, 7 Wastes, NAV / AV.
Analyze: Cause & Effect FMEA, Pareto.
Improve: Kanban, 5S.
Control: Control Charts.

The main results of applying Lean Six Sigma and the aforementioned tool, is shown in Table 5.

Table 5. Lean Six Sigma results in the industrial sector

Author	Year	Type of industry	Results obtained with the application of Lean Six Sigma Articles studied
A. Thomas, R. Barton, C. Okafor-Chuke	2014	Automobile and aerospace parts	• OEE (Overall Equipment Effectiveness - General Equipment Efficiency) of the plant increased from 34% to 55%; • downtime reduction of 5% to 2% equipment; • bounce rate reduction in the pilot line of 55%, indicating a potential savings during the year of £ 29,000; • A 31% increase in parts produced per hour (pph) of the production system; • Reduction of 12% of energy use per year.
R. Andersson, P. Hilletofth, Manfredsson P. O. Hilmola	2014	Telecommuni-cations equipment	• The total savings per year exceeded £ 1,000,000; • continuing reduction of the unplanned stop; • Reduction in production cost; • Reducing the number of accidents in production; • Reducing the lead time and standby time; • more pleasant and healthy environment to work.

Table 5. Lean Six Sigma results in the industrial sector (continued)

Author	Year	Type of industry	Results obtained with the application of Lean Six Sigma Articles studied
A. Thomas, Francis M., R. Fisher, P. Byard	2016	Aerospace structures	• Reducing the production time by 20.5%; • VA Reduction (Activities that add value) at 5%; • NAV reduction (activities that do not add value) at 44.5%; • OTIF (On Time Delivery and complete) increase of 26%; • Reducing the cost per aircraft at £ 45,000; • total annual savings by £ 2.8 million.
M. Kumar, Antony J., Singh R., Tiwari M., Perry, D.	2013	Castings for machinery	• Economies defect reduction at $ 46,500 per year; • The decrease in downtime of the machine 1% to 6% helped increase the OPE (Overall Plant Effectiveness - General Plant Efficiency) and OEE (Overall Equipment Effectiveness - General Equipment Efficiency). This resulted in estimated savings of more than $ 40,000 per year; • The inventory of the production process reduced by over 25% and resulted in estimated savings of more than $ 33,000 per year; • The 5S helped to significantly reduce the number of accidents in the workplace. This reduced the amount of compensation that the administration needed to be paid to injured employees (about $ 20,000 on average per year).
J. Garza-Reyes, M. Al-Balushi, Antony J., V. Kumar	2016	Iron ore	• 30% reduction in process capability; • Reduction of more than 30% in the ship's load time; • Savings of $ 300,000 per year in terms of delay rates; • more satisfied with the charging time.
Indrawati S., M. Ridwansyah	2015	Iron ore	• The study found a few points need to be improved, NVA (activities that do not add value) by 33.7%, production efficiency by 52%, process capability at 2.96 sigma; • The proposed improvement program was developed to overcome the problems which consist of redesigning the gutter dust collector, standard weighing procedures, BC facility 05, vibrometer installation and nitrogen plant installation.
Mandahawi N. Fouad A., S. Obeidat	2012	Paper	• Increased OEE (Overall Equipment Effectiveness - General Equipment Efficiency) when printing in 21.6%; • Increased OEE (Overall Equipment Effectiveness - General Equipment Efficiency) cut into 48.4%;

Table 5. Lean Six Sigma results in the industrial sector (continued)

Author	Year	Type of industry	Results obtained with the application of Lean Six Sigma Articles studied
Goat M., Domingues J., J. Requeijo	2015	Bolts	• 50% reduction in average stock level between the two workstations; • 10% increase in the level of availability of embossing machine, eliminating the possibility of missing material; • This increased availability of the machine resulted in an improvement in production capacity per hour of 15%; • Reduction of production costs.
Vinodh S., Gautham S., A. Ramiya	2011	Automobile parts	• 50% reduction in defects per unit (DPU); • Increased OEE (Overall Equipment Effectiveness - General Equipment Efficiency) in 17.6%; • 25% reduction in time to check out; • 18.5% reduction in production lead time; • Increased FTR (First Time Right - right the first time) of 98.2% to 99%, allowed savings of 28,000 valves per month of being rejected.
Filardi F. Berti D., Moreno V	2015	Petroleum	• Significant improvement of cost allocation indicators and time; • not sigificativa improvement of indicators of efficiency, effectiveness and satisfaction;
M. Franchetti, P. Barnala	2015	Recycling	• The reduction (NAV activities that do not add value) allowed to increase the productivity by 7.3% paper bales, bales of mixed 12.8% and 1.6% by corrugated metal bales; • Increased production efficiency 7-12%; • Savings of more than $ 65,000 per year.

