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Production model based on lean manufacturing and SLP to increase productivity in an apparel sector MSME

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***Abstract* --- In this scientific article, an integrated production model is presented to face the problems faced by a company in the clothing sector, which has low productivity, much lower than the industry standard. For this, in the said model, the use of VSM as a diagnostic tool, the application of lean manufacturing tools (5S & Kanban), and systematic layout planning as a solution to the problems presented by the analyzed pajama manufacturing company. With the application of the proposed integrated model, it is planned to increase the company's competitiveness, increasing its productivity by 23.86% to reach the industry standard. Furthermore, after analyzing and comparing the simulation results in the Arena Simulator software of the current situation and the proposed integrated production model, an increase of 30.61% in the company's productivity was observed. This result is due to increased efficiency and effectiveness, reduced waiting times, and transport waste.**

Keywords --- kanban, SLP, 5S, lean manufacturing, industry textile, clothing, productivity, SMEs.

I. Introduction

The manufacturing industry is the second largest sector of the Peruvian national economy since it participates in the GDP of 12.5%; in 2019, the textile and clothing industry was the third activity with the highest contribution to manufacturing GDP, equivalent to 6. 3 % [1]. The national textile-clothing industry is characterized for being the manufacturing activity that contributes the most to the generation of employment in Perú since it is responsible for hiring 26% of the employed Economic Active Population (EAP), representing 2. 3% nationally, which translates into 400,000 direct positions [23]. According to the last Industrial Census by the Ministry of Production, 99.5% of the companies registered are MSMEs [3]. In 2020, the manufacture of clothing registered a 55.6% drop compared to 2019 due to the paralysis of the industry as a result of covid-19. In addition, some problems can be identified, such as low inventory turnover, production losses, imported garments at a lower price than in the local market, level of order fulfillment, and others.

The problems identified by the sources may be due to overproduction of garments, low stock turnover, reprocessing, delays in delivery times, waste of waiting times, and transportation in production. All these problems generate low productivity, low product delivery rate, a high percentage of shrinkage, and defective products. Nevertheless, the success stories show that the sector still has deficient processes, which generates low productivity, which is why it is of the utmost importance to continue investigating research that exposes these problems and how companies from different parts of the world have been able to improve. Their processes attack the root cause of their problems to find the best ways and tools to solve these setbacks.

To visualize the impact of lean and SLP tools, the success story of a Peruvian investigation that proposes a model to optimize production based on the application of SLP and lean tools to increase productivity in footwear manufacturing SMEs was taken as a reference. Said conference paper exposes as the main problem the low productivity generated by deficient and non-standardized processes; after simulating in Arena the current scenario and the proposed model, an increase in productivity of 22.5% was obtained [4]. This article proposes a model that brings together solutions from different success stories; in this model, the implementation of SLP and different lean tools such as 5S, VSM, and Kanban are proposed. This scientific article is divided into five parts: Introduction, State of the Art, Contribution, Validation, and Conclusions.

II. State Of The Art

A. *Application Model of Lean Manufacturing Tools*

The main problems that SMEs are going through that affect productivity, and the level of service are long delivery times, high reprocessing flows, high scrap rates, waste of time, and delays in the production line. Therefore, implementing a model for applying Lean Manufacturing tools is necessary to improve working conditions, delivery management, production, safety, order, and efficiency to provide maximum value and minimize wasting time and resources. [5][6][7][8][9][10]. In this situation, applying the 5's, VSM, and Kanban tools are essential for diagnosing and reducing waste in the production process, cycle time, increasing order fulfillment, and increasing profitability. These techniques aim to improve working conditions, safety, production, and work environment, which are critical aspects of a clothing workshop. [5][9][11][12][13].

B. Plant Distribution Model Applying the SLP Methodology

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The distribution of a plant is of the utmost importance in any company since a poor distribution of the plant can bring with it a large number of problems such as unused spaces, unnecessary movements and transport, low level of service, low productivity, over costs in material handling and very high delivery times [7][8][9][18]. For all the problems mentioned above, they need a solution for which Systematic Layout Planning will be applied; SLP uses quantitative criteria that propose the best possible distribution [17]. With the implementation of Systematic Layout Planning, it was possible to identify improvements in the reduction of cycle time and order fulfillment, quickly responding to customer demands that are of vital importance to increase the profitability of the company [7][9] [18]. In addition, with the mapping of the activities of the supply chain, opportunities for improvement can be identified regarding the poor distribution of the plant, unused spaces, unnecessary transport, poorly located tools, and machines that end up negatively impacting productivity and the level of production services [18].

