Improvement Proposal Applied in a MSE in the Textile and Clothing Sector: Case Study in a Baby Clothing Company

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Abstract

The textile and clothing sector is one of the activities that contributes the most to the economy. In 2019, it contributed 6,345 million soles to Peru's manufacturing gross domestic product (GDP); however, in recent years, this sector has lost participation due to the contraction in its production. The objective of this research is to reduce the production cycle time of baby socks, which impacts the monthly production levels and productivity in a clothing Micro and Small-sized Enterprise (MSE). Success cases previously obtained through literature review were analyzed, and a proposed model was designed by applying lean manufacturing tools such as Value Stream Mapping (VSM) in the diagnosis component, Total Productive Maintenance (TPM) to improve Overall Equipment Effectiveness (OEE) score, and Single-Minute Exchange of Die (SMED) to reduce setup time. The model was validated through simulation in Arena software. The result obtained showed a decrease in the production cycle time of 5.45% (from 1,829.53 minutes to 1,729.77 minutes). This result is explained by the expected improvement of OEE by 13.88% and the expected reduction of setup time by 36.61%, so monthly production is expected to increase from 1,134 dozen socks to 1,200 dozen socks. Finally, the initial productivity of 1.82 dozen/man-hours reached a final value of 1.92 dozen/man-hours, representing an increase in productivity of 5.49%. This case study can lead to the implementation of the model in MSEs in the textile and clothing sector that seek to improve productivity. Likewise, it can guide MSEs on the inclusion of lean manufacturing tools as an opportunity for continuous improvement.

Keywords
Lean manufacturing, Cycle time, TPM, SMED and OEE.

1. Introduction
According to the Institute of Social and Economic Studies (2021), the textile and clothing sector is the third activity with the highest contribution to Peru's manufacturing GDP. In fact, in 2019, it had a 6.4% participation rate, which represented 6,345 million soles, only behind the industries of oil refining (13.6%) and non-metallic products (6.7%). However, since the last decade, the contribution of the textile and clothing sector to the Peruvian economy has decreased due to the contraction in the production of the textile sub-sector and the clothing sub-sector.

The Ministry of Production of Peru (2023) indicated that in 2022, Peru recorded growth in the production of baby clothing compared to what was reported in 2020 and 2021; however, it is still below production level registered between 2013 and 2016 (see Figure 1).

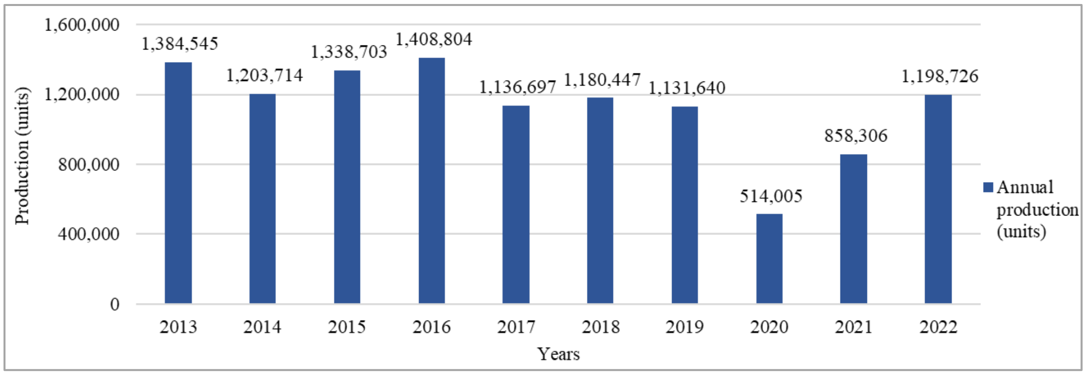

Figure 1. Annual production of baby clothes in Peru (2013-2022) (Ministry of Production of Peru 2023)

The National Society of Industries (2021) assures that this drop in national production is due to the entry of garments of Asian origin. For example, according to the Peruvian Exterior Commerce Society (2018), Chinese textile and clothing exports represent a threat since they easily enter the Peruvian market due to their low prices because Chinese manufacturing sector takes advantage of its low-cost labor and economies of scale.

Additionally, Micro, Small and Medium-sized Enterprises (MSMEs) in manufacturing sectors in emerging countries like Peru and Colombia are characterized by have low productivity results, a weak productive structure, and problems in supply chain management. The main causes are that 32% of these MSMEs have not invested in the acquisition or improvement of machinery and equipment; 28.80% have not invested in business innovation activities; and 25% have not invested in engineering, design, or creative or training activities (Larios and Ferasso 2023).

