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Improvement of the sustainable performance in a textile company using the lean-green methodology

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Abstract:

The textile industry represents one of the greatest threats to the environment. It is the second most polluting industry, generating hazards with its solid waste, gas emissions, water pollution, among others. The objective of this research was to assess the effects of the implementation of the Lean Green methodology within the textile industry to optimize the sustainable performance of the companies and to address the problems of the sector mentioned above. The case study selected was the dyeing area of a Peruvian textile company where the Lean Green methodology was implemented in a sequential design of six phases to then evaluate its effects on sustainable performance. The findings show that the implementation of the proposed model improves water consumption by 18% and electricity consumption by 43%, which has a positive economic impact. Not only in the environmental area, there is also a 120% increase in productivity. The value of this proposal lies in the fact that it can be replicated in other companies in the sector, both locally and regionally. It was also proposed to include the operational criterion in the measurement of sustainable performance for a better dimensioning of the improvement.

Key words:

Sustainability, lean-green, textile industry, sustainable performance.

1. Introduction

Nowadays, the textile industry is ranked as the second most polluting industry after the oil industry (Sagapova et al., 2022). Many studies show the threat it poses to the water and atmospheric ecosystem, contributing to global warming and the generation of polluting waste (Wiedemann et al., 2020). This industry represents the fifth largest producer of greenhouse gases, which contribute to a myriad of negative environmental impacts, such as decreased air and water quality (Bailey et al., 2022; Patti et al., 2020). Additionally, since 2000, fiber production has doubled, increasing per capita consumption by 82% to 13.8 kg/person in 2018 (Peters et al., 2021). This event resulted in the production of 92 million tons of waste from the textile industry in 2015 (Bailey et al., 2022).

In Peru, environmental pollution is a problem that has been increasing in recent decades. Rivers and lakes have been heavily polluted due to the discharge of domestic wastewater and mainly industrial wastewater, which is seriously damaging them and compromising the health of the surrounding populations (Apaza, 2013). This high level of pollution is of concern for the textile industry, as it is of high relevance as it represents 7.2% of GDP in the first quarter 2022 (Instituto Nacional de Estadística e Informática [INEI], 2022). Considering the magnitude of the industry and its great growth potential, it is critical to ensure sustainable development in the coming years.

In this context, the use of the Lean Green methodology was proposed because, unlike others, it not only seeks to increase productivity, but also to mitigate the

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environmental impact. Likewise, the adoption of this methodology has been evaluated in different sectors such as auto parts distributors, medium and small foundries, motorcycle component manufacturers, and more, evidencing potential improvements in sustainability performance (Abualfaraa et al., 2020). However, a gap was found in the literature, the absence of implementations in the textile sector. On the other hand, Lean-Green stimulates innovation in processes to achieve sustainability with the highest degree of efficiency, using the minimum amount of resources, reaching progressively greater operational excellence (Siegel et al., 2022; Tripathi et al., 2021).

Over the years, research began to focus on methodologies that not only improve processes, but also reduce the pollution that industries produce. Therefore, various articles began to popularize the term Lean-Green, describing it as a synergy between two important paradigms: Lean manufacturing and Green practices (Choudhary et al., 2019). This new methodology has been widely discussed in the literature, establishing that, although they have different origins and approaches, they have the same ultimate goal, to reduce waste and promote the efficient use of resources (Bhattacharya et al., 2019). Although the concept of Lean-Green is relatively new, it is a research topic that is attracting a great deal of interest, but still needs to be further developed, especially in terms of ways to measure the Lean-Green maturity level of an organization (Reis et al., 2018).

2. Methods

In order to propose and validate an improvement in sustainable performance through the implementation of Lean-Green tools, a medium-sized textile company located in Lima (Peru) was taken as a case study.

2.1. Case Study

The company under study belongs to the textile industry with more than 27 years of experience in the Peruvian market. It is oriented to the production of flat fabrics made of cotton fiber and polyester blends, such as luxurious bed linens, as well as terry cloth, towels and bathrobes. The company has a wide range of customers, depending on the products offered, ranging from small retail stores to luxury hotels.

