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Lean Manufacturing Production Model to Increase Productivity under the DMAIC Approach in Peruvian SMES Garment Manufacturers

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Abstract. In recent years, exports of the clothing textile sector in South America has been surpassed by countries in Central America. Peru is the only South American country with a relevant position, so it has a great opportunity at the regional level to be the leader in the clothing industry. The present work seeks to face the challenges of Peruvian clothing companies related to time, cost, and above all product quality. According to the aforementioned, it is essential to monitor all production processes to find the most notable deficiencies. Likewise, it is possible to conclude that the common problems of the sector under study are about the level of productivity and quality control. Because of this, the presentation is based on a complement of the Six Sigma, 5S, and Standardization tools of the work in a Peruvian textile company; all the data is executed in a simulation in the Arena software to corroborate the variation in productivity. Using the proposed model, thus obtaining an 82.98% increase in productivity.

Keywords: 5S, Standardized Work, textile company, productivity, DMAIC

1. Introduction

In the latest report of the World Trade Organization (2020), it is mentioned that the manufacture of clothing continues to hold second place in world exports. In addition, according to the Ministry of Production (2021), the Peruvian textile sector of clothing is nowadays the second most important in the manufacturing sector. In the national economy, this sector is very important, due to the added value it produces and the direct jobs it generates, especially because of the number of registered companies, where only 0.4% of the sector is made up of large companies and 94.7% are micro-companies [1]. Similarly, the Association of Exporters (ADEX), asserts that the textile industry represents 31.53% of total Peruvian exports, where 2.61% are clothing. In addition, it's observed that the main exporting garment companies in the country have decreased their exports by 30.09% from 2014 to 2017 [2]. One of the principal issues found by these clothing exporting companies is the delay in product deliveries and the low level of quality [3]. This shows that the common weaknesses are productivity and quality in their production processes because entrepreneurs are focused on billing rather than designing strategies that generate added value to the product [4]. On the other hand, the problem has been evidenced in national investigations and other countries too. As a fact, the largest garment production center in Pelileo (Ecuador), had a deficit in productivity due to excess waste of time due to unnecessary trips. It is important to focus on possible solutions to be used by clothing companies interested in standardizing their processes and increasing their productivity. Through the search for higher production performance with minimal resources and the objective of achieving the proposed goals, efficiency is achieved, which is the basis of productivity [5]. In this way, an improved model that involves the Six Sigma tool, 5S, and Standardized work is proposed, to achieve beneficial objectives regarding the productivity of the processes of a Peruvian textile company. The objective of carrying out this research is to develop a combination of specific tools and be able as well, to determine and implement an improvement to benefit the operation of textile clothing companies. In this direction, this article is composed of the following structure. The first section presents the state of the art where important concepts on the subject under study are detailed, obtained from the various articles reviewed. Next, the contribution is developed, where the proposed model, its components, and indicators are presented. Third, the validation of the model presented

above is detailed. In the next section, the results of the analysis performed are presented, explaining the data found. Finally, the conclusions of the investigation are presented.

2. State of the Art

For this research, the following concepts were considered; they were obtained from a preliminary exploration of the subject under study. Next, the main aspects to be developed and the relationship between them will be detailed.

2.1. Productivity

Productivity from a mathematical approach is the result of the productive system on the number of resources used [5]. The statement alludes to the efficient use of resources during the production of goods or services. It should be noted that the main factors that impact productivity are waste of time at work, high temperature in the work area, excess inventory, poor quality material, bad distribution of the area, the sequence of poorly defined operations, and unnecessary processes [2]. Plant shutdowns are the main factor affecting productivity in a production line [6].

2.2. DMAIC

Six Sigma is a well-structured improvement methodology with strong links to organizational strategy, high levels of management involvement, customer focus, and financial results [7]. This method is data-driven to bring quality to levels close to perfection; as well as correct problems before they arise. For this reason, Six Sigma should be seen as a valuable tool for achieving the company's vision and strategy, as well as for continuous improvement in operations, but especially to enhance compete capabilities [8]. It is important to mention that, by implementing the methodology, the organization not Indicator Control of activities that do not generate Unnecessary travel control Reprocess control Cut control only obtains benefits in terms of cost savings, productivity, and process improvement. Also, an integral part of the Six Sigma value Pérez Gao initiative is the DMAIC quality strategy; used to improve defect rate. Through the DMAIC method, we can achieve optimized use of resources, reducing costs to increase competitiveness against companies in the same field [15].