Note a pattern gain in the results of case studies. In all they found reduced costs, and increased productivity of the production process, or in the sector involved in question. The reduction in costs that won most prominent was in Aerospace Structures sector, with a total annual savings of 2.8 million euros, followed by the telecommunication equipment industry, with an annual total savings of 1 million euros. NAV and AV activities also achieved significant results and helped in the process of improving productivity, as well as indicators such as OEE (Overall Equipment Effectiveness).

There were all the articles that reported difficulties in the implementation of Lean Six Sigma, but we showed that, were these:

- culture change in the organization;
- senior management and all staff resistance to implement a new thought presented by Lean Six Sigma, following a line of reasoning based on facts, through the tools used in the methodology, and not only through intuition;
- Participants do not prioritize or not engaged with the implementation;
- external events interfere with the team's commitment towards implementation;

- Lack of knowledge or training employees with the Lean Six Sigma methodology and tools;
- Keep the focus of the Lean Six Sigma methodology, after its implementation and results obtained.

The application of any methodology or tool generates difficulties and implications because it often involves changing a culture. This fact could be seen among the difficulties encountered in the articles.

It is important to note that in any study, the presentation of the difficulties encountered can help with future applications of the same.

3.2. Analysis of Lean Six Sigma in the services sector

Lean thinking and Six Sigma are two process innovation approaches that are extremely popular in the manufacture. The healthcare organizations industries have begun to accept the concepts of Lean Six Sigma after they have been fully developed and tested in the manufacturing industry by large corporations such as Motorola, Toyota and General Electric (SHIKHAR et al., 2015).

Among the tools that can be used in non-industrial settings, including: software development, service industries, such as customer service centers, education, administrative functions, such as finance and order processing, procurement of materials and new development product (BOSSERT & GRAYSON, 2002).

According to the articles selected for this work, the sixteen articles related to the service sector are in Table 6, as well as the type of service which was used Lean Six Sigma methodology.

Table 6. Lean Six Sigma application in the Services sector

Country	Service
England	Call center
U.S	Construction
U.S	Construction
Brazil	Gas distributor
England	Educational
Portugal	Financial
India	Financial
Australia	Logistics
Thailand	Non Governmental Organization
Brazil	Healthcare
U.S	Healthcare
U.S	Healthcare
Italy	Healthcare
Italy	Healthcare
Ireland	Healthcare
India	Outsourcing

Among the selected articles, the sector of healthcare outstands, displaying six case studies, two in the United States and two in Italy, one in Brazil and one in Ireland. The construction and financial sectors are followed by two case studies each, in different countries. Finally, central sectors of care, education, retail, telecommunications and outsourcing gain space at work, containing a case study each.

A summary of the Lean Six Sigma implementation of the objectives in the articles analyzed are shown in Table 7.

Table 7. Application goal of Lean Six Sigma in the service sector

Author	Year	Kind of service	Lean Six Sigma implementation of the objective in Article studied
Laureani A., J. Anthony, Douglas A.	2009	Call center	The objective of this study was to demonstrate the power of lean six sigma about performance in a call center.
N. Anderson, J. Kovach	2014	Construction	This case study describes how a specialized construction company used the Lean Six Sigma methodology to reduce welding defects in turnaround projects.
M. Isa, M. Usmen	2015	Construction	The objective of this work was to present a case study on the use of principles and Lean Six Sigma tools to study the improvement in design and construction services at a university. The quality of universities in facilities services has been criticized by users asking for improvements.
Milk D., R. Montesco Sakuraba C.	2017	Gas distributor	This work, a Lean Six Sigma project was implemented using DMAIC in a LPG cylinder distribution company to reduce truck load time for deliveries, increasing the company's net profit.
Antony J. N. Krishan, Cullen, D., Kumar M.	2012	Educational	The objective of this study was to critically assess whether the Lean Six Sigma (LSS) could be a powerful method of improving the efficiency and effectiveness of higher education institutions.
C. Delgado, M. Ferreira, M. White	2010	Financial	This paper presented results of a case study of a financial services organization that initiated the implementation of LSS methodologies ten years ago, the pursuit of excellence in service.
Vijaya M. Sunder	2016	Financial	The objective of this study was to highlight the importance of LSS in the banking sector through a process improvement study in real time.
Leopoldo Gutierrez-Gutierrez Sander	2016	Logistics	This article reviewed the application of Lean Six Sigma structure, supporting the continuous improvement of logistics services.
C. Cheng Chang Q.	2012	Non Governmental Organization	In the case study presented here, the tools and principles of Lean Six Sigma were used to increase the efficiency of resource management services on devices for disabled people.