The company's production is generally made to order. Recurring customers place a purchase order specifying the requirements they need in their products. The company then orders a production batch with these requirements. In this case, the production of Prince sheets is studied.

1.1 Methodological Design

A mixed approach was chosen, allowing the integration of quantitative and qualitative methods. For a better understanding of the methodological design followed, Figure 1 shows the workflow, details of the steps and tools used during the research.

3. Results

3.1. Process Analysis

Process mapping illustrates the movement of materials, products, services and information, helping to identify areas or sub-processes that need improvement. The flowchart, validated by two experts, facilitated the development of a Green Integrated Value Stream Mapping GIVSM of the

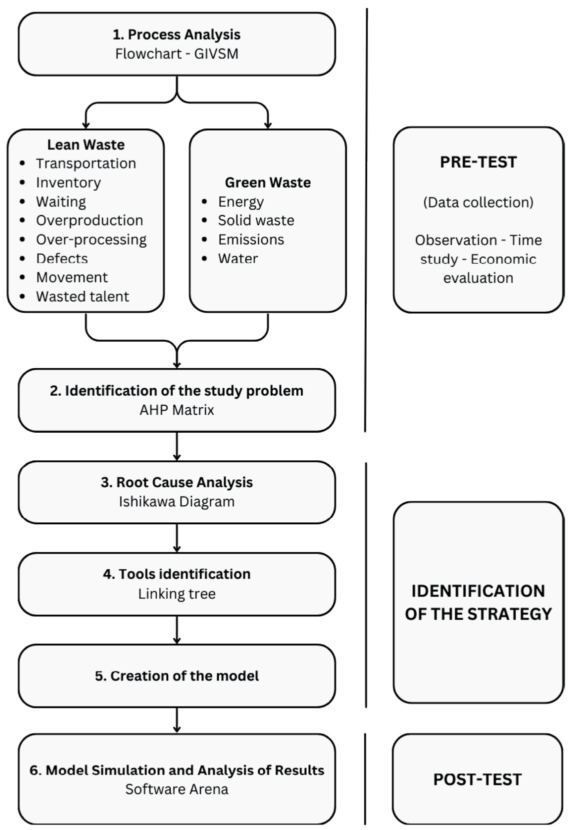

Figure 1. Workflow diagram.