C. Increased productivity in manufacturing companies in the textile and clothing sector

MSMEs in the textile and clothing sector often need help directly linked to productivity. Given this situation, work standardization is an ideal activity that helps mitigate the root causes identified, such as process disorganization, defective products, and waste of time. And transportation and poor quality of products. [12][18][19]. Likewise, these companies have a low level of service, that is, deficient delivery levels triggered by low productivity in micro, small, and medium-sized companies in the clothing industry. That is why applying an integrated model with different lean manufacturing tools is essential to deal with this problem. [11][18][19]. In order to measure the impact generated by the implementation of the proposed integrated model, it is important to use a tool that simulates the current scenario and the one improved by the proposed model. For this, it is recommended to use the Arena Simulator program for the validation stage [9][11][12].

III. CONTRIBUTION

A. Basis

The present study reviewed forty papers on Lean Manufacturing techniques, SL P, and validation of models applied to case studies. Table 1 shows the comparative matrix of the components and scientific articles that correlate most with the tools applied in the proposed model.

TABLE I. COMPARATIVE MATRIX OF THE COMPONENTS OF THE PROPOSAL VS. STATE OF THE ART

Root cause / Article scientific	**Waste of waiting time**	**Waste in transport time**	**Defective products**
Martin Collao -Diaz, et al. 2022	5S	5S	5S
Silvana Ruiz, et al. 2019	5S and SLP	5S and SLP	5S
J. Montalvo-Soto, et al. 2020	5S and Kanban	kanban	5S and Kanban
Alberto Flores-Perez, et al. 2022	kanban	kanban	kanban
Proposal	SLP, 5S and Kanban	SLP, 5S and Kanban	5S and Kanban

B. Model Components

The model proposes using lean manufacturing and SLP techniques to increase productivity in an SME in the clothing sector; for this purpose, it has been divided into four components: diagnosis, contribution generation, and planning, implementation, and validation.

Component 1: Diagnosis

In the first phase, the current situation of the sector and the company will be studied; here, indicators are collected to compare the sector's standard with that of the company find the technical gap. Once the technical gap was revealed, the problem was analyzed. For this, a time study was carried out in the clothing workshop; Value Stream Mapping was also used; this diagnostic tool helped to identify the processes that do not add value (waiting and transport times). Finally, for the analysis of the root cause, a problem tree, a confrontation matrix, and a Pareto diagram were elaborated.

Component 2: Input generation and planning

In this phase, a systematic literature review was carried out to identify the appropriate techniques to solve the problems found in the diagnosis. As a result, it was possible to study 40 articles published in Scopus, international magazines, and official government pages, where they studied the case and proposed the best solutions to combat the problems exposed and how to apply these solutions in companies in the textile and clothing sector. Of all the articles investigated, 21 were chosen, which were the ones that had the most correlation with the investigation.

Likewise, three typologies have been defined that help to group the articles with the most significant correlation and discrepancies with each other: Increased productivity in manufacturing companies in the textile and clothing sector, plant distribution model applying the SLP methodology, and Lean Manufacturing tool application model. After the analysis, 5s, Kanban, and SLP were selected to implement in the model.

Component 3: Implementation

In this phase, the selected tools were executed. The first technique selected was 5'S, which aims to improve working conditions, order, cleanliness, staff motivation, and the organization's productivity. With the tool above, improvements are proposed, such as

