Implementation of Lean Manufacturing Tools to Improve the Fulfillment of Orders in a Footwear Company in Peru

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***Abstract*— The objective of this article is to reduce non-fulfillment of orders in a line of footwear that, in the last 03 years, has tripled to 20%, which generates economic losses for the company. There are two main factors that affect the problem: On the one hand, the loss of availability of the compressor machine that provides compressed air throughout the production process and, on the other hand, the inadequate spare parts warehouse, which generates disorder and delay in the search for spare parts. Based on the above, this document proposes a maintenance management model based on 3 tools of the Lean Manufacturing philosophy: Total Productive Maintenance (TPM), 5S and Visual Management as support for the standardization of the location of items in the warehouse. The validation method is a simulation in ARENA of the repair of the critical machine. After the simulation, the MTTR was lowered and the MTBF increased, so the availability increased by 10.96% and consequently the non-fulfillment rate was reduced by 12%. Likewise, there was additional income of S /. 189,275.72 annually. With a VAN of S /. 175,518.33, the project is viable.**

Keywords—*footwear, lean manufacturing, TPM, 5S, Visual Management*

I. INTRODUCTION

The footwear subsector is one of the most important activities in the economic development of the country, since Peru ranks fourth as a footwear producer in South America, behind Brazil, Argentina and Colombia. This has a contribution of 1.4% of manufacturing GDP in 2018, with a contribution of S/ 903 million in 2018 [1]. However, that same year there was a large reduction in the production of footwear for the domestic market, so there was a 45% decrease in production compared to 2017, in micro and small companies [2].

Likewise, the National Society of Industry reports, according to the last census of 2017, 3669 footwear producing companies nationwide, most of them concentrated in Lima (42.8%), followed by La Libertad (27.6%) and other departments (29.6%) [3]. In this regard, these industries are formed in clusters to increase their efficiency and specify the orders that the client requests; however, being mostly SMEs, they do not have production and maintenance methodologies in their processes

One of the main problems that afflict the manufacturing industries is the maintenance of machines due to repetitive breakdowns. Thus, 80% a trained operator, and 20% need a maintenance expert [4]. In addition, maintenance activities account for the majority of a company's budget and weigh heavily on operating costs [5]. As a consequence, non-compliance with orders, maintenance costs, loss of profit and dissatisfied customers are generated.

The proposal focuses on reducing the rate of non-fulfillment of orders of a footwear production line through the application (Total Productive Maintenance, 5S and Visual Management, these will attack the main root causes of the problem, with the purpose of increasing the availability of the compressor machine (machine that provides compressed air to the other machines and equipment), have the spare parts warehouse tidy up to minimize search times; also, improve the area of spare parts and maintenance. This in turn will generate an increase in the hours available to produce and an increase in productive capacity.

This article consists of 5 sections: After the Introduction; section 2 presents a review of the literature through the state of the art; section 3 deals with the construction of the contribution model and indicators; section 4 develops the validation of the contribution and section 5 shows the conclusions of the article.

II. STATE OF THE ART

A. *Lean manufacturing philosophy*

Various research indicates that the Lean Manufacturing philosophy is a very powerful technique that contributes to the growth of a company. In this sense, lean manufacturing has the objective of eliminating waste or residues, that is, everything that does not add value to the product or service [5].

B. *Total Productive Maintenance (TPM)*

According to authors, the TPM is a tool whose objective is to optimize the performance of machines and equipment to ensure their efficient use. Likewise, it needs the commitment of all levels of the company for its correct implementation. With the TPM it is sought to have a 100% availability of the equipment through unplanned stops [6].

Implementing TPM is not an easy task, according to research, only 10% of companies have successfully implemented this tool [7]. According to a study conducted in a footwear company in Ecuador, the implementation of the TPM helped increase the standard production of 8 machines by 5% and 8%, from 410 pairs to 429 pairs [8].

