

Lean Six Sigma methodology in process automation

Metodologia Lean Six Sigma na automação de processos
Metodología Lean Six Sigma en la automatización de procesos

Recebido

Received

Recibido

20 set. 2025

Sep. 20, 2025

20 sep. 2025

Aceito

Accepted

Aceptado

17 out. 2025

Oct. 17, 2025

17 oct. 2025

Publicado

Published

Publicado

25 out. 2025

Oct. 25, 2025

25 oct. 2025

<https://git.fateczl.edu.br>

e_ISSN

2965-3339

DOI

10.5281/zenodo.20169589

São Paulo

v. 4 | n. 1

v. 4 | i. 1

e41394

Outubro/Dezembro

Octobre/December

Octubre/Diciembre

2025



Amanda Oliveira Viveiro

amandalys35@gmail.com

Mauricio Henrique Benedetti

mauriciohenrique.benedetti@mackenzie.br

Universidade Presbiteriana Mackenzie

Abstract:

Process management must continually pursue excellence by ensuring high-quality standards, maximizing productivity, and minimizing operational costs. In response to these demands, the Lean Six Sigma methodology was developed to eliminate waste, reduce variability, and standardize processes with a focus on quality and efficiency. In today's competitive and fast-paced business environment, automation has become a vital part for organizations looking to modernize their operations and enhance performance. Lean Six Sigma plays a crucial role in building robust processes and driving continuous improvement. By applying its principles and tools, companies can effectively map workflows, identify inefficiencies, implement corrective measures, and implement strategic enhancements. This structured approach not only improves operational outcomes but also contributes to long-term success and sustainability. The integration of Lean Six Sigma with modern technologies enables organizations to remain agile, competitive, and responsive to market demands.

Keywords: *Lean Six Sigma; automation; Continuous improvement; People.*

Resumo:

A gestão de processos necessita buscar excelência, portanto, é preciso que haja qualidade dos processos, produtividade e o menor custo possível. Com isso, foi criada a metodologia Lean Six Sigma, visando eliminar desperdícios e padronizar os processos com qualidade. Além disso, a automação se faz essencial, nos dias modernos, de alta competitividade, por isso, as empresas buscam por modernizar seus processos, alimentando sua eficiência. Para isso, Lean Six Sigma é fundamental para a criação de um processo de qualidade e melhorias. Logo, com as teorias e práticas aplicadas, nota-se sua efetividade e ganhos ao mapear os processos, aplicar as ferramentas corretas, tratando as falhas e propondo melhorias para o sucesso de uma empresa.

Palavras-chave: *Lean Six sigma; Automação; Melhoria contínua; Pessoas.*

Resumen:

La gestión de procesos debe orientarse constantemente hacia la excelencia, garantizando altos estándares de calidad, mayor productividad y reducción de costos operativos. Para atender a estas exigencias, se desarrolló la metodología Lean Six Sigma, cuyo objetivo es eliminar desperdicios, reducir la variabilidad y estandarizar procesos con enfoque en la eficiencia y la calidad. En el entorno empresarial actual, caracterizado por una alta competitividad y dinamismo, la automatización se ha convertido en un elemento esencial para las organizaciones que buscan modernizar sus operaciones y mejorar su rendimiento. Lean Six Sigma desempeña un papel fundamental en la construcción de procesos sólidos y en la promoción de mejoras continuas. Mediante la aplicación de sus principios y herramientas, las empresas pueden mapear sus flujos de trabajo, identificar ineficiencias, aplicar medidas correctivas y proponer

mejoras estratégicas. Este enfoque estructurado no solo optimiza los resultados operativos, sino que también contribuye al éxito y sostenibilidad a largo plazo.

Palabras clave: Lean Six Sigma; Automatización; Mejora Continua; Personas.

1. INTRODUCTION

The pursuit of improvements within companies has been ongoing for some time, leading to the development of various methodologies to generate better results and achieve goals. Thus, in the 20th century, Motorola, focusing on cost reduction, process standardization, and customer satisfaction, developed a methodology called "Lean Six Sigma," combining the Lean principles of eliminating waste with Six Sigma's focus on reducing variations and defects.

