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Production Process Model Based on Lean Manufacturing, TPM and SLP to Increase the Service Level in Companies in the Textile Sector

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Abstract

The textile sector is highly competitive, so quality and efficiency are essential to improve the level of service of companies. For this reason, the implementation of a production model based on Lean Manufacturing, Total Productive Maintenance (TPM) and Simplified Logistics Planning (SLP) becomes a proposal for improvement for the optimization of companies' production processes. This paper will examine in detail the application of this improvement proposal through a case study and the impact that these models have on the efficiency, quality, and ability of the company to know customer demand.

Keywords
Lean Manufacturing, TPM, SLP, Textile, SMED

1. Introduction
In today's dynamic business landscape, companies in the textile sector face increasing pressure to deliver high-quality products with shorter lead times while maintaining competitive pricing. To meet these evolving demands and stay ahead in the market, textile manufacturers must continuously seek innovative approaches to enhance their production processes and improve overall operational efficiency.

In response to these challenges, the integration of Lean Manufacturing, Total Productive Maintenance (TPM), and Systematic Layout Planning (SLP) has emerged as a promising strategy to optimize production systems and increase the level of service in textile companies. Lean Manufacturing focuses on eliminating waste, TPM aims to maximize equipment effectiveness, and SLP enhances facility layout to facilitate smooth workflow and resource utilization.
This paper presents a comprehensive production model that leverages the principles of Lean Manufacturing, TPM, and SLP to enhance the level of service in a textile manufacturing company. By combining these methodologies into an integrated approach, the aim is to create a synergistic framework that addresses key inefficiencies, reduces lead times, and improves overall productivity.

1.1 Objectives
The objectives of this paper revolve around the development of an integrative project aimed at enhancing the production process within the textile sector through the implementation of Lean Manufacturing, Total Productive Maintenance (TPM), and Simplified Logistics Planning (SLP). Specifically, the paper aims to achieve several key objectives. Firstly, it seeks to establish a comprehensive understanding of the project's background and the current

state of the art by synthesizing existing literature, case studies, and industry reports related to Lean Manufacturing, TPM, and SLP in the textile industry. Subsequently, the paper endeavors to conduct a thorough analysis and diagnosis of the production process issues using industrial engineering tools such as process mapping and time studies to identify inefficiencies and areas for improvement. Building on this analysis, the paper aims to design and develop solution proposals that integrate principles from Lean Manufacturing, TPM, and SLP to streamline operations and enhance overall efficiency. Finally, the paper intends to validate the proposed solutions through pilot projects or simulations, assess their economic viability, and evaluate their impact on relevant stakeholders including employees, customers, and suppliers. Through these objectives, the paper endeavors to provide a structured framework for improving production processes in the textile sector, ultimately aiming to increase the level of service and efficiency within companies operating in this industry.

2. Literature Review

In the context of the textile industry, where maintaining production levels to meet customer demand is paramount, there is a growing interest in optimizing processes rather than simply increasing capacity through overtime or equipment purchases. This literature review explores the integration of Lean Manufacturing, Total Productive Maintenance (TPM), and Simplified Logistics Planning (SLP) as a means to enhance service levels within textile manufacturing companies.

Liza Ludeña et al. (2022) showcase the application of Lean Manufacturing tools like 5S and SMED to reduce delivery times in textile SMEs in Peru, resulting in a notable production improvement. Similarly, Sosa-Perez et al. (2020) focus on worker empowerment through techniques such as Value Stream Mapping and line balancing, achieving significant quality and yield enhancements in lean manufacturing setups.

Moreover, efforts to enhance productivity extend to service industries, as demonstrated by Calmet Olivos and Rosas Herrera (2022), who highlight the productivity gains achieved through process standardization in establishments like hairdressing and veterinary clinics.

Barrientos-Ramos et al. (2020) delve into waste reduction in textile production through Lean Manufacturing principles, yielding improved productivity via process standardization. Contreras and Huaynalaya (2020) explore inventory management models to cut storage costs in the textile industry, identifying benefits specific to each sector.

