Improvement of Productivity in the Circular Knitting Area, using Lean Methodologies in SMEs of the Textile Sector

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Abstract

In recent years, manufacturing SMEs have been of great importance for the Peruvian economy, representing 29.60% of the national GDP; however, a high percentage of these companies report various problems in their processes, since they do not have adequate management to carry out their activities. In relation to the above, an example of this is the unproductive times generated by unplanned stops that impact the productivity levels of a textile company based in southern Lima, so this research was implemented lean manufacturing tools such as 5S and SMED, with which it was possible to increase the ratio by 18.06%, also, the arena software was used in the process to simulate scenarios with the reduction of unproductive times structured through the proposed improvement of the Deming Cycle (PDCA).

Keywords
5S, SMED, Lean Manufacturing, Productivity, Textile, SMEs

1. Introduction

Small and medium-sized companies are considered the engines of the economy of Latin America and the country (Cañari 2019). These have the capacity to increase and promote both the economy and the sustainable development of a country (Gonzáles 2021). They are an important sector of the country's economy, since they represent a significant share of the gross domestic product and contribute to the increase in labor productivity; Likewise, it contributes to international trade and is a source of creation of various jobs (Larios 2017). The growth and relevance of the textile sector is reflected in the textile-clothing sector because exports have increased compared to pre-pandemic times, it can be assumed currently that this industry is one of the most important markets in different countries because of high Consumption (Palpán et al., 2020), having a value of USD 848 million between January-July 2021; this reflects a growth of 3.9% compared to the same period of time in 2019. But one of the reasons that generates low competitiveness in the market for SMEs such as those in the textile sector is inadequate management, lack of control and order of their processes, which leads to an unprofessional act, since they orient their goals to growth, but not to their methods. The lack of knowledge of the use of Lean and business management tools generates lower efficiency, productivity and the aforementioned lines of competitiveness in the market.

Before the pandemic, SMEs represented 99.6% of companies in Peru, where they accounted for 29.7% of GDP and approximately 59% of the workforce. These faced the measures taken by the executive to deal with the health crisis, presenting losses in their majority, reason for the exit of the market of almost three million companies in 2020 (Gonzáles 2021); however, in 2021 the textile sector represented 30.6% of the country's income (Carhuavilca et al., 2021). Currently, the competitiveness of manufacturing companies is increasing, their leaders are required to verify the best performance of both production processes and equipment maintenance and time measurement, in order to improve their competitive advantage (Sayuti et al, 2019). This is reflected, for example, in the investigation of a textile company in Juliaca-Puno, where when evaluating the times in the production process, 407.5 minutes of waste were found. This caused the daily production to be thirty-three divers, but by applying Lean Manufacturing techniques such as the 5s, an improvement of 12% was achieved, reaching thirty-seven divers per day (Luque and Rojas 2021). Likewise, the results of an investigation in a manufacturing company where Lean principles and tools were applied to improve productivity, by reducing unproductive time and waste, the added value of effective time increases for the entire process, this makes production redesigned. more useful and efficient (Punna et al. 2020).

In this context, Peruvian textile SMEs must seek efficiency in the use of their production times; given that, it was found that the main problem is the unproductive time generated by non-standardized stop times for correction in the area of circular knitting, Set Up and maintenance. In this sense, to solve this problem, a plan based on the use of lean manufacturing tools such as the 5s and SMED will be implemented.

This article will be divided into six parts, which are Introduction, Literature Review, Methods, Data Collection, Results and Discussion and Conclusions.

1.1 Objectives

- Reduce unproductive and excessive times in the Circular Knitting area, increasing the productivity ratio in SMEs textile.
- Increased productivity of the company using lean tools like 5S and SMED.
- Reduce the time of the weaving process through lean manufacturing methodologies.
- Increased utilization and performance of the circular knitting machine.

2. Literature Review

2.1. Lean Manufacturing

Philosophy based on change and continuous improvement, which seeks to produce more with fewer resources, eliminating waste (Luque and Rojas 2021); where it seeks to identify points without value in the production process to try to eliminate them and be able to increase productivity and, therefore, profits for the company (Palange and Dhatrak 2020). Therefore, one of its key principles is to generate products that have almost zero or zero waste values through continuous improvement (Anamalai et al. 2020).