These principles contribute significantly to the continuous improvement of processes and their overall quality. As Juran (2002) stated, quality planning for a product is crucial for its success; that is, it is necessary that the added value be recognized and satisfy customers.

For this to happen, Falconi (2004) discusses analyzing processes that do not add value to the product and eliminating them, thereby creating a lean, continuous flow, reducing costs and increasing productivity.

Currently, large companies control a significant share of production due to the automation technologies they use, which improve production quality through process standardization. However, in this scenario, it is necessary to have people involved in the management and execution of processes. Therefore, employees need to have an objective understanding of what is done in each activity and how tasks are performed. Additionally, there is a need for training in continuous process improvement because, by combining theory with practice, it is possible to create a culture of continuous improvement where the people performing each activity can significantly contribute to the development of better, safer, higher-quality practices with lower costs and reduced time, benefiting their productivity and personal growth.

Therefore, the expected result of combining Lean Six Sigma methodology with people trained in the tools and knowledgeable about a company whose culture promotes process improvement and a better work environment will be automated processes, reduced physical and mental strain on employees, higher profits, and greater customer satisfaction.

The theme "Lean Six Sigma Methodology in Process Automation" was chosen for this work to understand the contribution this tool makes to process improvement and to study the evolution of its application in activities that are performed manually and can be automated. The choice was based on the view that, even when automated, many activities have flaws because they are usually performed by technology professionals with the support of a restricted group of people, such as managers, who are not the people who perform the activities on a daily basis and who may leave gaps in the process. Therefore, using Lean Six Sigma will aim to ensure greater reliability and accuracy in processes, reducing errors.

2. THEORETICAL FRAMEWORK

Since the 20th century, with significant technological advances, several principles have been key to improving industrial production, such as scientific management,

which focuses on systems that increase productivity and deliver products that meet customer needs.

According to Juran (2002, p. 05, our translation), “A product is the result of any process. Economists define 'products' as goods and services.” Therefore, this is one of the areas that must be rigorously addressed in planning and execution, because any problems with the product can lead to customer dissatisfaction and, in turn, negatively impact on the product's processes and market image.

Juran (2002, p.13, our translation) states that “Quality planning is the activity of (a) establishing quality goals and (b) developing the products and processes necessary to achieve those goals.” Therefore, developing a strategic and tactical plan for the efficient execution of routine processes is crucial for achieving a satisfactory result, since the goal must focus on the needs of the customers, who are “[...] those who will be impacted or affected by the products and processes necessary to achieve the quality goals. Customers include both those who will be impacted if the goals are met, and those impacted if they are not met.” (JURAN, 2002, p. 45, our translation).

Furthermore, the company needs to add value to its processes so that customers are interested in purchasing its products, since Falconi (2004, p. 30) treats the company as an organization of human beings whose mission is to facilitate the struggle for survival of other human beings through the results of their goods. For this to happen, processes that do not add value to the product must be eliminated, and anomalies such as equipment breakdowns, maintenance issues, defects, and rework must be corrected, as these generate additional costs. To achieve this, it is necessary to standardize processes through effective methods.

Falconi (2004, p. 28, our translation) states that:

Managerial functions demand knowledge. The greater an individual's knowledge, the greater the possibilities of achieving goals never imagined. In the future, computerization and automation will concentrate human work on managerial functions, where knowledge is vital.

Therefore, creating standards, analyzing and improving existing ones is crucial for the evolution and improvement of activities, aiming for higher levels of excellence.

Falconi (2009, pp. 20-25) discusses methods as the path to be followed to achieve the expected result, that is, the management to be carried out. Therefore, there must be mastery of the methods by all people who make up the company, at all hierarchical levels, who together must find solutions to problems that hinder process excellence. The participation of people is, in fact, fundamental to everyone being engaged in achieving the goal and seeking ever-better results from teamwork.

One of the management tools that allows for continuous process improvement, standardization, and the participation of all people, widely used by large companies such as Toyota, Nike, and Nestlé, is PDCA, composed of 4 stages (Plan, Do, Check, and Act), which can be applied in various areas.

Falconi (2009, pp. 26-27) discusses the concept of a system in which the most

diverse areas are considered a single system; that is, organizational relationships and their functions are managed by objectives aimed at the organization's final goal. Therefore, if a problem occurs, it indicates a system dysfunction caused by a failure to fulfill the system's function correctly. And, to prevent this from happening, the company needs to focus on solving problems considering the strategic, tactical, and operational levels.