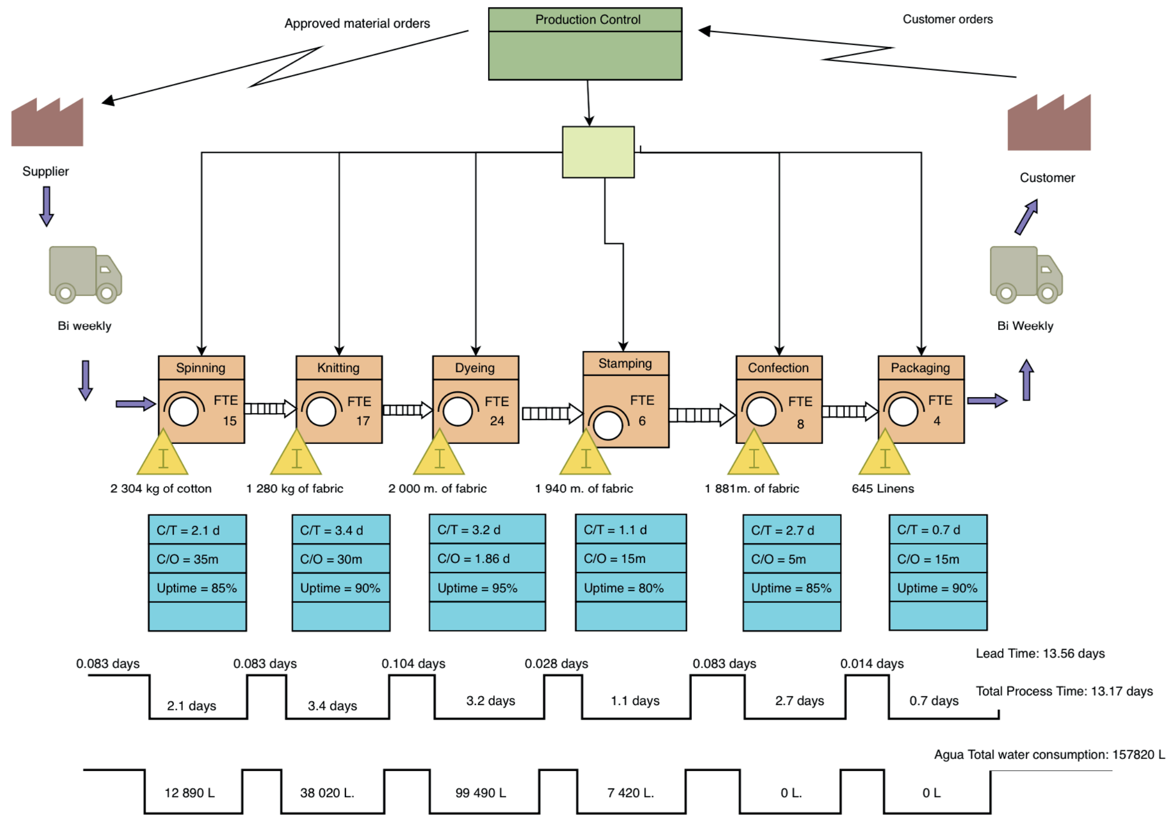

Figure 2. Green Integrated Value Stream Mapping.

initial process situation that showed the following results in Figure 2. This, unlike the traditional VSM, allows not only to measure operational efficiency but also environmental performance (Choudhary et al., 2019). In this case, it is measured in terms of water consumption, as this is the environmental measure that is most important in the industry.

3.2. Identification of the study problem

Based on the GIVSM diagram, an AHP Matrix was created to select the process to be studied based on the four criteria for measuring sustainable performance, shown in Figure 3.

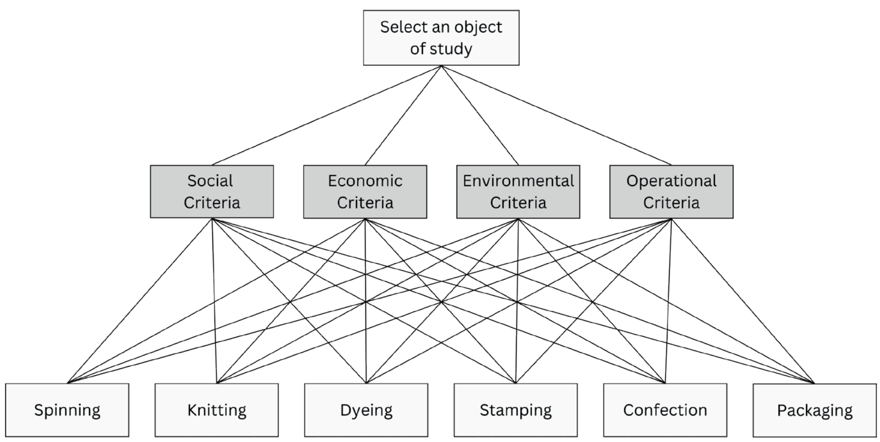

Figure 3. AHP Relationship Diagram.

Table 1. Process weighting table.

Process	Social Criteria	Economic Criteria	Environ-mental Criteria	Operational Criteria	Prioritiza-tion	%
Spinning	0.08	0.09	0.10	0.30	0.17	17.48%
Knitting	0.08	0.09	0.04	0.10	0.09	8.70%
Dryeing	0.04	0.04	0.04	0.10	0.06	**6.38%**
Stamping	0.08	0.09	0.10	0.30	0.17	17.48%
Confection	0.36	0.23	0.36	0.10	0.21	20.63%
Packaging	0.36	0.45	0.36	0.10	0.29	29.33%
Weight	0.05	0.39	0.16	0.39		

Based on the criteria and using the previously calculated weighting with its respective score, it was possible to compare each indicator in each process. After this, it was found that the process with the worst sustainable performance is the Dyeing process with 6.38% shown in Table 1. This determined that the object of study of this research is based on the dyeing area.

