

Integrated Lean and TPM Model to Increase the Level of Service in a Plastics Company in Peru.

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Abstract

In recent years, plastic has been part of the value chain of many different products, becoming a final consumer good. The enormous value of the plastics industry is beneficial for those who are part of the chain, reflected in the enormous figure of 1 trillion dollars a year, that is, 5% of the total trade of goods worldwide. This research is oriented to examine 3 tools to achieve a new model to optimize and improve the level of service, due to late delivery times and poor quality identified as the main problems within the company studied. The proposed model uses tools such as: Improvement of mold change time through the SMED Engineering tool, improvement of the organization and production tools through the 5S Engineering tool and improvement of operational efficiency under a Total Productive Maintenance approach obtaining an improvement for the company. Achieving an integrated model to improve the level of service that is suitable to be replicated in manufacturing companies.

Keywords

Lean, TPM, service level, SMED, engineering

1. Introduction

The plastics industry has an important effect on the world economy: an average consumer uses different items made of plastic daily, either for personal consumption or in productive activities such as construction, communications, transportation, storage. The versatility of plastic provides its rapid integration to any productive process or final product, which is the reason why the plastic industry currently holds an outstanding place in world economies (Góngora 2014) Within the Latin American context, demand greatly exceeds the industry's supply, which is why maximizing production ensures the sector's sales. Latin America accounts for 4.4% of world production, being the region with the highest production above the Independent States. In Peru, production also shows an annual growth of 3.2%, which makes it the fifth most innovative activity in the country; more than one million tons of plastic raw materials are imported annually. (SIN 2019). In addition to the above, the sector obtained a percentage growth of 31.5% of registered companies, with a predominance of small and medium-sized companies that represent 73% of the total number of companies, being these companies the ones that contribute the most value in the chain (Schrewe 1981). According to the literature research on plastic companies in Peru, one of the main problems in this sector is the high percentage of waste, which has an economic impact on the companies in this industry. Most of this is due entirely to the lack of management methods, practices and procedures or a standardization plan.

These problems have also been identified in several case studies. For example, an investigation conducted in a Peruvian company in the plastics sector identified the problem of machine failure with a 56.15% impact, due to inadequate calibration parameters and inadequate use of personnel (Flores et al. 2020) Another case study conducted in a Peruvian manufacturing company detected problems of low productivity, quality, and machine downtime (Raymundo 2020). On the other hand, the case of Productivity Latin America was identified, a company in the plastics

industry that had the problem of non-fulfillment of orders, having as the main reason for the cause of the problem the high unproductive times of the machines. This problem directly generated the availability, performance, and quality of the product (Ames 2019). The above shows that the search for new engineering solutions to this problem should continue.

In this context, it is essential for companies in the plastics sector to be able to take full advantage of the high demand in the sector. For this purpose, a case study was chosen to reflect the problem of high waste in the process. The problems presented were related to late delivery times, poor product quality and unfulfilled finished product quantities, the root cause being the low level of service (74.6%).

In this sense, to solve the problems described above, an integrated system was developed in which the Lean tools (SMED, 5S) and TPM will be applied. With these tools, SMED will be used to reduce the mold change time used in most of the plastic companies, then the 5S tool will be applied to workstation problems in order to improve the process flow. Finally, with TPM a reliable maintenance system will be established for the companies in the sector, and in this way the reliability of the process could be increased. This model was developed based on successful cases of similar problems. It seeks to solve the problems of the sector and contribute to the community of scientists. The present research offers an integrated model to increase the level of service in a company of the plastic sector.

The scientific journals studied present scarce information about the plastics sector, on the problem of the low level of service, especially in Peru. For this reason, the need arises to investigate and offer this research to the sector. The scientific article presented below is divided into seven parts: Introduction, Objectives, Literature Review, Methodology, Data Collection, Results and Discussion, Validation and Conclusion.