2.1. LEAN

In today's era of rapid access to information and a diversity of products, services, and experiences, the high level of competition among private companies to become market leaders and benchmarks is evident. It requires more than just understanding internal processes; they must also be optimized to better match the competition and gain a competitive advantage.

There is a correlation between people and processes; therefore, their management must be aligned to ensure the flow of activities proceeds as expected.

According to research conducted by FM2S (2020), there are general principles for implementing process management, including the Lean methodology, used by large companies such as Kimberly-Clark Corporation, Nike, and Intel, which have achieved success in their businesses.

Werkema 1995 (p.48 apud BRIALES, 2022, p. 46, our translation) "defines lean as a philosophy that seeks the elimination of waste, that is, of everything that does not add value to the customer, reducing lead time [...]".

According to Shingo (1996 apud FROTA; LOPES, 2015, p. 04), lean is also called the Toyota Production System (TPS), as it was developed at Toyota in the 1950s, based on reducing the 7 wastes, which are: overproduction, waiting time, unnecessary material transport, excessive processing, inventory levels, unnecessary movements and rework.

Therefore, it is important for the process flow to be carried out continuously and as lean as possible, with the client's needs in mind (pull system). To achieve this, leaders must promote a learning culture among their people by investing in training and involving them in the processes, so they can find the best solution together and continually improve the process.

2.2. SIX SIGMA

This high level of competitiveness among companies is one of the reasons for the development of strategies aimed at improving the quality and standardization of the manufacturing stages of their products; in other words, the closer the process is to perfection, the greater the competitive advantage.

Aguiar (2006) presents the positive results achieved by Motorola and, later, General Electric (GE) with the Six Sigma Program.

This is a methodology based on measurements and statistics for decision-making, promoting cultural change and positioning it to identify and treat problems, to achieve a high-quality standard (approximately 3 nonconformities per million units produced) and a large financial return.

Carlos et al. (2023, our translation) highlight that “Choosing this method is appropriate because it seeks a balance between better customer service and cost reduction, in addition to structuring a robust workflow for process management, reducing variability.”

Its application in projects and process improvements is done through a strategy called DMAIC, which consists of:

- Define – what are the improvement objectives;
- Measure – map and understand how each process occurs;
- Analyze – find where the errors are that cause variations;
- Improve – make the desired improvements;
- Control – Maintain the sustainability of the results obtained.

As shown in Table 1, the 6-sigma level indicates a higher probability of success, as its yield is practically 100%.

Table 1Sigma Level Classification		
Sigma Level	Parts per Million (PPM) errors	Performance (%)
1	691,460	30.85
2	308,540	69.14
3	66,807	93.32
4	6.210	99.38
5	233	99.38
6	3.4	99.99966

Source: Prepared by the author (2025)

2.3. LEAN SIX SIGMA

When Lean and Six Sigma are implemented simultaneously, there is significant potential for process improvement. According to Santos (2016), “[...] in a harmonious way, the two systems become more effective, since the strengths of one fill the possible gaps or deficiencies of the other.”

Therefore, this partnership adds value to the customer and keeps them satisfied, while also improving internal processes and leveraging the company culture, as implementing Lean Six Sigma management becomes part of the routine.

2.4. QUALITY TOOLS

According to Landiva (2021, p. 25), the methodology developed by Joseph M. Juran, known as Juran's Trilogy, is based on quality planning (what, how and for whom to produce), quality control (standard of procedures with maximum productivity) and quality improvement (maintenance and qualitative improvement of processes, whether implemented or in flow).

