Process Improvement Proposal for the Distribution Management to Reduce Lead Time Using 5S, SMED and Autonomous Maintenance in a Plastic Company

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Abstract: The plastic industry in Peru has grown by 4.5% in recent years, causing great competition among the different companies that exist. In this regard, the most common problem in the industry is low productivity, which causes companies to be unable to meet the lead time agreed with customers. Faced with these difficulties, this study proposes the implementation of Lean Manufacturing tools, specifically Autonomous Maintenance, SMED and 5S, seeking to eliminate waste and mainly reduce lead time. The results demonstrate the feasibility of using these methodologies. An improvement of 88% was obtained in comparison with the current situation that represents 70% of order fulfillment. This happens due to the increase in productivity to 86.83%, waste reduction to 6.74% and increased equipment efficiency to 86.33%.

1 INTRODUCTION

In Peru, the plastic industry is considered to belong to the non-primary manufacturing industry by "Banco Central de Reserva del Perú." In this country, the industry has significantly grown by 4.5% in recent years (Instituto de Estudios Económicos y Sociales, 2019), generating more than 650 thousand jobs (*Población Ocupada, Según Ramas de Actividad, Tamaño de Empresa y Categoría de Ocupación, 2007-2020*, n.d.). The article emphasizes the need to accelerate production systems and the proper use of resources in emphasized, since these produce negative economic impacts (Fernández Marca et al., 2020). Therefore, the results show that it is necessary to increase productivity to guarantee order fulfillment (Ames et al., 2019).

The problem, according to the literature, can occur due to several factors such as low productivity, high amount of waste, equipment downtime, among others (Flores Barbarán et al., 2020), which leads to the need to improve processes in companies in the industry due to increased customer requirements (Ribeiro et al., 2019). This problem has been noticed in different studies worldwide. For example, a company in the same industry in Portugal presented a high number of complaints from customers due to low performance, availability of equipment, low productivity and employee autonomy (Ribeiro et al., 2019). Another article from India found that orders were not being met on time due to misuse of resources, poor staff involvement, and inadequate maintenance (Shukla, 2018). Therefore, it is shown that companies that produce plastic products need solutions for the different exposed problems.

On this basis, it is essential that these companies seek to be more efficient in order to achieve the planned results. For this purpose, a case was chosen to demonstrate the problems of the plastic industry regarding the delay in lead time orders due to low productivity, poor equipment maintenance and high percentage of waste, waste that generates monetary losses of 7% of the utility from the study company. Therefore, in order to provide a solution to the above, an improvement model was proposed using Lean Manufacturing tools specifically Autonomous Maintenance, SMED and 5S. This improvement was carried out with the support of projects that have been

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successful with similar difficulties as the case study of Diana Fernandez and Karla Mostacero (2021), which seeks to increase the capacity in their production process, using 5S to standardize the order and cleanliness, SMED to reduce their times, and TPM to gradually obtain a system with zero breakdowns (Fernández Marca et al., 2020). Finally, there are very few scientific articles with relevant information about the mentioned problem in the industry, being the main motivation to carry out the corresponding study.

This scientific article is divided into five parts, which are Introduction, State of the Art, Contribution, Validation and Conclusions.

2 STATE OF THE ART

2.1 Autonomous Maintenance

Autonomous Maintenance is one of the six pillars of Total Productive Maintenance (TPM), which aims to teach workers to keep equipment safe through activities established in a schedule (Ames et al., 2019). Likewise, this tool seeks that production does not stop even when the machine faces serious problems (Acharya et al., n.d.). On the other hand, with the application of this pillar, the operators will have the possibility of being in charge of the maintenance so the maintenance technicians will be able to use their time in more serious activities (Fernández Marca et al., 2020).