Preventive Maintenance (PM) is also explored by Hardt et al. (2021) as a critical strategy in the production industry, aiming to eliminate accidental machinery failures. Furthermore, Medyński et al. (2023) investigate the functionality and effectiveness of specialized TPM software, emphasizing its role in achieving process sustainability.
Agustiady and Cudney (2018) underscore the integrated approach of TPM in equipment maintenance, emphasizing proactive and preventative maintenance to achieve near-perfect production processes. Bataineh et al. (2019) propose a sequential TPM scheme, integrating 5S and safety initiatives, leading to significant effectiveness improvements in equipment production.

SLP emerges as a prominent methodology utilized to optimize manufacturing plant layouts, with a primary focus on reducing lead times and improving energy management. Case studies demonstrate its efficacy in streamlining material flow, ultimately enhancing customer satisfaction and operational efficiency (Behin Elahi 2021)

Lastly, Aguilar-Schlaefli et al. (2022) propose a model integrating TPM with tools like 5S and autonomous maintenance to maximize efficiency in the plastics sector, resulting in notable improvements in efficiency and quality indicators.

The reviewed literature underscores the potential of integrating Lean Manufacturing, TPM, and SLP in textile manufacturing to enhance service levels, improve productivity, and optimize processes. These findings offer valuable insights for decision-making and strategy development within the textile industry.

3. Methods

This study focuses on developing a production process model based on Lean Manufacturing, TPM and SLP. This development entails a series of crucial steps. Initially, data collection and preprocessing are conducted to gather pertinent production data and ensure its cleanliness and completeness. Lean Manufacturing principles are integrated to eradicate waste and enhance efficiency throughout the production process. Total Productive Maintenance (TPM) practices are implemented to uphold equipment reliability and availability. Simplified Logistics Planning (SLP) methodologies are introduced to streamline logistics and supply chain operations.

Following these implementations, data analysis techniques are employed to evaluate key performance indicators (KPIs) and assess improvements in service levels. Through this comprehensive approach, companies in the textile sector can establish a robust Production Process Model that optimizes efficiency and customer satisfaction using our papers as a case of study.

4. Data Collection

In this paper, we will analyze a textile and apparel company located in La Victoria, Lima. It is currently considered a medium-sized company with approximately 80 workers with production lines to supply its own stores nationwide and for exports to other customers.

In relation to their production process, they have an approximate capacity of 20 thousand units per month. Due to the rapid fashion changes that exist today, the company has a production system of various product designs, and each of small batches of approximately 120 to 200 units. These products, being so varied, are classified among more than 80 families defined by the company, such as sets, pants, shirts, etc. However, this has generated a great difficulty for the company because it is no longer possible to define production lines by product since they need to change the order constantly.

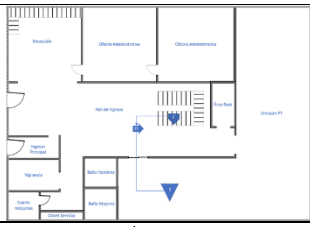
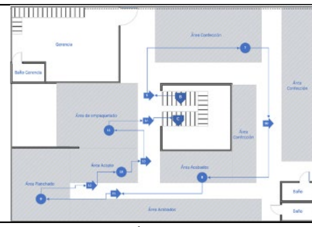
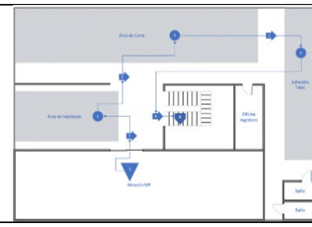
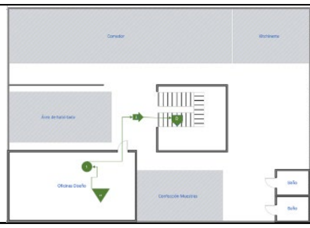
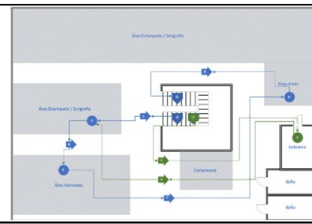
Because of this, we decided to focus on the level of service, since, having so many designs, but with only 120 garments manufactured for each design, the times vary with respect to the complexity of the designs.

