Integrated Lean-BPM Model to Increase Order Fulfillment in MYPES in the Textile Sector

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***Abstract*—The textile industry is one of the most important developments of the Peruvian economy; However, this sector has been presenting a series of challenges such as the necessity of reduce some relevant costs, high percentages of waste and low efficiency in the production line, all this problems evidence a low availability of machines that ranges from the hand with a disorganized production. In this way, the problematics mentioned before, generates cycle times shorter than Takt times, bringing as a fundamental consequence, the non-fulfillment of planned orders. In this research, we proposed an integrated model that uses lean manufacturing tools such as standardized work, SMED and TPM, hand in hand with the BPM philosophy, which provides a process-oriented approach. On this wise, the proposed model seeks to increase the current order fulfillment indicator of 72%, which, after implementation, showed an increase of 12.4%, verifying the effectiveness of the proposed model, in which the results were corroborated through a simulation.**

***Index Terms*—BPM, fulfillment orders, lean, SMED, TPM**

I. INTRODUCTION

In Peru, the textile sector is based-weight on the products and the dynamization it generates in the national economy, from the use of raw materials to the requirements of other industries [1]. In this way, the manufacturing sector, in which the textile industry is located, had a progressive decrease from 2019 to 2021 in the EAP with a variation of -16.3% [2]. Likewise, the textile production of yarns and fabrics, a fundamental matter of the sector, had a variation in the month of February 2020 of -15.2% and this percentage continued to show a constant decrease until October of that year [3]. This behavior is based on the atypical situation that Peru presented during 2020 and the 11.12% decrease in its GDP [4]. In this line, the data show that the main problem in the sector involves barriers in the adequate control, process organization and orders fulfillment.

Regarding the literature review, the problem found is related to the high percentages of waste, the long preparation times and the low efficiency in the process, generating a machines low availability; in addition to this, another important issue is that what the customer requests finally is not produced, which is evidenced in cycle times shorter than the Takt times throughout the entire production process. Thereby, all of the above results in non-fulfillment of orders [5].

Under the context presented before, companies in the textile sector must be more efficient to be able to fulfill the delivery of orders adequately. In this sense, in order to solve the problem mentioned above, it is common to apply a model that combines different Lean Manufacturing tools such as Value Stream Mapping (VSM), 5S, Takt time, Line balance and Kaizen [6].

Through the review of different scientific articles, limited information is evidenced on "Lean-BPM" work models for companies in the textile sector, especially in Latin America. For this reason, the need to carry out the present investigation is reiterated, which develops a new integrated model implemented in a company dedicated to the manufacture, quality control and export of yarns. The scientific article in development is divided into five parts, which are Introduction, State of the Art, Contribution, Validation and Conclusions.

II. STATE OF THE ART

A. Lean Manufacturing

The fundamental objective of Lean Manufacturing philosophy lies in the elimination of waste and activities that do not add value to the production system, using as a resource a variety of tools to improve performance. In this way, different studies recognize that Lean Manufacturing, seeks, as mentioned above, to reduce and / or eradicate the waste generated in the processes, thus raising the objective of increasing the value of the products. The implementation of this philosophy also has the objective of satisfying customer demand with a minimum delay time by reducing the setup of the machines [7, 8]. This last concept is defined as the amount of time elapsed between the last good piece of a product until the first good piece of the next product. In this line, is important to note that there is a variety of studies that detail the research and subsequent development of this philosophy in its processes, these projects were carried out almost entirely in small and medium-sized companies, which the implementation of the different Lean Manufacturing tools not only encourages improvements at the operational level, it also cultivates experience and therefore trust among staff, which leads to generating greater benefits for the organization [9]. Finally, an investigation indicates that quantitative Lean Manufacturing tools such as VSM, SMED, Kanban and OEE deserve more importance because they present greater possibilities of demonstrating improvement through their

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calculation [10], evidencing again, that the use of lean manufacturing tools is essential to obtain favorable results in business processes.

