Production Model Implementing Lean Manufacturing Tools to Increase Order Fulfillment in SMEs of the Textile Manufacturing Sector

Beatriz Martel, Patricia I. Kehuarucho, Martín Collao, Juan C. Quiroz*, and Alberto Flores

***Abstract*—Due to the context of the economic recession that the country is going through triggered by the covid-19 pandemic and considering the importance of the textile and clothing sector in Peru, order fulfillment is a requirement in the business world; when there is no control over it, it turns into an indicator of recurring issues for Small and Midsize Enterprises (SMEs) and Micro, Small & Medium Enterprises (MSMEs) of the textile manufacturing sector. This study proposes a production model focused on the mentioned indicator to improve efficiency in the coating process through a management model based on 5S, Total Productive Maintenance (TPM) (autonomous maintenance), and ergonomics with help of simulation software, such as Arena Simulator, Rapid Upper Limb Assessment (RULA) and Delmia V5. After the implementation of this model, positive results were obtained, which showed an increase in overall global efficiency of the machinery by 24.23%, a reduction of supplies search time by 10.63%, and improvements in the risk level due to bad posture to finally get an increase of 45.50% in order fulfillment, on time, in full.**

***Index Terms*—Total Productive Maintenance (TPM), 5S, ergonomics, order fulfillment, simulation**

I. Introduction

Since 2020, the global textile industry has been affected by COVID-19. Despite the rise of e-commerce, this effect has not been enough and sales have decreased by 30%, estimates the McKinsey consultancy (Salvatierra, 2021). During 2020, the production of the clothing industry in Peru registered a decrease of 23.1% in comparison to 2019, due to many factors, mainly associated with a demand decrease caused by the COVID-19 pandemic in Latin America. For this reason, an improvement of the processes of the textile sector is imperative, otherwise, a competitive loss would be produced since the country is facing an exportation recession (Andrade *et al.*, 2019a). Furthermore, taking into account the importance of this sector, which constitutes 6.4% of the gross domestic product (IEES, 2021) and is the second biggest industry in the manufacturing sector (Andrade *et al.*, 2019b), it is necessary to apply tools of continual improvement, of low cost, easy to implement, which are obtainable for businessmen and industrialist. The objective of this research is to increase the percentage of order fulfillment in the underwear manufacturing sector. Overall, this sector is associated with the low efficiency of the machinery and delays in the inspection process (Kshatra *et al.*, 2020). In the following paragraphs, the state of the arts, the problem analysis, the methodology, the contribution, the results, the discussion, and the conclusions are presented.

Manuscript received November 3, 2022; revised January 14, 2023; accepted March 21, 2023.

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II. State of the Art

A. 5S

5S is considered the most qualified Lean tool to use in companies that follow known norms to obtain an international certification (Zhou, 2016). This tool, whose name comes from five Japanese words, Seiri (sort), Seiton (set in order), Seiso (shine), Seiketsu (standardize), and Shitsuke (sustain), facilitates the conduction of activities because it creates an organized and clean work environment inside the company (Mejía and Rau, 2019; Vasquez *et al.*, 2018).

One of the benefits of this tool is the decrease in access times for materials and tools (Mejía and Rau, 2019). Additionally, an improvement in visual management is noticeable, which helps to localize defects in the products or any inconvenience in the machinery (León *et al.*, 2021). Also, the benefits in safety are highlighted since the signs help avoid any contingency (Durand *et al.*, 2020). Gallardo and Rau (2019) affirmed that, due to the implementation of 5S and autonomous maintenance, machinery malfunctions were reduced thanks to the correct cleaning and identification of dirt spots, thus, avoiding thread clogging. Kaneku *et al.* (2019) on this subject have shown that the implementation of this methodology decreases defects in the manufacturing industry and decreases late order delivery by 18%.

B. TPM

Total Productive Maintenance (TPM) is a Lean tool that promises continual and fast improvement in the manufacturing process, involving the workers by giving them training in the use of preventive methods and maintenance concepts (Andrade *et al.*, 2019c, Prasad *et al.*, 2020). This tool is considered one of the most useful for big industries and contributes to obtaining results such as decreasing repetitive machinery downtimes, waste, processes repetition, and increasing quality improvements, and sustainable commercial practices (Barrientos, 2020; Prasad *et al.*, 2020). Thus, Gallardo and Rau (2019) showed that this tool contributes to a mindset change in the operators, reducing the mistakes percentage, and therefore, reducing maintenance cost by 40% and work accidents by 70%. In this way, according to multiple studies of Mejía and Rau (2019), the implementation of autonomous maintenance, a pillar of TPM, alongside 5S, provides knowledge about continuous

doi: 10.18178/joebm.2023.11.3.751

improvement and involves the operators, giving them tools of simple concepts that contribute to the improvement of the work area and to decrease waste (Ahuja and Khamba, 2007).