The previously mentioned information shows that companies in the textile and clothing sector face problems related to production levels due to different causes, so a case study was carried out at a Peruvian MSE dedicated to the production of baby socks. Initially, it was identified that the company has a production cycle time for 100 dozen socks of 1,829.53 minutes, which impacts its monthly production levels and productivity. The following table shows the production of dozens of socks per month and the productivity obtained from July 2022 to December 2022 (see Table 1).

Table 1. Monthly production and productivity report

Indicator	July	August	September	October	November	December	Average
Production (dozens of socks)	1,350	1,250	1,150	1,000	1,050	1,000	1,134
Productivity (dozens of socks / man-hours)	2.16	2.00	1.84	1.60	1.68	1.60	1.82

For this reason, the general objective of the research is to improve the competitiveness of a company by reducing its production cycle time of baby socks by at least 5% through the application of lean manufacturing tools. Considering the general objective, the following specific objectives were determined:

- Improve the OEE score of the selected machines by at least 80% by applying the TPM tool.
- Reduce total setup time by more than 30% in the most critical processes by applying the SMED tool.

2. Literature Review

Lean manufacturing

It´s a management philosophy whose objective is to improve and optimize a production system by identifying and eliminating various types of waste, which means eliminating those processes or activities that don't generate value and involve the use of more resources than are strictly necessary through the application of various techniques and tools (Hernández and Vizán 2013).

Buer et al. (2020) ensure that lean manufacturing is considered a great alternative to improve the capacity, management, and efficiency of production processes, due to the success that companies from different sectors have had in implementing it. For example, a company in the textile and clothing sector that implemented a lean manufacturing model reduced the production cycle time by 34% and the non-added value time by 32% (Kumar et al. 2019). Furthermore, a company dedicated to the production of clothing can reduce its production time by 11.80% and increase its productivity by 16.66% (Mulugeta 2021).

Total Productive Maintenance (TPM)
This lean tool ensures proper functioning and avoids "waste" caused by loss of time due to equipment failure, which causes non-compliance with customers and expenses in the company. It covers activities such as maintenance systems, basic training in order and cleanliness, motivation and involvement of the human team, and activities to achieve zero stoppages and an accident-free workplace (Carrillo et al. 2019).

For example, a Peruvian Small and Medium-sized Enterprise (SME) demonstrated through the implementation of the TPM program that it was able to improve its OEE from 32.86% to 85.58% (Canahua 2021). Additionally, through research carried out in a MSE of the Peruvian textile and clothing sector, it was shown that through the implementation of the TPM program, the OEE of the company's machines improved by 16.17%, going from 68.21% to 84.38%, which solved its problem of low production efficiency in the washing and dyeing process (Quispe et al. 2020). Likewise, an industrial company reduced the number of machine failures by 23% by carrying out preventive and corrective maintenance activities, which generated an increase in machine availability and OEE by 5% (Pinto et al. 2020). Additionally, through the implementation of this lean tool, a company that manufactures clothing improved its OEE by 28%, from 56% to 84% (Mejia and Rau 2019).

Single-Minute Exchange of Die (SMED)
It's an improvement lean tool whose objective is to reduce the setup or preparation time on a machine, from the completion of the last unit of a run until the completion of the first unit of the next run (Kim and Alden 1997). According to researchers, businesses can increase their productivity, decrease downtime, and improve customer service by implementing this tool (Saravanan et al. 2018).

For example, a SME in the Peruvian manufacturing sector carried out an action plan through the implementation of the SMED tool to improve the efficiency of its clothing plant. As a result, the company reduced its setup time by 52% (Campoblanco et al. 2022). Likewise, a manufacturing company reduced its setup times by 58.3%, resulting in an improvement in its productive capacity (Rosa et al. 2017). Finally, a company in the textile and clothing sector in Pakistan reduced the setup time of its printing machines by 18%, going from 142 minutes to 117 minutes (Bukhsh et al. 2021).

Through the literature review, successful cases of companies that implemented TPM and SMED in their production processes were taken as references to determine the impact and quantitative results expected if the company under study applied these lean tools.