Magalhães (2016) states that these tools assist managers in decision-making and help reduce costs, and are classified into 7 types:

1. **Histogram** – a bar graph that allows for quick visualization of the variation in a process based on the distribution of numerical data, verifying the relationship between two or more variables and the degree of standard deviation present in the analysis;

2. **Check sheet** – A document containing data that can be collected more easily, ensuring that relevant data is collected. It can be used by multiple people, reducing the margin of error and standardizing record-keeping. The most used types are process variation check sheets and failure check sheets.
3. **Pareto diagram** - a graph that displays the main factors that make up an analysis, usually in descending order of data, whether they are single data points or data from different periods, to establish priorities for corrective action;
4. **Ishikawa Diagram (Fishbone Diagram)** – Based on universal symbolism, it visually represents the relationship between an effect and the possibilities of its occurrence, and the main causes become the basis for the 5W2H tool, which serves as a problem-solving tool;
5. **Flowchart** – a graphic representation of a sequence of actions (flow) of a job, product, or service for analysis of operational standardization;
6. **Scatter plot** – A graphical analysis of the relationship between two variables, mostly consisting of one independent variable (cause) and one dependent variable (effect). This correlation can be positive (both variables increase or decrease in the same direction), negative (both variables increase or decrease in opposite directions), or zero (when there is no correlation between the variables).
7. **Control Charts** – Observation of point trends over a period, which can be variable or discrete data.

It is therefore clear that quality management aligns with the requirements for implementing and sustaining Lean Six Sigma process improvements.

2.5. PROCESS AUTOMATION AND JOB ENRICHMENT

According to the article by Lopes (2023), the commercial dispute arises from the relationship between automation driven by structured tools and technologies and the Lean Six Sigma (LSS) methodology for improving processes and productivity. For this to occur, it is necessary to develop tools and adapt the system across infrastructure, information security, regulation, work reorganization, and efficient use of resources.

It is evident that there is a trend toward companies becoming increasingly independent of human labor in operational processes, transforming them into intelligent companies.

For companies, it is very important to implement technologies across their organizations to remain competitive in the market.

Thus, Lopes (2023, our translation) proposes that:

The integration of Lean Six Sigma with Industry 4.0 represents a holistic approach to optimizing processes, improving efficiency and driving innovation in industrial organizations. Both methodologies aim to increase quality, reduce costs and improve operational efficiency.

All the points presented here are fundamental for good management, productivity, and business growth, but, as the American Renne West (President and COO of the Excalibur Hotel and Casino, our translation) said, "You can have the best

strategy and the best structure in the world, but if you don't have the hearts and minds of the people who work with you, none of that becomes real." This helps us understand the importance of human beings in achieving corporate goals, and to do so, it is necessary to understand the needs, desires, and motivations of our employees.

Herzberg's Motivation Theory found that employee performance varies with job satisfaction, which in turn is a consequence of factors influencing their motivation or lack thereof, such as working conditions and special conditions like employee recognition for their actions.

To increase worker satisfaction, Lobos (1975) analyzed operational strategies aimed at this goal and addressed job enrichment, which involves increasing task complexity to demand more of employees' capabilities. In this way, the worker performs their activities more autonomously and assumes more responsibility; thus, many feel more motivated to perform their tasks, increasing the chances of promotions due to training and engagement, as well as expanding knowledge and contributing to process improvements and the organization's overall productivity.

The same is true today, although with much more technological and automated development, strategies to ensure employee motivation and productivity require mutualism between machines and humans in developing processes that facilitate daily tasks and enable greater availability to perform more demanding activities.

3. METHOD

The study adopted a qualitative approach, based on the descriptive and interpretative analysis of the logistics processes of a distribution center belonging to a multinational company in the automotive paint sector. This approach was chosen due to the complexity of the phenomena investigated, which involve operational, technological, and human variables.

The development followed Lean Six Sigma principles, starting with the identification of the current state through Value Stream Mapping (VSM). Following this, several flaws, operational and procedural bottlenecks, wasted headcount and time, and excessive resource use were identified, as well as areas for improvement, given the company's limitations. Finally, a strategic approach was formulated to reduce waste and defects, increasing quality and efficiency.