1.1 Objectives

Develop a model based on Lean tools to conduct the proposed implementation and through the indicators measure the results achieved and demonstrate through simulation that there were improvements.

To increase the level of service by 30% in a company in the plastics sector by reducing delivery delays and mold change time using the methodology based on the collection of scientific articles as the quantitative basis of the research.

Reduce unproductive time in the operations area by means of the chosen tools.

Reduce operation time using the SMED tool.

2. Literature Review

Single Minute Exchange of Die

Within the plastics manufacturing industry, a recurring problem was identified that generates time without value for the companies. Among them are excessive setup time and production line changeover operations that generate delays in the total setup time. (Poves et al. 2019). According to other authors, station setup time is recurrently employed due to those companies seek to differentiate themselves from other competitors by producing small batches. (Sahin and Kologlu 2022) (Amrina et al. 2018) Most agree that 3 simplified steps should be implemented: verification, function checks and improved process management. (Karasu and Salum 2018) The benefit of time reduction in mold changeover is to reduce the total time in hours to only minutes.

5 S in manufacturing companies in the plastics sector

This visual management tool is used in several successful companies. Its main objective is to optimize the work environment in a way that facilitates and enhances the work of employees. In one of the articles Amrina and Prasetyo (2018) used this tool and obtained results such as the reduction of setup time by 35% and an increase in productivity by 3%. (Amrina et al. 2018) On the other hand, Himanshu and Ganvir (2018) by applying this method managed to reduce the delivery time by 4-5%; the cycle time was reduced by 3-4% and the dispatch area was optimized in a satisfactory way. (Himanshu et al. 2018). The results of applying the methodology in another plastics company was the increase in efficiency from 67% to 88.8% in just one week (Shahriar et al. 2022).

Total Productive Maintenance

TPM promotes and implements team activities at all levels within the organization, with the same goal of zero defects and zero breakdowns. (Agustiady Cudney 2018) According to another author with this methodology it has been possible to increase performance, as well as improve certain efficiency problems (Ahuja and Khamba, 2008). On the

other hand, it was observed that the application of this tool brings substantial improvements to the processes with results not only immediately, but also ensuring long-term maintenance through the development of a culture and continuous improvement (Ames et al. 2019). This premise is supported by an application case where a 40% reduction in the number of failures is observed, as well as an increase in machinery availability by 6.45% (Ruiz and Munive 2020).

Kanban Methodology

According to a study conducted in Peru to achieve the right balance between storage costs and transportation costs, the optimal number of transportation outlets was found. All this, to minimize the total cost of the manufacturing company, in which Kanban was used, obtaining as a result a decrease in the total cost by 10% (Flores et al. 2020). For the case presented by the authors Guillen and Raymundo (2018), improvements were observed such as the reduction of reprocessed products by 3%, as well as the increase in delivery compliance that varied from 58% to 95%. (Guillen et al. 2018).

3. Methods

The proposal that creates the exposed research was conducted after a review of the tools in the state of the art. The comparative matrix of the components vs. state of the art is presented in which the tools that will be used in the present work are presented.

Table 1. Comparative matrix of the components of the proposals vs. the state of the art

Scientific articles	Lean manufacturing tools			
	5S	KANBAN	SMED	TPM
Ames, V., Vasquez, W., Macassi, I., & Raymundo, C. (2019).			Reduction of the preparation operation time from 70 6 minutes to 38.3 minutes.	The distribution of internal time decreased from 75% to 60%, while external time increased from 25% to 40%.
Guillen, K., Umasi, K., Quispe, G., & Raymundo, C. (2018).	Reduced defective products from 18% to 10%.			
Dieste, M., Panizzolo, R., & Garza-Reyes, J. A. (2019).				2 of the 5 companies where TPM techniques were applied improved substantially.
Flores, G., Valenzuela, R., Viacava, G., & del Carpio, C. (2020).	Waste decreased by 7.78%.	Overproduction decreased by 2.4%.		

