Revista ARACÊ
ISSN: 2358-2472

PROPOSAL OF LEAN MANUFACTURING TOOLS FOR THE ELECTROMECHANICAL MAINTENANCE AREA

https://doi.org/10.56238/arev7n3-165

Submitted on: 02/17/2025 **Publication date:** 03/17/2025

Daniel Rodrigues dos Santos[1], Carlos César Ribeiro Santos[2], Leonardo Sanches de Carvalho Filho[3], Guido Barbosa Velloso[4], Maria Luiza Teixeira de Jesus Soares[5] and Rafael Souza Sobral[6]

ABSTRACT

This research addresses lean tools applied in the area of electromechanical maintenance. A review of the literature and the practical application of both the 5S and the spaghetti diagram were used in order to understand how these tools can be applied to promote improvements in the area of electromechanical maintenance. In this sense, the research question was answered and the objectives achieved. It is concluded that the combination of the theoretical review with the practical application of Lean tools, in a real case, allowed to envision future proposals for improvements with perspectives of substantial gains such as the reduction in the displacement in the turning layout by 70%. Thus, these results highlight the potential of lean tools to reduce waste and increase productivity.

Keywords: Lean Manufacturing. Electromechanical Maintenance. Continuous Improvement Tools.

[1]Master in Industrial Management and Technology
SENAI CIMATEC
[2]Dr. in Computational Modeling and Industrial Technology
SENAI CIMATEC
[3]Mechanical Engineering Student
SENAI CIMATEC
[4]Mechanical Engineering Student
SENAI CIMATEC
[5]Mechanical Engineering Student
SENAI CIMATEC
[6]Mechanical Engineering Student
SENAI CIMATEC

Revista ARACÊ
ISSN: 2358-2472

INTRODUCTION

All segments of the industry need to think about improvement, waste reduction, cost reduction, and increased productivity. In this way, lean manufacturing brings all this into its essence. In this sense, the electromechanical maintenance area, the core of this work, needs to improve the way its activities are carried out in order to increase the availability of equipment/machines/components linked to the area, such as electric motors or water pumps.

The first reports of an electric motor were in the mid-nineteenth century in Europe, when they emerged with the purpose of being a machine capable of functioning, without the need for human force as a source of energy (SOUZA, 2018). All this in order to obtain a machine capable of standing out from the others at the time, aiming to meet the production demand driven by the Second Industrial Revolution.

Water pumps, on the other hand, appeared more than 4 thousand years ago in Egypt, with the purpose of irrigating the crops of the time in a more efficient way, raising the water to the desired level. Throughout history, several improvements and technological advances have been made, seeking to increase the capacity to raise this water, according to the needs of each era, resulting in several models of water pump that exist today (YANNOPOULOS, et al 2015).

In recent years, water pumps have undergone improvements in order to be able to meet the supply of increasingly larger homes, where there is a significant flow of water to be routed. In turn, electric motors have undergone constant technological innovations, in order to have models capable of delivering the necessary energy efficiency and at the same time, helping to reduce costs.

Thus, this research aims to understand how lean tools (5S and spaghetti diagram) can reduce waste and increase productivity in the area of electromechanical maintenance? The general objective of this article is to understand how lean tools (5S and spaghetti diagram) can be applied in the area of electromechanical maintenance and the specific objectives are: to list waste in a company in the field of electromechanical maintenance and to propose improvements for the company's team to execute at an opportune time.

Revista ARACÊ
ISSN: 2358-2472

LEAN THINKING

Lean manufacturing emerges and consolidates, from STP, as a philosophy that preaches lean thinking and the elimination of waste. The choice of the name "lean" is due to the fact that STP uses fewer resources compared to mass production, whether they are labor, physical space, investment, planning and production time, inventories or machinery, its creator was Taiichi Ohno (WOMACK, JONES and ROOS, 2004).

In this way, lean emerged in Japan, at the Toyota plant in the post-World War II period. The country's economy was devastated by the war and the government had to apply protectionist measures towards foreign capital to allow domestic industrial development. This context was vital for the Toyota Production System (TPS) to gain strength and space in the global automotive sector, aiming to increase production efficiency by continuously extinguishing waste (WOMACK, JONES and ROOS, 2004; DESHMUKH, et al, 2022).