Currently, the company has five knitting machines operating, which have an average OEE of 69%. Therefore, through the implementation of the TPM tool, their average OEE is expected to reach 80% and comply with the global standard proposed by Nakajima (1988). Likewise, the company's current setup time is 115.84 minutes; however, if the company implements the SMED tool, the setup time is expected to decrease by 35%. The following table shows us a comparison of the company's current indicators versus the expected indicators, taking the literature review as a reference (see Table 2).

Table 2. Comparison of indicators between scenarios

Indicator	Current Value	Objective	Variation (%)
OEE (%)	69.00	80.00	11.00
Setup time (min)	115.84	75.30	- 35.00

3. Methods

This research is a case study since first the critical causes that generate problems in a clothing company are known and then the application of lean manufacturing tools is proposed as a solution. Yin (1981) defines a case study as "an empirical inquiry that investigates a phenomenon within its real-life context". In addition, this research has a mixed approach because it collects, analyzes, and integrates qualitative and quantitative data to understand a phenomenon or problem (Hernández et al. 2014).

The proposed model was based on the application of lean manufacturing tools, such as TPM and SMED in a MSE in the clothing sector, whose main problem is the high production cycle time of baby socks. For its design, successful case studies obtained through literature review were taken as reference. Finally, the indicators of the current model were compared versus the model after the application on the lean tools to know the expected impact of the proposal. This model comprises three phases (see Figure 2).

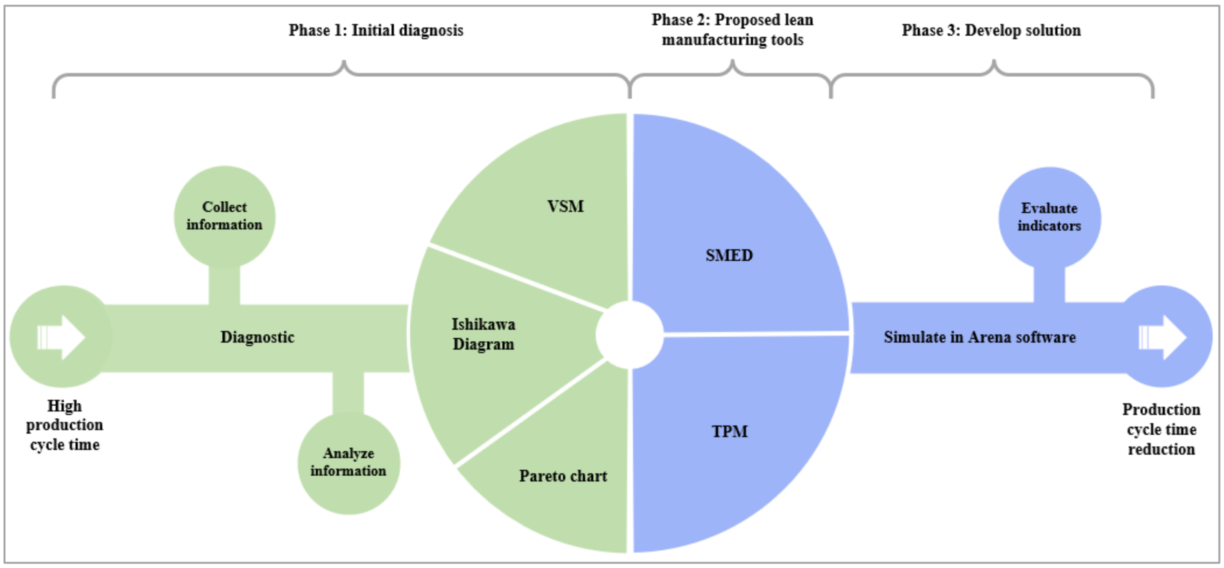

Figure 2. Proposed model

- **Phase 1: Initial diagnosis.**
  In this first phase, the problem was identified, and its causes were analyzed. The diagnostic tools were VSM, Ishikawa diagram and Pareto chart.
- **Phase 2: Proposed lean manufacturing tools.**
  In this phase, the TPM and SMED tools were proposed and explained as a solution to the research problem.
- **Phase 3: Develop solution.**
  Finally, in the third phase, the application of the lean manufacturing tools was simulated through the Arena software, and current indicators were compared versus the expected indicators after the application of the proposal.

4. Data Collection

The company under study produces an average of 1,134 dozen cotton baby socks per month.