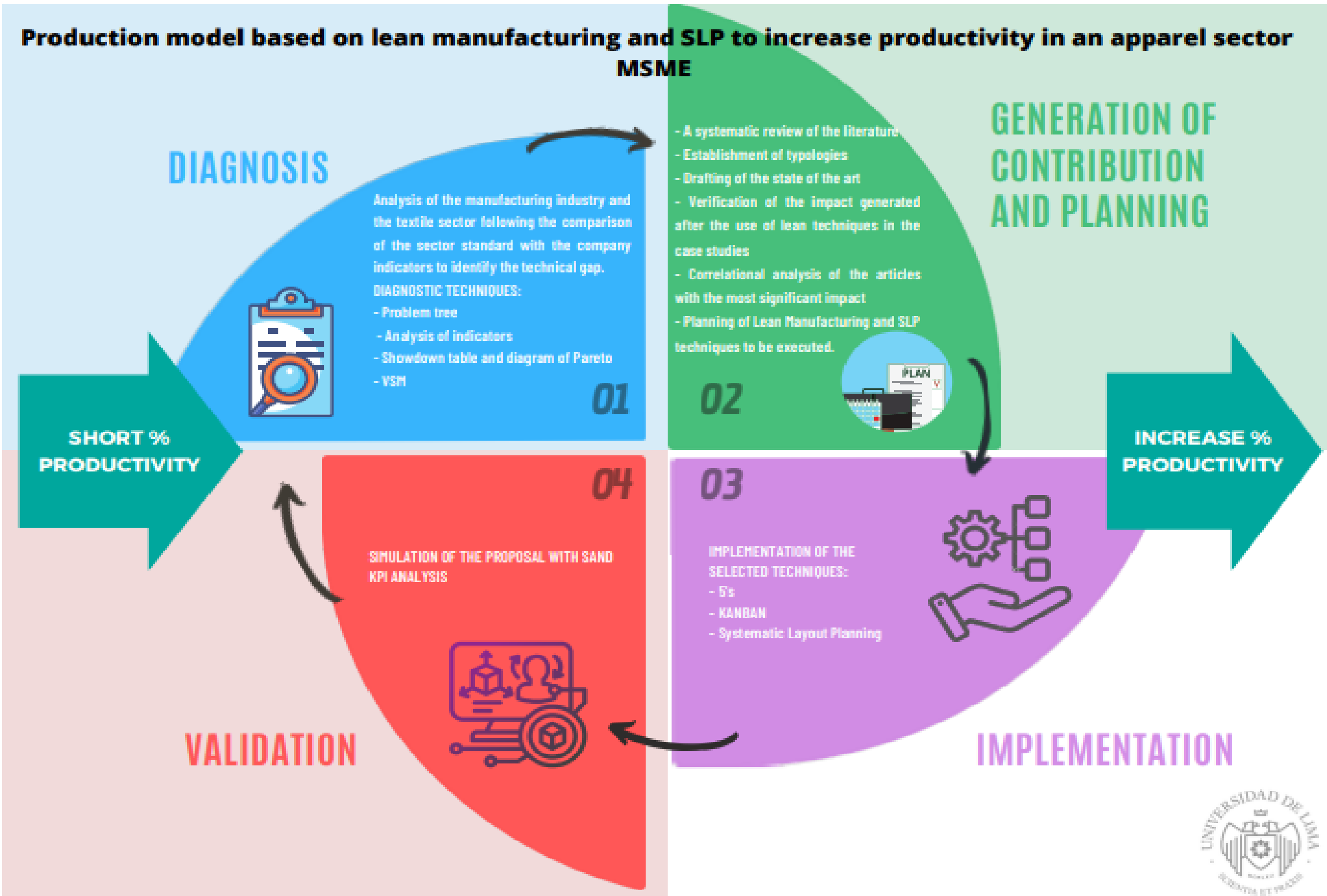

Fig. 1. Model Proposed

implementing a tool board, adequate lighting, the order in the workplace and shelves, and a correct delimitation of the work areas with yellow adhesive tape on the workshop floor. The second lean tool used is Kanban; this tool separates the work into three blocks: to do, in progress, and done; To quickly identify the sequence of tasks, a board and Kanban production cards will be implemented for said tool. Finally, Systematic layout planning was used to better organize the workplace by locating high-frequency areas and processes and with close logistical relationships; with the help of SLP, the clothing workshop will be distributed to reduce the distances traveled and the times of transportation. To develop this tool, an analysis of the production flow, a flow diagram (spaghetti), a relational table of activities, and an analysis of spaces will be carried out, where the static, gravitation, and evolution surfaces are considered.