Lean acts strongly with five principles, which are defined by WOMACK, JONES and ROOS, 2004; KNOL, et al, 2018; DESHMUKH, et al, 2022:

- **Value:** It is everything that the customer is willing to pay and that satisfies their needs and expectations;
- **Value stream:** it is the sequence of all activities that transform inputs into a product or service that adds value to the customer;
- **Continuous flow:** it is the search for an uninterrupted workflow, eliminating interruptions and delays, so that products or services flow smoothly and efficiently throughout the process;
- **Pull flow:** it is a system where production is started only when there is a customer demand, avoiding excess production and ensuring that products are delivered at the right time;
- **Perfection (or Continuous Improvement):** is the incessant search for the elimination of all waste and the optimization of processes, aiming to achieve maximum efficiency and quality.

These principles need to be understood by everyone involved in the improvement process so that waste can be identified and eliminated. In this sense, lean aims to eliminate eight wastes, according to Deshmukh, et al (2022), namely:

- **Overproduction:** which means producing more than necessary;
- **Waiting:** which is the time that products or people wait for the next step or process,

Revista ARACÊ
ISSN: 2358-2472

which may occur because of queues, lack of materials or imbalance in the production system;

- **Transportation:** which are the displacements with materials;
- **Excessive processing**: which can be excessive checks, reprocessing, among others that do not add value;
- **Inventory**: which is the excess of raw materials, products in process, or finished products;
- **Movement:** which is the unnecessary displacement of people to search, for example, for tools, materials or information, increasing the cycle time of the process;
- **Defects:** are products or services that do not meet the customer's requirements;
- **Intellect**: which means not using the potential of employees to solve problems.

Starting from the understanding of lean principles and the identification of waste, it is necessary to use tools that help correct the course of the area that is being mapped. Thus, the next section will deal with the 5S tools and spaghetti diagram.

LEAN TOOLS

As seen in the previous section, lean aims to identify and eliminate waste, but for that, it needs tools that help in this task. Thus, this work aims to deal with three tools in the context of a company that operates in the area of electromechanical maintenance and these are: 5S and spaghetti diagram.

5S is a Japanese method of organization that aims to improve efficiency, productivity, and safety in various sectors and types of companies. Based on five principles, each of them seeks to create a more orderly, safe, clean and efficient work environment. The five senses as per Randhawa and Ahuja (2017) are:

- **Sense of Use (Seiri):** means organizing the work environment, eliminating everything that is not necessary to carry out activities;
- **Sense of Organization (Seiton):** After eliminating what is not necessary, the next step is to organize what remains. Each item must have a defined and easily accessible place, making it easier to locate and avoiding wasting time in the search for materials;
- **Sense of Cleanliness (Seiso):** cleanliness is essential for an efficient and safe work environment, the ideal is to generate the feeling in employees that each one is

Revista ARACÊ
ISSN: 2358-2472

responsible for keeping their work environment clean;

- **Sense of Standardization (Seiketsu):** after cleaning, it is necessary to standardize the procedures and conditions of the work environment, including the creation of checklists and standard operating procedures (SOPs);
- **Sense of Discipline (Shitsuke):** it is necessary to create a culture of organization and cleanliness, involving all employees and leaders. Discipline is achieved through education, training, and creating a work environment where the organization is valued.

In accordance with the implementation of the 5S method, the spaghetti diagram has in its objective the mapping to represent the flow of movement of people, parts/products and documents in a given environment. From the visualization of the flow, it is possible to make more assertive decisions to optimize the layout, reduce costs, and increase efficiency (DANESHJO, et al, 2021).

The spaghetti diagram is of paramount importance for improvement in layouts, which for Slack, Jones, Johnston (2018) "physical arrangement" (layout) of an operation or process means how its transformation resources are positioned against each other, how its various tasks are allocated to these transformation resources, and the overall appearance of these resources.

Also according to Slack, Jones and Johnston (2018), the decision of physical arrangement is important because, if the layout is wrong, it can cause very long or confusing flow patterns, customer queues, long process times, inflexible operations, unpredictable flows, high costs and a weak response for those inside the operation, whether they are customers or employees.