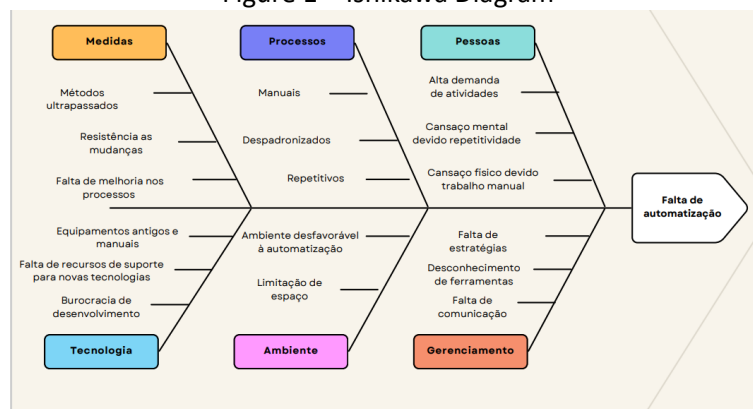
Furthermore, direct observations were conducted of administrative and operational activities, during which gaps in standardization were identified due to manual execution, resulting in errors and rework. For example, cargo routing is done manually by an employee using *Google Maps*; any error could lead to significant problems, including delivery delays, customer dissatisfaction, and increased freight costs.

On the other hand, order deliveries are tracked through the EDI-OCOREN file, which the carrier sends daily to the shipper. This process is semi-automated, as

the feature for receiving information via email has been implemented; however, the analysis is performed manually, making it not 100% reliable.

Therefore, to better understand the root causes of the failures, the Ishikawa Diagram (Figure 1) was used, revealing that the lack of automation in routine processes is the main factor leading to errors and rework.

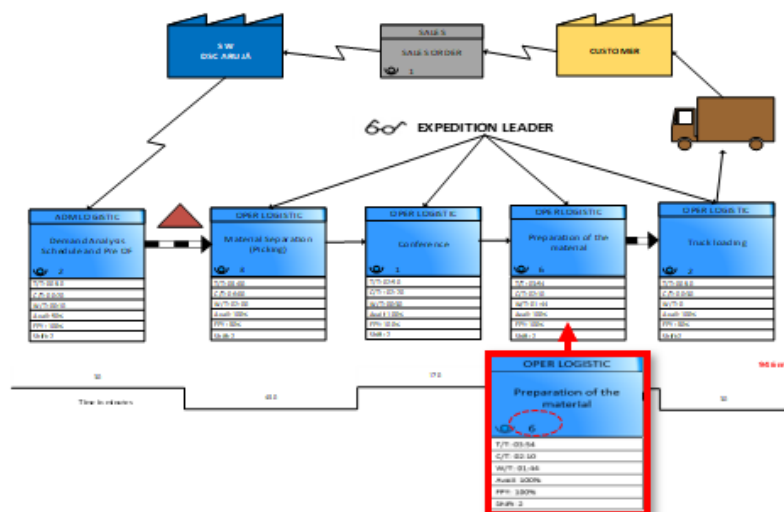
Figure 1 – Ishikawa Diagram



Source: Prepared by the author (2025)

During operational observation, it was identified that processes also occur manually, such as the separation and verification of orders (printed and physical counting), which makes the process slow and error-prone. Based on the analysis of the Value Stream Map (VSM) to better understand the end-to-end process of the organization, together with an employee, as shown in Figure 2.

Figure 2 – Value Stream Map (VSM)



Fonte: Elaborado pelo autor (2025)

The bottleneck identified was the manual wrapping of export pallets with stretch film (Figure 3), which required around 2 to 3 employees per shift to take turns. This was due to significant physical effort and time spent, and it also posted significant ergonomic risks to the employee. It was considered a very laborious and inefficient step, resulting in unsatisfactory service quality, since the lack of standardization in the quantity and points of stretching film wrapping compromises

material-handling safety and consequently increases the likelihood of damage, negatively affecting the customer.

Figure 3 – Manual wrapping of export pallets



Source: Prepared by the author (2025)

Given this, it was proposed to automate pallet wrapping using a *stretch wrapping machine* (Figure 4), and after a feasibility analysis, the donation of this machine to the distribution center unit was offered, thus replacing this manual process with a machine that only requires one employee to place the pallet, turn on the machine, remove the pallet, and turn off the machine at the end of the process.