C. Ergonomics

Musculoskeletal disorders produce injuries related to work in developed and developing countries (Öztürk and Esin, 2011). These are most common in sewing machine operators due to the constant bad posture that they adopt in the workstations and the constant movements they make with their hands (Dianat *et al.*, 2015). For this reason, the anthropometry re-design of the workstation in the remeshing process encompasses a series of techniques and procedures that seek to organize this process. Furthermore, a worksheet is used, in which the process sequence is defined to increase productivity in the industry (Abeysekera and Illankoon, 2016; García *et al.*, 2011).

Also, the implementation of this tool led to obtaining the main results, such as the increase of work productivity by 19.83% and the decrease of the risk level in the positions by 54%. Because of the implementation, the cycle time was reduced by 26%, the delivery time by 7%, the waste by 43%, and defects by 18% (Abeysekera and Illankoon, 2016).

III. Materials and Methods

The proposal is focused on the need to improve the results of the order fulfillment rate of Comercial Edu S.A.C., a textile company. A detailed analysis of the main issues that cause a low level of service is performed, raising objectives to eliminate the unproductive times related to coating processes, increase the machinery availability, and improve staff performance to significantly optimize the level of order fulfillment.

Thus, the corresponding tools are selected according to the recommendations and efficiency of multiple authors in the papers featured in Table I.

TABLE I: Models Comparison Matrix

Cause / Author	Wrong design of the position	Malfunction of the coating machine	Long material searching times
C.S Garcia *et al.*, (2021)	Ergonomic re-design of the station		
Mejia Carrera, S., Rau Alvarez, J. (2019)		autonomous maintenance and 5s	
Durand-Sotelo, L. Monzon Moreno, M. Chavez-Soriano, P. Raymundo-Ibañez, C. Domínguez, F. (2020)			5s
Gallardo Huamani, A., Rau Alvarez, J. (2020)		Autonomous maintenance and 5s	5s
Tools used in this research	Ergonomic re-design of the station	Autonomous maintenance and 5s	5S

A. Component 1:Problem Diagnosis

In the first stage of this model, featured in Fig. 1, the diagnosis is conducted. This allows identifying the weaknesses of the study case using the Rapid Upper Limb Assessment (RULA) method, Value Stream Mapping (VSM), Pareto Diagram, Ishikawa Diagram, and Problem Tree to establish the appropriate tools, according to the data collected in each stage of the underwear production process to evaluate a series of indicators in the initial state of the company.