METHODOLOGY

For the theoretical foundation of this article, a literature review was used, with articles, theses and dissertations researched in databases such as Scopus, Web of Science and Google Scholar. Field research, in this stage, visits were made to the company, with part of the workforce and management. The research involved the analysis of the possibilities of improvements with 5S, studies of the company's layout with the spaghetti diagram to propose improvements in the layout.

In addition, the research has limitations, such as with regard to the solution of the problems/opportunities identified in the company, in addition, the implementation of the

Revista ARACÊ
ISSN: 2358-2472

proposed improvements was not monitored in this work, being the responsibility of the company. Despite these limitations, the results obtained can serve as a basis for future research and improvement projects in the area of electromechanical maintenance.

THE COMPANY

The case study was developed in an electromechanical company located in the city of Salvador - BA, whose main scope is the maintenance services of water pumps, electric motors and alternators, according to the catalog described below in figure 1.

Figure 1: Catalog of equipment for maintenance service

Source: The authors, 2024.

Founded in 1954, the company opened its doors in a small house and performed its first services operating with little equipment, some of them developed by the founder himself. Always under family management, the company managed to consolidate itself in the market and generate value for its customers. As a consequence of the increase in demand, it was necessary to expand, in an organic way, the administrative facilities and the workshop. Due to physical limitations, this growth occurred vertically, so that today the

Revista ARACÊ
ISSN: 2358-2472

company has a 3-story building, which often makes it difficult for its employees to move around and transport equipment internally.

Today the company has contracts with large industries and with the city's water supply company, contracts that add up to most of the demand for services they receive. Due to the fact that the company has always grown in an unplanned way, it was possible to observe opportunities for improvement and implementation of Lean tools, 5S and the spaghetti diagram in its production process. These opportunities will be detailed in the results and discussions chapter.

RESULTS AND DISCUSSIONS

The 5S method, as mentioned in the literature review section, has as its main aspect "tidying up the house", that is, generating a more organized, clean and conducive environment to carry out work safely. Thus, the main opportunities for improvement from the 5S method are shown below.

OPPORTUNITIES FOUND IN THE 5S METHOD SENSES

In the evaluation focused on the sense of use, we noticed that there is a need to organize the work environment and eliminate everything that is not necessary to carry out the activities (with emphasis on the tools that employees use on a daily basis) as shown in image 1 below.

Image 1: Opportunities for improvement in the sense of use

Source: The authors, 2024.

As a proposal for improvement, you should check what is being used in the employee's space and if not, remove the equipment/utensils. And bring to yourself what is frequently used. There are tools in cans that have been adapted as a storage place, in

Revista ARACÊ
ISSN: 2358-2472

addition, there are objects scattered with a special emphasis on the pumps that are waiting for service, thus making it difficult to visually manage the process.

Another point to be improved are the traffic areas that are most often obstructed, very much related to the fact that the workshop grows vertically and does not have space to grow horizontally, there are certain areas obstructed for the movement of people. A point to be evaluated would be the accumulation of pumps and the lack of a specific space for them. It may even cause problems that affect the integrity of the employee and/or visitor.

Regarding the sense of organization and cleanliness, image 2 below brings an environment with several opportunities, because in addition to materials being arranged in inappropriate places, there is dirt in the environment.

Image 2: Opportunity for organization and cleaning

Source: The authors, 2024.

The sense of organization has at its core that each equipment/tool has its specified location, which we did not find at the time. With regard to cleanliness, in the environment there is no selective collection and discipline for those who dirty, also be responsible for cleaning, as shown in the image above.

As an improvement, the initial suggestion is to promote a cleaning task force that needs to happen from the first sense, arriving at this with little to be done and implement a selective collection of products that are waste, so that the work environment is healthier.

Regarding the sense of standardization and self-discipline, the company has other opportunities for improvement, such as safety signage, information flow, as shown in image 3 below.

Revista ARACÊ
ISSN: 2358-2472

Image 3: Opportunities for standardization and self-discipline

Source: The authors, 2024.

The suggestion is to signal all points of attention in the workshop, even for those employees who have been in the company for a long time, safety cannot be neglected. In addition, it is necessary to reinforce the painting of the safe paths of the workshop.

In the sense of discipline, it is important to initially evaluate whether people practice safety standards, establish motivational talks, safety, the importance of maintaining a clean, organized and safe environment.