In the case of the level of service, the engineer in charge of the operations area pointed out that, having national and foreign demands for imports, the company prioritizes exports and leaves aside the local market. The delivery time is 45 to 60 days, however, for orders that are to be stored it can take up to 2 months. To design the proposal, TPM, SLP and Lean manufacturing tools (SMED and work standardization) were used.

For the SLP tool, the flow and relationship of the company's activities was identified. With this, a relational table of activities was elaborated to determine the order of the activities and thus be able to develop proposals for optimal relational diagrams. Then, the proposals will be evaluated according to the importance of the chosen criteria and the selected layout alternative will be detailed to make a floor plan proposal.

The processes are structured throughout the 5 floors of the building. On the first floor is the administrative office area, the finished goods warehouse, and the dispatch area. On the second floor is the production area that includes the area for tailoring, ironing, and packing to make the final product. On the third floor is the raw material warehouse that includes all the inputs to be used, as well as the main raw material which is the fabric and the cutting process. On the fourth floor is the research and development area, as well as the meeting offices and dining space. Finally, on the fifth floor is the screen-printing area. It should be noted that this last floor has soaring ceilings and is outdoors due to the chemicals used in this area to make the prints and the screen-printing process on the fabrics. The flow of the material through the entire process, from the time it leaves the raw material warehouse to the finished product warehouse, is then presented through route diagrams. This current route has a length of 187.5 m (Table 1).

Table 1. Plant before the implementation of SLP

Before		
1st Floor	2nd Floor	3rd Floor
		
4th Floor	5th Floor	
		

For SMED, times will be measured in the assembly area to reduce the time of changing and configuring the pole line. With this tool, you will manufacture products as quickly and efficiently as possible without sacrificing product quality. A process will be designed where garments can be changed quickly and easily with minimal downtime. This will be achieved by analyzing the workstation and standardizing the tools and components used. Several steps will be applied, such as observation, where all the activities carried out in the process of making the polo shirt will be identified. Then the internal and external activities are separated, the internal ones are the ones where the machine is used and the external ones where the machine is not working. The times of each activity will be determined (Table 2).

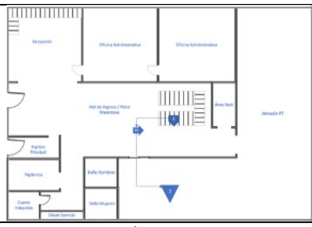
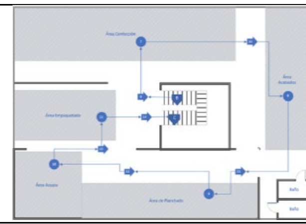
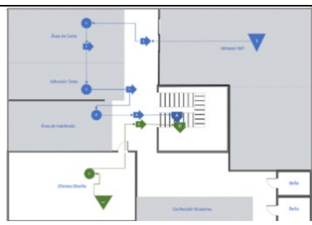
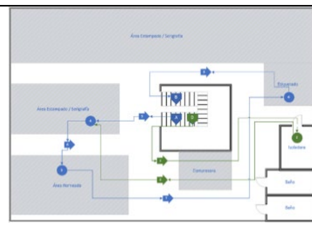
Table 2. Internal and external activities before SMED

	Internal	External
Plug in	45	
Receiving Molds		40
Receiving screens		42
Separating mold according to garment		82
Collect supplies		55
Insert roll into cone holder	24	
Insert the thread	33	
Attach Coil	22	
Putting needle in the machine	12	
Placing thread on the needle	24	
Locating Fabric Molds in the Machine	79	
Join mold to fabric		52
Assembling the product	648	
Leave the assembled product on the table		45
Remove excess thread	42	
Remove thread and fabric debris		26
Calibrate Machine	180	

5. Results and Discussion

With all the collected data, different proposals were made using the tools that were selected. First, with the SLP tool, a new structure of the plan was proposed where the length of the new route went from 187.5 to 161.8 meters (Table 3).