Table 7. Application goal of Lean Six Sigma in the service sector (continued)

Author	Year	Kind of service	Lean Six Sigma implementation of the objective in Article studied
P. Ramos, E. Bonfá Goulart P., Medeiros M., Cruz, N., P. Puceh dandelion, Feiner B.	2016	Healthcare	In this study, the objective is to analyze the impact of a process improvement project at a large public university hospital, aiming to reduce the delays in the first surgery of the day.
S. Agarwal, J. Gallo, Parashar A. K. Agarwal, S. Ellis, U. Khot, R. Spooner, E. Tuzcu, S. Kapadia	2015	Healthcare	Study the impact of the implementation of Lean Six Sigma to improve efficiency and the patient's stay in a cath lab.
Tagge E., J. Lenart, A. Thirumoorthi, Garberoglio C., Mitchell K.	2017	Healthcare	Determine whether the implementation of LSS can improve efficiency when applied simultaneously to all the services of a children's academic hospital.
A. Chiarini, Bracci E.	2013	Healthcare	Examine ways of using Lean Six Sigma in the healthcare industry in Italy.
Chiarini A.	2015	Healthcare	This article tried to understand if some Lean Six Sigma tools were useful for reducing the risk of health and safety for nurses and doctors who administered cancer drugs. An additional objective was to analyze the economic improvements achieved through Lean Six Sigma.
Laureani A., Brady M., Antony J.	2013	Healthcare	This article examined various Lean Six Sigma projects carried out in an Irish hospital.
Ray S., John B.	2011	Outsourcing	This paper presents an application of Lean Six Sigma to reduce cycle time by outsourcing services companies.

Note that the main objectives are summarized in understanding the Lean Six Sigma behavior in the respective sectors analyzed. The health sector with six case studies, had different objectives regarding the implementation of Lean Six Sigma, were these: reduce delays in the first surgery of the day, improve efficiency and waiting time of the patient, reduce health and safety risks to nurses, and analysis of the application of the methodology. The financial sector, with two case studies show similarity in their applications, both seek improvement in process and efficiency. But the construction sector, also with two case studies, presented differences in their applications, the first focused on solving a specific problem, reduction of welding defects, the second looked for improve its design and construction services.

The Lean Six Sigma allows the use of various quality tools in its implementation, in the selected articles from the service sector, the main tools used in the Lean Six Sigma methodology, is arranged in table 8.

Table 8. Main tools used in the service sector

	Principais ferramentas utilizadas no setor de serviços																
Tipo de serviço	DMAIC	VSM	5S	Cause Effect	FMEA	SIPOC	VoC	7 Wastes	NAV/AV	Kaizen	Pareto	Histrograma	Control charts	QFD	5W1H	5 PQs	Check sheets
Call center	✓					✓		✓			✓		✓				
Construction	✓			✓	✓	✓					✓	✓	✓			✓	
Construction	✓			✓	✓		✓				✓						
Gas distributor	✓			✓		✓						✓	✓		✓		
Educational		✓	✓	✓		✓				✓	✓						
Financial	✓	✓			✓		✓							✓			
Financial	✓			✓				✓					✓				
Logistics	✓	✓				✓	✓										
Non Governmental Organization	✓		✓	✓		✓	✓		✓								
Healthcare	✓	✓															✓
Healthcare		✓						✓		✓			✓				
Healthcare	✓			✓		✓			✓		✓	✓					
Healthcare	✓	✓			✓				✓				✓				
Healthcare	✓	✓		✓	✓		✓	✓			✓					✓	
Healthcare	✓	✓	✓	✓				✓					✓				✓
Outsourcing	✓	✓											✓				

It is observed some standard tools being used in the case studies, as shown in figure 5, the percentage of using these tools.

