The Impact of Implementing Lean Manufacturing Tools in the Productivity of the Dyeing Area of a Textile Company

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***Abstract*—Peruvian textile industries have suffered a considerable decrease in terms of clothing exports during these recent years, partly because of the economic crisis caused by the COVID-19 pandemic. Additionally, fierce competition with Asian countries in this sector has forced South American countries to take measures of industrial competitiveness by offering high quality products. Inadequate inventory management, a high percentage of faulted batches and a high rate of non-fulfillment of orders are some frequent problems that directly affect the productivity of textile Small and Medium Enterprises (SMEs) in these areas. The main objective of this research is to prove how the implementation of Lean tools can improve the productivity of the dyeing area, minimizing the amount of defective fabric and increasing completion of the production plan. The proposed model is made up of Lean tools such as: Standardized work, 5S methodology and Kanban. Furthermore, simulation by the Arena software was used to validate this proposal in the fabric dyeing area of a textile company. The results of this simulation were an increase in compliance with the production plan by 8.63% and a reduction of 5.07% in the percentage of fabric reruns.**

***Keywords*—lean manufacturing, Kanban, 5S, standardized work, textile company, dyeing area**

I. Introduction

Currently, the manufacturing sector represents 13% of Peru's GDP [1], with textile companies being of the most importance for the Peruvian economy. For the last two decades, these textile companies have suffered a steep decline in market share globally, compared to Asian countries such as China, India, and Vietnam [2]. Most of these went out of business because they didn't innovate in their production process and continued to use outdated methods. This resulted in less productivity, closing of textile workshops, loss of jobs and the necessity of selling products at a low price [3]. Usually, the dyeing area is the bottleneck of the whole textile process, due to the difficulty of maintaining the right shade of colors for every batch. For these reasons, national textile manufacturers are looking to implement new methods in their processes to increase productivity and regain competitiveness in the global market.

There has been success in the implementation of methods to increase productivity in the textile sector. One study found that implementing the 5S method and a Kaizen culture in a sewing workshop in Peru increased the sustainability and competitiveness between workers, creating a better work environment [4]. Another investigation project concluded that the implementation of quality management tools and training schemes in the sewing, cutting, and finishing areas of a textile company in Peru resulted in better quality compliance and a significant decrease in the number of defective products [5].

In this context, small, medium, and large companies in Peru should try introducing these types of methods in their production process to compete with the Asian powerhouses in the textile industry. For this study, a medium size Peruvian textile company was chosen. Its main problem occurs in the dyeing area, where the compliance with the production plan is more than 7% below the standard. The objective of this research is to measure the impact of Lean Manufacturing methods in the productivity of said area.

This study differs from others which are also based on lean manufacturing mainly because it is focused in the dyeing area, as well as the laboratory and the preparation area. These parts are related and are co-dependent, but they aren't normally studied together. The lean methods applied in this case study will encompass the three areas, to attack the root causes of the main problem.

II. State of the Art

A. Lean Philosophy in the Manufacturing Sector

Nowadays, in the manufacturing sector there are various operational problems that can be solved through different mechanisms. However, over time the Lean philosophy has had positive results in terms of its implementation and operational results [6]. The main problem facing manufacturers today is how to offer high-quality products at low cost [7]. Therefore, the implementation of lean philosophy in the manufacturing sector is evidenced in an improvement in cost performance, where elimination of waste increases the optimization of resources and productivity in a high percentage [8]. A recent study of five manufacturing companies from different sectors affirms that the implementation of these tools can be challenging, because each context is different and if you choose an inappropriate tool for the situation, it could be unfavorable in terms of productivity. However, the five companies had positive long-term results presenting some difficulties during the implementation of Lean Manufacturing [9].

B. Application of the 5S's Tool

The implementation of this tool in the production area not only saves costs, but it can also create a noticeable change in the organizational culture of the company which brings benefits for the future. This method was found to be efficient in companies of different sectors [10]. Current research

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identified that many companies in Latin America lack competitive models and strategies such as lean techniques and that is why they are losing market share compared to other continents. Thanks to 5S's implementation, they managed to clear the involved area by 22%, allowing a better flow and reduction of times. On the other hand, a different author proposes an implementation model of this method in 6 phases for Peruvian Small and Medium Enterprises (SMEs). This model achieved an increase in productivity of 24.8% and a reduction in penalty payments of 84% [11].