2.3. 5S / Standardized work

Many organizations implement Lean tools because employees feel better in their workplace and the effectiveness of continuous improvement creates less waste and better quality products, making the organization more efficient, more profitable, and competitive in the market [9]. Based on this, the application of Lean Manufacturing tools: 5S and work standardization allow reducing waste and optimizing production, minimizing the frequency of stops, waste, steps repetitive, as well as quality improvement, and above all the achievement of sustainable business practices [10]. To achieve the aforementioned, the implementation of the 5'S focuses on each “S” under a principle, to direct the development of the tool and facilitate awareness of all the members of the organization, allowing the model to be adapted to all areas that require it [14]. This, together with the Standardization tool, will allow establishing procedures, instructions, and controls to carry out the work in the best way, identifying the activities and generating a work sequence. And the union of both guarantees the efficiency and effectiveness of the process.

2.4. Textile Business

The textile and clothing industry encompasses various activities ranging from yarn manufacturing to garment manufacturing. It is known that the main Peruvian clothing exporters have decreased their exports and suggests that they should take action to overcome this decline as this would significantly affect their economic situation [11]. Textile companies seek volume and planning to obtain economies of scale, offer good design and quality at moderate prices with a global focus [12]. Due to this, in most of the clothing companies dedicated to export, there is a constant evaluation of quality levels carried out by the clients who hire them, so they do not exceed certain parameters and the export contract is seen at risk [3].

3. Contribution

3.1. Model Basis

Nowadays, high levels of competitiveness in textile clothing industry drive constant improvement in terms of productivity in order to achieve optimal positioning against the competition. To eliminate any operational problem that may arise and achieve continuous improvement at the organizational level, a search was made for tools, models, and methodologies that meet the previously expressed needs. For this reason, the following double entry table is presented where the different Lean tools are compared with the tools that will be used in this research.

Table 1: Components of the chosen sources.

Indicator	Control of activities that do not generate value	Unnecessary travel control	Reprocess control	Cut control
Pérez Gao Montoya, M. (2017)			Six Sigma	
Tinoco Gómez, O., Tinoco Ángeles, F. y Moscoso Huaira, E. (2016)	5S	5S		
Solís, L., Pérez, O., Balón, I. y Carrasquero, E. (2021)	Six Sigma	Kaizen		
Beltrán Esparza, EL, Fornés Rivera, RD, Gonzaléz Valenzuela, E., & Kimoto Okuda, S. (2018)			Standardized Work	
Pérez Sierra, V. y Quintero Beltrán, L. (2017)			Standardized Work	5S
This research	Six Sigma, 5s & Standardized Work			

3.2. Proposed Model

It is concluded that the proposed model will be based on the Six Sigma methodology, the Lean tool for 5S, and Standardized Work because they are the most appropriate and with them ideal results were also obtained (increase in productivity in considerable numbers), evidenced in the evaluated articles in show table. The proposed model will be developed in 3 phases; it will first start with the Six Sigma methodology, which aims to make improvements in the processes and reduce defective products [13]; through the sequence of DMAIC steps, the objectives to be achieved are defined. Identifying the aforementioned, during the improvement stage the 5S philosophy will be implemented. Then the standardization tool is implemented, increasing efficiency, and eliminating waste.

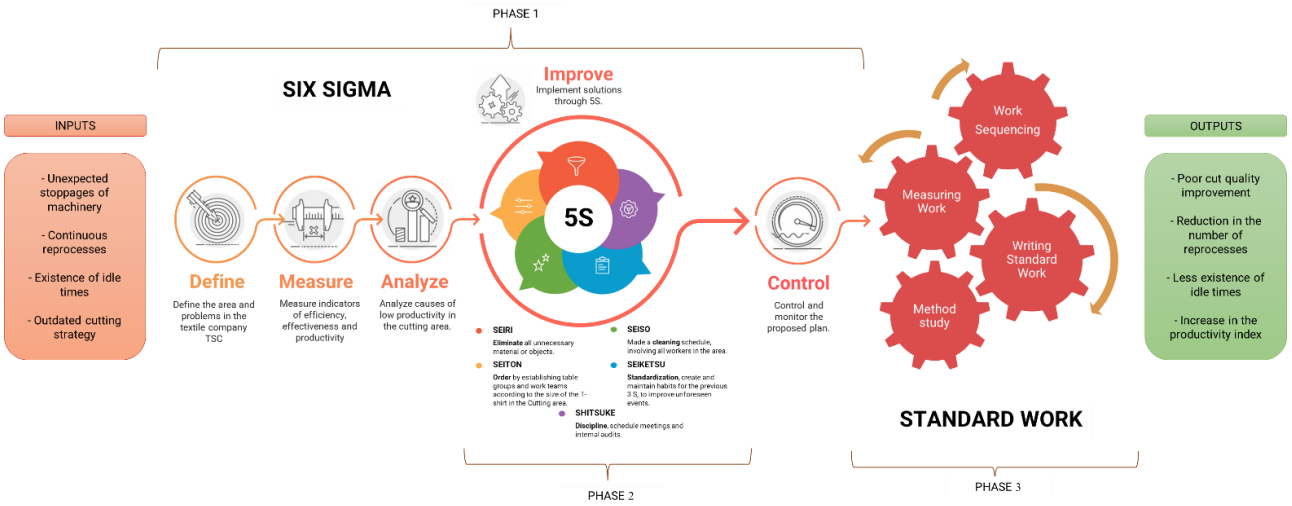

Fig. 1: Components of the chosen sources.