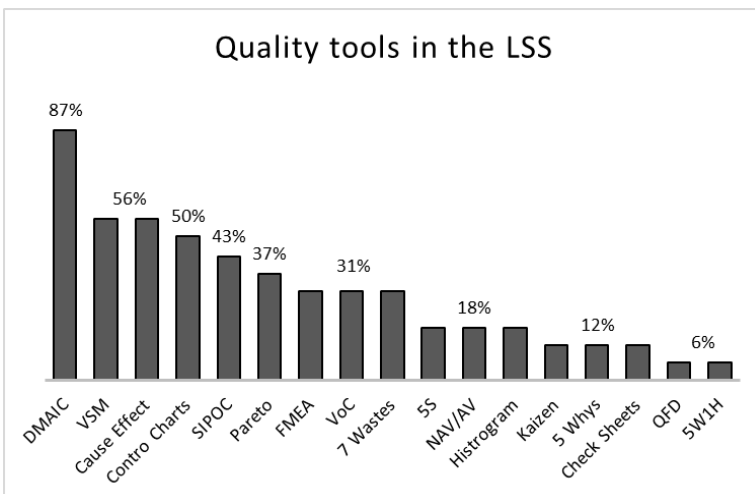

Figure 5. Percentage of use of the tools in LSS in the service sector

The DMAIC cycle in the service sector, was not present in all case studies. The education sector, for example, had its focus on lean methodology of continuous improvement, using tools to better identify causes that could affect the process, and then seek to improve them continuously. As well as the health sector, which has shown concern for the satisfaction of his client, seeking continuous improvement in the quality of service.

Among the sectors that used DMAIC cycle, tools distributed in its stages, were distributed as follows:

Sets: VoC, SIPOC, SWOT.
Measure: VSM, 7 Wastes, NAV / AV.
Analyze: Cause & Effect FMEA, Pareto, Histogram, 5PQs, 5W1H, QFD.
Improve: 5S, Check Sheets.
Control: Control Charts, Kaizen.

The main results of applying Lean Six Sigma, is shown in Table 9.

Table 9. Lean Six Sigma results in the service sector

Author	Year	Kind of service	Results obtained with the application of Lean Six Sigma Articles studied
Laureani A., J. Anthony, Douglas A.	2009	Call center	• Better use of resources by eliminating unnecessary operations; • Reduced operating costs on average $ 200,000 per year; • Improved customer service, improvement actions have reduced the percentage of first connections unresolved 11.82% to 8.45%.
N. Anderson, J. Kovach	2014	Construction	• Over 25% reduction in welding repair rate; • Economy more than $ 90,000 per year; • More prepared and motivated to function.
M. Isa, M. Usmen	2015	Construction	• The elimination and activities that do not add value, allowed an increase in operational efficiency and effectiveness.
Milk D., R. Montesco Sakuraba C.	2017	Gas distributor	• Gains of approximately R $ 67,000 yearly, for an investment of R $ 350.00 for a five-month project; • Improved process control, reduced loading time 90 minutes to 55 minutes; • Reduce conflict among employees; • Improved customer service.
Antony J. N. Krishan, Cullen, D., Kumar M.	2012	Educational	• Lean Six Sigma has an important role to play in university processes to improve its efficiency and effectiveness. But for the tool to work, all management must take due care and attention so that all areas are engaged in the improvement, enabling the organization to thrive.
C. Delgado, M. Ferreira, M. White	2010	Financial	• Improved productivity, resulting in improved processes; • Increase in customer satisfaction, resulting in an increase in revenue; • Reduction in operating costs because of improved efficiency.
Vijaya M. Sunder	2016	Financial	• The economies of the project were documented in 1.6 million INR, about $ 25,000 per year; • Reduction of rejection percentage from 10% to 3.4%; • Improvement in process productivity; • Improvement in customer satisfaction.

Table 9. Lean Six Sigma results in the service sector (continued)