3.1 Proposed Model

The model is based on the application of Lean techniques such as 5S, Kanban, SMED, TPM, as shown in Figure 1. The main problem, the low level of service, is addressed through data analysis and evaluation of the causes. In the deployment of the improved model, together with the current model, the most important KPIs will be evaluated and subjected to a simulation in arena software to compare the indicators with the proposed objectives.

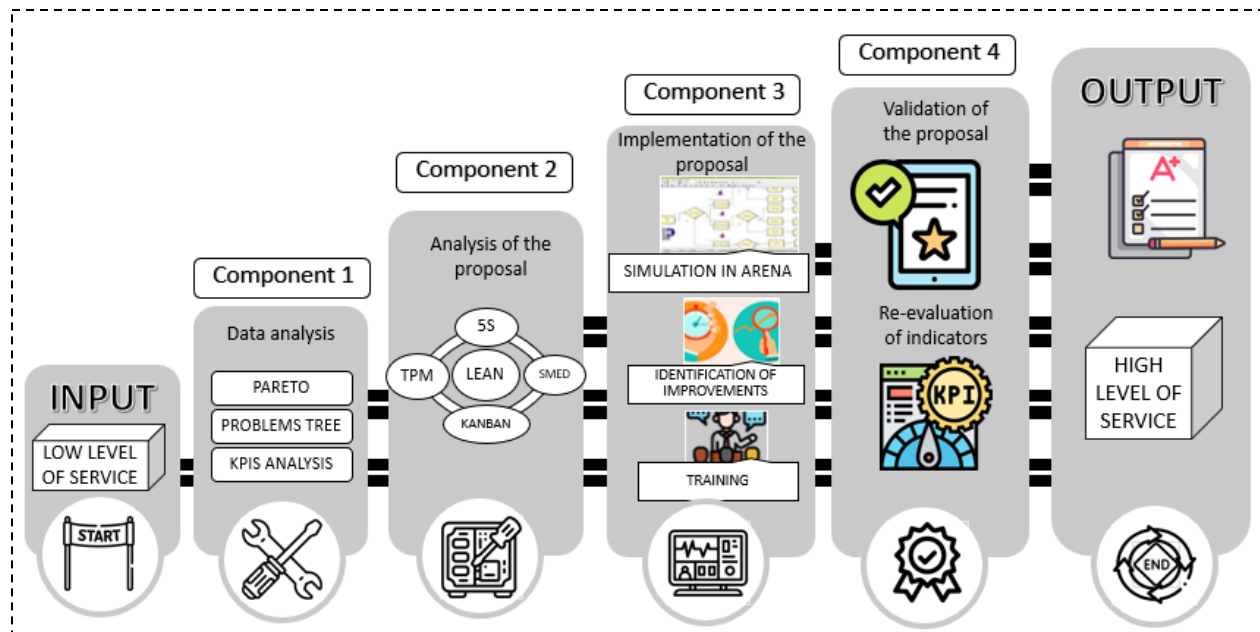


Figure 1. Proposed Model

The model to be proposed is based on three components, which will be detailed below:

1.1.1 Component 1: Data Analysis

In this phase, the information was compiled, and Pareto diagrams were drawn up to identify which of the causes had the highest frequency. Finally, with the above information, a problem tree was drawn up showing the technical gap in the level of service, the economic impact, the frequency percentages, the reasons, and the causes. With this, each of them was analyzed and certain tools were proposed to solve them.

1.1.2 Component 2: Proposal analysis

This phase is based on the analysis of the most appropriate techniques to solve the problems. The tools that were chosen were 5S, TPM, KANBAN, SMED. It is important to mention that the times will be planned using Gantt charts to evaluate the main indicator (Service Level) and thus take corrective actions.