B. TPM

The implementation of the Total Productive Maintenance (TPM) seeks that the machines, facilities and among other components that are part of the production system, work in optimal conditions and provide their highest performance. Research argues that the application of TPM is focused on eliminating losses due to inefficiencies through the development of new autonomous maintenance (AM) and preventive maintenance (PM) plans. Likewise, the 5S tool is applied as the basis of the TPM methodology because it provides order and cleanliness in the workplace and, the most important result is that it generates discipline for the machines operators, as well as strategically implementing of each TPM pillars. The philosophy of total productive maintenance is based on the failure data that contributes to eliminating large losses, especially those related to machines in which any type of maintenance is applied before [11]. The TPM has as fundamental pillars the autonomous and preventive maintenance, which are key to achieve an increase in the equipment efficiency in any production process.

C. BPM

Business Process Management or better known universally as BPM, constitutes a fundamental and necessary tool for the adequate development of companies, which goes hand in hand with obtaining results such as an increase in performance, compliance with the system and greater innovation [12]. BPM is defined as a discipline that integrates strategies and objectives of an organization, focusing on the processes that it follows from start to finish [13], thus it is important to highlight the versatility and disaggregation of areas that the Business Process Management methodology presents, which include modeling, automation, execution, control, measurement, optimization of active business flows and among others [12].

D. Lean-BPM

Lean Manufacturing and BPM tools provide a relatively new initiative that combines two fundamental philosophies for process analysis and operations control. On the one hand, Lean Manufacturing principles and techniques are widely used in textile manufacturing to achieve a competitive advantage [14], in general, this philosophy offers the tools used to reduce waste within and between different processes to be able to increase the value of products [7]. On the other hand, BPM constitutes a discipline that guarantees the performance of processes in an organization to produce consistent results and understand opportunities to improve performance [15]. So, the combination of both methodologies shows a direct and positive effect on operations related to standardization and efficiency. In this way, the most used application which there are records, is the division of the Lean Manufacturing philosophy into two fundamental aspects; the first one, that is based on the implementation of hard and tangible practices, oriented to systems and quantification [16] And, on the other hand, the introduction of soft practices, oriented to the principles of Business Process Management since they have a positive impact on the performance of organizations [16].

III. Contribution

A. Proposed Model

The proposal value focuses on the necessity of increase the order deliveries fulfillment of a textile company, through the application of a Lean Manufacturing and BPM tools integrated model. Based on the literature review, it was determined that the integration of these two methodologies shows a positive and significant correlation in performance at the time of its application in the manufacturing sector. In this way, this integration generates a high level of clarity and order at the time of the process execution, showing that although the tools within each philosophy works properly, their integration takes the investigation to the next level. With this model, the main objective is to eliminate operational problems and / or waste such as the low percentage of trained personnel and the low availability of the machines. Consequently, it seeks to increase the service level of the company.

Next, a comparative matrix between the proposed model causes and the state of the art is shown.

TABLE I. Comparison Matrix of the Causes of this Research vs the State of the art

Causes / Scientific articles	Setup Management	Waste Management	Maintenance Management	Process/resource Management	Delivery compliance management
Amrani, A., & Ducq, Y. (2020)	SMED	Standardized work			
Pinto, G., Silva, F. J. G., Fernandes, N. O., Casais, R., Baptista, A., & Carvalho, C. (2020)	SMED		TPM		
Mahendrawathi E.R., Buce Trias Hanggara, Hanim Maria Astuti, (2018)				BPM	
Sahoo, S. (2020)			TPM	BPM	
Wickramasinghe & Perera (2016)					Lean-BPM
This research	SMED	Standardized work	TPM	BPM	Lean-BPM

B. Model Components

The proposed model will be developed in three components. They will be described in greater detail below.

1) PHASE 1: Problem analysis

Previously, the current situation diagnosis of the company was made by collecting data and necessary information from the different stages of the yarn production process. This analysis made possible to identify the operational waste and the main problems evidenced in the company's processes that finally allowed to achieve the goal of being able to determine the appropriate tools for the implementation of the planned improvement. The methodologies used for this diagnosis were the calculation of indicators, Value Stream Mapping (VSM), Motives Pareto Diagram, Ishikawa Diagram and Problem Tree. This problem analysis represents the first part of the model that is shown in Fig. 1.