Author	Year	Kind of service	Results obtained with the application of Lean Six Sigma Articles studied
Leopoldo Gutierrez-Gutierrez Sander	2016	Logistics	• Improved productivity and process performance; • Reduction in the flow time; • Improvement in the quality of service offered.
C. Cheng Chang Q.	2012	Non Governmental Organization	• Improved storage management, raising the rates of resource use; • Reduction of transfers and waits, increasing process cycle efficiency (PCE) 28%; • Improvement in customer satisfaction.
P. Ramos, E. Bonfá Goulart P., Medeiros M., Cruz, N., P. Puceh dandelion, Feiner B.	2016	Healthcare	• The late onset percentage decreases from 62% to 31%; • Reduction in the average delay of 56 minutes to 34 minutes; • Increased utilization of the operating room, from 70% to 73%; • Reduction in the proportion of cases delaying from 9% to 7%.
S. Agarwal, J. Gallo, Parashar A. K. Agarwal, S. Ellis, U. Khot, R. Spooner, E. Tuzcu, S. Kapadia	2015	Healthcare	• Significant improvement in selected metrics: time shift, medical downtime, medical arrival on time, the patient's arrival on time and the procedure to remove the coating of tools; • Increase in the percentage of cases with great time of 43.6% to 56.6%; • Reducing the percentage of time spent to get the coating of tools, from 60.7% to 22.7%.
Tagge E., J. Lenart, A. Thirumoorthi, Garberoglio C., Mitchell K.	2017	Healthcare	• Improving hospital efficiency, without firing or hiring people; • The time between the departure of a patient from the operating room and patient entry of a new cut 41 minutes to 32 minutes; • Interval between application and subsequent surgical dressing surgical wound fell from 81.5 minutes to 71 minutes.
A. Chiarini, Bracci E.	2013	Healthcare	• Lean Six Sigma can be applied to the health sector to achieve goals that are not necessarily economic or financial goals, but also political, legal and customer satisfaction.
Chiarini A.	2015	Healthcare	• Improvements in terms of movements, transportations and reduction of the team-time were achieved; • Reducing security risks; • Reduction of financial costs; • Other improvements, such as training, job instructions, implementation of barcodes and new software for ordering medicines also contributed to the success project.

Table 9. Lean Six Sigma results in the service sector (continued)

Author	Year	Kind of service	Results obtained with the application of Lean Six Sigma Articles studied
Laureani A., Brady M., Antony J.	2013	Healthcare	• The project has shown clear improvements in the process, proving to be of direct benefit to medical records and surgical departments; • The project resulted in a deposit, clean, properly stocked and suitable for use; • The lead time of the prescription process was reduced from 15 days to 3 days, and did not require increased costs or resources applied; • Reduction in the level of hospital falls.
Ray S., John B.	2011	Outsourcing	• Increased profit margin; • Reduction of 60-minute cycle time at 15 minutes

The gains achieved after the implementation of Lean Six Sigma vary from case study to case study. But all have improvement in process efficiency and customer satisfaction involved. Not all studies reported in quantitative values the outcomes obtained after the implementation of the methodology, however, those who showed the sector that stood out under economies, was the call center in England, pointing around US $ 200,000 per year.

There were all the articles that reported difficulties in the implementation of Lean Six Sigma, but we showed that, were these:

- culture change in the organization;
- Participants do not prioritize or not engaged with the implementation;
- Difficulties in obtaining a macro view of the process being analyzed, often problems were seen alone do not encompass all processes that might be triggering the problem in question;
- Lack of knowledge or training employees with the Lean Six Sigma methodology and tools;
- Financial investiment.

The application of any methodology or tool generates difficulties and implications because it often involves changing a culture. This fact could be seen among the difficulties encountered in the articles.

It is important to note that in any study, the presentation of the difficulties encountered can help with future applications of the same.

3.3. Differences and similarities between the industrial and service sectors

In both sectors, the case studies highlighted the importance of leaders are engaged with the implementation of Project Lean Six Sigma, to obtain this success. The implementation of LSS in organizations requires planning, commitment, rigorous execution and present governance, leadership plays a very important role throughout the DMAIC flow (Vijaya, 2016). In addition to top management arising leadership, leadership skills acquired from the participants themselves through Lean Six Sigma project, have been enhanced to contribute to the achievement of results (Laureani et al, 2012).

It is visible through the case studies, in both sectors, such as culture change in an organization, that is, change the way you view or do an action, presents resistance from the workers. Kumar et al (2006) highlights to convince senior management to the implementation of Lean Six Sigma is the most difficult task as well as finding resistance from workers when introduced a new way of doing business (Antony et al.,

2005, KUMAR et al. 2006). also, important to note that training on the Lean Six Sigma methodology and tools were needed in both sectors.

In applications in the industrial sector, it was observed that in Articles Lean Six Sigma helped companies to reduce their costs significantly. Pyzdek (2003) states that it is impossible to start a Lean Six Sigma project, without waiting for an economy is generated. In contrast, the service sector, highlighted the health sector, the studies showed no savings generated by the Lean Six Sigma, proving Chiarini et al (2013), saying that improvements in health sector projects may not promote savings, yet add costs because they need investment. However, improving the processes of the service, by doing investments or not, anyway it is ensured the best customer satisfaction.