At the time of this survey, there was no 5S audit form in the area. The suggestion is that in addition to the audit form, people should initially be trained, representatives should be chosen to carry out the audit in the area and establish a rotation in the responsibility for this performance, focus on the points of compliance with the 5S requirements and reassess the points that were addressed in the first audit carried out.

What is not being fulfilled, we suggest a conversation with the employee to understand the main difficulties he has to be able to comply with the rules and jointly establish goals and deadlines.

OPPORTUNITIES FOUND WITH THE SPAGHETTI DIAGRAM

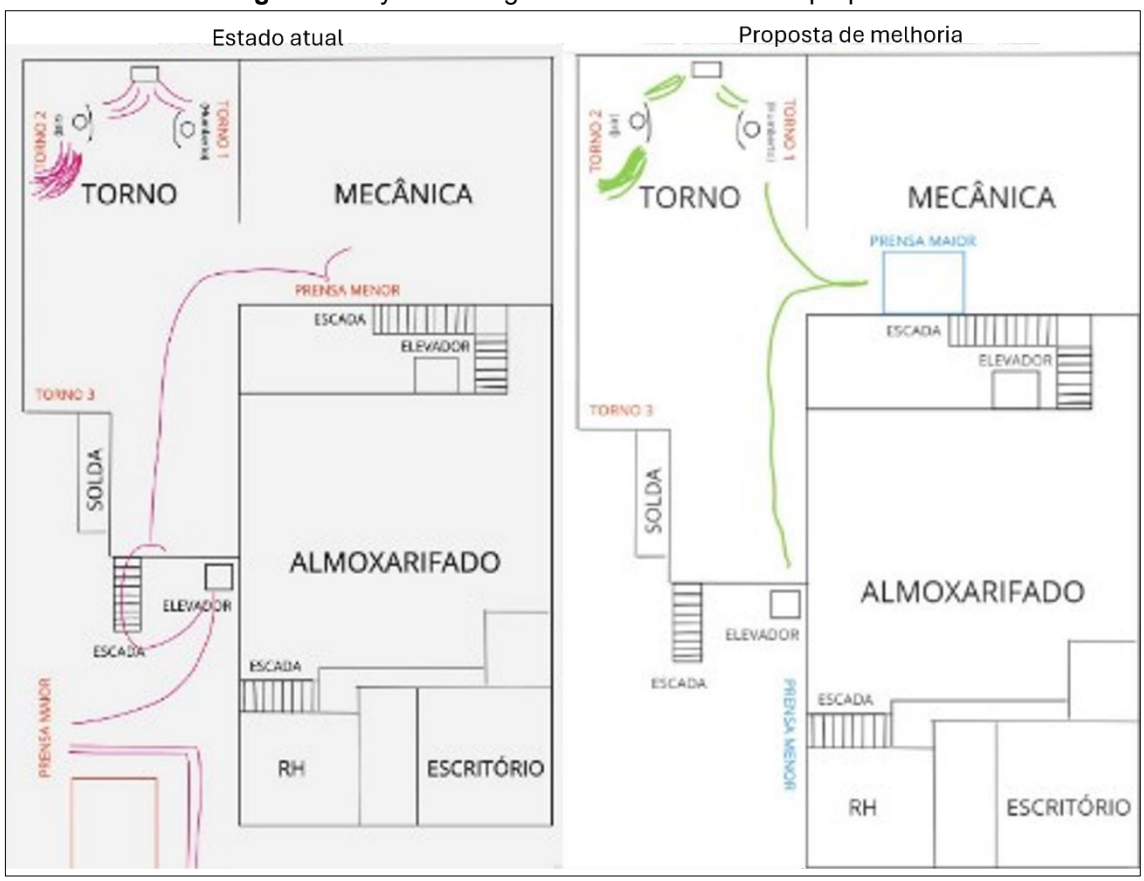
As mentioned in the literature review section, the spaghetti diagram has in its objective the identification of unnecessary displacements in the factory layout. In this tool, the professional's displacement is measured by counting steps taken within a 10-minute sampling interval. Within this range, the measurement of 0.7m, equivalent to the distance of one step of an adult male of medium height, is used as a measurement criterion (DANESHJO, et al, 2021).