1.1.3 Component 3: Implementation of the proposal

With the help of the 5S tool, we seek to attack the causes of disorder in the tooling area and the lack of availability of finished product at the time of the order deadline. In the case of the SMED tool, the aim is to reduce the high unproductive times. The TPM tool is used to reduce high unproductive times and poorly calibrated machines. The main process was simulated by means of the arena software and the improvements were demonstrated by means of the KPIS.

1.1.4 Component 4: Proposal validation

By means of the evaluation of the indicators and the improvements within the simulation, the initial operation was evaluated with the current problems, and the final operation improved with the tools described above. Six indicators were proposed, and the results of the simulation are with the orders, and lots entered in the company.

Table 2. Indicators and their algorithm

Indicators	Algorithm
Thousands of nonconforming bottles T1	$\frac{\text{Millares con defectuosos}}{\text{Millares totales}}$
Cycle time of an order T1	Total order preparation time
Non-productive time T1 (%)	$\frac{\text{Tiempo de cambio en la maquina}}{\text{Tiempo de producción}}$
Rejected Orders Q1 (%)	$\frac{\text{Pedido rechazados}}{\text{Total de pedidos}}$
Service level (%)	$\frac{\text{Pedidos entregados a tiempo}}{\text{Total de pedidos}}$

4. Data Collection

To obtain the data, it is important to point out that they were obtained from a bottling company that produces PET bottles of varied sizes. In which, by means of qualitative observation, the times of each critical process within the company were collected. From the entry of PET test tubes to the exit of packaged goods. The critical processes were the change of mold and the packaging of orders.

Data was collected for 57 days for the 3 activities included in the main bottle production operation. The summarized data will be presented in the following table and were collected over 6 months.

Table 3. Comparative matrix

	Activities in minutes		
	Quality control	Blowing	Heated
Prom	44.6	33.5	40.1
Max	47.7	36.7	43.5
Min	41.0	30.5	36.4

With the help of the arena program, the collected times were entered in the Input Data tab to predict the corresponding distribution depending on each activity. These are then used in the application of the production cycle.

On the other hand, the total data of mold change between the machines within the selected plant was collected. There is a maximum maintenance time of 70 minutes and a minimum of 60 minutes that were observed during the observation days.

5. Results and Discussion

5.1 Numerical Results

The SMED tool was used to analyze the mold change operation, which, by applying the technique of order of external and internal activities, was able to eliminate and reduce the time of the activities and theoretically reduce from 59 to 38 minutes. On the other hand, the TPM tool was used to implement preventive maintenance and thus avoid unplanned machine stoppages that affect production.

The Arena software was used as a validation tool, with the objective of validating the viability of the tools in the production model, evidencing the improvements through indicators within the process.

5.2 Improvement -Simulation proposal

The simulation conditions such as the system scope and the distributions used in the simulator are detailed below.

For the initial scenario, a simulation was carried out to attend to orders that arrive in a time interval that adjusts to a uniform distribution of 1 to 3 hours. The order is assigned to an injection molding machine according to mold size,

and it is also assigned a lot number to be produced. It should be noted that the probability of selecting a T1 injector is 60%. Once the injector is assigned, the batches follow the following sequence: Heater, Blowing and Quality Inspection. In the case of the T1 injector for the Heater operation it follows a triangular distribution of 35,37.1 and 41 min. Likewise, for the Blowing it follows a triangular distribution of 25, 28.7 and 32.8 minutes. On the other hand, with respect to the T2 injector, the Heating operation follows a triangular distribution of 36,40 and 44 min, and the Blowing operation follows a triangular distribution of 30, 33 and 37 min. Regarding the mold change operation, it depends on the injector as well as on the mold. For the initial model, the mold change varies from 59 minutes to 112 minutes, because when an order is finished, the mold is changed. Finally, in the quality control operation, the T1 injector follows a uniform distribution of 35 to 41 minutes per batch. At the end of this sequence of operations, a validation is performed in case the batch has been non-conforming. The batch is separated and assigned as a non-conforming batch.