Value Stream Mapping (VSM) was used as a diagnostic tool to graphically show the current production process and identify critical points and indicators for an order of 100 dozen baby socks during a work week. Likewise, the company has three workers, and their work schedule is a nine-hour shift per day (from 08:30 a.m. to 05:30 p.m.), including a one-hour break (from 01:00 p.m. to 02:00 p.m.), for six days a week (from Monday to Saturday) (see Figure 3).

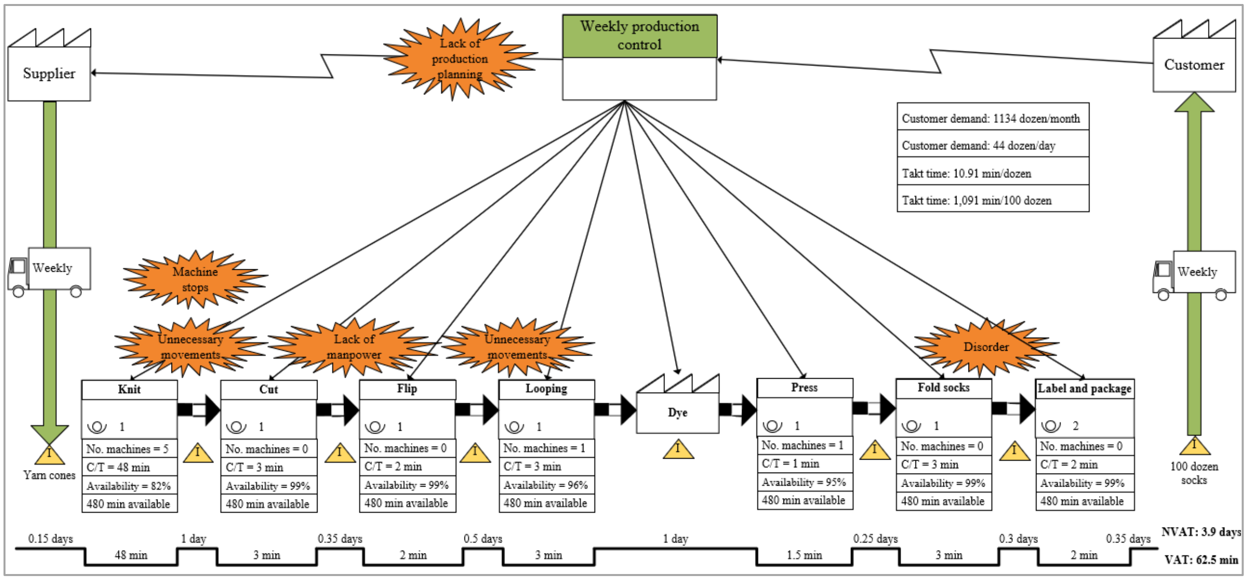

Figure 3. Current Value Stream Mapping (VSM)

Analyzing the current VSM, it was found that the value-added time (VAT) was 62.50 minutes, while the non-value-added time (NVAT) was 1,872 minutes. The sum of these two indicators results in a lead time or delivery time of a batch of 100 dozen sock of 1,934.50 minutes or 4.03 days, which means that the value-added time represents only 3.23% of the lead time. Likewise, a takt time of 1,091 minutes was obtained, which means that a customer should buy a batch of 100 dozen every 1,091 minutes.

Based on the diagnoses made and information previously obtained, the Ishikawa diagram was used to identify the root causes of the problem related to the high production cycle time of batches of baby socks (see Figure 4).