Revista ARACÊ
ISSN: 2358-2472

Figure 2 below shows the opportunities for improvements in the layout considering the turning activity, the employee walked an average of 47 meters during the 10 minutes of observation, considering a working day the employee may exceed 2km of displacement in this layout, which suggests a need for change.

Considering the proximity of the benches, their repositioning, such as the press that was suggested to be placed in the mechanics area, it is possible to reduce excessive displacements in the place by up to 70%, avoiding the use of stairs and the freight elevator.

Figure 2: Layout turning current state and future proposal



Source: The authors, 2024.

In order for the suggested improvements to be implemented and lasting, a culture of continuous improvement is necessary in the company and this involves periodic meetings, training, greater management participation and employee engagement with the sense of belonging and ownership.

CONCLUSION

Revista ARACÊ
ISSN: 2358-2472

The combination of the theoretical review with the practical application of Lean tools, such as 5S and the spaghetti diagram, in a real case, allowed us to envision future proposals for improvements with perspectives of substantial gains such as a reduction in the displacement in the turning layout by 70%. In this way, the research question and the proposed objectives were achieved as both the theoretical framework was built and the visits were carried out.

The proposals prepared for the company aim to eliminate waste, optimize processes and improve quality, bringing greater productivity and greater customer satisfaction.

The tools presented are fundamental within Lean, which build a solid foundation for future improvements. However, success is not a point of arrival, but a continuous cycle of advances, continuous improvements, based on the Kaizen mindset, ensure that practices are evaluated, improved and adjusted, which adapt to internal and external changes.

Therefore, the company, in addition to achieving operational efficiency, also has the ability to create and cultivate a culture of learning, adaptation, and especially innovation, empowering people for continuous evolution.

New practical studies are recommended that use other tools such as Earned Value Analysis (VLE), Yamazumi, Value Stream Mapping (VSM) among others for new improvement proposals.

Revista ARACÊ
ISSN: 2358-2472

REFERENCES

1. Daneshjo, N., Rudy, V., Malega, P., & Krnáčová, P. (2021). Application of spaghetti diagram in layout evaluation process: A case study. TEM Journal, 10(2), 573-582. https://www.temjournal.com/content/102/TEMJournalMay2021_573_582.pdf

2. Deshmukh, M., Gangele, A., Gope, D. K., & Dewangan, S. (2022). Study and implementation of lean manufacturing strategies: A literature review. Materials Today: Proceedings, 62, 1489-1495. https://doi.org/10.1016/j.matpr.2022.02.314

3. Knol, W. H., Slomp, J., Schouteten, R. L. J., & Lauche, K. (2019). The relative importance of improvement routines for implementing lean practices. International Journal of Operations & Production Management, 39(2), 214-237. https://doi.org/10.1108/IJOPM-01-2018-0010

4. Randhawa, J. S., & Ahuja, I. S. (2017). 5S–a quality improvement tool for sustainable performance: Literature review and directions. International Journal of Quality & Reliability Management, 34(3), 334-361. https://doi.org/10.1108/IJQRM-03-2015-0045

5. Souza, D. F. de. (2018). Uma avaliação do desempenho de motores elétricos de indução trifásicos comercializados no Brasil entre 1945-2016 e o impacto da legislação brasileira [Tese de doutorado, Universidade de São Paulo]. Repositório da USP. https://www.teses.usp.br/teses/disponiveis/106/106131/tde-11072018-185050/publico/Danilo.pdf

6. Slack, N., Brandon-Jones, A., & Johnston, R. (2018). Administração da produção (8th ed.). Atlas.

7. Womack, J. P., & Jones, D. T. (2003). Lean thinking: Banish waste and create wealth in your corporation. Free Press.

8. Womack, J. P., Jones, D. T., & Roos, D. (2004). A máquina que mudou o mundo: A história da produção enxuta - o segredo da Toyota nas guerras globais do automóvel que está revolucionando a indústria mundial. Campus.

9. Yannopoulos, S. I., Lyberatos, G., Theodossiou, N., Li, W., Valipour, M., Tamburrino, A., & Angelakis, A. N. (2015). Evolution of water lifting devices (pumps) over the centuries worldwide. Water, 7(9), 5031-5060. https://doi.org/10.3390/w7095031