Model of Optimization of Production Based on the Application of Lean Tools to Increase Productivity in Footwear Manufacturing SMEs

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***Abstract*—The demand for footwear in Peru has increased significantly in recent years even though domestic production has decreased, on the other hand, it has been shown that imports have grown substantially. This shows that the domestic sector has difficulties in offering good quality products, which is directly related to low productivity and lack of innovation. In this sense, an integral Lean-SLP model is proposed based on the combination of tools such as total redesign of facilities, 5s, process standardization, work design, and Jidoka to improve the current productivity of 0.56 generated by deficient and non-standardized processes. The model was validated through arena software where a cycle time reduction of 42.95% and a productivity increase of 22.5% were obtained. This proposal allows SMEs in the footwear sector to be more competitive in the foreign market by producing shoes of higher quality and therefore better acceptance.**

***Index Terms*—Footwear, SME, productivity, 5s, lean manufacturing, Jidoka, SLP, design work**

I. Introduction

SMEs currently represent 99.6% of formal companies and are considered a fundamental part of the growth of the national economy since they generate around 59% of the employed EAP, thus being the source that produces the most employment [1]. 8.2% of the companies belong to the textile manufacturing sector at the national level and only in metropolitan Lima the textile and leather industry represents 35.4% of the total manufacturing companies [2]. For the country, the manufacturing sector represents 13% of the national GDP and only 0.1% of the GDP belongs to the leather and footwear manufacturing sector [3], however as a result of the paralysis of productivity and the restriction of sales outlets due to the COVID-19 pandemic, demand decreased which caused the footwear industry to work at only 19.5% of its installed capacity and deplete its entire stock [4]. Only in 2019 US$ 6 million was disbursed for the value of antidumping duties(import levy) , this is due to the increase of footwear imports against the domestic industry due to problems in productivity, low innovation capacity and lack of adequate infrastructure [5], likewise theInstitute of Social Economic Studies [2] points out that the national footwear industry during the period 2018 precipitated by 29% due to causes such as low productivity level, low business management capacity and low use of modern technology, all this presented mostly in micro and medium enterprises (SMEs).

This shows that the footwear sector's industries have difficulties in offering good quality and sophisticated products, which is directly associated with the sector's low productivity and lack of innovation.

The problem identified according to the literature leads us to the case study of a footwear company in Peru where the main problem is the lack of attention in a large percentage of orders as a result of delays in production and defective parts, which occur within the process of sewing and gluing of insoles and parts [6]. In another investigation of an industrial footwear company in Mexico, low productivity was observed due to poor sequencing in the order of operations, flow of materials, and station equipment, which were caused by the reduced spaces between activities and the lack of design [7], this problem has also been identified in another research in Bangladesh where inefficiency and excessive lead time in shoe production are associated with simple manufacturing processes that include the production of one unit at a time and the relocation of resources, which causes a reconfiguration in machines and design for each demand [8]. For all the above mentioned, it is shown that the footwear industry presents deficient and in some cases, unnecessary production processes that do not generate added value, so new solutions to this problem should continue to be investigated.

For this research, a case study was chosen to reflect the productivity problems of the sector, identifying the following difficulties: increase in operating costs due to inefficient control of defective products, high level of non-compliance, and low productivity. In this sense, to solve the problems described, an improvement model was developed combining the tools jidoka, 5s, Job Design, SLP, and standardized work, all under the combination of Lean and SLP methodologies. The present research offers a new combined Lean-SLP model applied in a footwear production line. It should be noted that several types of research using both methodologies in footwear SMEs separately, however, none combines both tools for the sector. This study aims to disseminate and validate the combination of Lean-SLP tools in the situation of Latin American economies and the leather footwear sector, to serve as scientific evidence and contribute to the productive improvement of the sector, it should be noted that the highest percentage of micro-enterprises in the footwear sector work with non-standardized processes and poor working methods, so the chosen methodology is essential for the leather footwear industry. This scientific article is divided into Abstract, Introduction, Diagnosis, State of the Art, Contribution, Validation, Discussion and Conclusions.

Manuscript received Jaurauy 23, 2023; revised March 12, 2023; accepted April 10, 2023; published May 10, 2023.