Likewise, in a footwear manufacturing plant in Peru, the production of non-defective footwear was increased from 266 to 305 pairs. [9] Similarly, in one study, the authors identified high breakdown rates and low machine availability. Here, Autonomous Maintenance was applied, after this implementation the number of incidents due to breakdowns was reduced by 24%, and availability increased by 10%, [10]. A study in a textile factory indicates that the implementation of TPM increased availability by 5%, and the standard production of parts also increased from 3410 pieces to 3847 pieces per shift [11]. Another investigation in a manufacturing industry allowed to increase the availability of the line by 13%. [12]

C. Methodology 5S

Several studies show the success of implementing the 5S, in organizations. The application of the 5S in a cardboard company allowed to better organize the tools and the work area. Likewise, the movements of the operators in three machines were reduced; the first at 47%, the second at 48% and the third at 6%. [13] A second study carried out in a footwear SME, in Peru, with the 5S tool, improved the organization and cleaning activities by 38% and increased pending orders by 82%. [14] On the other hand, a study reveals a 57.24% reduction in delivery time. [15] In a footwear production plant, the 5S was implemented along with plant distribution in the cutting area and the warehouse as they are critical areas, after the implementation the production of 10,000 additional pairs was increased that allowed the company to fulfill customer orders [16].

D. Visual Management

This tool is a mechanism that has information that is easy to understand at all levels of the organization. In a plastic company this tool was complemented with the 5S and allowed to facilitate the execution of tasks and perceive an autonomous work environment [17]. Visual management is a complement to other lean tools such as the 5S and the Kanban system. Therefore, this system works as a process of control and continuous improvement, facilitating the understanding and disposal of waste. [18].

III. CONTRIBUTION

A. Basis of the Proposal

The proposal model has been developed based on three investigations. The first of these is the TPM implementation model, where four phases are identified (Preparation Introduction, Implementation and Consolidation).

Of this methodology, only three phases have been taken, which has been improved according to another study, whose authors proposed the TPM + RCM model.

In this, the first two principles of the TPM are presented in 3 phases and for the RCM in 5 phases. From this [8] [4], we chose to define our model of the proposal in three phases. A third model of implementation of Lean Manufacturing and Change Management tools allowed to locate the supported 5S methodology of Visual Management [14] in the second phase, that is, implementation.

B. Proposed Model

The proposed model associates three tools of lean manufacturing, TPM, 5S and Visual Management. The model is comprised of three phases. In phase 1, arrange the preparation activities. In phase 2, the first two pillars of TPM will be applied: Autonomous Maintenance and Planned Maintenance. For a correct implementation of the TPM, ssimultaneously, the 5S will be implemented in the spare parts warehouse. In the third phase, the proposed tools will be monitored through internal audits.

Compared to other models, this one includes Visual Management as a support tool in the fourth S", standardization. The success of its implementation will be based on the participation and involvement of all levels of the organization. The aim of the proposed model is to reduce the rate of non-compliance with orders by a footwear SME. The proposed model is shown in Fig. 1.

C. Model Detail

Phase 1: *Starting point*: It presents the initial considerations before the application of the proposal, such as the decision to implement the tools, team building and training. The improvement team will be made up of the production manager, 1 line operator and the maintenance technician.

Phase 2: *Implementation*: At this stage the TPM and the 5S are implemented with the support of Visual Management.

1) TPM

The objective of the Mantenimiento Autónomo program is, in the short term, to reduce downtime, in order to increase the availability of the compressor machine.

The autonomous cleaning tasks will be carried out by the manufacturing line personnel and by the maintenance technician, these will have an execution time of 10 and 15 minutes, respectively.

On the other hand, Planned Maintenance whose purpose is to reduce downtime and corrective maintenance times. Here a planned maintenance plan will be made, in which the maintenance of the machine components is carried out by the maintenance technician every 25 days, and at other times, every 50 days.

2) Methodology 5S

- Seiri (Select)

Accessories, spare parts, objects that are not useful and typical of the area are removed. Also, you start by filling a matrix with the items found. With this classification and based on three criteria, the number of items needed in the warehouse is determined. These criteria are: Utility, use and style.

- Seiton (Order)

The number of shelves is decided according to the classification made in the first S and, from this, an order is determined for the items and their location in the furniture by priorities.