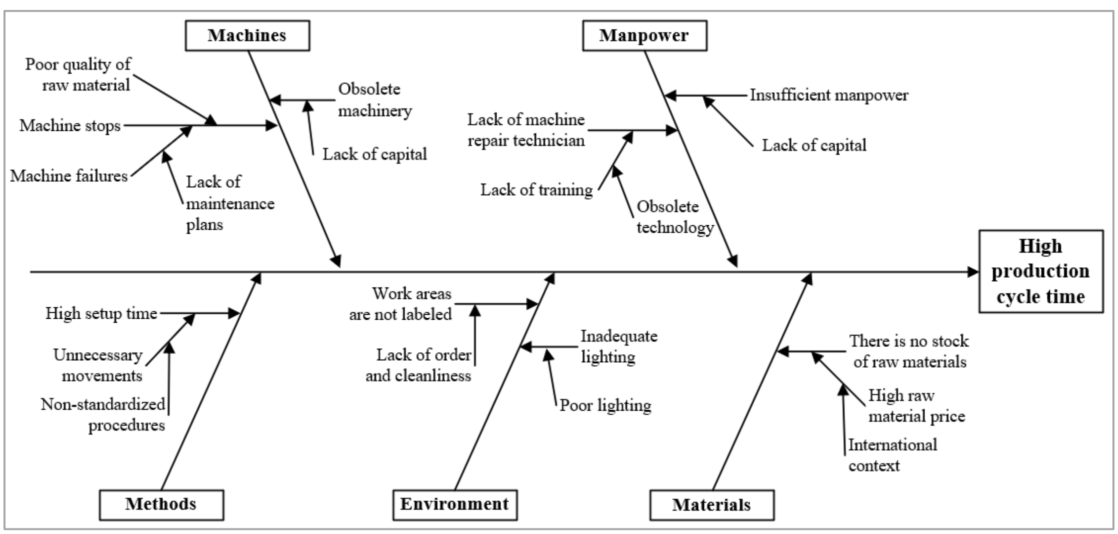

Figure 4. Ishikawa diagram

Additionally, the Pareto chart was used to rank the root causes of the problem based on their frequency of occurrence and potential impact on the company. As a result, the main causes related to the high production cycle time are machine stops, high setup time, obsolete machinery, and lack of machine repair technician (see Figure 5).

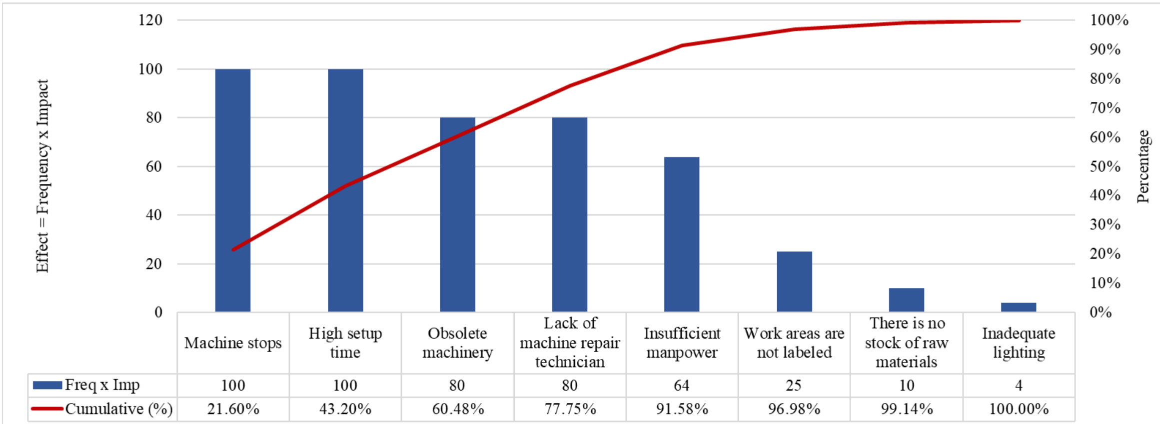

Figure 5. Pareto chart

Application of Total Productive Maintenance (TPM)

The condition and technical characteristics of all the machines were analyzed, and it was identified that the knitting machines have the lowest availability percentage since they have the shortest Mean Time Between Failures (MTBF). The reason for the high MTBF numbers is due to the high number of times that machines fail per month, which results in shorter operating time (see Table 3).

It should be noted that the following formulas proposed by Nakajima (1988) were used to calculate the machine's availability:

$$Mean\ Time\ Between\ Failures\ (MTBF) = \frac{Total\ operational\ time}{Total\ number\ of\ failures}$$

$$Mean\ Time\ to\ Repair\ (MTTR) = \frac{Total\ maintenance\ time}{Total\ number\ of\ failures}$$

$$Availability = \frac{MTBF}{MTBF + MTTR}$$

Table 3. Availability calculation

Machines	Available time (hours)	Failures per month	Total maintenance time (hours)	Total operational time (hours)	MTBF (hours)	MTTR (hours)	Availability (%)
Knitting 1	208	20	36.97	167.15	8.36	1.85	81.89
Knitting 2	208	19	36.65	167.47	8.81	1.93	82.05
Knitting 3	208	19	36.80	167.32	8.81	1.94	81.97
Knitting 4	208	17	36.63	167.49	9.85	2.15	82.06
Knitting 5	208	17	36.55	167.57	9.86	2.15	82.10
Looping	208	2	6.32	192.95	96.48	3.16	96.83
Pressing	208	0.25	12.00	196.00	784.00	48.00	94.23

The five knitting machines obtained a final average OEE score of 69% (see Table 4). According to Nakajima (1988), these machines have regular performance and low competitiveness because the availability, performance, and quality indicators are below the global standard.

