Production Model to Increase the Level of Order Fulfillment through the Implementation of Lean Tools and Ergonomics in SMEs of the Textile Sector

Antoni Rafael-Abad, Alexis Ancalle-Polanco, Juan Carlos Quiroz-Flores*, Martin Collao-Diaz, and Alberto Flores-Perez

***Abstract*—This research work was born from a common problem in most textile manufacturing companies, which is the non-fulfillment of orders. A Peruvian textile manufacturing company dedicated to the production of baby clothes was taken as a case study. In this case study, an in-depth diagnosis will be carried out to identify the causes that lead to the company's inability to fulfill orders on the defined dates. Once the causes have been identified, we will proceed to evaluate the methodologies to be implemented to increase the order fulfillment indicator. The most relevant indicators to know if the objective for which the research was carried out was met are order fulfillment, which the current KPI was 71.31% and with the improvement turned out to be 81.32%; machine availability, which the initial diagnosis was 81.5% and the final diagnosis was 89.28%; efficiency in the ironing area, which started with 87.88% and ended with 92%; and finally the percentage of a defective product, which started with 10% in the stamping area and 12% in the cleaning area and ended with 5% in both areas.**

***Index Terms*—Textiles, lean manufacturing, order fulfillment, TPM, FLD, standard work, ergonomics**

I. Introduction

Over the years, the textile industry has undergone a significant evolution driven by globalization, fashion and technology; this causes a constant change in demand, so companies must have adequate tools and methodologies to meet this demand. However, most Peruvian textile companies do not have optimal production levels, which causes them to fail to meet orders on the established dates [1]. In recent years, the production level of the textile and apparel sector has been decreasing, reaching a drop of 4.2% in 2019. This is reflected in the low utilization of installed production capacity in the textile and apparel sector with a level of 63.3% in 2019 [2]. Therefore, Peruvian mypes should focus on improving their production levels to mitigate the problem of delivery times.

Low order fulfillment has also been identified in other research works in the textile sector, as is the case of a company located in Lima (Peru), which has a high rate of defective products, disorder in the workstations and delay in the preparation of the machines that is reflected in its efficiency with 55%, which impacts on its order fulfillment represented by 18% [3]. Another study conducted in a textile company identified a low production level due to constant machine failures, lack of quality control and high production times, which resulted in not producing the desired batches to meet the projected demand [4].

Companies in the textile and apparel sector need to be more efficient and be able to meet delivery deadlines. The case study reflects the sector's problems in terms of order fulfillment due to causes such as the high rate of defective products, low machine availability and a low level of efficiency in a company dedicated to the production of baby garments. Under this premise, a production management model was developed that combines TPM, Standardized Labor, FLD, Anthropometry and Ergonomics tools.

The case study is divided into seven parts, which are Introduction, State of the Art, Methodology, Contribution, Validation, Acknowledgement and Bibliography.

II. State of the Art

A. Production Models to Increase the Order Fulfillment Rate in the Textile Industry

Companies in the textile and apparel sector usually present problems with order fulfillment, so improving productivity in the work areas is essential to meet the demand on the established dates. On the other hand, micro and small manufacturing companies present high rates of waste, which reduces their production efficiency causing them to fail to meet their scheduled delivery dates [5, 6]. Given this situation, MSEs should strive to implement new manufacturing techniques to improve their production cycle times [7, 8].

B. Lean Manufacturing in the Textile Sector

Lean Manufacturing methodology is defined as a set of practices that work synergistically to create an optimized and high-quality design to produce at the pace of customer demand [9]. One of the Lean tools is standardized work that helps to synchronize the production process; it also provides efficient methods and rules for each type of operation [10, 11]. Another tool is the Facility Layout Design (FLD) that seeks to improve the workstations by reducing the distance of objects and optimizing the flow between materials, also this reorganization of the workstations will allow to assign to each operator their respective area, delimiting their area as optimal as possible [9, 12]. In addition, the working posture is a relevant factor since a bad posture generates losses of working time and economic losses. In this situation, ergonomics plays an important role, since it identifies the workers' postures and evaluates the risk factors in the workplace [13].

C. TPM in the Textile Sector

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Total Productive Maintenance (TPM) is an equipment maintenance plan used to reduce losses in production activities, increase equipment life and ensure proper equipment utilization. [2]. One of the pillars of TPM is autonomous maintenance (AM), which is based on training operators to inspect and perform daily maintenance of equipment [14, 15]. Another pillar is preventive maintenance (PM), which consists of diagnosing the machinery from time to time so that it operates optimally and does not stop production [16].