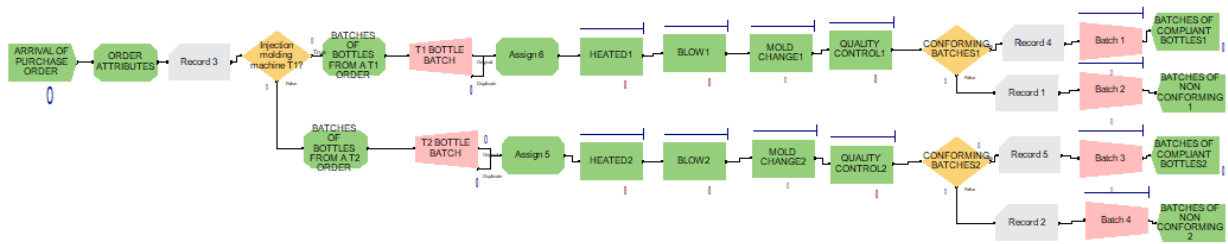


Figure 2. Simulation of batch injection process

In the improved scenario, the mold change time was reduced by 30% based on the initially analyzed papers, it should be noted that the percentage was reduced in the 5 types of molds simulated. In addition, as part of the TPM plan, a failure that follows a uniform distribution of 2 to 6 hours was simulated, with a maintenance time of 60 to 70 minutes, which was improved since the new maintenance plan had a single stop during the day that followed a uniform distribution of 30 to 40 minutes. The heating, blowing and quality inspection times were maintained since these operations depend on the efficiency of the operator.

Table 4. Indicators between scenarios

Problem	Current	Target	Enhanced	Cause	Indicator	Current	Target	Enhanced
Service Level	56,4%	80.0%	90.4%	Lack of standardization and organization in the area	Percentage of non-productive time (%)	30.26%	20%	8.32%
					Percentage of Conforming Orders (%)	56%	80%	82%
				Lack of work guidelines and disorder of the area	Thousands with defectives (mll)	4	3	1
					Cycle time of an average order (min)	164.69	160	152.58
					Mold change time (min)	59.06	49	43,07

				Absence of a preventive maintenance plan in the injection operation.	Efficiency	75.64%	80%	90.13%
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5.3 Graphical Results