Table 4. Current indicators of OEE calculation

Indicators	Current value (%)
Availability	82.01
Performance	85.42
Quality	98.50
OEE	69.00

There are many pillars on which TPM rests, but in this case, it was proposed to implement the planned maintenance pillar in the five knitting machines of the company, which is made up of a series of actions to be carried out (see Figure 6).

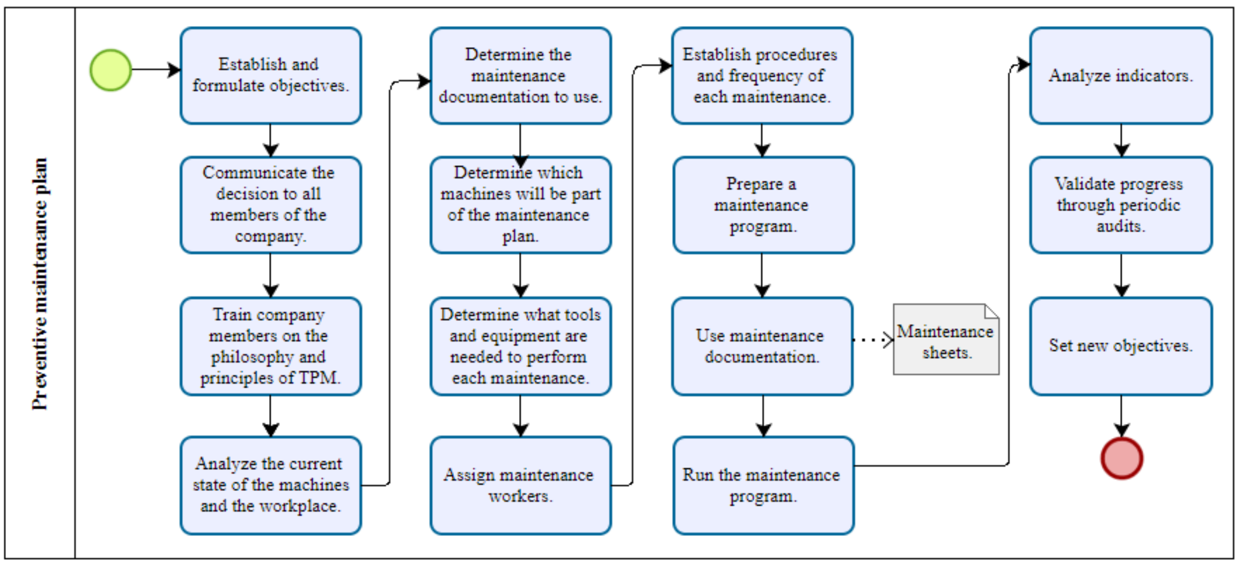

Figure 6. Proposed preventive maintenance plan flow chart

Application of Single-Minute Exchange of Die (SMED)

Shingo (1993) was a Japanese industrial engineer who indicated that SMED tool is based on four stages:

- Understand the changeover process: The company members must analyze and understand in detail all the activities that are performed during the changeover process.
- Separate internal activities from external: The activities of the setup process are classified as internal or external. Internal activities can only be done when the process is stopped, whereas external activities can be done when the process is still running.
- Convert internal activities to external: In this stage, the company members define the action plan to turn each of the previously selected internal activities into external ones to eliminate or reduce the non-value-added time.
- Improve internal and external activities: Improvement ideas are proposed to reduce the execution time of activities. For example, setup time can be reduced by eliminating unnecessary movements or carrying out activities simultaneously.

Therefore, as part of the methodology that comprises the SMED tool, first a list of the internal activities that are part of critical processes such as knitting and looping was made, considering the production of a batch of 100 dozen baby socks, then the internal activities that could be optimized or that could become external activities were identified to reduce setup time (see Table 5 and Table 6).