Table 3. Proposal of plant after the implementation of SLP

After		
1st Floor	2nd Floor	3rd Floor
		
4th Floor	5th Floor	
		

With the implementation of SMED, after identifying the internal and external activities, some adjustments of the work area and activities for shirt production were proposed to reduce the time. In the next table are the new estimated times (Table 4):

Table 4. Internal and external activities after SMED

	Internal	External
Plug in	20	
		55
		23
Insert roll into cone holder	24	
Insert the thread	33	
Attach Coil	22	
Putting needle in the machine	12	
Placing thread on the needle	24	
Locating Fabric Molds in the Machine	79	
		52
Assembling the product	493	
		20
Remove excess thread	42	
		15
Calibrate Machine	180	

For the work standardization tool, four steps will be followed to design the work standard. First, the process that must be standardized will be analyzed and identified, in our case it is the clothing area. A process operation diagram will be used to identify all the key activities of making a shirt, finally getting the next standard times (Table 5):

Table 5. Standardize process for shirt confection

Standard Operating Times		
1	Paste application in front	0.54
2	Join Right Shoulder	0.22
3	Front gareta edge	0.09
4	Back pocketing	0.09
5	Glue 1 & 2 & Dock	0.37
6	Join Left Shoulder	0.22
7	Gluing sleeves	0.57
8	Close Side/Label	0.79
9	Clench Fists x2	0.44
10	Stick Fist x2	0.86
11	Bagging Neck	0.32
12	Glue Neck	0.83
13	Pick up carpet	0.32
14	Mat Sitting	0.54
15	Neck stitching	0.36
16	Coated with coarse skirt	0.56
17	Pick Up Mark	0.60
Total		7.72

For the TPM tool, 7 steps aligned to the pillars of this tool will be followed. First, the TPM steering committee will be defined. Objectives will be established that will be aligned in the company's vision and strategy, as well as be measurable, achievable, and specific. The next step will be to identify the key processes which have the greatest impact on the quality of the final product and the profitability of the company. In our case, the key process identified was the cutting and sewing area. Value Stream Mapping (VSM) will be developed to measure and analyze these processes to identify areas of opportunity and critical points that require greater attention. To this end, performance indicators will be established, and information will be collected and made to identify causes and areas for improvement. Short-term and long-term goals and the times to be implemented will then be defined. AM and PM plans will be developed. The next step will be to implement improvements in the cutting and sewing processes, which will require a detailed action plan that involves the operators who use these machines. The information required by the company will be the number of machines, type of machines, how often they are maintained, production times. The last step is to evaluate the results obtained and adjust them according to the needs of the operators.

The action plan is related to autonomous maintenance, which consists of training operators to supervise their own equipment, as well as doing daily checks and inspections of the machines they work with. This includes cleaning stations and machines. Education and training will also be used in the action plan, which is related to training employees in the proper use of equipment to reduce wear and tear over time. These activities will be carried out within SMED's proposed plan and will be part of the machine's set up time.

The total budget consists of S/ 2,544.00 of materials for the implementation of the proposals, S/ 19,762.50 in personnel hours (both company and consulting), preventive maintenance (S/ 5,400.00) and monthly follow-up audits of compliance and monitoring (S/ 7,680.00). The total budget is S/ 35,386.50.

To resume all the improvements, the next table shows the actual and the improved values for each tool (Table 6):

Table 6. As is to be after simulation

Tool	Selected Indicator	Unit	As Is	To Be	Estimated Improvement	Simulation Result	Improvement obtained
Lean Manufacturing, TPM, SLP	Service Level	Percentage	71.72%	86%	14%	90.56%	19%
SLP	Distance Travelled	Meters	187.5	180	-4%	161.8	-14%
SMED	Set up time	Minutes	24.18	14.27	-41%	18.2	-25%
TPM	Cost of Loss	Suns	9560	0	9560	5400	-44%
Work Standardization.	Average time per garment	Minutes	10.81	8.65	-20%	8.23	-24%

5.1 Desing Validation

To demonstrate the effectiveness of the designed solution proposal, we will use the simulation validation method in the arena software. With this software, a process flow diagram will be created where certain parameters will be established such as input variables, optimal sample size, entities, resources, among others. For this research, a pilot test was used to have results closer to reality.