The difference in Lean Six Sigma's focus on the application towards the service sector and the industrial sector is that the first aims to improve its processes to achieve the best customer satisfaction, as the second, is interested in improving their process and deliver your final product ensuring quality at lower cost. For example, in the healthcare industry customers are the patients themselves, and unlike the industrial sector, customers, patients participate in the process, rather than just to benefit from a single final product; which shows the trend of the implementation of Lean Six Sigma in the healthcare industry to be guided to the satisfaction of its customers (AGARWAL et al, 2015).

In both sectors, was evident from the results obtained with the implementation of Lean Six Sigma to decrease activities that do not add value, improve processes, productivity, efficiency, quality of the run and offered service, increased customer satisfaction, reduced costs and generating savings.

3.4. Theory versus practice

Lean Six Sigma is a focused approach to improving the quality of products, processes and services, reduce variation and eliminate waste in an organization. It is the combination of two improvement programs: Six Sigma and Lean Manufacturing (Furterer, 2009).

By improving the quality, improve processes and systems, productivity increases, and defects decrease, customers buy better products, which automatically increases the share of the enterprise market, leading to a better return on investment (DEMING, 1986).

Because organizations possess many policies and systems that allow deviations from what is really required, they lose a lot of revenue for doing wrong, having to redo. Crosby (1979) estimated the loss in revenue to the industrial sector by 20% (twenty percent), and the service sector by 35% (thirty five percent).

For Shewhart (1931), the goal of the organization is to establish cost-effective ways to satisfy customers and thus reduce everything possible to routines that require minimal human effort. The author states that there is variation in the processes of any manufacturing industry, but the change could be understood by applying simple statistical tools (OAKLAND, 2003). And through statistical concepts, it was considered possible to establish limits in routine activities and then allocate economic returns to them. Thus, there is a deviation from a routine task, then the same will not bring economic returns until it resolves (Shewhart, 1931).

In order to verify that the application of Lean Six Sigma in the case studies present in the work were entitled to define Furterer (2009), Table 10 shows the relationship of the three objectives listed above: improve quality, reduce variation and eliminate waste, for the industrial sector.

Table 10. The theory versus practice in the industrial sector

	Goals			
Type of industry	**Improving quality**	**Reduce variability**	**Eliminate waste**	**Others**
Automobile and aerospace parts	X	X	X	
Telecommunications equipment	X	X	X	X
Aerospace structures	X	X	X	
Castings for machinery	X	X	X	
Iron ore	X		X	
Iron ore		X	X	
Paper	X	X		
Bolts	X	X	X	X
Automobile parts	X	X	X	
Petroleum	X	X	X	
Recycling	X	X	X	

It appears in Table 11 that the three main objectives according to the theory, are sought when applied in the case studies of the industrial sector. Among the articles that presented other aim, there is a reduction in costs, which is a consequence of the application of Lean Six Sigma.

The same was made to the service sector, shown in Table 11.

Table 11. The theory versus practice in the service sector

	Goals			
Kind of service	**Improving quality**	**Reduce variability**	**Eliminate waste**	**Other**
Call center	X		X	
Construction	X	X		
Construction	X	X	X	
Gas distributor	X		X	
Educational	X			
Financial	X			
Financial	X		X	
Logistics	X		X	
Non Governmental Organization	X	X		
Healthcare	X	X		
Healthcare	X	X	X	
Healthcare	X	X		
Healthcare	X			
Healthcare	X		X	
Healthcare	X		X	
Outsourcing	X		X	

Table 11 shows that the theory is consistent with the practice, when applied to the articles selected service sector. Highlighted, the search for improving the quality of its processes and services, was intended to improve customer satisfaction.

5. Conclusions

Lean Six Sigma involves practices that focus on improving quality, reducing breakability and eliminating wastefulness, seeking to obtain a quality product or service, which at the same time contributes to the reduction of costs in the processes involved, also ensures customer satisfaction.

The objective of the present work was to identify the improvement in the service and industrial sectors, from the adoption of Lean Six Sigma and specific objectives: to point out the purpose of using the Lean Six Sigma methodology in the industrial and service sectors in problem solving, present the tools used through the Lean Six Sigma methodology, generically discuss the results obtained by the sectors in the application of the Lean Six Sigma methodology and verify if the theory presented by Lean Six Sigma corresponds with its execution in the case studies.

The study included 27 articles to better illustrate these points, 11 facing the industrial sector and 16 for the service sector.