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DOI: 10.7763/IJMO.2023.V13.827

II. State of the Art

A. Productivity of the Footwear Sector

The footwear industry in Peru has slowed down its growth in recent years, which we can observe in the offer utilization table published by INEI [3], even though the sector's trend towards faster, more flexible production and lower prices has accelerated since 2005 [9]. Likewise, it is known that the main market of the footwear industry in our country is the domestic market, which produces 98.6% of sales and 1.4% of leather footwear is exported as raw material in addition to other manufacturing components. This situation has an important impact on the country since domestic manufacturers must reduce their prices to be able to compete with the footwear they bring in through imports [6].

B. Lean Manufacturing

Lean manufacturing is a methodology whose main function is to increase productivity, based on the elimination and identification of non-value-added processes and waste, as well as the standardization of operations and the correct design of workstations [6, 10, 11]. Research tells us that this methodology groups theoretical and executable instruments in search of progress in production operations to achieve a high level of quality at the lowest cost [12].

In the case study of an SME in the footwear sector, it had a low level of orders delivered due to insufficient production and a high waiting time between processes, which could be mitigated by applying slp and lean tools, so that they increased deliveries by 82% and increased production capacity from 213 pairs to 237 pairs per month [13]. Another case study is that of a company in the footwear sector that had a high rate of defective and low-quality products due to the lack of standardized processes, which once implemented the tool reduced the defective from 44 to 36 pairs, increasing its efficiency by 75%. [6]. Similarly, another footwear company in Ecuador with low productivity decided to standardize tasks through a diagram of operational processes, obtaining an improvement in productivity and efficiency of 5.49% [14]. On the other hand, a manufacturing company in India dedicated to the manufacture of steam boilers had low efficiency, poor working conditions, and poor plant design, so it implemented the 5s tool in a comprehensive manner, which improved labor productivity by 11.04% [11]. Likewise, a textile company used 5s to reduce the unnecessary time from 84% to 16% to increase productivity [15].

C. SLP

Systematic layout planning (SLP) is a methodology that improves usability and optimizes the use of existing resources in operations through the redistribution, organization, and relocation of work areas [16]. In the successful case of a vehicle manufacturing company in Jordan that implemented SLP methodology to solve bottlenecks and congestion in certain areas, overlapping space used between the department and difficult to track material flows, increased its productivity by up to 88% [17].

On the other hand, an SME in Pakistan engaged in the manufacture of switchgear equipment has problems with facilities management limiting economic savings, therefore SLP was applied thus increasing space utilization by 50% which contributed to minimizing costs of electricity services [18]. Likewise, another loudspeaker manufacturing company that incurs high transportation costs due to poor distribution of facilities, once it applied SLP obtained a saving of 11.63% in transportation costs concerning the initial situation [16].

Finally, a sewing company that has a processing time that exceeds the standard redesigned the new facility layout using SLP, whereby the distance and transfer time improved by 23.88% and 34.01% respectively [19].

III. Contribution

A. Model Basis

Currently, many SMEs in the Peruvian footwear sector have low productivity compared to industry standards, which has led to less and less competition with foreign products. Under this scenario, the search for different tools, models and methodologies that can eliminate these problems has been generated. In that sense, we found in the literature Lean Manufacturing and SLP as the most required work philosophies for the identified problem because, despite having more than 23 work tools between the two, there is still much to explore between the different benefits and synergies that each of these can bring.

TABLE I. Comparison Matrix of the Proposal Components vs the State of the Art

	Causes				
Scientific Article	Non-Standardized procedures	Infefficient control of defectives	Inappropriate Design Work	Poor Optimization	Waste deposited in station
Abanto, P *et al* (2020)				SLP	5S
Dextre, C *et al* (2020)	Standarized work			SLP	5S
Jadhav, G *et al* (2020)			Design Work		
Deuse, J *et al* (2020)		Jidoka			
Real,V *et al* (2020)	Standarized work		Design Work		
Proposal	Standarized work	Jidoka	Design Work	SLP	5s