2) PHASE 2: Intervention

This component focuses on the application of the tools for continuous improvement and Lean Manufacturing selected through the diagnosis made. In the first place, the "Total Productive Maintenance" or better known as TPM will seek to ensure the availability, reliability and operation of the equipment, which will improve the problem of low availability of the equipment detected in the investigation. Second, standardized work will allow the creation of a homogeneous, robust and consistent process, which can improve processes and provide greater agility. Third, the use of SMED or "One Minute Die Change" will seek to obtain a reduction in changeover time and also increase the process reliability. Finally, the implementation of Business Process Management is the key to unify the entire process and achieve improvements in the software and hardware used by the company, solving the two main problems detected; on the one hand, the excessive percentage of waste and on the other, the machine stoppages. This intervention represents the center of the model that is shown in Fig. 1.

3) PHASE 3: Development and implementation of the intervention

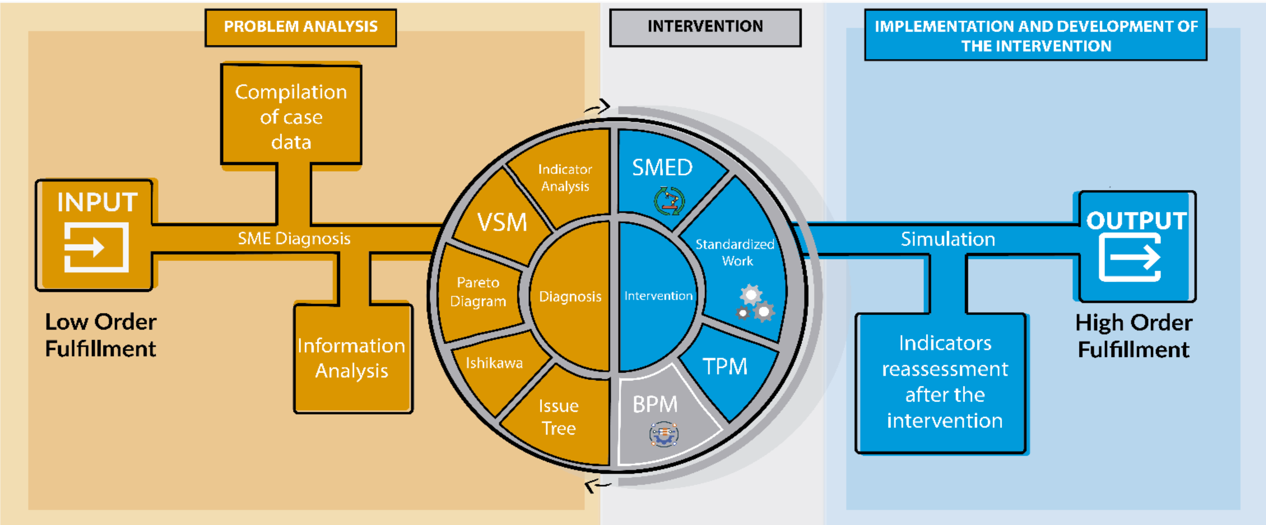

Fig. 1. Proposed model for reducing delivery compliance.

This component seeks to make a comparison between the results analyzed in the company current situation and the indicators reassessment based on the proposed model, this by conducting a simulation in the software Arena 16.10 that will provide a much broader and clearer picture of the improvements to be achieved with the proposal. This implementation is shown in the final part of the model that considers the outputs, the main resource to evaluate the effectiveness of the initiative propose.

C. Indicators

In order to evaluate the proposed model implementation and make the comparison mention before, the chosen indicators for the investigation are detailed below.