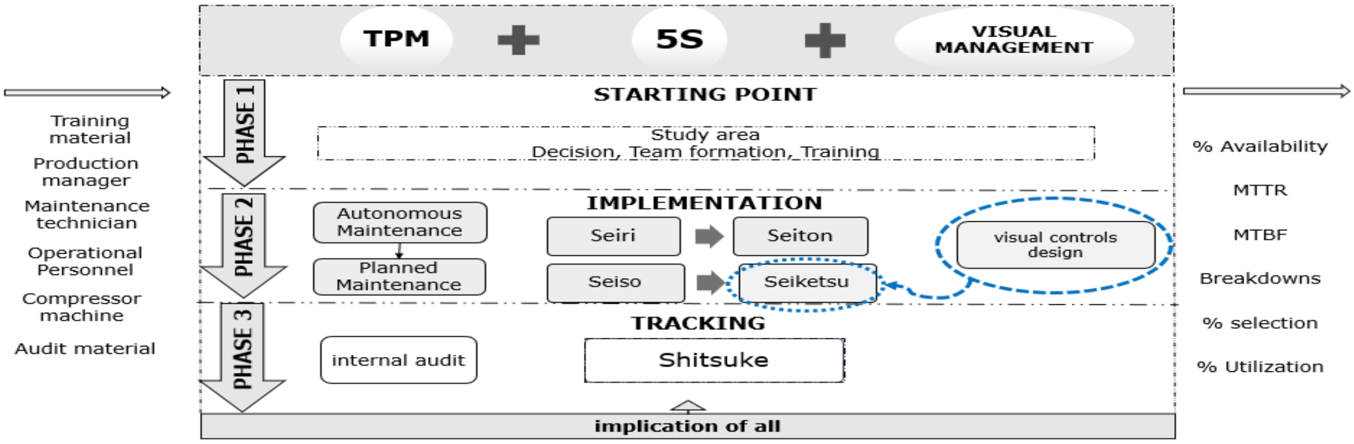

Fig. 1.Proposed model

- Seiso (Cleaning)

This third step allows you to clean the areas where the spare parts are stored. The goal of this third S is to maintain a culture of cleanliness. To do this, a cleaning program is carried out prioritizing those areas that are used most frequently.

- Seiketsu (Standardization)

This step is supported by Visual Management, through the design of visual controls on each shelf of the warehouse. Se design vignettes of three colors according to priority: Red for priority 1 shelves, blue for priority 2 and green for priority 3.

Phase 3: Tracking: In this phase, the last S is executed, that is, Shitsuke (Discipline), which allows an audit of the compliance of the previous 4 S. The proposed maintenance programs are also evaluated.

D. *Process Suggested*

The contribution is given by a series of phases as shown in Fig. 2. Phase 1 (Starting Point) is composed of 4 tasks. For phase 2 (Implementation), we chose to define the blocks by colors. The blue blocks correspond to TPM, the red ones to 5S and the green to Visual Management, which is included within the fourth "S"- Standardization. Finally, phase 3 (Tracking) has 4 tasks to run.

E. *Indicators*

This part presents the metrics that will measure the results of the proposed contribution.

1) Order non-compliance rate (OCR): Measure the percentage of orders not fulfilled in a period of time. Expression (1) shows the way of calculation.

$$OCR = \frac{ONT_t}{TOF_t} \times 100\% \tag{1}$$

Where:
ONTt: Orders not fulfilled in a time (pairs of shoes).
TOFt: Total orders fulfilled in a time (pares de calzado).

2) Mean Time Between Failures (MTBF): It measures theaverage time at which the equipment is running without failure. It is measured in hours. the formula for this indicator is shown in the expression (2).

$$MTBF = \frac{TPRT}{NF} \tag{2}$$

Where:
TPRT: Total Productive Time is the difference in available time and time per stop (in hours)
NF: Number of Faults

3) Mean Time to Repair (MTTR): Measures the average time the equipment is stationary while it is repaired. Measured in hours. The expression (3) shows the way of calculation.

$$MTTR = \frac{TFT}{NF} \tag{3}$$

Where:
TFT: Total failure time (hours)
NF: Number of Faults

4) Availability Rate (AR): this is the percentage that determines whether the computer is fit for use and is operating satisfactorily. The shape of the calculation is shown in the expression (4).

$$AR = \frac{MTBF}{MTBF+MTTR} \times 100\% \tag{4}$$

5) Selection rate (SR): Measures the percentage of items needed within the spare parts area. Expression (5) shows the way this indicator is calculated.

$$SR = \frac{NIN}{NIT} \times 100\% \tag{5}$$

Where:
NIN: Number of Items Necessary
NIT: Number of Items Total

6) Rate of use of furniture (RUM): Measures the proportion of area occupied by useless furniture within the spare parts area, as indicated by the expression (6).

$$RUM = \frac{ATF}{ATW} \times 100\% \tag{6}$$

Where:
ATF: Area Total of the Furniture (m^2)
ATW: Area Total del Warehouse (m^2)