3.3. Model Components

The proposal is divided in three phases, as mentioned below.

Phase 1: Six Sigma For the development of the first phase, the Six Sigma tool was executed. The activities to be accomplished are grouped into 5 stages (DMAIC). In the first stage, Define, a general evaluation of the understudy company will be carried out, to identify the product with the highest percentage of participation based on the total demand for garments in 2019. Being selected T-shirts, a value flow diagram (VSM) will be made, where the most affected area related to productivity will be identified. Thus, the cut area is detected as an opportunity for improvement. Next, in the Measure stage, the area data will be collected to compare the effectiveness, efficiency, and productivity indicators in relation to the previously reviewed literature. Then, in the Analyze stage, the causes will be evaluated, through Ishikawa, Pareto diagrams, and other tools that show the possible root causes of the opportunity area. After, in the Improve stage, solutions to the root causes will be determined. To execute the proposed improvement, the 5S philosophy is represented by phase 2 of the model. Companies must promote training and/or training of all members of teamwork, adopting new tools that enable organizational improvement over time [20]. Finally, the last Control stage is focused on inspecting and monitoring the results to sustain the feasibility of the proposed model.

Phase 2: 5S The second phase consists initially in the application of the 5S, the proposal is focused on a new distribution by groups and worktables and a 5S manual. As well, before the development of the five stages, the action plan will be executed using a Gantt chart. In the first stage: Seiri (Eliminate in Japanese) all unnecessary material or objects will be eliminated, to preserve what is suitable for the cutting operation. For this reason, if it is considered an unnecessary object, a red label will be placed, to differentiate it from others and separate it to another place. Continuing with the next stage Seiton (Order in Japanese), the cutting process will be organized by establishing table groups according to the size of the T-shirt and the conformation of teams work for each desk in the Cutting area (Cutter, Tender, and Enabler). Then in the Seiso (Clean in Japanese) stage, a cleaning schedule must be made to assign activities to preserve the facilities and supplies in order and adequate hygienic conditions. We proceed with the Seiketsu (Standardize in Japanese) stage; this step preserves the newly installed chassis using the chosen storage configurations and color codes. Finally, in the Shitsuke (Discipline in Japanese) stage, meetings will be scheduled to review the progress since the implementation of the 5S tool, internal audits will also be carried out to monitor the development of the proposals. In addition, various control formats will be used to guarantee the sustainability of the improvement proposal over time.

Phase 3: Standardized Work The standardized work approach is often completed in 4 key stages; these steps consist in organizing tasks to understand stability and consistency in daily operations. The first step, to Study the process, is obtained by observing the practical work to capture all specific details, future ergonomics, and organizational workstations improvements. Then, Writing the standardized work, to determine each task by writing instructions clearly and correctly; it must be authenticated by the complete group to verify that the standard applies to all relevant resources. In the next scene, Measuring work, becomes important to measure

the factors that are only identified in the standardized work and exclude waste of time and move, if is necessary to identify the potential of a workstation. Finally, Work sequency, determine the biggest effective sequence to maintain busy resources (people and materials). Finally, the sequencing step is to determine the biggest effective sequence to maintain busy resources (people and materials). An auditor can be included at certain periods to verify the apply of standards are authentic. The standardized working approach can be completed in the four main steps; these, are sorting tasks to ensure the stability and consistency of daily activities.

3.4. Indicators

The proposed model is focused on the cutting area, for the corresponding analysis. The following indicators were used for the evaluation and verification of the study case, after the proposal had been applied.

Table 2: Indicators

Indicator	Formula	Use
Effectiveness	(Pieces cut x month / Pieces planned) * 100%	Measures the level of compliance with the number of pieces cut per month, concerning the goal of pieces cut.
Efficiency	(Real-Time / Scheduled Time) * 100%	This indicates the relationship between the time worked over what is established due to the different stops or other activities.
Productivity	% Effectiveness *% Efficiency	It indicates the relationship between time and production units. Combining the result of the previous two.

4. Validation

4.1. Initial Diagnostic

The study case is focused on the cutting area of a textile manufacturing company, which needs to increase productivity; in order to obtain greater compliance with the established demand spending less time. The main causes of the aforementioned problem are deficiency of control and order methods, cuts with wrong measures, and inadequate distribution of workload. In the current scenario, the company maintains a productivity of 70.76%, with an annual impact of 609 592 soles per year, which represents 1.2% of annual income.