Regarding the industrial sector, it was possible to identify the purpose of the application of the Lean Six Sigma methodology. It was highlighted that the main objectives were summarized in: increasing production capacity, improving productivity and consequently reducing costs. The tools used in the application of the Lean Six Sigma methodology were presented, the most used being: the cycle DMAIC, VSM, 5S and the Diagram of Cause and Effect. It was discussed on the results obtained in the case studies and, predominantly, was achieved the reduction of costs and increase in productivity of the production process. The three main objectives of the Lean Six Sigma methodology, according to Furterer (2009), to improve quality, reduce variability and eliminate waste, could be found in all articles analyzed. In particular, the pursuit of these three main objectives expanded to a fourth objective, achieving cost reduction.

As for the service sector, it was possible to identify the purpose of the application of the Lean Six Sigma methodology, in general the process was sought to improve efficiency, productivity and good customer service, which will have its satisfaction guaranteed. in the application of the Lean Six Sigma methodology. The most commonly used are: DMAIC, VSM, Cause and Effect Diagram and SIPOC. In all results obtained in the articles, it was possible to detect some kind of improvement in process efficiency and customer satisfaction and satisfaction. Among the three main objectives of the Lean Six Sigma methodology, according to Furterer (2009), highlighted the search for improving the quality of the processes and services provided, with the purpose of improving customer satisfaction.

It was evident that in both sectors, process variability and waste was eliminated, eliminating activities without adding value, improving process quality, productivity, efficiency, service provided, increasing customer satisfaction, reducing costs and generating savings

The main difference in the focus of the application of Lean Six Sigma in the two sectors was that the industrial sector looked for improving the processes in order to achieve the reduction of the costs involved, on the other hand, the service sector sought to improve its processes to better serve its customers and then ensure satisfaction.

This work could help better understand the results of applying the Lean Six Sigma in the industrial and service sectors of the last decade, according to the inclusion and exclusion criteria used herein. It was found that Lean Six Sigma is a versatile tool that can be adapted and applied to any segment, providing potential opportunities for new research and applications.

References:

Agarwal, S., Gallo, J. J., Parashar, A., Agarwal. K. K., Ellis, S. G., Khot, U. N., . . . Kapadia, S. R. (2015). Impact of Lean Six Sigma Process Improvement Methodology on Cardiac Catheterization Laboratory Efficiency. *Cardiovascular Revascularization Medicine*, *17*(2), 95-101.

Anderson, N., & Kovach, J. (2014). Reducing Welding Defects in Turnaround Projects: A Lean Six Sigma Case Study. *Quality Engineering*, *26*(2), 168-181.

Andersson, R., Hilletofth, P., Manfredsson, P., & Hilmola, O. (2014). Lean Six Sigma strategy in telecom manufacturing. *Industrial Management & Data Systems*, *114*(6), 904-921.

Antony, J., Kumar, M., & Tiwari, M. (2005). An Application of Six Sigma Methodology to Reduce the Engine-overheating Problem in an Automotive Company. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture*, *219*(8), 633-646.

Antony, J., Krishan, N., Cullen, D., & Kumar, M. (2012). Lean Six Sigma for higher education institutions (HEIs) – challenges, barriers, success factors, tools/techniques. *International Journal of Productivity and Performance Management*, *61*(8), 940-948.

Cabrita, M., Domingues, J., & Requeijo, J. (2015). Application of Lean Six-Sigma methodology to reducing production costs: case study of a Portuguese bolts manufacturer. *International Journal of Management Science and Engineering Management*, *11*(4), 222-230.

Cheng, C-Y., & Chang, P-Y. (2012). Implementation of the Lean Six Sigma framework in non-profit organizations: A case study. *Total Quality Management & Business Excellence*, 23 (3-4), 431-447.

Chiarini, A. (2012). Risk management and cost reduction of cancer drugs using Lean Six Sigma tools. *Leadership in Health Services*, *25*(4), 318-330.

Chiarini, A, & Bracci, E. (2013). Implementing Lean Six Sigma in healthcare: issues from Italy. *Public Money & Management*, *33*(5), 361-368.

Delgado, C., Ferreira, M., & Branco, M. (2010). The implementation of Lean Six Sigma in financial services organizations. *Journal of Manufacturing Technology Management*, *21*(4), 512-523.

Furterer, S. L. (2009). *Lean Six sigma in service: applications and case studies*. CRC Press.

Garza-Reyes. J., Al-balushi, M., Antony, J., & Kumar, V. (2016). A Lean Six Sigma framework for the reduction of ship loading commercial time in the iron ore pelletising industry. *Production Planning & Control*, *27*(13), 1092-1111.

Indrawati, S., & Ridwansyah, M. (2015). Manufacturing Continuous Improvement Using Lean Six Sigma: An Iron Ores Industry Case Application. *Procedia Manufacturing*, *4*, 528-534.