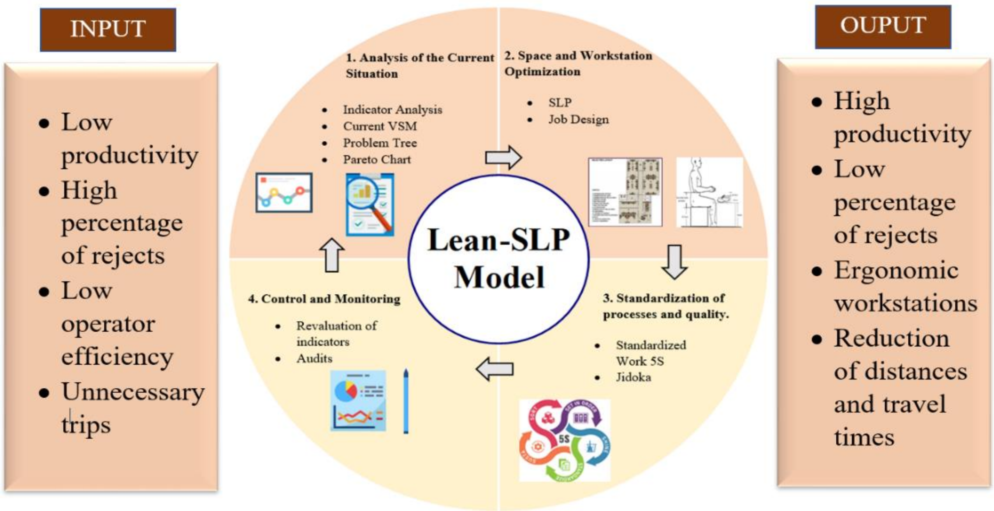

Fig. 1. General view of the model Lean and SLP tools.

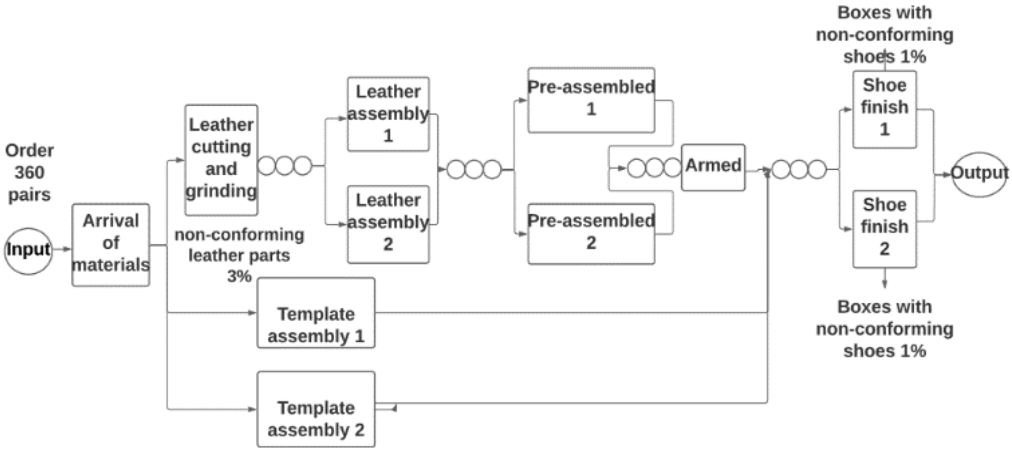

Fig. 2. System representation.

B. Proposed Model

The generation of value of our proposal was raised through the tools highlighted in the state of the art, in this problem we propose an integrated Lean -SLP model as the main solution. The tools to be used are diverse due to the number of difficulties that were delimited in the problem tree, these are focused on enhancing our model, mainly those that stand out for their implementation are the standardized work and Jidoka which will be able to define a standard of procedures and have control of defectives, on the other hand, we have excessive losses in the jobs in which 5S will be used and finally, we have the poor distribution and design of the jobs in which the jobs have to be redesigned and SLP used for their respective correction.

C. Model Components

1) PHASE 1: Analysis of the problem

This phase is made up of all the activities before the implementation of the proposed model. To identify the problems, present in the case study, a previous analysis of the current situation and a VSM must be carried out to learn more specifically about the process, distinguishing waste, and determining the efficiency of each station. To calculate the indicators that support the determined problem, the historical data of the demand, orders delivered and the list of defective products should be used. A problem tree must be made to find the sub-causes of the root problem and delve into these to identify the methodologies and tools necessary for its solution. Finally, using a Pareto, the problems to be corrected with higher priority will be identified.