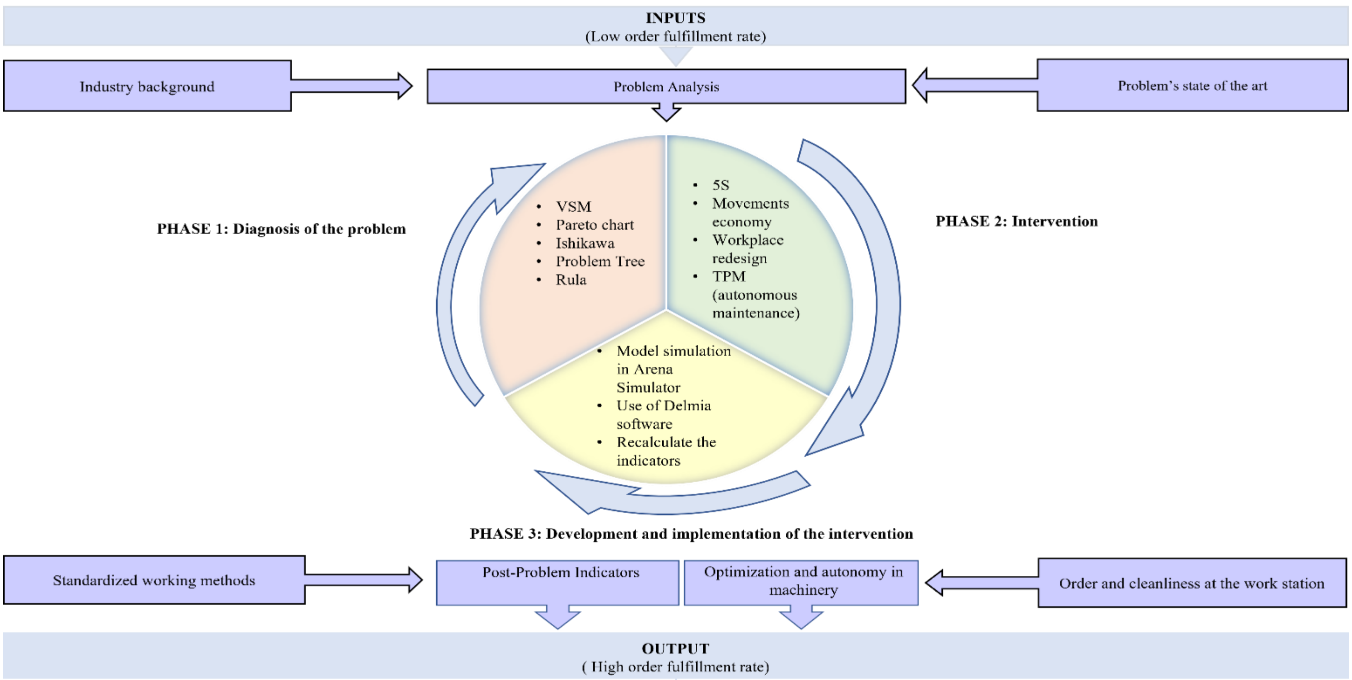


Fig. 1. Management model.

B. Component 2: Intervention

The intervention is conducted to make improvements, implementing 5S, TPM (automatic maintenance) tools, the Ergonomics principles

With 5S the activities that add value are sorted, the tools and the supplies layout are organized to decrease the search time, as well as helping with a cleaning plan to keep an organized space, standardize the cleaning processes, and conduct an audit plan. Automatic maintenance, a pillar of TPM, helps in the training of operators on maintenance activities and machine cleaning, reducing the machine downtimes and improving the Overall Equipment Effectiveness (OEE). Furthermore, for the implementation of the anthropometry re-design of the coating station, techniques such as the principle of motion economy that allows analyzing the coating station were used. Finally, the ergonomic evaluation of the corresponding activity was performed.

C. Component 3: Development and Implementation of the Intervention

To compare the impact of the implementation of the model, a simulation is performed with the help of the Arena and Delmia software, which makes possible the variation of measure in the indicators between the initial and final situation of the incorporation of the tools.

D. Indicators

To validate the implementation of the proposed model and analyze the comparison between the current situation and the expected one, the application of indicators are proposed below:

Order fulfilled on time, in full (OTIF)

$$OTIF = \frac{Number\ of\ orders\ fulfilled\ on\ time}{number\ of\ orders\ fulfilled} \times 100\%$$

The objective is to get an increase of 22% on the order fulfilled on time to generate confidence with the customer's, improve the company cost-effectiveness and the answer´s capacity.

Reduction of Ergonomic Indicators in Workstations

$$REI(\%) = \sum \left(\frac{\frac{initial\ score\ i - final\ score\ i}{initial\ score\ i}}{\#evaluations} \right) \times 100\%$$

The objective is to reduce the ergonomic risk level in the workstation.

Cycle time (CT)

$$CT = \sum times\ of\ the\ activities\ spent\ in\ the\ workstation$$

The objective is to get a reduction of 39% on the cycle time. Reducing unnecessary movements on the workstation

Supplies search time (SST)

$$SST = \sum Times\ of\ activities\ spent\ on\ supplies\ searching$$

The objective is getting reduce the time spend on search supplies.

Overall Equipment Effectiveness

$$\boldsymbol{OEE} = Availability \times Performance \times Quality$$

The objective is to get an increase of 24% on the Overall Equipment Effectiveness of the coating machine.

IV. Result and Discussion

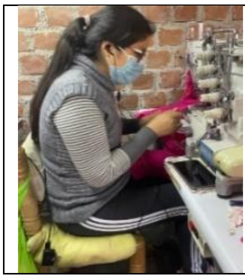
The validation is conducted with the use of different tools during the process involved. On this point, we can show evidence of improvements in underwear order fulfillment in SMEs. Rula was used for the diagnosis, the software Delmia V5 was also used for the ergonomic design of the chair and table. Finally, Arena was required for the simulation of autonomous maintenance.

A. Ergonomic Evaluation

The Software RULA was used for the analysis of postures in the coating station. This method allows us to evaluate the risk level considering the angles formed by body parts referred to a specific reference point in every work cycle evaluated.

The results are featured in Table II.

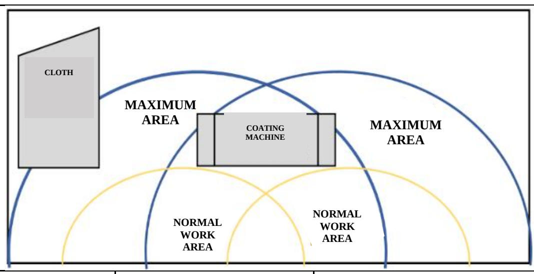
TABLE II: Evaluation before the Redesign of the Station

	Evaluation
	Ergonomic tool: RULA
	Score: 6
	Action Level 3: Requires rapid changes in job design

B. Redesign of the Coating Station

The economy of movements in Table III was used to analyze the coating station, this tool reduced unnecessary movements and simplify them to optimize the correct development of the activity.