Isa, M., & Usmen, M. (2015). Improving university facilities services using Lean Six Sigma: a case study. *Journal of Facilities Management*, *13*(1), 70-84.

Kumar, M., Antony, J., Singh, R., Tiwari, M., & Perry, D. (2006). Implementing the Lean Six Sigma Framework in an Indian SME: A Case Study. *Production Planning & Control*, *17*(4), 407.423.

Laureani, A., Brady, M., & Antony, J. (2013). Applications of Lean Six Sigma in an Irish hospital, *Leadership in Health Services*, *26*(4), 322-337.

Laureani, A., Douglas, A., & Antony, J. (2010). Lean six sigma in a call center: a case study. *International Journal of Productivity and Performance Management, 59*(8), 757-768.

Leite, D., Montesco, R., & Sakuraba, C. (2017). Increasing a gas distributor net profit through Lean Six Sigma. *Quality Engineering*, 1-12.

Gutierrez-Gutierrez, L., & De Leeuw, S. (2016). Logistics services and Lean Six Sigma implementation: a case study. *International Journal of Lean Six Sigma*, *7*(3), 324-342.

Liberati, A., Altman, D. G., Tetzlaff, J., Mulrow, C., Ioannidis, J. P. A., Clarke, M., Moher, D. (2009). The PRISMA Statement for Reporting Systematic Reviews and Meta-Analyses of Studies That Evaluate Health Care Interventions: Explanation and Elaboration. *PLoS Med*, *6*(7). Retrieved from https://doi.org/10.1371/journal.pmed.1000100

Mandahawi, N., Fouad, R., & Obeidat, S. (2012). An Application of Customized Lean Six Sigma to Enhance Productivity at a Paper Manufacturing Company. *Jordan Journal of Mechanical and Industrial Engineering*, *6*(1), 103-106.

Pyzdek, T. (2003). *The Six Sigma Handbook: The Complete Guide for Greenbelts, Blackbelts, and Managers at All Levels*. Revised and Expanded Edition, McGraw-Hill, New York.

Ramos, P., Bonfá, E., Goulart, P., Medeiros, M., Cruz, N., Puceh-Leão, P., & Feiner, B. (2016). First-case tardiness reduction in a tertiary academic medical center operating room: A lean six sigma perspective. *Perioperative Care and Operating Room Management, 5*, 7-12.

Ray, S., & John, B. (2011). Lean Six Sigma application in business process outsourced organization. *International Journal of Lean Six Sigma*, *2*(4), 371-380.

Ray, B., Ripley, P., & Neal, D. (2006). *Lean Manufacturing - A Systematic Approach to Improving Productivity in the Precast Concrete Industry*, *51*(1), 62-71.

Snee, R. D. (2010). Lean Six Sigma - getting better all the time. *International Journal of Lean Six Sigma*, *1*(1), 9-29.

Sreedharan, R. (2016). A systematic literature review of Lean Six Sigma in different industries. *International Journal of Lean Six Sigma*, *7*(4), 430-466.

Tagge, E., Lenart, J., Thirumoorthi, A., Garberoglio, C., Mitchell, K. (2017). Improving Operating Room Efficiency in Academic Children's Hospital Using Lean Six Sigma Methodology, *Journal of Pediatric Surgery*, 52 (6), 1040-1044.

Thomas, A., Francis, M., Fisher, R., & Byard, P. (2016). Implementing Lean Six Sigma to overcome the production challenges in an aerospace company. *Production Planning & Control*, *27*(7-8), 591-603.

Thomas, A., Barton, R., Chuke-Okafor, C. (2008). Applying lean six sigma in a small engineering company – a model for change. *Journal of Manufacturing Technology Management*, *20*(1), 113-129.

Sunder, V. (2016). Rejects reduction in a retail bank using Lean Six Sigma, *Production Planning & Control*, *27*, 1131-1142.

Vinodh, S., Gautham, S. G., & Anesh, R. (2011). Implementing lean sigma framework in an Indian automotive valves manufacturing organization: a case study. *Production Planning & Control: The Management of Operations*, *22*(7), 708-722.

Ana Carolina Martins Rosa
Federal University of Technology of Paraná (UTFPR),
Ponta Grossa
Brazil
anacarolina_mrosa@hotmail.com

Evandro Eduardo Broday
Federal University of Technology of Paraná (UTFPR),
Ponta Grossa
Brazil
broday@utfpr.edu.br