To validate in the arena software, the model to be simulated was defined. It will simulate the process of making a printed children's cotton polo shirt. The objective of this simulation is to optimize times in the production process, identify bottlenecks and evaluate the efficiency of the manufacturing process of children's cotton polo shirts. The scope of the simulation is from the issuance of the production order to the bagging pole in the finished goods warehouse.

To do the pilot tests, 60 production data will be collected, such as time, the garment area and cutting times. To design in the arena, you create a representation of the process using blocks that represent the workstations, queues, and memories you use. The parameters must be configured and the initial conditions for the simulation must be set. The simulation is then run in the sand and evaluated by taking initial information from a representative sample.

Finally, the results generated by the simulation are analyzed to obtain information about the performance of the process in the current scenario compared to the improved scenario.

5.2 Economic Validation

It was decided to evaluate the investment project to establish whether it is viable. The following criteria were used to determine the viability of the project: net present value (NPV), internal rate of return (IRR), payback period, and benefit/cost ratio. For the economic evaluation, a total investment of S/. 35.386.50.

Net present value (NPV) is the net benefits generated by the project using opportunity cost (COK) minus the investment made. The COK used was 18.70%. The NPV was greater than 0, so it is advisable to make the investment in the project. The IRR is a rate that indicates the average return (in this case monthly) generated by the capital that remains invested in the project. In this case, the IRR is higher than the COK, which is interpreted as the return on capital generated by the project is higher than the minimum acceptable for the realization of the project. The project must be carried out.

The benefit/cost ratio is used to analyze the benefits associated with the investment decision against the costs of the investment. The B/C ratio is 4.22, which means that for every sol invested, you earn 4.22. The payback period is less than one month. The investment will be recouped within 24.3 days from the start of the project (Table 7).

Table 7. Economic indicator for the project

Indicators	
VAN	S/ 114,050.18
NPV	122%
VNA	S/ 149,437
B/C	4.22
Recovery Period	0.81

6. Conclusion

With a cause-effect analysis of the identified problem, it was possible to determine three main causes that affect the Service Level, these being the low quality of the product, the non-compliance with the delivery time and the non-compliance with the delivery quantity. Likewise, a Pareto diagram identified that the first two were the ones with the highest weight on the analyzed indicator with a total weight of 83%.

Through the elaboration of the state of the art related to the case study, the main tools to be applied to each of the causes of the problem encountered were identified and determined. These tools are SLP to reduce process travel distances, SMED to eliminate times external to the use of the machine and thus optimize the key process that is the manufacture of garments, standardization to equalize the work done by all operators and thus reduce time and quality problems; and, finally, TPM, to reduce machine failures, thus improving product quality and reactive maintenance downtime.

With the implementation of the proposed tools and through a simulation of the production process, it was possible to identify significant improvements in the different stages. In total, it was possible to increase the level of service from 72% to 91%. This is due to the reduction of the travel of 25.7m in SLP, of times with SMED of 4.9 minutes of set up and with the standardization a reduction of 1.9 minutes per garment.

As part of the stakeholder analysis, it was necessary to focus on the impacts of the activities on them. One of the most important is the environmental and health impacts, in which it was possible to identify that the most aggravating activity for both factors is that of printing due to the emission of polluting odors.

Based on the financial analysis carried out for the investment of the improvement, this proposal is quite profitable since it has a positive NPV of S/ 114,050.18 and an IRR value higher than the percentage of COK obtained. Likewise, the risk analysis was carried out with the @Risk tool, identifying that even within the pessimistic scenario, this project continues to be profitable.

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