Table 5. Proposal in the knitting process

No.	Internal activities	Proposal	Setup time before changes (min)	Setup time after changes (min)
1	Clean and organize the workplace.	Convert internal activity to external.	6.10	0.00
2	Check needles.	-	21.60	21.60
3	Move yarn cones to manufacturing area.	Convert internal activity to external.	13.80	0.00
4	Load each knitting machine with yarn cones.	-	21.50	21.50
5	Turn on the motor.	-	2.62	2.62
6	Turn on the knitting machines.	-	3.33	3.33
7	Move goods in process to finishing area.	Optimize internal activity.	30.12	15.06
		Total	99.07	64.11

Table 6. Proposal in the looping process

No.	Internal activities	Proposal	Setup time before changes (min)	Setup time after changes (min)
1	Move yarn cones to manufacturing area.	Convert internal activity to external.	2.50	0.00
2	Load the looping machine with yarn cones.	-	3.80	3.80
3	Turn on the looping machine.	-	0.32	0.32
4	Move socks to the finishing area.	-	5.20	5.20
5	Empty the basket that contains waste.	Convert internal activity to external.	4.95	0.00
		Total	16.77	9.32

It was proposed that internal activities such as organizing and cleaning the workplace or moving yarn cones be carried out while the machine is in operation; that is, they can become external activities, which results in the time of these activities being reduced to zero. Likewise, if internal activities cannot be converted into external activities, the duration of these activities can be optimized if a worker moves several batches of products to the finishing area at the same time. Another way to reduce setup time is by improving the location and identification of tools and items (Ahmad and Soberi 2017).

Currently, the total setup time during the knitting and looping process is 115.84 minutes. However, if the quantity and duration of the identified internal activities are reduced, it is expected to obtain a total setup time of 73.43 minutes.

5. Results and Discussion

5.1 Numerical Results

Taking as reference success cases obtained through the literature review, the company is expected to reduce its production cycle time for a batch of 100 dozen socks from 1,829.53 minutes to 1,729.77 minutes if it applies TPM and SMED tools, so monthly production is expected to increase from 1,134 dozen socks to 1,200 dozen socks and productivity to increase from 1.82 dozen/man-hours to 1.92 dozen/man-hours. These results are explained by the expected improvement of OEE by 13.88% and the expected reduction of setup time by 36.61% (see Table 7).

Table 7. Results of the initial situation vs. expected situation

Indicators	Initial situation	Expected situation	Variation (%)
Availability (%)	82.01	89.82	7.81
Performance (%)	85.42	93.18	7.76
Quality (%)	98.50	99.03	0.53
OEE (%)	69.00	82.88	13.88
Setup time (min)	115.84	73.43	-36.61
Production cycle time (min)	1,829.53	1,729.77	-5.45
Monthly production (dozen)	1,134	1,200	5.82
Productivity (dozen/man-hours)	1.82	1.92	5.49

The application of the TPM tool would allow the company to improve the availability, performance, and quality indicators of its knitting machines, resulting in an improvement in their average OEE score. To do this, the previously mentioned proposal must be carried out (see Figure 6), which involves improving the knowledge and skills of workers through adequate training on the TPM methodology and putting into practice the preventive maintenance pillar. Furthermore, the application of the SMED tool would allow the company to reduce the setup time of critical processes such as knitting and looping because it was mainly proposed to convert internal activities into external activities.

5.2 Graphical Results

The production process of a batch of 100 dozen baby socks was simulated through the Arena software, considering the new indicators obtained by applying the improvement proposal. As a result, the production cycle time was 1,729.77 minutes (see Figure 7).