Component 4: Validation

Lastly, the validation aims to validate the impact of the techniques established in the proposed model. Arena Simulator was used to simulate the improved scenario after the implementation of the integral model and compare it with the initial scenario to show the results and feasibility of the action plan. Validation and the other three components above are part of the proposed method; see Figure 1

C. *Indicators of the proposed model*

The indicators planned to be improved in the proposed model are productivity, waiting times, defective products, and transport times.

Productivity: This indicator is one of the leading indicators since, with it, we can measure the level of work of the organization.

$$\text{Productivity} = \text{Efficiency x Effectiveness}$$

$$\text{Efficiency} = \frac{\text{Man} - \text{Hours workeds}}{\text{Man} - \text{Hours estimated}}$$

$$\text{Efficacy} = \frac{\text{Obtained products}}{\text{Expected products}}$$

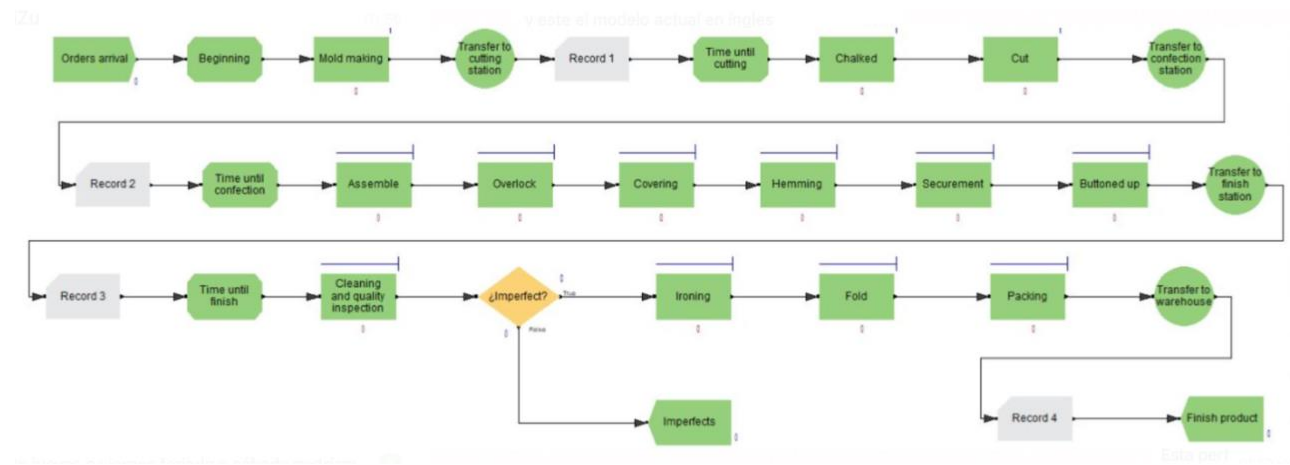

Fig. 2. SIMULATION OF THE CURRENT SITUATION

Waiting times (%): This indicator shows the time wasted due to processes that do not generate value. The production process was timed to find this KPI, differentiating the added value times and the waiting times.

$$\text{Waiting time} = \frac{\text{Waiting time}}{\text{Value added time} + \text{W.T} + \text{Trans.T}}$$

Transport times (%): This indicator shows us the time wasted moving materials or products from point "A" to point "B". It is considered that moving a good if it does not need processing is a waste of time since said transfer does not add value.

$$\text{Trans.Time} = \frac{\text{Transportation Time}}{\text{Value added time} + \text{W.T} + \text{Trans.T}}$$

Percentage of defective products: This indicator measures the percentage of defective products in production.

$$\text{Defective product} = \frac{\text{Defective products}}{\text{Products obtained}}$$

IV. VALIDATION

The Arena Simulator software has been used to quantify the improvements in the proposed HH variables; transport times traveled, and the number of defective products that directly impact the productivity of the process. This tool will be focused on simulating the implementation of the Lean Manufacturing model where the use of 5s, kanban, and Systematic Layout Planning is proposed. It should be noted that the simulation has been designed to contemplate different distributions for each activity, which have been calculated based on a time study in which the same activity was timed 30 times independently.