- **Delivery Fulfillment:** It is the orders percentage that the company delivers appropriately and, in the times, agreed with their customers. The objective of this indicator is to increase it by 15%, so the company will be able to generate greater satisfaction with its clients.

$$Delivery\ Fulfillment = \frac{Orders\ delivered\ on\ time}{Total\ orders\ delivered} \times 100$$

- **Service Level:** It constitutes the agreement between the business and their clients, hand in hand with the satisfaction that is desired as compensation to obtain. It is expected to increase the service level by 25% in connection with the current value offered to customers

$$Service\ level = \frac{Orders\ delivered\ as\ agree}{Total\ orders\ delivered} \times 100$$

- **Waste Percentage:** It constitutes the material waste that is used for the production of any type of good. The objective is to reduce the **percentage** in the carding and thread generation stages by at least 15%.

$$Waste\ \% = \frac{Kg\ of\ total\ PM - Kg\ of\ PM\ used}{Kg\ of\ total\ pM} \times 100$$

- **Availability:** machines capacity and their components to remain in an active state to be able to perform the function assigned to them in an appropriate way and in a certain interval of time. It is expected to increase availability in thread generation from 89.25% to 94%.

$$Availability = \frac{Total\ hours - Stop\ hours}{Total\ hours} \times 100$$

- **Overall Equipment Effectiveness:** Fundamental indicator to **measure** manufacturing productivity. The objective is to increase the indicator from 88.25% to 92%.

$$OEE = Availability\ X\ Performance\ x\ Quality$$

- **Setup time:** It is the time between the last valid part for a series production until **the** obtaining of the first correct part of the following series. It is expected to reduce the setup time by 40%.

$$\%\ reduction\ in\ setup\ time = \frac{Initial\ setup\ time - Final\ setup\ time}{Initial\ setup\ time} \times 100$$

IV. Validation

The tools that conform the Lean-BPM model will be applied in the different stages of the yarn manufacturing process in order to verify the results previously obtained. It should be noted that the service level of the company is 52%; nevertheless, this indicator, for the textile industry, is in the range of 90% and 100%, which is why the necessity of an improvement is appreciated in this case study.

A. Initial Diagnosis

The initial diagnosis made to the SME shows that there is a gap and economic impact in relation to the causes that originate the problem under study, which is the orders fulfillment. Currently the company indicator is 72%, causing economic losses of S /. 181,614.6 per year in order to the total costs of the company.

This means that the SME economic impact is approximately 6%. In the same line, the main causes of low delivery compliance are the following: high waste percentage, especially in the carding process, and constant machine stoppages, mainly in the yarn generation process.

B. Validation Designand Comparison with the Initial Diagnosis

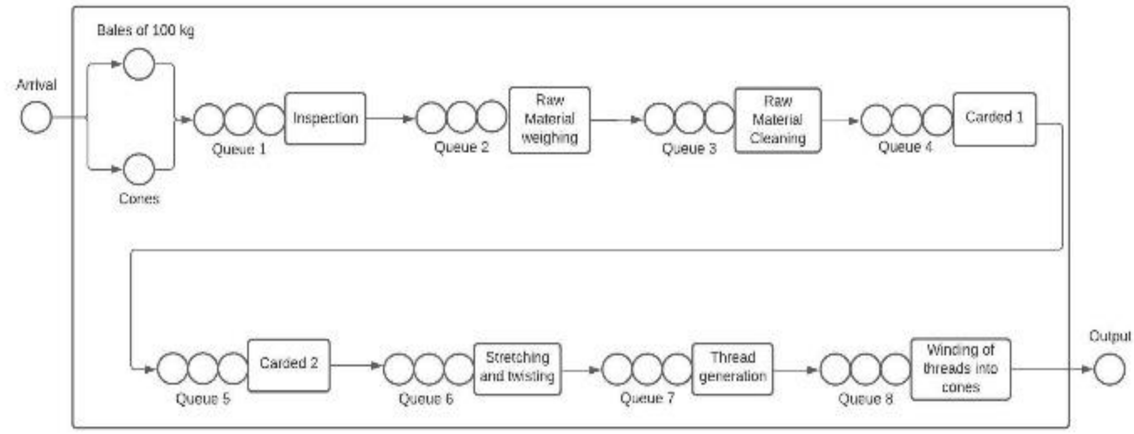

Fig. 2. System representation.