Figure 4 – Stretch wrapping machine



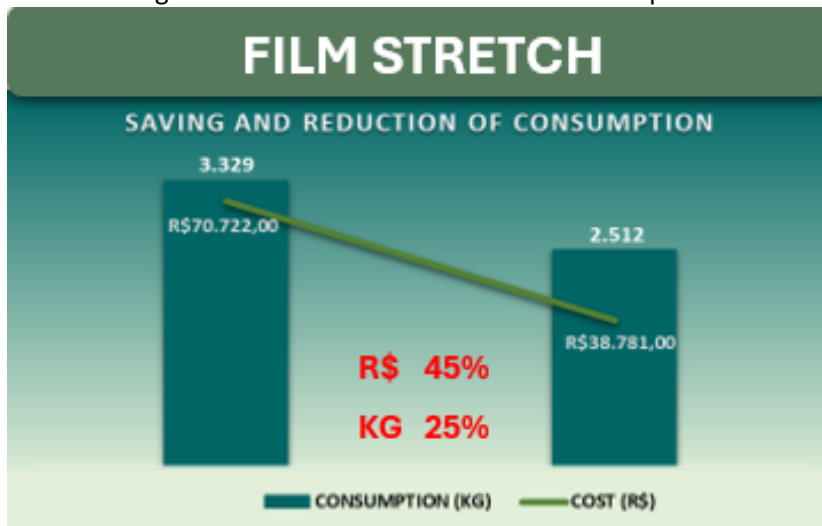
Source: Prepared by the author (2025)

4. RESULTS AND DISCUSSION

During this change phase, employees trained in tools such as Kaizen, 5S, Takt Time, and SOP (Standard Operating Procedure) actively suggested ideas. They readily accepted the change, as it enriched and improved working conditions. After 6 months of implementation, a new process study was conducted, and the improvement was positive not only for ergonomics but also for sustainability,

material savings for palletizing, headcount reallocation, a reduction of 1 hour and 16 minutes in the total process time, and a decrease in employee complaints of pain and absenteeism, as shown in Figures 5, 6, and 7.

Figure 5 – Reduction in stretch film consumption



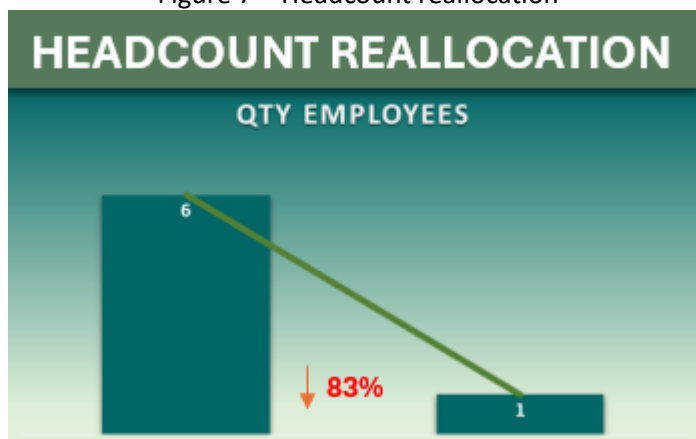
Source: Prepared by the author (2025)

Figure 6 – Reduction in activity time



Source: Prepared by the author (2025)

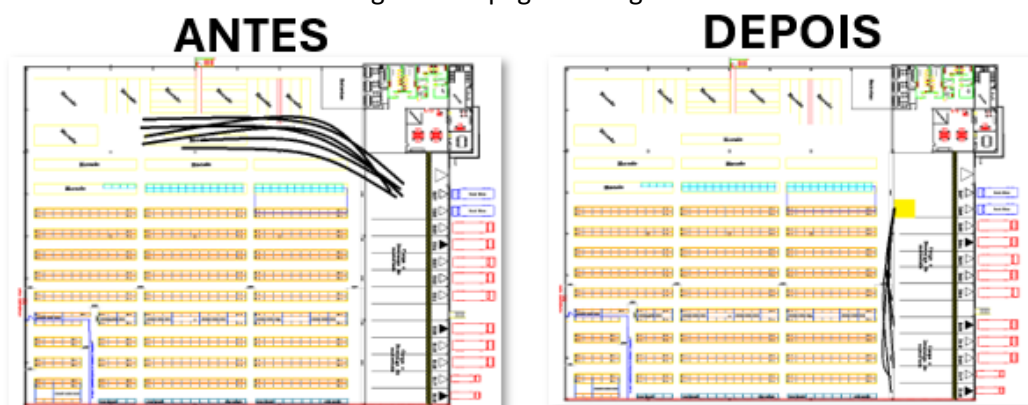
Figure 7 – Headcount reallocation



Source: Prepared by the author (2025)

The project also helped reduce the distance traveled, thereby increasing warehouse capacity by freeing up areas that were no longer needed for palletizing loads (Figure 8).