C. Application of the Kanban Tool and Standardized Work

Kanban is a visual method which optimizes control production in an optimal way. It is characterized by a system of signals throughout the entire supply chain that involves replenishment operations based on information about what the customer demands, until the final product is obtained [12]. On the other hand, the application of Line Balance and Lean Standardization tools in a textile company helped eliminate the two residues that had the greatest impact on this company. This achievement increased the efficiency of the production line from 55.88% to 76.79%. In addition, it allowed increasing individual efficiency and effectiveness ratios, influencing the company level [13]. Apart from the Kanban tool, there is another engineering tool named Heijunka which controls production and inventory. Additionally, the Heijunka board serves to level the number of orders, contributes to the planning of the inputs of the process and avoids a possible delay by taking preventive measures [14].

III. Contribution

A. Model Basis

Fig. 1 shows the proposed model, which is inspired by the different Lean methodologies studied in the state of the art. These were evaluated, selected, and adapted to fit the current situation. The implementation of the 5S method, standardization of work and Kanban are optimal to the solution of the low compliance of the production plan in the dyeing area of the company studied. The model will apply not only to the dyeing area, but also to the areas in which it depends on to work correctly.

B. Proposed Model

The proposed model integrates the three Lean methods mentioned before to solve the main problem of the production process. Table 1 shows the comparison matrix that was developed to compare the proposal with the works of other authors related to the topic.

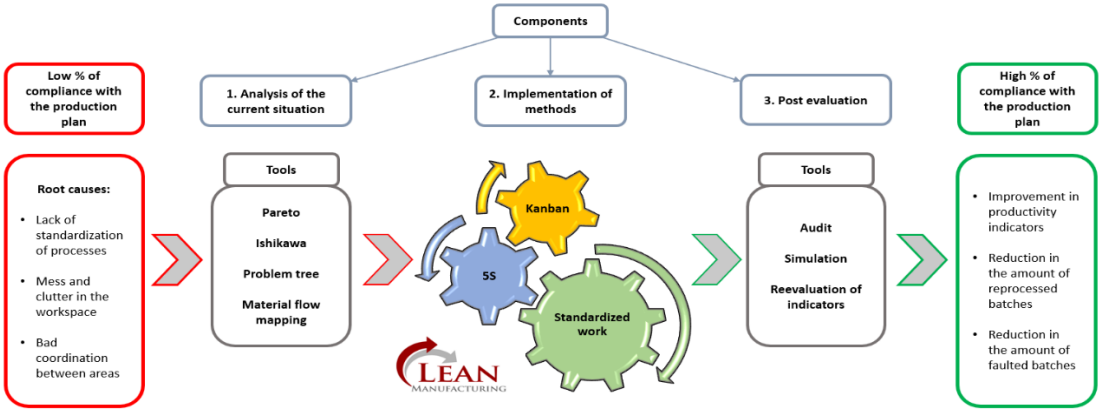

Fig. 1. Proposed model.

Table 1. Comparison matrix of the proposal components vs the state of the art

	Scientific Article			
Causes/ Scientific Article	Lack of standardized processes	Clutter in the workspace	Poor wash schedule between fabric batches	Poor coordination between warehouse and dyeing area
Cespedes, R., J Hurtado, Macassi, I., Raymundo, C. and Domínguez, F.	Standardized work	5 S		
Muthukumaran. V., Hariram V. R., Padmanabhan. K. K.				Kanban and Heijunka
De la Cruz, H, Altamirano, E. and Del Carpio, C		5S and Kanban		Kanban, Heijunka and Just in Time
Barrientos, M., Tapia, L., Maradiegue, F. and Raymundo, C.	Standardized work	5S	Standardized work and TPM	
Mejía, S. Y Rau, J.		5S	SMED	
This research	Standardized work	5S	Standardized work	Kanban

Firstly, the model aims to reduce the high percentage of reprocessed batches in the dyeing area. One of the root causes identified was the lack of standardization of procedures in the area, as well as the color laboratory. The standardization of work according to lean as well as the training scheme that goes with it will help solve the problem. On the other hand, the mess and clutter in the workspace is a common problem in this area. This lowers the productivity of the workers and causes unwanted mistakes throughout the process. The 5S method was the most fitting to solve this issue.

Secondly, machine availability is another problem which results in the incompleteness of the production plan. After

this problem was identified, it was found that this mainly happened due to delays from the laboratory in the delivery of dyeing recipes and a lack of prepared fabric from the preparing area. Therefore, the Kanban method was proposed to generate a continuous flow of the fabric from one area to another.