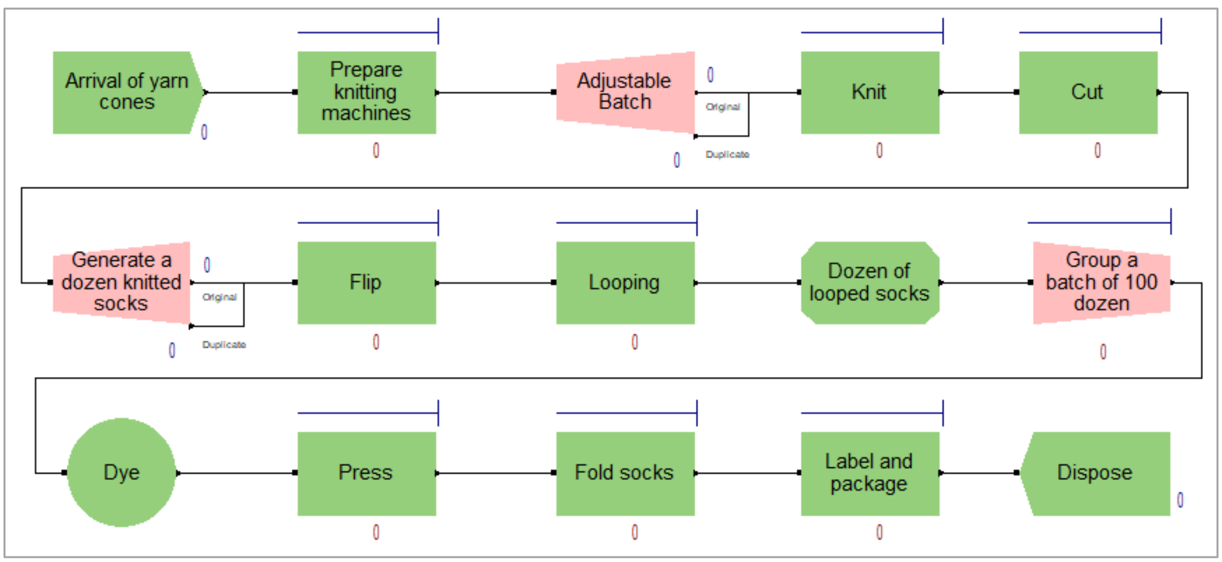

Figure 7. Model in Arena simulation software

5.3 Proposed Improvements

The three previously mentioned phases were developed. In Phase 1, company data was collected to understand its sock production process, and it was identified that the company currently has a high production cycle time due to machine stops and a high setup time. In Phase 2, through the review of the literature, a model was designed that proposes the application of lean manufacturing tools such as TPM and SMED with the objective of improving the OEE and reducing the setup time. In Phase 3, the proposal was simulated in the Arena software, and a production cycle time of 1,729.77 minutes was finally obtained. By reducing the production cycle time, the company is expected to increase its monthly production, going from producing 1,134 dozen to 1,200 dozen socks, and increase its productivity by 5.41%.

5.4 Validation
By validating the proposed model through simulation in the Arena software, the company is expected to reduce its production cycle time by 99.76 minutes, or 1.50 hours, due to the expected improvement in OEE by 13.88%, which means that the knitting machines would go from having a regular score of 69% to having an acceptable score of 82.88%. This result is related to other success cases, such as the case of a MSE in the textile and clothing sector in Peru, which, by implementing the TPM tool, increased its OEE by 16.17% and production efficiency by 5.12% (Quispe et al. 2020). The same situation happened in a company dedicated to the manufacturing of clothing, which increased its OEE from 56% to 84% (Mejia and Rau 2019).

This reduction in production cycle time is also due to the expected reduction in setup time by 36.61%, going from 115.84 minutes to 73.43 minutes. This result obtained is related to the literature review, as is the case of a company in the Asian textile sector that, by implementing SMED, reduced the setup time of its machines by 18% (Bukhsh et al. 2021). Another company in the sector that implemented the SMED tool reduced the setup time by 52% (Campoblanco et al. 2022).

It should be noted that some potential constraints or challenges could be evident during the proposed improvement process, such as the lack of prior knowledge of the company's workers regarding the lean manufacturing methodology and resistance to change in the organization because workers will have to put into practice new standardized procedures when applying lean manufacturing tools.

6. Conclusions
It was identified that the main causes of the problem related to the high production cycle time in the company are machine downtime and high setup time. Therefore, successful cases obtained through the literature review were taken as references, and a model was designed that proposed that the company apply TPM and SMED. As result, the company is expected to reduce its production cycle time by 5.45% and finally increase its monthly production by 5.82% and its productivity by 5.49%. These indicators were obtained due to the expected improvement in OEE by 13.88% and the reduction in setup time by 36.61%, so the objectives set at the beginning were achieved.

Likewise, there is little research that proposes a model to reduce production cycle time in MSEs, so this case study can guide MSEs from different sectors, mainly those that belong to the textile and clothing sector, on the inclusion of lean manufacturing tools as an opportunity for continuous improvement. Additionally, the validation of the improvement proposal through simulation in the Arena software makes it possible to analyze the company's current and future production processes and predict scenarios, so it can serve as a theoretical basis for future academic research.

Finally, for future research, it is suggested to extend the analysis in larger companies that belong to other industries. It is also recommended to carry out a pilot study to validate the results obtained through a literature review and the simulation and expand the scope of the research by focusing on other processes that are part of the supply chain management that will allow finding new opportunities for improvement in companies.

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Biographies

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