2) PHASE 2: Intervention

The second phase is based on developing the tools identified in the improvement model. The first methodology to be implemented is SLP, which is aimed at the efficient use of resources and the resolution of distribution problems in the footwear production plant. For the evaluation of the alternatives, two criteria were taken into account, the first the minimization of the flow of materials since in this way we increase productivity and the second criterion is the proximity between areas to reduce unnecessary routes.

Once the plant has been redistributed using SLP, an ergonomic diagnosis of the working conditions in the shaping the area is carried out to subsequently carry out the necessary changes in the station's furniture.

Regarding the implementation of 5s with standardized work, both tools will reinforce the methodologies already implemented, since the first one aims to create and maintain cleaner work areas, more organized to give a better quality of life at work.

And the second has the objective of standardizing the main processes of the company to achieve a stable behavior that generates a product of low cost and homogeneous quality.

Finally, the Jidoka tool will be implemented, which aims for each process to have its quality self-control, thus avoiding incurring costs for defectives. It also helps to identify the root cause of the problem, allowing it to be eliminated and preventing it from recurring in the future.

3) PHASE 3: Check

In this phase, it will be evaluated and verified if the objectives set in the implementation are being met through indicators, to ensure the development of the improvement model. For the durability of the 5s implementation, an audit format will be implemented in which it will be verified if the proposed activities are being fulfilled, which must be executed before and after its implementation.

Once the indicators that support the operation of each implemented tool have been calculated, they will be compared with their behavior before their execution, in this way the impact generated by the new model will be observed.

D. Indicators

- Efficiency: Measures the performance of the resources used with respect to the desired production.

  Objective: Increase efficiency to 95%.

$$Efficiency = \left(\frac{Actual\ production}{Expected\ production}\right) \times 100$$

It is the relationship between the resources used and the achievements made with the same.

- Effort: Evaluate the effort used by the operator for each transfer or trip made.

  Objective: To estimate tangibly if the implementation of the SLP tool improved the working conditions of the operators. Therefore, the shorter the trip, the lower the effort

$$Effort = Distance\ (m) \times Quantity(Kg)$$

It is the effort made by the operator concerning the distance traveled and the amount held.

- Productivity: Increase productivity to 0.65 which is the industry standard.

$$Productivity = \frac{Units\ produced\ \times Price}{Work\ force + MA + MQ + Overhead}$$

It is the ratio of total outputs to a subset of inputs.

- Cycle time Cycle time: Decrease cycle time by at least 20%.

$$Cycle\ time = \frac{Sum\ of\ observed\ times}{Number\ of\ cycles\ observed}$$

The time it takes to produce a unit of product.

IV. Validation

A. Initial Diagnosis

The initial results of the case study show the technical gap concerning the multifactorial productivity of the company, obtaining an average of 0.56, which is below the sector with a difference of 13.7%. The current impact is S / .6,583.09 for lost opportunity cost, which represents 7.7% of the net profit during the 7 months studied, this impact is caused by orders not being delivered on time because the goal is not reached of planned production and the cost of opportunity lost by the low productivity for the sector. The economic impact generated by the rejected index amounts to S/.13,761.8, this represents 3.89% of the total operating cost and 16.25% for the net profit obtained during this period. Among the main causes that cause this problem is a) low efficiency in the forming station, b) inadequate layout of the work area, and c) lack of time to carry out activities. The results of the application of the proposed model and the evaluation indicators will be shown below.

B. Validation Design and Comparison with the Initial Diagnosis

The first tool implemented was the SLP, so a PQ-ABC analysis was performed. The nalvaro shoes were established as the most represented item so that the distribution of the plant was made around this product. Next, a relational analysis was carried out; then, an analysis was made using matrix tables, determining that the current quantity that is moved is 49950 Kg in each transfer; it was also resolved that the current distance traveled was 34.5 meters, and a total effort of 172327.5 Kg-m was obtained. Next, the Gurchet analysis was performed, where it was determined that the total required area is 138.73 m2. From this analysis, the current space used, which was 161.5 m2, was compared with the total space, obtaining a difference of 22.7 m2. Thanks to this, it was established that the area for the raw material was too large while the area of the forming station was tiny; finally, it was observed that the main criterion of the order of the process was not being respected, which generated a lot of traveled footage from the area to area. Considering the criteria established from the Gurchet, two new distribution alternatives were proposed where, based on a matrix analysis of each alternative, the one that generated the least amount of material and effort was chosen. The result was that the distance was reduced from 34.5 meters to 20.5 meters, which meant an improvement of 41%. Finally, the stress was calculated and reduced from 172327.5 Kgm to 102397.5 Kgm, thus obtaining a reduction of 40.6%.