C. Model Components

The proposed model shown in Fig. 1 consists of three components which will be described in the next section:

1) Component 1: Analysis of the current situation

This first phase has the objective of locating the main problems before a solution can be applied. To identify these problems, the first step is to map the process with the VSM tool. The next step is identifying the main indicators which will be intervened, comparing them with the company's objectives to obtain the current deviation. Next, it's necessary to check the historic data of these indicators to identify a pattern. Subsequently, an Ishikawa diagram must be developed to identify root causes, as well as a pareto diagram to determine the importance of the problems. Using this information, the adequate lean tools must be selected to solve the problems starting from the root causes.

2) Component 2: Implementation of methods

The first method to be implemented is the 5S's and it consists of seven steps. First a visual mapping must be made of the area which will be intervened. An audit must be made to judge the current condition of the workplace on a scale of 1 to 10. The second step is to inform the workers of the 5S method and provide training. After this, steps 3 through 7 are the implementation of the 5S's: sort, set in order, shine, standardize, and sustain.

The second method is the standardization of work. This will be applied to the area in question as well as the areas it is connected to. To achieve this, a detailed flow chart must be created with every relevant activity of the process. Next, the control, monitoring and critical points of the process must be determined. Details and instructions must be made for each of these points. The final scheme must be revised with the experts of the area and finally the workers must be trained to follow the instructions correctly.

The last method to be introduced is Kanban. This will ensure a continuous flow of material through the areas intervened. First the route of the materials must be established, and an analysis of the demand must be made. Next the flow of material will be scheduled and standardized to avoid waiting periods. Finally, the Kanban board needs to be developed, with the correct steps of material management for the workers to follow easily.

3) Component 3: Post evaluation

The last component is the evaluation of the method's success. For the 5S method, weekly meetings must be carried out to ensure the activities have been carried out correctly. For the other two lean methods, the main indicators will be evaluated every month to see if they are meeting the company's objectives. Employees from the areas intervened will be assigned to carry out these evaluations.

D. Indicators

1) Compliance with the production plan (dyeing area)

This indicator refers to the amount of fabric dyed in the process in a month vs the amount of fabric which was scheduled to be dyed.

Company's objective: increase the percentage of compliance in the area to 95%.

$$\%\ of\ compliance = \frac{Monthly\ production(ton)}{Montly\ scheduled\ production(ton)} \times 100 \quad (1)$$

2) Machine availabilit

This indicator reflects the percentage of time in which a machine is operating with respect to the total time the factory works, without considering Sundays and holidays.

Company's objective: Increase the machine availability to 85%.

$$\%\ Machine\ availability = \frac{Machines\ productive\ time}{Total\ production\ time} \times 100 \quad (2)$$

3) Percentage of faulted batches

The percentage of faulted batches refers to the number of batches which were dyed incorrectly. This classification is made in an inspection after the process.

Company's objective: Reduce the percentage of faulted batches to 15%.

$$\%\ de\ faulted\ batches = \frac{Number\ of\ faulted\ batches}{Total\ number\ of\ batches} \times 100 \quad (3)$$

4) Percentage of batches with shade variation

This indicator represents the number of batches that have a shade of color that differs from the one produced by the laboratory. This is defined at the inspection after the dyeing process.

Company's objective: Reduce the percentage of batches with shade variation to 10%.

$$\%\ of\ batches\ with\ SV = \frac{№\ batches\ with\ SV}{Total\ number\ of\ batches} \times 100 \quad (4)$$

IV. Validation

A. Initial Diagnosis

The company under study is dedicated to the manufacture of different types of garments, ranging from weaving to packaging. The main problem of the company is the low compliance with the production plan in the dyeing area. For that reason, this area was the one that brought the main problem since it was established as a bottleneck for the company. The fulfillment of the production plan for the first half of 2021 was 7.23% below the ideal and generated costs of $ 1,869,516 for fines and reprocesses. This is due to two general causes.

The first is the high percentage of defects which appear on items such as shade variation, cracks, stains of dye and other reasons. The second is the low availability of machinery, which resulted in 73.54% when it should be 85%. This is due to the constant stops caused by machine washing, lack of recipe and the lack of supply of prepared fabric.