Once the study problem was identified, certain indicators were evaluated to perform an initial analysis of the area's situation with respect to sustainability, considering the factors mentioned above. The results are shown in Table 2. Likewise, a study was carried out on loading and unloading times by collecting historical data. This made it possible to find the distribution of time used for this task in each activity of the process. These data are shown in Table 3.

3.3. Root Cause Analysis

An exhaustive analysis of the selected area was carried out using various resources such as the Ishikawa Diagram and the problem tree. In this way it was possible to find the root causes to combat. It was identified that the main issue was the excessive use of water in the process followed by the high percentage of reprocesses and the elevated rate of wastewater contamination.

3.4. Tools Identification

In order to correctly identify the tools to be used, the problem tree was linked to the tools that best matched each root cause, which is shown in Figure 4.

After an exhaustive background and strategy search, it was agreed to use the following tools for the proposal: Kaizen, SMED, Standard Work and Total Productive Maintenance (TPM). All the Lean tools had a more Green focus, applying also the Green Manufacturing Planning (GMP) tool.

3.5. Creation of the Model

Footnotes or According to the research carried out, a model was developed that interlaces both Lean Manufacturing and Green Practices tools.

Table 2. Comparison of Indicators.

Dimension	Variable	Indicator	Pre Test	Post Test	% Improvement
Operational	Capacity	Productivity (batches/30 days)	46.00	101	120%
	Time	Cycle Time (d)	3.45	2.42	30%
		Process Lead Time (d)	2.09	0.56	73%
		Unexpected Failure Repair Time (h)	4.50	-	100%
	Process Failures	Percentage of products with quality failures (m)	0.04	3%	25%
		MTBF (h)	1,440	-	100%
		Reprocesses (%)	0.06	3%	50%
Environmental	Water Consumption	Liters of water (L/kg)	124.36	102.32	18%
	Electrical Consumption	Electricity consumption (KWh/kg)	2.40	1.37	43%
Social	Workforce Satisfaction	Satisfaction Index	Low	Alto	+ 2 levels
	Training	Training(Hours/Month)	0.33	2	300%

Table 3. Comparison of Set Up Time.

	Activity	Pre- Test	Post test	% Improvement
Singeing	Loading	27.00	20.00	25.93%
	Unloading	24.00	18.00	25.00%
Drying	Loading	The time is included in the unload of Singeing		
	Unloading	Time is included in the wash load		
Washing	Loading	22.00	18.67	15.15%
	Unloading	Does not come out of the machine	12.00	-100.00%
Dyeing and Rinsing	Loading	Does not come out of the machine	21.00	-100.00%
	Unloading	13.00	11.00	15.38%
Branch	Loading	17.00	15.00	11.76%
	Unloading	14.00	12.00	14.29%
Calender	Loading	18.00	16.00	11.11%
	Unloading	14.67	11.00	25.00%
Quality control	Loading	12.00	9.00	25.00%
	Unloading	1.50	1.00	33.33%

This model consists of improving sustainable performance based on a detailed analysis of the area to be analyzed, quantifying its problems by means of the indicators established in Table 2, using a tree diagram to determine the most appropriate tools for each problem. It is also important to mention that surveys were conducted with plant personnel to determine their satisfaction and take it as input for some social indicators, as well as to learn more about possible problems that currently exist.

For the elaboration of the model, different models of different authors on the use of this methodology were taken into account, as well as the tools they use. Thus, according to what was found, the four tools mentioned are used, demonstrating their effectiveness by means of their simulation in Arena. This model is shown in Figure 5.

Green Manufacturing Planning

Since a large part of the problem involved the waste of water, a vital resource, it was proposed to have a "greener" vision in the use of all the tools to improve the sustainability of the processes and machinery.