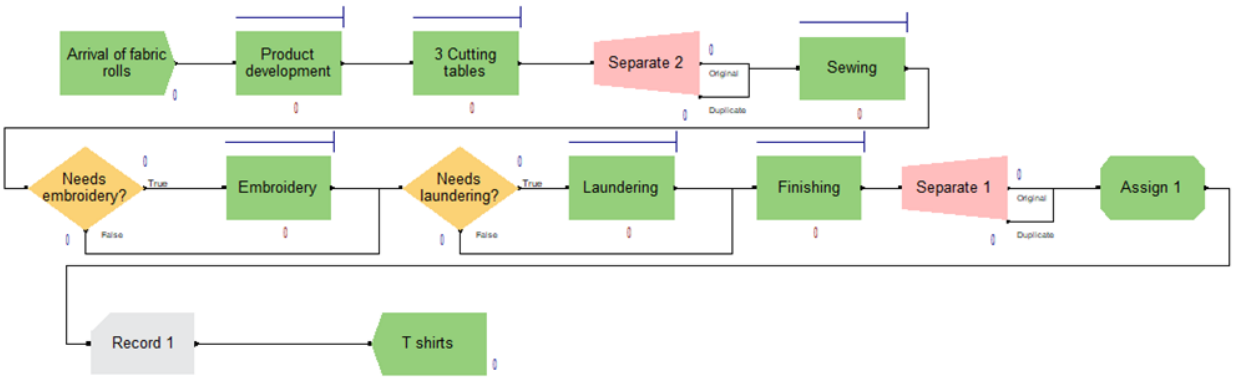

Fig. 2: Simulation in Arena.

4.2. Validation Design and Comparison with the Initial Diagnosis

To validate the proposed improvement, the Arena program was used to simulate the implementation of the model. Two simulations were carried out, the first focused on the current situation of the company; while the second represents the improved situation after having implemented the proposal of the model with the tools selected and previously explained. In this way, it seeks to increase productivity by more than 85%.

4.3. Improvement Proposal Simulation

The simulation carried out for both cases is the representation of a production day, which is made up of two shifts of 8 hours each; that is, in one day 16 hours of work. Likewise, the daily production is 11,100 T-shirts, to meet the established monthly demand. On the other hand, for the analysis, the number of T-shirts produced per day, the time in line, the number of entities waiting in the cutting area, the use of the cutting tables and the cycle time in the cutting area. It is important to specify that the improved scenario has been simulated taking into account an estimated reduction of one third of the cutting time. Simulation shows the improvements after having applied the new work system focused on the distribution of groups and tables, transit inspections, and standardized work. The following table compares the results of both simulation reports.

Table 3: Simulation Report

Indicator	Current Scenario	Enhanced Scenario
Number of t-shirts produced	11 020	13 452
Cycle time cutting area (hr)	10.86	9.93
Use of cutting tables	37.46%	14.04%
Waiting time in cutting area (min)	11.68	1.3

With the training and the new work system, it´s observed that there is a considerable change concerning the initial scenario because a higher production is achieved using less cycle time in the cutting area. It should be noted that the training for the groups in charge of the control of fabric in transit avoided wasted time due to the replacement of fabric not being suitable for the process. Due to the new distribution for cutting the pieces by size, in 3 tables, which influenced the allocation of more equitable workload, speeding up the cutting process. Also allowing to reduce the cycle time in the cutting area, and the waiting time for rolls entering the area. Similarly, the use of cutting tables was 14.04%, allowing greater control by tables. The following table shows a summary of the theoretically proposed indicators and the results obtained from the implementation.

Table 4: Indicators Table

Indicator	Current	Objective	Improved
Effectiveness	99.28%	> = 100%	121.19%
Efficiency	74.91%	> 70%	68.47%
Productivity	74.37%	> 85%	82.98%

5. Conclusion

With the results of the simulation, it was possible to demonstrate that with the implementation of the improved model in the case study, it obtains the expected increase in productivity, this being 83%. The tools allowed us to evaluate better the process and have control of the area that we seek to optimize, eliminating

waste and generating adequate efficiency for the current model Also, it was feasible to reduce the cycle time in the cutting area by 9.3%, allowing the number of T-shirts produced to be increased by almost 22% per day. This is reflected in the productivity indicator although it didn´t reach the desired level (85%); it was relatively close to doing with an increase of approximately 9% compared to the initial situation, achieving 83% productivity. This represents a production of 2 432 more T-shirts per day, thus obtaining an improved scenario with a production of 58 400 additional t-shirts per month. It´s recommended for future work to have more historical data on expenses and costs oriented to an income statement to develop a better analysis of the economic impact on the company. Likewise, we recommend an extension of the data collection for less variation, a reduction of the error, and increased precision of the information obtained at the time of the simulation.

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