D. Lean Production Models and TPM in the Textile Industry

The tools have been applied to common situations with order fulfillment problems. Therefore, several authors have decided to combine Lean Manufacturing and TPM tools to mitigate this problem. The application of such tools is done with the objective of increasing machine availability, reducing technical failures, in turn, this combination increases production efficiency by producing more units with the same resources [8, 17].

III. CONTRIBUTION

The collected sources show the application of the mentioned tools for different problems as shown in Table I. Unlike other models applied in the textile sector, the model proposed by us combines tools such as FLD, standardized work, ergonomics and TPM. In addition, this proposal focuses on a company producing baby clothes, which has not been investigated in depth by other authors.

A. Proposed Model

According to the review of the selected scientific articles, a model is proposed to improve the rate of order fulfillment based on the application of standardized work, FLD, Ergonomics and TPM (autonomous maintenance and preventive maintenance) in the MYPES of the textile and apparel sector, as shown in Fig. 1. Fig. 1 shows the model is made up of 3 components, which are as follows: Analysis of the current situation, intervention and validation.

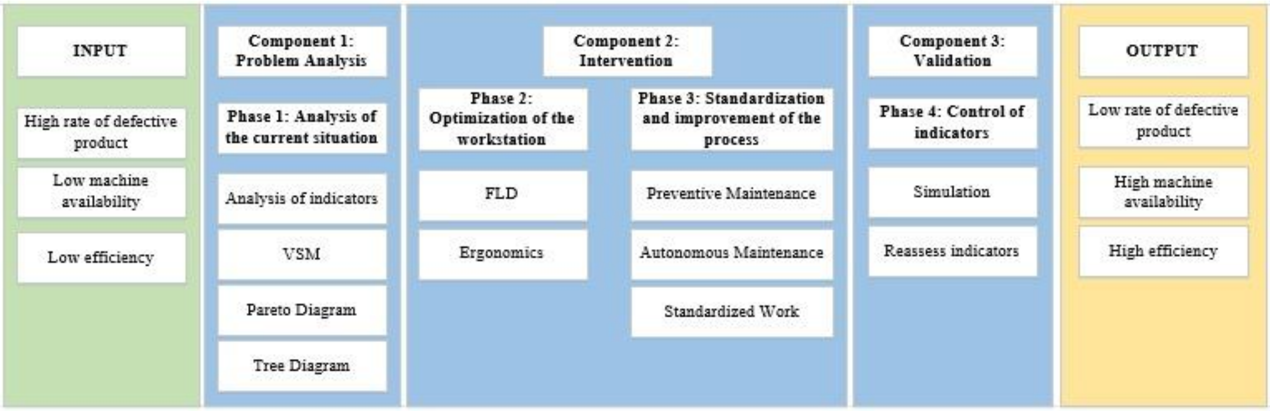

Fig. 1. Proposed model for order fulfillment improvement.

TABLE I: COMPARISON MATRIX OF THE CAUSES OF THIS RESEARCH VS THE STATE OF THE ART

Scientific articles	Defective product	Low machine availability	Work area not delimited	Low Efficiency
Arrascue, G., Cabrera, J., Chavez, P Raymundo, C. & Perez, M. (2020)		TPM	5S	
García, C., Marroquín, A., Macassi, I. & Alvarez, J. (2021)				Ergonomics Standard Work
Kovács G. (2020)			FLD	
Dos Santos, D., Dos Santos, B., & Dos Santos, C. (2021)	Standard Work			
Mejia, S. & Rau J. (2019)		TPM		5S
Flores,G., Valenzuela,R., Viacava, G. & Del Carpio, C. (2020)	Standard Work	TPM		KANBAN
This research	Standard Work	TPM	FLD	Ergonomics

The inputs and outputs of the process will be detailed to better understand the situation of the case study. The inputs of the model are the historical data, the high rate of defective product, the low machine availability and the low labor efficiency. The outputs are the low rate of defective product, high machine availability and high labor efficiency.

B. Model Components

1) Phase 1: Analysis of the current situation

This stage consists of the activities prior to the implementation of the proposed model. First, an analysis of the indicators was carried out to determine the situation of the company with respect to the sector to which it belongs. In the same way, the VSM was used to identify the activities that present problems within the production chain. Once the diagnosis was completed, a Pareto diagram was drawn up to identify the most relevant causes to be addressed. Finally, a tree of objectives was used to propose the tools that would help mitigate these problems.