Kaizen

The high consumption of unnecessary resources led to choose Kaizen as a Lean tool to improve the company's performance. This methodology is

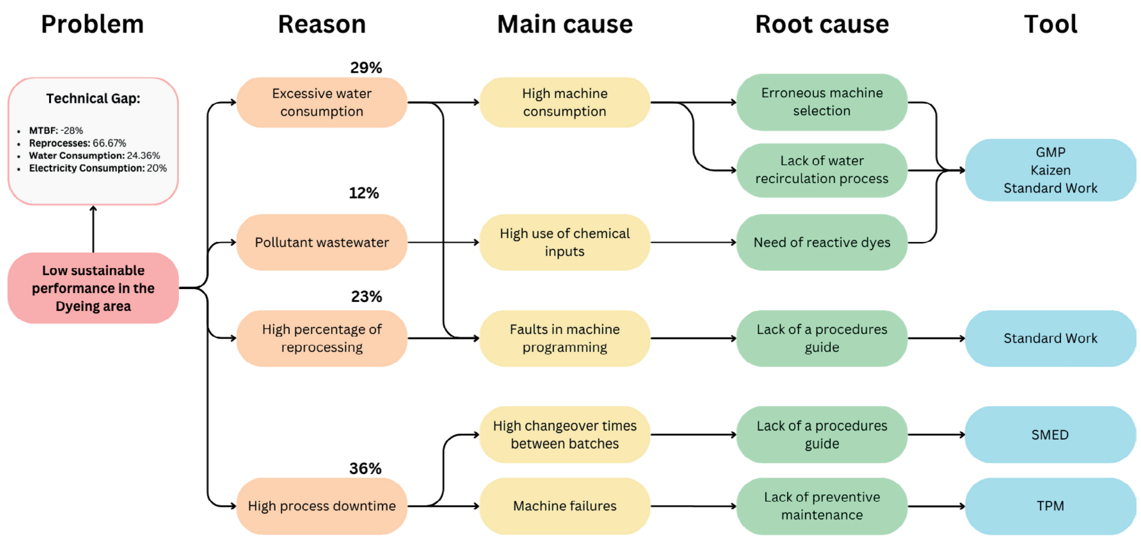

Figure 4. Tree with linkage of solution tools.

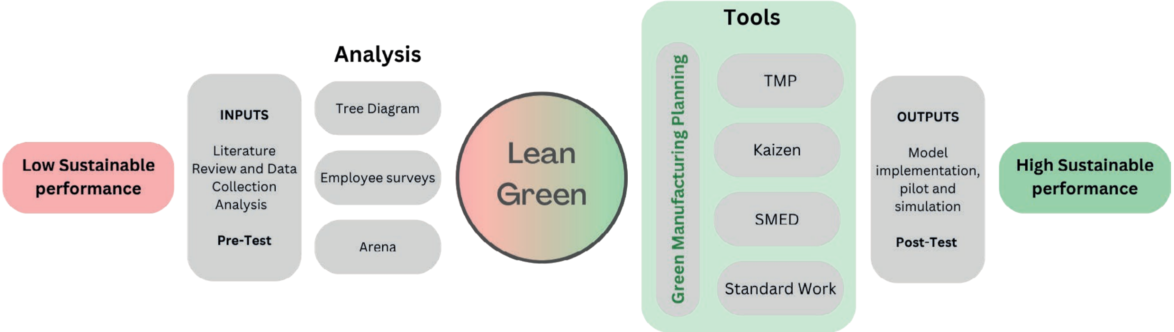

Figure 5. Optimization model (Based on Schoeman et al., 2020; Zhu et al., 2020; Morales Méndez & Rodriguez, 2017; Robertsone et al., 2021; Indah et al., 2020; Marques et al., 2022; Tanash et al., 2022; Ebrahimi et al., 2023; Toki et al., 2023; Ortiz Vigo et al., 2023; Thanki & Thakkar, 2018).

based on continuous improvement and pursues the reduction of inefficiencies to achieve improvements in competitiveness. In view of this, using PDCA, a way to reduce water consumption and improve cycle time was sought. To this end, a comparative analysis was made of the available machinery and it was found that the washing machine, which was in stock, has a theoretical productivity that is 20% higher in terms of water consumption compared to the machine that was in regular use, so a change of machine in the washing activity was proposed. Furthermore, we actively consulted with the operators to listen to their ideas and their attitude towards the proposed changes.

Standard Work

The constant clutter within the process led employees to make mistakes that could have been avoided if proper information had been available. Common mistakes such as incorrect machine time settings could lead to fabric that was irregular in color or simply not the right color. This forces the operator to reprocess the fabric from the first step, which causes discomfort and inconvenience to the operator, as well as overhead in light and water consumption, and reprocessing, which lengthens the cycle time and makes production more expensive.