The application of Lean Manufacturing has had favorable results for the organizations that have implemented it by improving efficiency, productivity, and quality. Where in the textile sector it can face problems such as overproduction, reprocessing, movements, unnecessary transport, and defective products (Sosa et al. 2020), to these are added the high inventory, waiting times and waste of human talent that also they are waste for Lean Manufacturing (Palange and Dhatrak 2020). All the waste that has been mentioned, if found in textile production, is considered one of the main factors for not reaching production goals, as happens in SMEs. (Cortez et al. 2020).

2.2. 5S in manufacturing companies

Excellent Japanese philosophy that is optimal and necessary for any type of organization in the world (Carvallo et al. 2019), considered a great industrial technique that makes the difference in market competitiveness between one company and another (Shahriar et al. 2021). For any organization that wants to be recognized as a responsible producer with proper management, this tool should be the starting point (Veres et al. 2018); therefore, in an SME it is the first tool that must be used to be able to conduct a total implementation of the management (Ruiz et al. 2019). The steps to implement the 5s are:

Seiri: Classifying is the first step, where what would really be useful to us is separated from what is not, the latter are discarded as they are no longer a contribution, but a waste of space.
Seiton: Order the elements that are useful to us must be ordered according to their relevance of functions; To do this, you can make use of a circle of frequency of use and determine the ideal location in the workplace.
Seiso: Clean is the stage where you completely remove clutter, the goal of which is to remove the root causes of debris, dirt, and damage, as well as cleaning the workstation itself.
Seiketsu: Standardize procedures and rules, to maintain continuity in all areas, the use of each element of the workplace must be detailed in its functions and that anyone can easily understand or obtain its information.
Shitsuke: Continue and maintain discipline in each of the steps given above, so you do not lose focus.

These mentioned steps help us create and maintain a more efficient and productive workplace (Agrahari et al. 2015).

2.3. SMED methodology in the textile sector

SMED is a tool used in Lean Methodology, which was created in Japan by Shigeo Shingo (S. Shingo, 1985). The focus is on reducing the time required for modification and operation, i.e., setup, this includes the time required to make all necessary machine setups until the next unit is produced to the requested specifications. This tool focuses on the process of efficiency and cost reduction that a company needs in a competitive environment (Sahin and Kologlu 2021). Every company knows that in order to be competitive in the market it needs change, in order for them to achieve better results, some of the basic principles, methodologies and tools must be adopted (Monteiro et al. 2019).

2.4. Models to increase productivity in the textile sector

Industry 4.0 models focus on innovative technologies and are used in big companies, leaving SMEs on the way where there are many reasons for this slowdown, but the costs and human impacts can be listed. Solving the problems of SMEs and finding the levers to increase their performance requires the combination of existing methodologies and tools (Laouenana et al. 2022). Understanding of the relationship between TPM and manufacturing performance in low-tech, labor-intensive manufacturing industries, such as textiles, has been limited (Wickramasinghe and Perera 2016), so the development of these will have an impact positive in the global sector of the textile industry. The application of the TPM is a production element that leads to greater organizational performance (Wickramasinghe and A. Perera 2016), it is aimed at creating a corporate system that maximizes the efficiency of the entire production system, establishing a system that prevents losses in all company operations, that is, "zero accidents, zero defects and zero failures" throughout the life cycle of the production system (Vásquez et al. 2022).

3. Methods

The method is based on the collection and study of scientific articles related to our case study as shown in **Table 1**, to take these proposals as references and be able to make our contribution.