2) Phase 2: Intervention

In the intervention phase, the tools presented for the proposed model will be developed. The first methodology to be applied is the Facility Layout Design (FLD), whose objective is to minimize the workflow, thus improving productivity and reducing the total distance of the flow of goods. This tool was applied to redesign the cleaning station to reduce the distance to the sewing area to improve the workflow, additionally, this redesign of the station was used to delimit the cleaning area since it presented high levels of clutter and little space to work, which affected production. As it was in the case study of György *et al*. [12], where he applied FLD to reduce the material workflow, handling cost and reduce the travel distance of the station to be improved.

The next tool to be applied is ergonomics, whose objective is to avoid disorders in muscles, joints, nerves and blood vessels, since these cause loss of working time. It was identified that the ironing area presents inadequate postures to perform the activities, so the REBA method was used to evaluate the exposure of workers to risk factors that can cause cumulative traumatic disorders. The other method is the OWAS, which evaluates the postural load from the observation of the different postures adopted by the worker. In the case study of Garcia *et al*. [13], who chose to analyze and apply ergonomics, he was able to improve inefficient movements by 66%, which led to reduce the standard time by 19% and improved productivity.

Another tool is standardized work, which aims to improve production times through optimal work methods. This tool was used in the cleaning area to identify activities that do not contribute value and eliminate them to form a standard work sequence. Similarly, Flores *et al*. [18] who performed the creation of a standard sheet for each operator based on the activities they perform. The objective of the application of this tool was to create a work routine focusing their efforts on the assembly line.

On the other hand, two pillars of TPM will be applied in the sewing area. The first is autonomous maintenance, which focuses on reducing labor costs by training operators to perform basic maintenance tasks, and the second pillar is preventive maintenance, which aims to increase machine reliability by performing maintenance before breakdowns occur. Arrascue *et al*. [19] used autonomous maintenance to promptly detect and deal with equipment failures; also, they implemented preventive maintenance to maximize equipment life to have better production without machine downtime.

3) Phase 3: Validation

In this phase, a simulation will be performed before and after applying the proposed model, to support the need to implement the proposed model to the production system and its work areas. For this purpose, the Arena Simulation software will be used.

Once the new indicators have been calculated, they will be compared with the initial indicators, to evaluate the impact generated by the proposal and whether the objectives were met.

C. Indicators

In this research work, the following six indicators were used to evaluate the improvements obtained and to verify the increase in the level of compliance in an MSE in the apparel and textile sector.

Level of order fulfillment: Allows you to view the number of orders delivered on time over the total number of orders requested. The objective is to increase order fulfillment to 84%.

$$Level\ of\ order\ fulfillment = \frac{Orders\ delivered\ on\ time}{Total\ orders\ demanded}$$

Machine availability in the sewing area: It allows to see the effective time that the machine works deducting the hours stopped for maintenance. The objective is to increase machine availability in the sewing area to 90%.

$$Availability = \frac{Total\ hours\ - Hours\ down\ for\ maintenance}{Total\ hours}$$

Efficiency in the ironing area: Allows to analyze how well the production objectives are being met. The objective is to increase efficiency in the ironing area to 90%.

$$Efficiency = \frac{Actual\ production}{Expected\ production}$$

IV. Validation

A. Initial Diagnosis

The object of study was a Peruvian textile workshop that manufactures baby clothes. The company has a low level of delivery performance below the technical gap of the sector. The three main causes that were diagnosed are: high rate of defective product, low machine availability in the sewing area, and low efficiency in the ironing area.

In the initial diagnosis, a negative economic impact can be identified due to the non-fulfillment of orders on the agreed date. These costs generated due to non-compliance represent 6.81% of the company's profitability.

B. Initial Diagnosis of the Case Study

As a validation tool, the simulation of the improvement will be carried out in the Arena software. The following points will be considered: Scope of the system, input variables, calculation of the optimal sample size, entities and elements of the system, the test period and the optimal run size. Fig. 2 shows the representation of the simulation system.

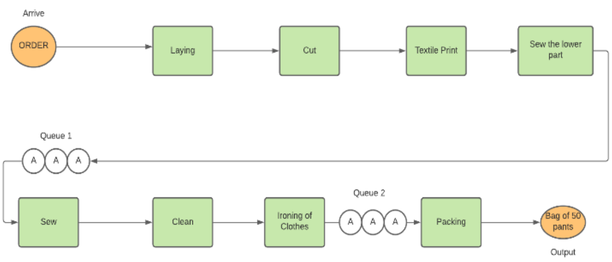

Fig. 2. System representation.