Because of this, a card model was implemented using the Standard Work tool that will standardize the machine programming process to achieve a reduction in errors at the time of configuration and a more orderly process flow. The cards are mobilized with each batch of fabric and contain all the necessary information that the operator needs to perform the correct configuration of the machine.

On the other hand, several procedure manuals were developed for each activity involved in the dyeing process. In this way, the employees' performance with the machinery would be improved, reducing the percentage of errors at the time of programming. In the same way, this measure was reinforced with visual management, programming a range of colors for certain buttons, placing clearer tops and facilitating the quick location of the manuals.

Single-Minute Digit Exchange of Die

One of the biggest problems that the company has is the delay that occurs when a batch change is made. Because there are different varieties of fibers, with very specific requirements, each batch greatly changes the way the machinery needs to be programmed and this generates a long changeover time between batches.

What the SMED tool seeks to do is to convert the internal tasks (those performed with the machine stopped) into external tasks (those performed with the machine running), thus reducing machine downtime and making better use of the available time.

One task that was identified as a possible external task is the collection of instructions on fabric specifications, which generally must be consulted in another environment, in addition to the inputs required for each material. Due to the improvements proposed with the Standard Work tool, the fabric specifications will move along with the batch, which means that the operator will no longer have to move to get this information and the collection of inputs will become an external task to be performed while the previous batch machine is still running.

TPM

Finally, an action plan was implemented for the continuous maintenance of machines, avoiding their untimely failure. To this end, the seven steps for the correct execution of TPM were followed.

First, an initial cleaning was carried out to inspect the improvement points. It was also identified that one of the main sources of dirt was due to the poor condition of the roof covering the machines, which allowed the entry of rain and dust, so it was proposed to improve the roof.

Then, a cleaning and maintenance program was established with daily and weekly tasks to be performed by the operators themselves, which allowed reducing the time lost due to unforeseen failures. Apart from this, it is important that a more exhaustive preventive maintenance is carried out by expert personnel in which they can discover and correct any defects in the machinery.

Finally, to maintain the improvement, checklists were implemented that workers must check off when cleaning, which allowed for better control of maintenance.

3.6. Model Simulation and Analysis Results

Based on the proposed model, the simulation was carried out in the Arena software, considering all the processes and quantifying the use of resources. As well as the amount of reprocesses that are generated and the failures that occur in the machinery. The data after the improvement were obtained through pilot tests carried out during the process and information from time studies which were introduced in the Input Analyzer of the tool to obtain the distributions that best fit.

The model was set up to input fabric batches of between 1500 and 2500 meters each, set randomly through a distribution, for 30 days. The model was run with 300 samples and a 95% confidence interval. It is presented in Figure 6.

Once the model was run, the data were extracted and compared with the data obtained before the improvement to show the percentage improvement, which are shown in the Table 2.

4. Discussion

After performing the pertinent studies and analyzing the results obtained, it is possible to verify that there was an improvement in all the proposed indicators. Likewise, the technical gap in certain indicators was overcome. As can be seen in Table 2, the cycle time was improved by 30%, thus allowing a higher monthly productivity, which increased by 120%. The improvements achieved are in "agreement" with studies such as Tripathi et al. (2021) who states that it is possible to have a better operational efficiency using an environmental approach of Lean manufacturing. One of the most important improvement points was to reduce process changeover times by implementing SMED as a tool, which is shown in Table 3. An improvement of 73% in Lead Time was perceived, indicating higher efficiency, which coincides with a case in the Bangladeshi garment industry where SMED effectively achieved higher efficiency and