The proposed model in this article was verified by performing a simulation in the Arena 16.10 software, where the total yarn manufacturing process was modeled. The representation of complete system is shown in Figu. 2. In this way, by comparing the current indicators, what is expected and finally, what is obtained after the simulation, the effectiveness of the proposed proposal will be evidenced.

C. Improvement-Proposal Simulation

The simulation began with the collection of input data provided by the company under study. In this way, the times calculated in each of the manufacturing process stages were ordered to be able to find the optimal sample size for an adequate functionality of the simulation. Thus, for this operation a confidence level of 90% and a sampling error of 10% were used.

The collected data was entered in the Input Analyzer tool where the most appropriate distribution for each process stage was obtained thanks to the statistical adjustment made by the software. The choice of the mentioned distribution was based on obtaining a p-value greater than 0.05 in the chi-square and Kolmogorov-Smirnov tests. The corresponding values obtained are shown below.

TABLE II. Fit Distribution Values

Process	Fit Distribution
Raw Material Arrival	UNIF(21,24)
Inspection	TRIA(1.12, 2.88, 4)
Weigh	NORM(2.68, 0.596)
RM Cleaning	NORM(15, 1.32)
Carded	NORM(25, 1.07)
Carded 2	NORM(22.4, 1.11)
Stretching and Twisting	UNIF(23, 26)
Thread Generation	NORM(19.3, 0.813)
Winding Thread Into Cones	NORM(16, 0.953)

The second step consisted of diagramming the process and entering the previously calculated parameters, in order to know and validate if the proposed model shown improvements after its respective implementation.

After running the software, the replications optimal number was calculated thanks to the half-width obtained, for this we rely on the Output Analyzer software, verifying that 41 replications will be necessary for an effective simulation.

Finally, when calculating the indicators based on the outputs obtained, an increase of approximately 4% was evidenced in all indicators related to the implementation of the autonomous (7 steps of implementation) and preventive (6 steps of implementation) maintenance pillars of the TPM, standardized work (4 steps), and BPM (4 steps of implementation), as well as a 40% decrease in set-up time, related to the implementation of SMED (6 steps of implementation), finally obtaining an improvement in delivery fulfilment and Service level of 12%.

In the table shown below, the current values of the case study are presented, the expectation gathered by the literature review carried out by each tool and, finally, the real result obtained after the simulation.

TABLE III. COMPARISON MATRIX OF THE CURRENT SITUATION, EXPECTATIONS AND THE SIMULATION RESULTS

Indicator	**Current**	**Expectation**	**Simulation Results**
Delivery Fulfillment	72%	89%	84%
Service level	52%	77%	64%
% of waste	36%	21%	32%
Availability	94.56%	95%	98.56%
OEE	88.25%	92%	91.78%
Setup time	2-2.5 hours	1.5 hours	1.36 hours

V. CONCLUSIONS

The development of the Lean-BPM model allowed to increase order fulfillment and service level by 12%, which shows the effectiveness of the proposal and the possible application that companies in the same sector could carry out.

Likewise, the use of tools based on the Lean Manufacturing philosophy used in the model, make it possible to eliminate waste and activities that do not generate value, thus reaffirming their effectiveness in the textile sector, as well as the use of the "Business Process Management" in production processes.

In the future, it is recommended to have a greater focus on all the stages involved, since, as demonstrated in the present research, a small readjustment can generate excellent results that will benefit both the company and its clients.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Alithú Ankara Márquez-Ordinola conducted the research, analyzed the data, and drafted the manuscript. Judith Anita Vásquez-Solis-Echegaray supervised the research. Alithú Ankara Márquez-Ordinola, Judith Anita Vásquez-Solis-Echegaray, Juan Carlos Quiroz-Flores, Alberto Enrique Flores-Pérez and Martín Fidel Collao-Díaz had approved the final version.

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