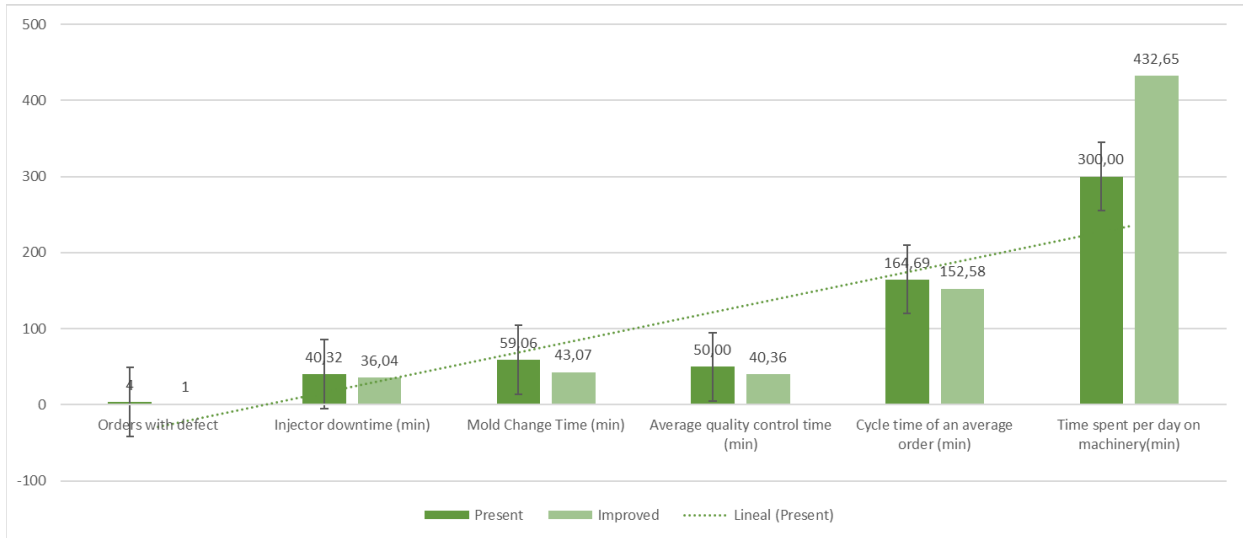


Figure 3. Comparison of Indicators

The figure above summarizes the results executed by the Arena software, and it is emphasized that more indicators than those proposed above were used to obtain more information and to observe how they vary among themselves. As can be seen, with the same number of orders, the trend is improving, as a result of the proposed model.

5.4 Proposed Improvements

In the following section, the comparison analysis of the initial and final key indicators after the implementation of the improvement will be carried out. First, it refers to the application of the SMED and TPM methodology validated in the simulation. Then, the results obtained will be compared.

After the validation of the applied tools, the service level increased from 56% to 90.4%, which was the indicator with the highest variation increasing more than 34%, compared to other authors in increment was higher (Poves-Calderno et al. 2019). (Himanshu M. Shukla and Ganvir 2018). This change was related to the reduction of unproductive time, which depended on the mold change operation, it is in this activity in which SMED was applied and a reduction of 22.5% was achieved, which is a higher reduction compared to other works which obtained a reduction of 20.8% in the mold change time.(Amrina et al. 2018) (Jurik et al. 2019).

Likewise, the cycle time was reduced from 164 to 152 minutes, which obtained a reduction of 7.35% which stands out compared to other works that obtained a percentage of 3%. (Himanshu M. Shukla and Ganvir, 2018). In addition, it was possible to increase the number of compliant thousands which influences the increase in the level of service and competitiveness of the company.

Finally, the level of machine utilization was increased by more than 14%. (Shahriar et al. 2022). This improvement would have an economic and productive impact on the company. This indicator was increased thanks to the maintenance plan within the simulation, i.e., a daily machine revision activity was applied to reduce unscheduled stoppages (Ruiz and Munive 2020). This indicator surpassed several authors who achieved an average of 89% (Leksic et al. 2020).

In this way, it was possible to demonstrate the competitiveness and feasibility of the application of the proposed model through simulation in a medium-sized company in the plastics sector. All this, using SMED, 5S, TPM tools that improve various aspects within the organization such as the level of service, machinery efficiency, among other indicators. It is expected that this model can be adopted in other companies in the plastics manufacturing sector that present the same problems such as high unproductive times, disorder in the area and absence of a maintenance plan.

5.5 Validation

5.5.1 Initial diagnosis

The company's service level is 56.4% below the ideal of 90%, generating an economic impact of 9,973 soles for non-fulfillment of orders. It was found that the company over 6 months of study and a percentage of 56.4% was obtained, this indicator generates a technical gap of 33.6%, which shows an opportunity for improvement.

Three main causes of the low level of service were found: late delivery time, which represents 71%, poor quality, which represents 21%, and the unfulfilled quantity of finished product, which represents 8%. Figure 2 shows the problem tree that summarizes the diagnosis made in the case study:

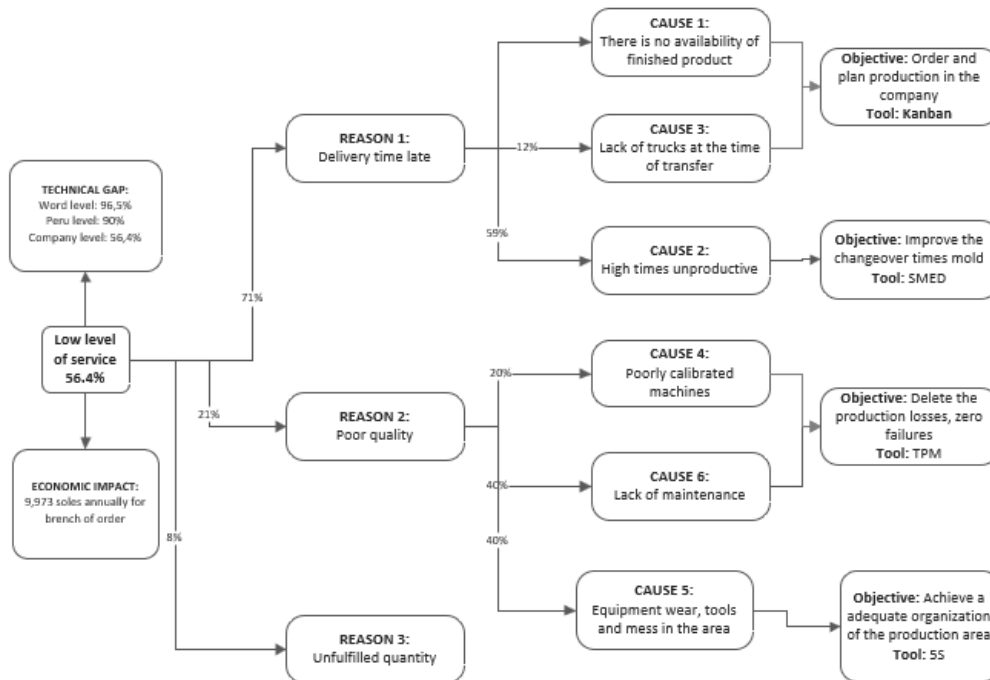


Figure 4. Problem tree

5.5.2 Validation of the design and comparison with the initial diagnosis

To validate the design, it was necessary to cover four different components. The first component is focused on the analysis of the data to identify the root causes of the low level of service from a problem tree, where it was obtained that 71% is due to late delivery time, 21% of the time it is due to poor quality and 8% to unfulfilled quantity of the finished product. The second component is based on the analysis of the most appropriate techniques to solve the problems. The tools chosen were 5S, TPM, KANBAN, SMED.

Component three applies the tools described in the model. The fourth component is based on a re-evaluation of indicators with the objective of measuring the KPIs previously established in the implementation.

6. Conclusion

After the present study, it is concluded that the application of Lean Manufacturing methods can lead to the improvement in the improvement of production process times in a company of the plastic sector. An improvement is evidenced in the final indicators compared to the initial ones. The service level went from 56% to 90.4%, surpassing the target service level. Through the use of the Pareto diagram and the analysis of causes, it became evident that the two main causes of the low level of service were the late delivery time with a percentage of 71% and the low quality with 22%.

When analyzing the main root causes, it was concluded that the production area was affected by high unproductive times caused mainly by the delay in mold changes, as well as the disorder and lack of organization in the work area. Therefore, with the improvement proposal using the Lean methodology and TPM in the simulation, it was possible to improve the mold change times in the production area where the heating and blowing process is performed, obtaining a result of 43.07 minutes compared to the initial situation of 59.06 minutes, all this in relation to the unproductive time within the area improved with the SMED tool theoretically. The correct application of the 5s in the production area would achieve an improvement in the organization and distribution of work tools in the area achieving a cycle time of 152.58 minutes versus the initial situation of 164.69 minutes, according to the scientific articles investigated. In summary, the level of service increased by 34.4%. With respect to economic losses, there were fines due to non-compliance with orders. Through the implementation of Lean and TPM tools, a total of 9,973 soles could be saved annually with respect to the current situation. The simulation model was validated in Arena software. The results obtained in the final situation show a favorable environment for the companies of the plastic sector, since with the proposed model an efficiency of 90.13% of the process was achieved.

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Biography

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