The next step was the standardization of the processes, which aims to achieve a stable behavior to eliminate unnecessary time in the process and achieve a homogeneous quality. For its implementation, the process was first documented in order to identify time losses and the duration of each activity in order to optimize them, and then the possible improvements and their estimated times were shown. The improvements identified through standardization were simulated through Arena software.

We then applied the 5s tool, starting with a mandatory initial audit, which generates an implementation map with scores ranging from 1 to 5, in which the 5 parts that make up the tool are evaluated, obtaining the highest score of 1.5 and an average score of 1.04, which means that it is below optimum. Next, a checklist of the tools was executed in which they were classified according to their condition (Optimal and worn), followed by another checklist with the quantities and their locations. From this, the use of red labels was implemented as a complement to maintain order and the system with the checklists. Secondly, a proposed model of a shelf was made together with an organizational scheme of the tools and their proposed location. Thirdly and lastly, a cleaning checklist is elaborated with the appropriate criteria for its realization together with a cleaning policy.

TABLE II. GENERAL INDICATORS RESULT

Indicators	Current	Expected
Efficiency	79.17%	95%
Productivity	0.56	0.65
Cycle time (hours)	23.63	18.89

C. Improvement-Proposal Simulation

To understand the effect of applying these tools, a simulation was performed in Arena software covering the entire footwear manufacturing process, from the arrival of the materials to the final inspection of the product.

For this, we proceeded to collect a series of data provided by the company which was validated through the input analyzer software. For greater reliability of the data entered, 300 observations were made for each variable, it was also determined that the optimum number of replicates that make the simulation reliable in the Arena Software should be 30. After detailing in the flow the process activities and their adjusted distributions together with the implemented improvements, the results detailed in the following table were obtained.

TABLE III. SIMULATION CURRENT SITUATION VS IMPROVED SITUATION

	Cycle Time (hours)	Waiting Times (hours)	Productivity	Efficiency (%)
Initial situation	23.63	45.23	0.52	79.17
Improvement situation	13.48	27.46	0.68	153.5

The results obtained from the implementation showed that the cycle time was reduced from 23.63 hours to 13.48 hours, which means an improvement of 42.95%, making the process more efficient. Waiting times were also reduced from 45.23 hours to 27.46 hours, a reduction of 39.28%. Both indicators showed progress due to the detailed analysis of the current situation, where one of the main opportunities for improvement was identified as the rotation of idle operators to stations where the foreman was at almost 100% of his usefulness. Among other improvements implemented was the use of fans for the pre-assembly and assembly stations, since these were left to dry outdoors, thus reducing drying time by 50%.

From the data obtained from the simulation, it was concluded that the company went from producing 348 pairs to 614 pairs per week, increasing production by 76.46%, so the company's productivity went from 0.56 to 0.68, which means an increase of 22.5%, also this result is slightly above the productivity of the sector which is 0.65. In the same way, the efficiency of the current situation and the improved situation was calculated, which increased from 79.17% to 153.5% efficiency, far exceeding the expected situation which was 95%.

V. CONCLUSION

It has been possible to demonstrate that through the application of a Lean Model and SLP it is possible to improve productivity by 22.5%, thus reducing the level of unfulfilled orders and improving production capacity.

By changing the layout of the plant, the effort made by the operator concerning the distance traveled improved by 41%, which reduced unnecessary trips. On the other hand, the improvements implemented in the simulation had a great impact in terms of positive results, since the cycle time decreased by 42.95%.

In the future, it is recommended to simulate in the Arena software the current situation of the process before implementing a pilot test. From this, it is feasible to recognize opportunities for progressive improvement that are difficult to observe with a simple analysis.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Manuel Valenzuela-Ramos conducted the research, analyzed the data, and drafted the manuscript. Alejandra Pacora-Valverde supervised the research. All the authors had approved the final version.

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