C. Validation Design

At this stage, the historical data of the company was collected to carry out the simulation. Once the historical data was collected, we proceeded to define the adjusted distribution for each activity to have a better reliability of the system as shown in Table II.

The next step was to simulate the model in ARENA to analyze the outputs and define the minimum number of replicates needed to improve the reliability of the system.

Table III shows the results found and allows visualizing the before and after improvement. It also identifies whether the objectives have been achieved. The representation of the model used in ARENA is shown in Fig. 2.

TABLE II: FIT DISTRIBUTION VALUES

Process	Fit Distribution
Order	UNIF (800;1200)
Laying	UNIF (75,79)
Cut	UNIF (60,64)
Textile Print	UNIF (11;14)
Sew the lower part	UNIF (22,25)
Sew	UNIF (203,207)
Clean	UNIF (41;44)
Ironing of clothes	UNIF (29;31)
Packing	UNIF (14;17)

TABLE III: COMPARISON MATRIX OF THE CURRENT SITUATION, EXPECTATIONS AND THE SIMULATIONS RESULTS

Indicator	Current	Expectation	Simulation
Order fulfillment	71.31%	84%	81.32%
% Of defective product in stamped area	10%	5%	5%
% Of defective product in cleaning area	12%	5%	5%
Availability	81.5%	90%	89.28%
Efficiency	87.88%	90%	92%

The simulation reflects a 10% improvement in order fulfillment after applying lean and TPM tools. Durand *et al.* [7] applied lean manufacturing and standardized work to improve order fulfillment, which improved by 18%. Likewise, Tapia *et al.* [6] applied 5S and line balancing to improve order fulfillment and increased it by 15%. It can be identified that according to the mentioned authors, the improvement in order fulfillment is an average of 16%, which justifies the improvement made in this case study.

The number of defective products could be reduced by 50% by applying the proposed model. Similarly, Mejia *et al.* [16] managed to reduce this indicator by 50% by applying Lean Manufacturing and TPM. Kaur *et al.* [20] conducted a statistical evaluation on the impact of implementing Lean Manufacturing in manufacturing companies, among the indicators investigated it was obtained that the defective products index is reduced by an average of 40%. so, the result obtained in the case study can be validated, since it is in the average range of improvement which is 45% according to the authors.

Efficiency in the ironing area was improved by 4%. In the research of Céspedes *et al.* [21], the efficiency of a textile manufacturing workshop was increased by 3% by applying the lean manufacturing methodology. In the case Kahur *et al.* [20], it started with an efficiency of 38.4%, after applying Lean Manufacturing it could be improved to 62.12%. Our case study had an efficiency result of 92 % so our simulated improvement can be validated with reference to reviewed literature.

The availability of assets in the sewing area improved by approximately 8%. In the case study of Arrascue *et al.* [19], they managed to improve availability by 10% by applying lean manufacturing and TPM. Similarly, Nafis *et al.* [22] achieved an average improvement of 4% by applying TPM in a textile apparel company. Based on the literature reviewed, the improvement implemented can be adduced.

V. CONCLUSIONS

The main objective of this research was to reduce the level of non-fulfillment of orders by the manufacturing company. The technical gap of the sector was taken into account as a reference to see the situation in which the company found itself. After implementing the proposed improvements, a compliance level of 81.32% was obtained, despite not reaching the technical gap of 84.5%, this indicator is within the permitted parameters since it does not present a variation greater than 5% respect to the sector.

To improve the indicators that helped to meet the objective, Lean and TPM tools were used. These were applied to the root causes found in the diagnosis of the initial situation of the company.

In the validation of the proposed model, Arena software was used to simulate both the initial situation and the improved situation with a confidence level of 95%. This required an adequate data collection in order to find the best distribution for each activity.

It is important to mention that the choice of this workshop is due to the ease of access, both to the facilities and to the information. On the other hand, the proposals obtained the expected results, given that they were applied to a textile manufacturing mype that, in general, present great opportunities for improvement.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Juan Quiroz-Flores, Martín Collao-Diaz, and Alberto Flores-Perez provided the conceptual and theoretical parameters for the research and writing. Antoni Rafael-Abad proposed the subject of study and the new model. Antoni Rafael and Alexis Ancalle-Polanco conducted the research and analyzed the data. Antoni Rafael did the proposed model design and wrote the article. Alexis Ancalle calculated the indicators and launch the pilot. All authors had approved the final version.

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