B. Validation Design and Comparison with Initial Diagnosis

For the application of this model and its validation, Software Arena 16.10 was used. Figure 2 shows the scope of the proposed system, comes from two different slopes which end up joining for the dispatch of batches of prepared fabric to the dyeing area. In the first place, there is the elaboration

of the recipe by the laboratory area, and on the other hand, various activities are carried out on the raw fabric received from the warehouse in the preparation area, so that it is ready for dyeing. After these two steps, there is a dyeing process carried out in 10 different machines. Finally, a supervisor checks if the fabric color is according to the sample made by the laboratory.

After diagramming the current process, a better model shown in the figure above based on Kanban Methodology was proposed to minimize queue time before start dyeing process. Thus, operators will be able to verify the machine availability before they start preparing raw fabric.

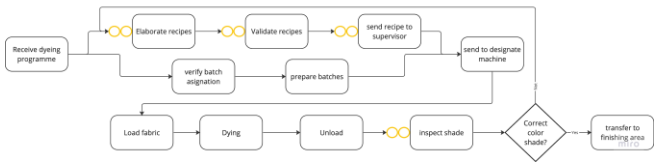

Fig. 2. Representation of the improved process.

C. Improvement-Proposal Simulation

To begin the simulation, Input Analyzer from the Arena software program was used to determine which is the most appropriate distribution at each stage of the process. Thus, for this operation a confidence level of 95% and a sampling error of 10% were used. Table 2 shows the distribution values obtained from these data.

Table 2. Fit distribution values

Activity	Fit distribution
Elaborate recipes	NORM (41.5, 4.5)
Validate recipes	9.5 + WEIB (4.51, 1.98)
Send recipes	3.5 + 8 × BETA (1.68, 1.61)
Prepare batches	TRIA (24.5, 35, 46.5)
Verify machine availability	TRIA (7.5, 10.4, 14.5)
Transfer to machine	POIS (3.59)
Load fabric	TRIA (4.5, 9, 17.5)
Dye	264 + 689 × BETA (1.32, 2.56)
Unload	NORM (14, 1.95)
Inspect shade	4.5 + WEIB (4.68, 1.5)

Accordingly, Output Analyzer software was used to optimize the number of replications for an effectiveness simulation. For this reason, 207 replications were necessary to complete the simulation process. In the first place, for a period of one month, it was possible to increase the number of ready dyed items from 535 to 588. This represents a positive increase in the fulfillment of the production plan, which would become the main indicator of the optimization model. In addition, the improved system model manages to eliminate items that used to be obsolete in the staging area.

Likewise, it was able to reduce the queue time prior to machine dyeing from 58.2 to 31.2 h. This reflects the order implemented by the 5S's methodology, Kanban, and standardization in the dyeing area. Finally, in terms of items with shade variation, the improved results were considered by the standardization method in the preparation of the recipe and the fabric dyeing. Thus, achieving less faulted items in the system, and consequently less time and less resources used. Table 3 shows the improvement in the main indicators after the simulation.

Table 3. Comparison matrix of the current situation, expectations and the simulation results

Indicator	Current	Expectation	Simulation results
Compliance with the production plan	87.77%	95%	96.40%
Machine Availability	73.54%	85%	90.40%
Percentage of faulted batches	24.87%	15%	19,80
Percentage of batches with shade variation	13.35%	10%	11.44%

V. Conclusions

In conclusion, Lean Manufacturing methods can lead to an improvement in the productivity of an area of a company in the textile sector.

For this reason, through the improvement proposal using the Kanban methodology in the simulation, it was possible to improve production times in the preparation area and in the laboratory area, obtaining a result of machinery availability of 90.4%.

Additionally, the correct application of the 5S and the standardized work, both in the laboratory and dyeing area, managed to reduce the number of defects and number of batches with shade variation. Consequently, the percentage of faulted batches decreased by 5.07% while the percentage of items with shade variation decreased by 1.91%.

In future works, its recommended to validate the implementation of the model in different scenarios, using different types of fabric and garments. Also, it is important to consider all areas involved with the process that will be intervened. This is important because the root causes may lie another area. Finally, it is recommended to introduce a training program which lasts several weeks for every worker involved in the process which will be improved. This will ensure the correct development of the Lean tools and will promote a continuous improvement culture in the company.

Conflict of Interest

The authors declare no conflict of interest

Author Contributions

A.J.K.-Q. and A.N.-T. conducted the research; M.C.-D. analyzed the data; A.F.-P. wrote the article; J.C.Q.-F. supervised this project and contributed ideas for the document 's drafting; all authors approved the final version.

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