Table 1. Comparison table of the Proposal Components vs State of Art

Scientific Articles	Lean Manufacturing Tools	
	5S	SMED
Ruiz, S., Simon, A., Sotelo,F. & Raymundo, C. (2019)	Unnecessary moves reduced to 16%	
Agrahari, S., Dangle, P. & Chandratre, K. (2015)	Increase storage place with 30%	
Shahriar, M., Parvez, M., Islam, M. & Talapatra, S. (2022)	18% reduction in block searching time for the printing operation.	
Veres, C., Marian, L., Moica, S. & Al-Akel, K. (2017)	Implementing 5S method in the company leads to improved performances.	
Bukhsh, M., Khan, M., Zaidi, I., Rabail, Y., Khalid, A., Razzaque, A., & Mazhar, A. (2021)		The changeover time was reduced in 25 minutes.
Monteiro, C., Ferreira, L., Fernandes, N., Sá, J., Ribeiro, M., & Silva, F. (2019)		Setup time has been reduced around 40%
Karam, A., Liviu, M., Cristina, V., & Radu, H. (2017)		30% reduction of bottleneck time.
Sahin, R., & Kologlu, A. (2022)		Setup times have been reduced more than 45%.

3.1 Proposed Model

The model proposed for the research is based on the use of Lean Manufacturing tools as 5S and SMED, distributed in the Deming cycle (PDCA), show a in **Figure 1**, as an alternative solution to the main problem, which is the high unproductive times as a consequence of non-standardized periods due to production stoppage. correction, set up and maintenance, in response to the problem indicators were analyzed with data collected from the production process. In the implementation of the proposal, an improvement scenario was introduced that, with the current model, is simulated using the arena software to compare the key indicators.

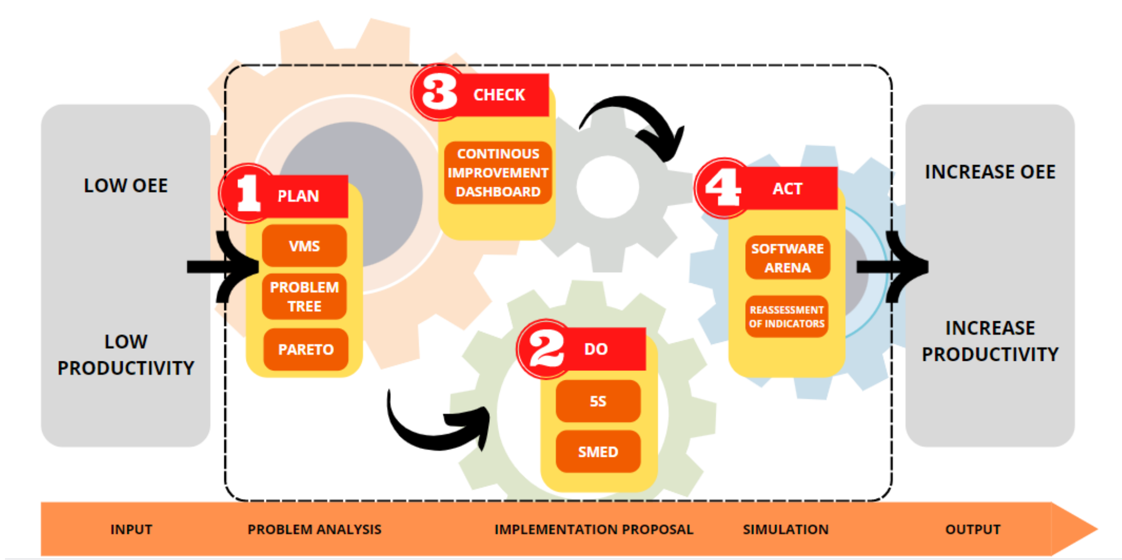


Figure 1. Proposed Model

As noted above, the stages of the model are organized according to the Deming cycle (PDCA) of proposed distribution.

3.1.1 Phase 1: PLAN

In this first phase, the analysis of the problems that develops in the circular knitting area is reflected through the Value Stream Mapping diagram to define the control of the process, with these graphs it is possible to identify the production times, whether productive or unproductive in the process, so you can define the KPIs, show in table 2, that will be used to measure the contribution.