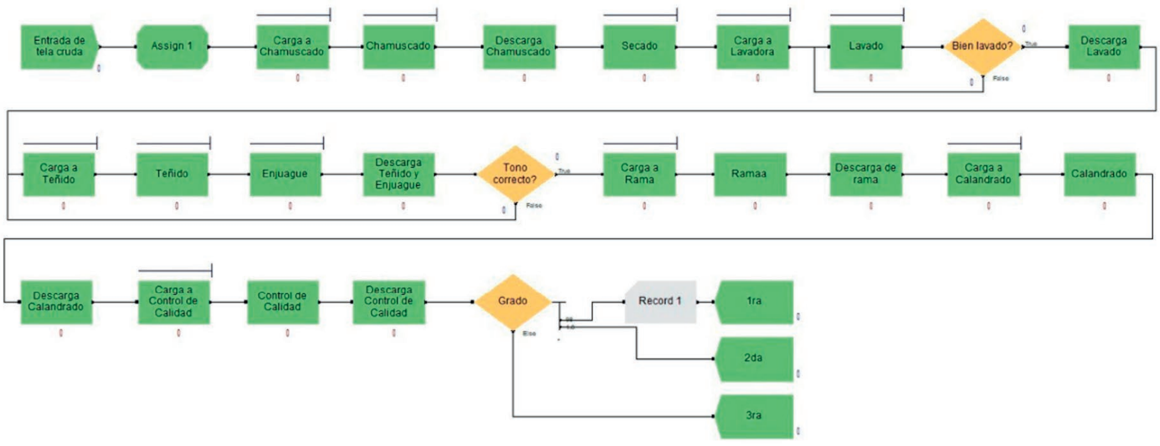

Figure 6. Arena model.

lower time consumption (Toki et al., 2023) and a case in the food industry that achieved the same result (Garcia-Garcia et al., 2022).

The environmental aspect focused on reducing both water and energy consumption, since both are major environmental impacts within the textile industry. By implementing a new machine and increasing the efficiency of the process in general, it was achieved the reduction of water and energy consumption by 18% and 43% respectively, closing the technical gap and even surpassing the industry in the case of energy, demonstrating that Lean green brings with it a better management of energy and water, reducing the environmental impact (Silva et al., 2020). The reduction in the consumption of supplies and the increase in productivity achieved an economic saving of S/2350 (647.2USD) per month for the company. This improvement ratifies the idea of Thekkoote (2022) who established that by improving the equipment and the production process it was possible to reduce the use of resources and therefore the cost of production. This validates that the reduction of waste and the optimization of production processes through Lean Green have resulted in a decrease in operating costs and greater efficiency (Dieste et al., 2019; Cherrafi et al., 2017).

Although Lean Green has demonstrated tangible benefits in economic and environmental terms, it is more difficult to quantify improvements in the social area. Due to this fact, the social dimension has received less attention in literature and practice and there are few social indicators sufficiently developed and used for industries (Butnariu & Avasilcai, 2015). However, despite the fact that improvements in the social domain are not equally quantifiable as operational improvements, they can be seen to be directly related. According to the surveys given, high Set-Up Time, low levels of training and amount of rework, decreased motivation and reduced job satisfaction (Patterson et al., 2004). By reducing these problems, it was ratified by another survey that satisfaction improved, as well as the work environment as Lora-Soto et al. (2021) states, the reduction of operational problems leads to an increase in satisfaction which, in turn, leads to better productivity, which is highly enhanced with the use of Kaizen.

However, according to Hashim et al. (2022) the implementation only brings welfare in the long term, since in the short term there is a lot of dissatisfaction explained by the fear of change that often delays the project and negatively affects productivity. This would show that, although employees increase their satisfaction when achieving results, their attitude during the implementation process is not necessarily positive. It is necessary to develop lines of research focused on improving the social impact, not only as a collateral effect, but also as the main objective.

One point to note is the search for information on the industry standard for certain indicators such as productivity or cycle times. This was hampered due to the highly variable nature of the dyeing process and the difficulty in finding a case study that sufficiently resembles the specific conditions of the company, considering both the processes and the organization and size of the plant, which are the factors that will most determine the values of such indicators.

In addition, the textile industry has undergone a constant evolution in terms of technologies and practices used. New dyeing techniques, dyestuffs and equipment have emerged over time, leading to greater diversification of processes. These developments may not be properly documented or standardized in the existing literature, making it even more difficult to identify and measure indicators.