Figure 8 – Spaghetti diagram



Source: Prepared by the author (2025)

Therefore, the results revealed that the principles of Lean Six Sigma are effective for process automation, since the elimination and reduction of errors significantly contribute to the satisfaction of internal and external clients with standardized quality products and services, and to excellence with 100% accuracy.

5. CONCLUSION

In conclusion, investing in structured procedures, as proposed by the Lean Six Sigma principles, promotes awareness of daily, often unnoticed, actions that negatively impact the business. It also encourages proactive improvement initiatives that leverage technology and integrated employee participation, fostering continuous improvement across diverse areas.

REFERENCES

- AGUIAR, Sylvio de. **Lean Six Sigma: Introduction to Lean Six Sigma Tools**. São Paulo: Saraiva, 2006.
- ANTONY, Jiju. **Lean Six Sigma for Business Excellence: A Manager's Guide to Sustaining Continuous Improvement**. 2nd ed. Boca Raton: CRC Press, 2023.
- BRIALES, Sergio. **Lean Management: How to Apply Lean Manufacturing in Organizations**. 3rd ed. São Paulo: Atlas, 2022.
- CARLOS, A.; LOPES, B.; SILVA, C. **Six Sigma in Practice: Strategies for Continuous Process Improvement**. Rio de Janeiro: LTC, 2023.
- FALCONI, Vicente. **The True Power: Management Practices that Lead to Revolutionary Results**. 5th ed. Nova Lima: Falconi Consultores de Resultado, 2009.
- FALCONI, Vicente. **TQC: Total Quality Control (Japanese style)**. 10th ed. Nova Lima: Falconi Consultores de Resultado, 2004.
- FROTA, L.; LOPES, M. **Lean Manufacturing: Concepts and Practices**. 2nd ed. São Paulo: Bookman, 2015.
- IMAI, Masaaki. **Kaizen: The Key to Japan's Competitive Success**. New York: McGraw-Hill, 1986.
- JURAN, JM. **Quality from the Design: New Steps for Quality Planning in Products and Services**. 3rd ed. São Paulo: Pioneira, 2002.
- LANDIVA, Carlos. **Quality Tools: Fundamentals and Practical Applications**. 4th ed. Rio de Janeiro: Elsevier, 2021.
- LIKER, Jeffrey K. **The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer**. 2nd ed. Porto Alegre: Bookman, 2021.
- LOBOS, Mário. **Job Enrichment Strategies: Analysis and Applications**. 2nd ed. São Paulo: Atlas, 1975.
- MAGALHÃES, Carlos. **The 7 Quality Tools: A Guide for Managers**. São Paulo: Atlas, 2016.
- SANTOS, Joaquim dos. **Lean Six Sigma: Integration and Continuous Improvement**. 3rd ed. Rio de Janeiro: LTC, 2016.
- FM2S. **General Principles for Implementing Process Management**. 2020. Available at: <https://www.fm2s.com.br>. Accessed on: October 20, 2023.
- LOPES, Renan Araujo. **Integration of Lean Six Sigma in Industry 4.0 Aiming at Operational Excellence**. *Production Engineering*, v. 27, n. 129, Dec. 2023.
- SANTOS, Aézio Almeida dos. **Lean Six Sigma: Together Against Inventory**. LinkedIn, 2023. Available at: <https://www.linkedin.com/pulse/lean-six-sigma-juntoscontra-o-estoque-a%C3%A9zio-almeida-dos-santos/?originalSubdomain=pt>. Accessed on: November 9, 2023.
- SILVA, Jéssica. **Integration of Lean Six Sigma in Industry 4.0 aiming at operational excellence**. *FT Magazine*, 2023. Available at: <https://revistaft.com.br/integracao->

do-lean-six-sigma-na-industria-4-0-visando-a-excelencia-operacional/. Accessed on: May 17, 2024.

"The content expressed in the work, as well as the copyright of figures and data, and its spelling and compliance with ABNT standards, are the sole responsibility of the author(s)."