3.1.2 Phase 2: DO

In this second phase of the proposal, the 5s tool will be used because, resulting from the data collected from the production process, incidents with inadequate process management can be observed in a greater proportion, these mostly caused by lack of methodology to carry out activities and lack of established order in the area, likewise, SMED will be applied as a tool to improve unproductive times, this will focus on reducing stoppages due to set up, positively impacting the process, making it more efficient.

3.1.3 Phase 3: CHECK

In the third phase, the indicators of the updated process will be verified versus the initial state, discarding the activities that do not add value and an optimal process control management is proposed to improve the level of productivity and competitiveness of the circular knitting area**.**

3.1.4 Phase 4: ACT

In this last phase, the impact of the proposal will be analyzed, the effect obtained in the arena software will be compared in order to have conclusions for the case, in addition, these actions will be controlled with controlled evaluations in order to maintain the improvements made.

To measure the effectiveness of the proposed model, the model indicators are shown in **Table 2**.

Table 2. Parametric indicators

Parametric Indicators	Algorithm
Machine availability	$\frac{effective\ time}{available\ time}$
Machine performance	$\frac{current\ production}{ideal\ production}$
Overall Equipment Effectiveness	$availability \times performance \times quality$
Productivity	$\frac{Total\ production}{time\ used}$

4. Data Collection

The entire model is based on the study of an SMEs in the textile sector located in the district of Villa el Salvador, south of Lima. The circular knitting area was chosen because it is the center of the entire process, where some downtime problems were observed, leading to a decrease in the OEE indicator, which is currently well below average.

For this study, it was analyzed in the first quarter of 2022, initially finding an OEE (Overall equipment effectiveness) of 36%, due to the low availability and performance of the machine, which causes a loss of 231, 328.08 PEN per year.

For the proposed simulation model, it was first necessary to define the input entity to the system (thread cone boxes) to then define the system that goes from the reception of the necessary cones to the packaging of the rolls of fabric for the customer. Then the input variables were defined using the Input Analyzer, where all the measured times were placed so that it gives us an expression of distribution in time for each simulation activity, in addition to its failures. With this build the Arena model.

Throughout the simulation entities such as yarn cone boxes, yarn cone and fabric roll were used; as well as the weight attribute and to be able to obtain the data for the relevant indicators.

Subsequently, table 4 shows for the comparison of the final data, the confidence interval had to be determined first using the Minitab tool, which was 95%. With this, the optimal number of interactions or replications (**n**) of the simulation was calculated, resulting in 312 replications, as shown in table 3. $n = n_0(\frac{h_0}{h})^2$

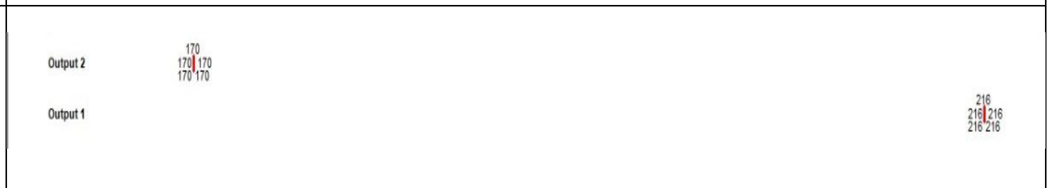
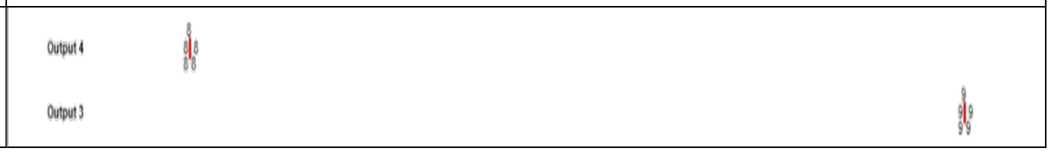
Table 3 shows the calculation of the number of replicates for the simulation of the proposed model:

Table 3. Calculation of number of replicates

Parametric Indicators	n	Initial number of replicates (n0)	Initial amplitude (h0)	Desired amplitude (h)
Machine availability	312	30	14.52	4.5
Machine performance	312	30	14.52	4.5

Table 4 shows the confidence intervals of the simulation, comparing the current situation vs. the improved situation:

Table 4. Confidence intervals

Parametric Indicators	**■Current** **■Improved**
Machine availability	
Machine performance	

5. Results and Discussion

5.1 Numerical Results

In this chapter, the results are presented quantitatively. After running the Arena software, in both simulations, the data collected from the production process of the circular area were used. Still, with a variation of their time in a range of ±2% to ±5%, to obtain scenarios that no do differ significantly concerning what is to be measured, the improvements can be seen in **Table 5.** Consequently, when working with historical data of the processes, it is ensured that the system, concerning its scenarios, has the same material contribution. As for the indicators, there is no overlap between them; that is, there is a significant difference between the improved model over the current one.

Table 5. Parametric indicators

Parametric Indicators	**Current**	**Improved**
Machine availability	62.5%	84.17%
Machine performance	57.69%	80.77%
Overall Equipment Effectiveness	36.06%	66.62%
Productivity	66.11%	84.17%

5.2 Graphical Results

In this part, the line of both models is shown in order to visually demonstrate the contribution of the lean manufacturing tools applied in this case. The F**igure 2** show simulate the process in the circular knitting area; however, since the main changes and improvements are internal, the structure of the model is not affected, as shown in F**igure 3**. It should be noted that the route that adds value to the product is analyzed in the models.

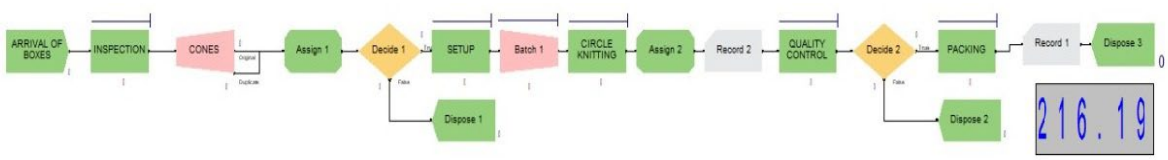


Figure 2. Initial Model in Arena software

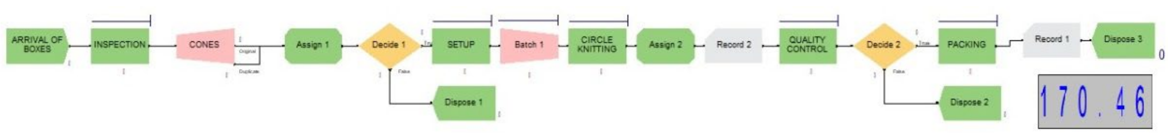


Figure 3. Improved Model in Arena software

Likewise, analyzing the operations of the machine and the personnel in charge of the processes, data was collected to obtain the history of the main process and identify unplanned delays, then the activities of the mechanic were divided into internal and external, latter being the most important. Since it has an added value in terms of the time of the activities of the productive chain, following this line, it is about converting internal activities into external ones, managing to reduce unproductive or unplanned times.

On the other hand, and as part of the improvement of the studied process, an internal analysis was carried out to define the best method in the production workshop, as shown in F**igure 4**, said analysis showed a high level of disorganization in the work area, since there was no the implementation of an adequate technique to manage their activities, that is why through the lean tool: 5s, a better distribution and order of the work materials that intervene in the weaving process was proposed, obtaining high benefits in the knitting area.