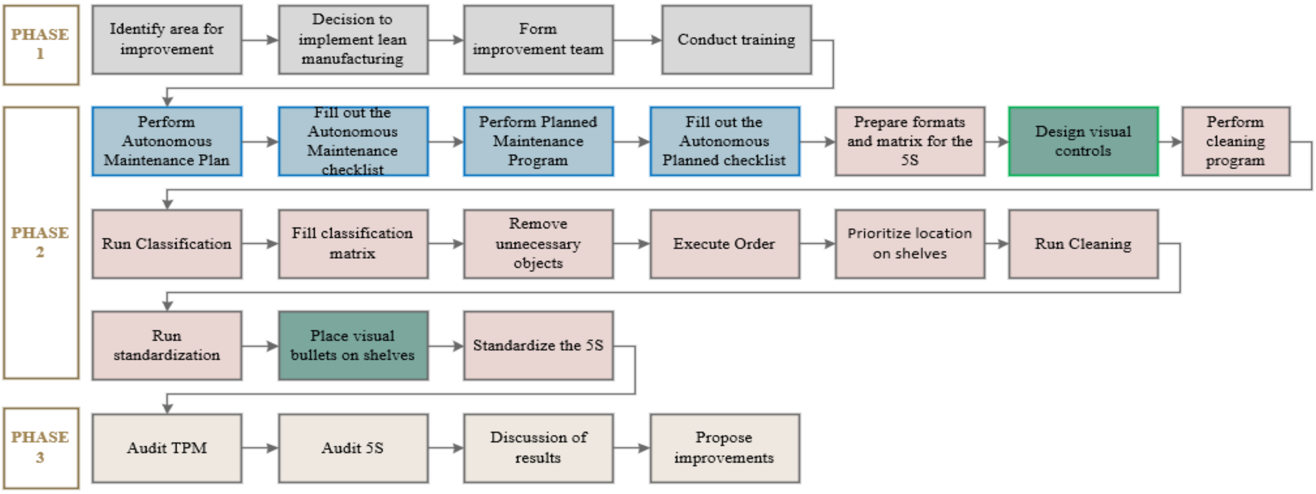

Fig. 2. Steps for The Implementation of the contribution

IV. Validation

A. *Initial Validation Scenario*

The simulation will focus on the repair process of the compressor machine. The objective is to know the average cycle time from the time the failure occurs until it is solved. In this way, it will allow to obtain indicators that allow to determine the increase in the availability of the manufacturing line. The compressor simulation model is shown in Fig. 4.

B. *Initial Diagnosis*

1) *Main problem:* In recent years, the non fulfillment of orders for the Andean fabric footwear model has tripled in the last 03 years, as illustrated in Fig. 3.

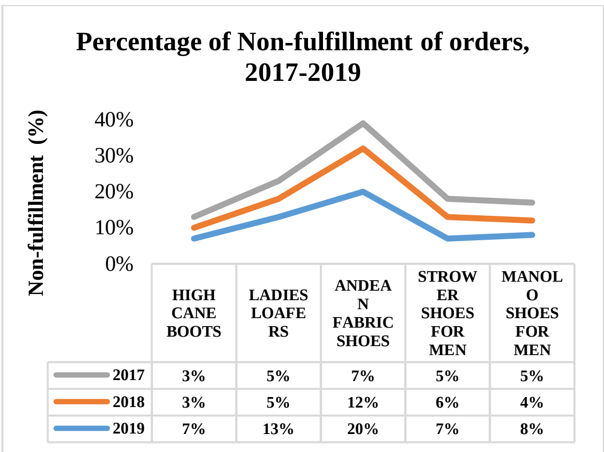

Fig. 3.Problem identification

As shown in Fig. 3, the non-fulfillment of orders for this model increased from 7% to 20% in the last three years, which classifies it as the most significant product of all. Therefore, the analysis is focused on the last year, as a noticeable increase is evident.

1) *Main causes:* By means of a Pareto Analysis it was determined that the s majoris the causes of the main problem is due to*:*

- Loss Availability

  The availability of critical equipment has fallen in the 03 years, from 96.76% to 77.67%, as constant shutdowns and corrective maintenance time have increased considerably.