With the effects of simulating the system, an analysis of sample times was carried out to find the ideal and adjusted distributions of each activity that could be the ideal inputs to carry out the simulation in Arena, which can be seen in Figure 2. As seen in Table II, five indicators were proposed that directly attack the improvement of the leading indicator: the increase in productivity. First, regarding transport times, the simulation showed us an improvement of 2.68% after applying the SLP method. Secondly, applying the 5's and Kanban model, it was possible to improve the defective rate by almost 2%, achieving the estimated improvement.

Third, waiting times were reduced by almost 10% by applying the same tools; for this case, the expected rate of improvement was also achieved. Finally, all these results directly impacted productivity improvement by up to 30.36%.

TABLE II. CURRENT SCENARIO RESULTS VS IMPROVEMENTS

Indicators	Current Scale	To be	Improved	Gets better
Productivity	71.94%	95.80%	102.55%	30.61%
Efficiency	76.49	88%	89.06%	12.57%
Effectiveness	94.04	109.5%	115%	20.96%
Transportation time	11.82%	7%	9.14%	2.68%
Wait time	23.50%	10.00%	13.63%	9.87%
% Defective products	5.96%	2%	3.97%	1.99%

V. DISCUSSION

After observing and timing the activities of the current situation, it was possible to determine the current times of both value-added, transport, and waiting time. Also, thanks to this, the corresponding statistical distributions could be found to carry out the simulation that corroborates the following indicators. For example, in the current situation, the clothing workshop managed to obtain 30 units of product in an 8-hour day. On the contrary, after simulating the proposed improvements, the number of finished products increased by eight units, resulting in a 33% decrease in defective products. In other words, it went from generating approximately 6% of defective products to 4% of defective products.

Regarding the leading indicator, productivity, initially, the company had productivity of 71.94%, which was planned to improve by 23.86% to reach the standard productivity of the sector, which was 95.80%. However, after the simulation in Arena Simulator, it was observed that after applying the integrated model based on the Lean Manufacturing tools (5S and Kanban) and SLP, not only the stated objective of the investigation was reached, but it was also exceeded since the productivity reached 102.55%, which is equivalent to an improvement of 30.61% over the current scenario.

In addition, to carry out the validation through Arena, a study of the distribution of the workshop for SLP was made, in which the distances traveled of the complete production process of the current system were measured, resulting in 69.9 meters traveled. Therefore, the main reason for the extensive tour was the plant's distribution. However, after applying Systematic Layout Planning, it was validated how many meters would be reduced after a redistribution of the plant, in which the cutting and sewing area was exchanged. Said reduction was 35.05%, carrying out the same production process with only 45.4 meters traveled.

One of the limitations found in the study is that not many article references were found that propose an integrated model based on lean manufacturing tools to increase the productivity of a company and that is validated with a pilot test; most of the articles they studied and proposed validation through simulation software such as Bizagi and Arena Simulator, which were improved in the present investigation. Therefore, based on the exposed limitation, there is an opportunity for researchers to develop the application of models and for these to be validated not only with simulation software but also for a pilot test to be carried out in the company in which it is going to analyze.

VI. CONCLUSIONS

It can be concluded that the application of an integrated model of lean manufacturing and Systematic layout planning achieved the main objective of increasing productivity in the MSME in the clothing sector analyzed since Arena Simulator validated that after the application of the 5S tools, Kanban and SLP in the company of the manufacturing sector, it was possible to increase productivity by more than 30%.

It is also concluded that after the application of the Arena Simulator simulation tool, it was possible to validate the current scenario versus the improved one of the company under analysis, resulting in a circumstantial improvement of transport time by 2.68% and waiting time by 9.87%. Furthermore, defective products in 1.99%, thus impacting an improvement in productivity of 30.61%, achieving the objective.

Although Lean Manufacturing and Systemaic engineering tools Layout Planning were the correct ones to mitigate the problems in the productive processes of the analyzed company, the diagnostic tools such as the Value streaming mapping, problem tree, and confrontation tables were of crucial importance to be able to identify the root causes which are defective products, waste of transportation and waiting times. With this analysis, it was possible to focus on 80% of the problems with the most significant impact.

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