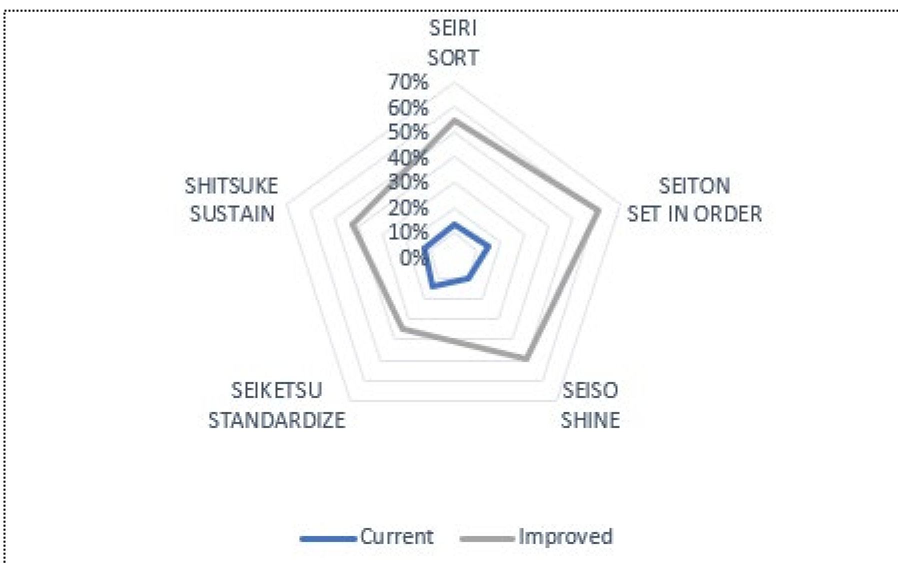


Figure 4. 5S Audit

5.3 Proposed Improvements

For the validation of the model, the stages developed for the present case were considered, as the beginning of this, historical data were collected to be able to understand the operation of the process in order to find points of improvement and use of resources is how after the analysis the high time of unproductiveness of the process in the circular area was determined, with the information collected and the use of complementary tools it was determined that the process with the lowest productivity was the weaving process, in this way this operation was achieved selected for an improvement implementation based on a proposal, expressed graphically and quantitatively. Followed stage, with the support of antecedents such as scientific articles oriented to the topic to be developed, information was collected that was reflected in the choice of tools to be used. Then, in order to have a more precise control, indicators were chosen to determine quantitatively and with greater precision the impact for an improvement scenario, implementing them in a simulation through the arena software to contrast the current scenario and the proposed scenario. For this case, the use of lean methodologies was proposed, such as: 5S and SMED, which allow increasing productivity in the processes, based on an optimal distribution of the instruments that intervene in the process, as well as an adequate order to avoid reduce times productive; As a complement, the SMED technique was developed, this allows taking advantage of time resources, converting internal tasks into external ones, the latter being defined as operations that are carried out with the machine running.

5.4 Validation

The problem of this work focuses on the high unproductive times that affect the productivity of the company. These unproductive times are reflected in the low availability rates of the machine and its performance. With current values of 62.5% and 57.69%, respectively, which are values below the world average of 90% and 95% respectively. This problem generates a loss of 231,328.08 PEN per year.

The values of the indicators in table 5 have achieved a significant improvement, due to the Lean Manufacturing tools used. Where the 5s and SMED helped increase availability by 21.67% and performance by 23.08%. Whereby applying the work of the 5s with the standardization and SMED with the reduction of the Setup times, said improvement in the indicators was achieved.

The limitations of space within the company still do not allow these indicators to be increased to a greater extent, since they are under construction in some areas. What is expected with the implementation of these is to increase the indicators up to at least 90% in both, therefore, increase productivity.

6. Conclusion

In the present case, the main problem was the high level of unplanned downtime that resulted in high costs of using the machinery due to inefficient use for production, the importance of this study as the use of an adequate alternative through of lean manufacturing tools allowed a correct reduction of unwanted times, likewise, a greater use and performance of the machinery involved in the process was increased, because by implementing techniques such as the 5s that allows an optimal order and distribution of everything involved in the activity followed by the SMED technique that takes advantage of the time of the machinery in operation so that tasks that add value to the process can be developed by the operator, this development allowed the fulfillment of the objective.

The proposed methodology of Lean Manufacturing tools such as 5s and SMED incorporated in the Deming cycle (PDCA), helped reduce downtime, it has been shown that Lean Manufacturing tools are very useful in companies and as mentioned above, it is even more vital that SMEs can implement them, as it will help them grow in a more orderly and professional manner.

Increasing productivity is what every company seeks, and with the implementation of Lean Manufacturing tools in the present company under study, it was possible to increase 18.06%, taking as a valuable resource to use, the time used in production. This increase is thanks to the implemented lean manufacturing tools.

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