- Area spare not suitable

  On the one hand, there are unnecessary objects that use the shelves to be stored which generates disorder and difficulty in quickly accessing the necessary and useful objects. On the other hand, the space is overused because of the useless shelves that does not allow the transit of maintenance personnel or operators. These occupy 59% of the total warehouse area.

C. *Results Vs Diagnosis*

Table I presents the results after improvement:

TABLE I
Final Indicators

Indicator	Before	After	Improvement
Order Non-fulfillment Rate	20%	8%	12%
MTTR	13.02	6.43	51%
MTBF	45.43	50.43	11%
Availability	77.73%	88.69%	10.96%
Number of Faults	50	11	78%
Serious Fault Rate	88%	27%	61%
Selection Rate	100%	60%	40%
Furniture Utilization Rate	59%	35%	24%

Due to the increase in the availability of the compressor by 10.96%, the footwear manufacturing line has benefited, as it has 309 overtime hours to produce, which expands the production capacity. In this sense, there is an opportunity for extra production of pairs of footwear of 4028. That is, of the 7313 pairs not initially attended, now they become 3285 pairs. Therefore, the rate of unfulfilled orders was reduced from 20% to 8%, which meant the reduction of 12%.

Therefore, the rate of unfulfilled orders was reduced to 12%. Likewise, with the sales opportunity, an additional income of S/. 189,275 per year is generated.

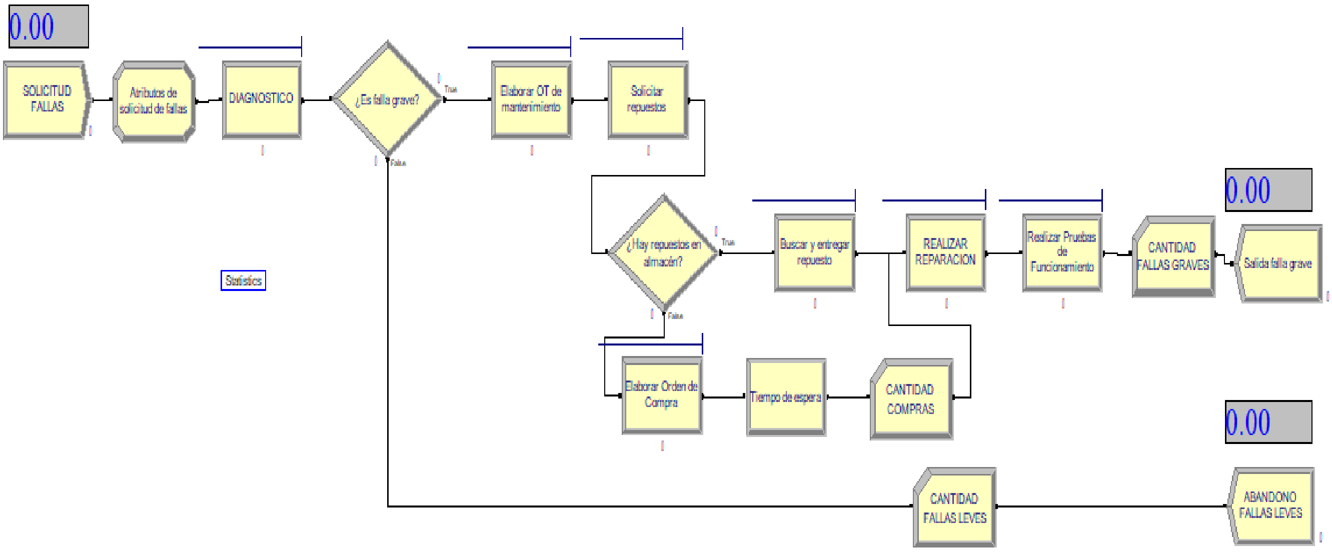

Fig. 4. Simulation model of the repair process

V. CONCLUSIONS

The Order Non-Compliance Rate in the Andean fabric footwear line was reduced by 12%, so Compliance increased to 92%, this thanks to the 10.96% increase in the Availability Rate.

Regarding the 5S, the Selection Rate decreased by 40%, that is, the number of items needed was reduced from 30 to 18. With this, the Utilization Rate of Unnecessary Furniture decreased by 24%. Economically, the proposal brought additional revenue of up to S/. 189,275 annuals.

Two direct causes were found, loss of availability and inadequate spare parts area.

The proposal was validated with the Simulation Software ARENA. In addition, with the 5S the spare parts area was ordered for easy detection and location of the items.

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