TABLE III: Coating Station Proposed



Indicator	Initial situation	Improved situation
Cycle time	12,58 Minutes	8,19 Minutes

C. Simulation Using the Delmia V5 Software

Delmia V5 was used to propose the design of an ergonomic table and chair for the workstation. The use of this software verifies the improved scenery in a 3D picture.

TABLE IV: Proposed Model

	Evaluation
	Ergonomic tool: RULA
	Score: 6
	Action level 1: Acceptable risk level

The differences can be seen in Tables II and IV, achieving in the second case a better performance in the work activities because of the improvements in the ergonomic design

D. 5S Methodology

To improve the organization of the supplies warehouse, 5S was implemented. The objective was to generate a culture of order and cleanliness based on five principles with the use of the following tools:

1S: Red cards
2S: Labels and signs
3S: Cleaning schedule
4S: Standardization methods
5S: Audits

These tools were validated by an implementation in the workshop and the results are displayed in Table V.

TABLE V: INDICATORS OF THE IMPROVED SITUATION

Indicator	Initial situation	Improved situation
Supplies searching times	13.8 minutes	2.25 minutes

E. Simulación Software Arena Simulation

Regarding the operating system of the coating machine, a schedule was developed to carry out the Autonomous Maintenance, which includes a cleaning plan, calibrations, inspection, lubrication, and others. This process was executed using the Arena Simulation software and the model simulation for this case can be seen in Fig. 2.

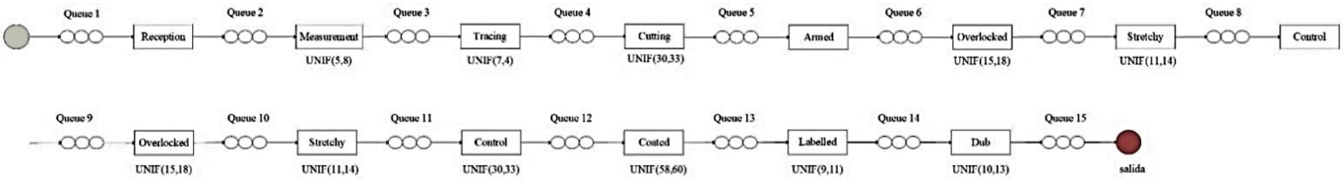


Fig. 2. Proposed Arena Simulation Model.

Table VI indicates the main indicator used to measure the improvement in autonomous maintenance, the machine has less downtime due to operational deficiencies. In other words, the operation is more efficient and productive.

TABLE VI: SIMULATION OF THE CURRENT SITUATION VERSUS THE IMPROVED SITUATION

Indicator	Initial situation	Improved situation
Overall Equipment Effectiveness	62%	86.23%

In Table VII can be seen there was an increase in the main indicator, order fulfilled on time, in full of 45.50%, using Arena Simulator evaluations, 5S methodology, and Delmia V5 software to solve the three main causes for the proposed model.

TABLE VII: ORDER FULFILLED ON TIME, IN FULL

Task	Evaluation	% of improvement	% Root cause	% Order fulfilled on time, in full
Malfunction of the coating machine	Arena Simulator	39.08%	52.28%	20.43%
Long material search times	5S	83.70%	17.25%	14.44%
Wrong design of the position	Software Delmia V5	34.90%	30.47%	10.63%
Improvement				45.50%

V. CONCLUSION

This model generates knowledge to solve the problem of non-fulfillment orders for other SMEs. It shows an increase of the order fulfilled on time, in full indicator (OTIF) by 45.50%, showing a correct implementation of 5S, TPM (autonomous maintenance), and Ergonomics methodologies.

The implementation of the 5S and Autonomous Maintenance generates greater efficiency in the coating process, increasing the overall effectiveness of the machinery by 24.23%. Likewise, these two tools together with the redesign of the workstation generate an improvement in the attitude of the workers who consequently can count on a suitable environment for their work.

In the future and in accordance with the approaches, it is advisable to apply Lean manufacturing tools to satisfy the demand for orders for quality products and thus be able to solve the problem of fulfilling orders delivered on time in small and medium-sized companies.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Beatriz Martel and Patricia Kehuarucho conducted the research and wrote the paper; Martin Collao, Juan Quiroz and Alberto Flores analyzed the data; all authors had approved the final version.

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