On the other hand, there is a lack of implementations in the sector in question. Moreover, the existing ones lack data that prove their effectiveness quantitatively, which makes comparison difficult. Most of the existing studies and publications focus on ideal scenarios or typical processes, which may not reflect the actual conditions and circumstances of a particular production plant. This resulted in a limitation due to the variability of the dyeing process. Each company has particularities in terms of raw materials used, technologies employed and specific production practices. Therefore, the identification of standardized indicators is complicated, which implied the need to adapt them to the specific characteristics of the company under study.

The concept of sustainable performance has gained relevance in various industries and has been subject of discussion in the literature. However, there are different perspectives and approaches regarding its definition and application in each sector, which have evolved over time from considering only long-term economic performance to including environmental and social aspects (Habib et al., 2020, Siegel et al., 2022), which has been mainly associated with economic performance, social responsibility and environmental impact. From this perspective, the focus centers on optimizing production processes to reduce the consumption of natural resources, minimize waste generation and reduce pollutant emissions. An idea that dates back to Elkington et al. (1994) who introduced the concept of the "triple bottom line" considering economic, environmental and social aspects, which has been validated by authors such as Ahmad et al. (2019)

It is important to note that these perspectives are not exhaustive and that the concept of sustainable performance may vary depending on the context and specific objectives of each industry. Moreover, authors such as Siegel et al. (2022) comment that the biggest challenge in arriving at sustainability is its demonstration due to the absence of clear metrics to measure it. This statement is seconded by Joung et al. (2013) This fact meant a clear challenge in terms of measuring improvement. However, they all converge on the idea that sustainability, whether from an environmental, social or economic perspective, is essential for the long-term success of companies and society in general (Artiach et al., 2010).

After analyzing the literature for this case study, it was found that in order to improve sustainability it is essential to adequately define and measure the concept of sustainable performance. For this, it is necessary to consider social, economic and environmental criteria, which have traditionally been addressed in the academic literature (Alayón et al., 2022; Joung et al., 2013, Siegel et al., 2022). However, the inclusion of the operational criteria in the definition of sustainable performance has been little explored, which limits its applicability in the context of production processes, since it was more focused in the area of only Lean Manufacturing (Jum'a et al., 2022). The present research aimed to propose a definition of sustainable performance that integrates these four criteria, taking into account the textile dyeing process as a case study.

The main contribution of this research to the literature lies on the proposal of a Lean Green implementation model to a previously unresearched industry and the inclusion of the operational criteria within the definition of sustainable performance. By considering this aspect, a more complete and practical vision of sustainability in the business environment is achieved, since it takes into account the efficiency and effectiveness in the production process. This incorporation of the operational criteria is aligned with the Lean Green methodology, which seeks to combine the principles of Lean production with environmental sustainability. Moreover, this criteria was considered essential for the definition of sustainable performance, since a company can be socially responsible and environmentally conscious, but if it is not able to operate efficiently, its long-term sustainability is compromised.

5. Conclusions

Given the results obtained, it can be validated that the adoption of Lean and Green techniques can lead to significant improvements with an average of 62% in the established indicators, with a minimum improvement of 18% in water consumption and a maximum improvement of 120% in production productivity. While the research demonstrated an improvement in sustainable performance, reducing water and energy consumption, it is vitally important to continue researching and addressing sustainability in the textile industry due to its alarming degree of environmental pollution. As the textile sector continues to expand globally and the demand for textile products increases, the negative impacts on the environment become more significant.

On the other hand, the proposed Lean-Green based model has proven to be highly effective in improving sustainable performance and increasing productivity in companies in the textile industry. By combining Lean Manufacturing principles with sustainable approaches, this methodology has enabled companies to identify and eliminate unnecessary activities, reduce waste and optimize production processes. However, it is important to note that the successful implementation of Lean-Green requires continuous commitment from top management and the active participation of all employees. It is necessary to establish a culture of continuous improvement and promote environmental awareness at all levels of the organization.

By establishing operational criteria within the definition of sustainable performance, the door has been opened to a more comprehensive analysis and deeper understanding of the impacts and implications of sustainable practices in different areas. This not only encourages further investigation of how to define sustainable performance globally, but also facilitates the integration of sustainable practices into the planning and management of organizations, making it possible to identify areas for improvement, detect possible inconsistencies between objectives and actual results, and adjust strategies and actions accordingly.

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