2.2 Single Minute Exchange Die (SMED)

The Single-Minute Exchange Die or better known by its acronym SMED was developed by Shigeo Shingo, who sought to reduce changeover times on machines (San Antonio Ignoto et al., 2018). SMED is effectively used to improve quality and accelerate lead time to meet customer needs (Haddad et al., 2021). For its implementation in an industrial company there are seven steps, starting with the observation of the current situation, followed by staff training, creation of an equipment programming schedule, data review on mold changeover times, data collection on improvement times for later comparison, application of the proposed improvements and finally, in the last step the collection of information on the implemented improvements, including the staff training (Cervantes Esparza & Zorilla Briones, 2018). In addition, the methodology is defined by four phases. In phase zero there is no difference between the internal and external operation of the setup. Phase one separates the internal and external operation. Phase two convert internal operations to external. Phase three apply the improvement of all the setup operations (Antosz & Pacana, 2018).

2.3 5S

The 5S tool was created by the Japanese engineer Shigeo Shingo. This methodology combines five steps which ensure that the environment is kept clean, safe, and efficient (Ribeiro et al., 2019). The five phases are called Seiri, Seiton, Seiso, Seiketsu and Shitsuke, which in English mean Sorting (separate what is not used), Organizing (assign a place for each element), Cleaning (leave the environment in optimal conditions), Standardization (standardize operations) and Discipline (ability to do things while respecting established guidelines) (Shahriar et al., 2022). The application of this Lean Manufacturing tool is crucial as it helps to achieve productivity improvements in the work environment with less human effort, equipment, space and time (Fernández Marca et al., 2020).

3 CONTRIBUTION

3.1 Basis

For the proposal development to improve the lead times of orders in the company of the plastic industry, references of several scientific articles related to Lean Manufacturing tools, mainly 5S, Single Minute Exchange of Die (SMED and Autonomous Maintenance, were considered. Compared to other studies, this one focuses on the development of the worker regarding the use and solution of machinery failures. In addition, waste management proposal was added. Next, the comparative matrix between the causes of the proposed model and the state of the art is shown below.

Table 1: Comparative matrix of causes of the proposal vs. State of the art.

Causes / Items	Maintenance management	Waste management	Productivity
Flores B. and Valenzuela C. (2019)	Autonomous maintenance	5S, Standard work	Kanban
Victor Ames, et. al (2019)	Autonomous maintenance	-	Kanban
Diana Fernandez, et. al (2021)	Autonomous maintenance	5S	SMED
Himachu Shukla, et. al (2018)	-	5S	Kaizen
Carlos Arroyo, et. al (2022)	Autonomous maintenance	5S	SMED
David Romero, et. al (2019)	-	Jidoka	-
P. Ribeiro, et. al (2019)	-	5S, Visual Management	SMED
Proposal	**Autonomous maintenance**	**5S**	**SMED**

3.2 Proposed Model

The proposed model is based on the implementation of three tools, 5S, SMED and Autonomous Maintenance in the production process to improve the order fulfillment on time. At the same time, the impact of the application of these will be positive on productivity, equipment efficiency and the output of defective products. Likewise, the model was developed in three phases: diagnosis, proposal, and implementation.

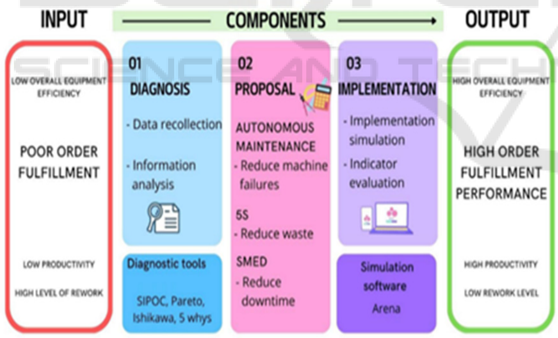

Figure 1: Proposed model.

3.3 Model Components

3.3.1 Component 1: Diagnosis

The first phase, called Diagnosis, was based on the collection of the company's historical data. Limits were established with the help of the SIPOC tool, Pareto and Ishikawa diagrams were applied to determine, the main problem and its root causes, and more precise causes were obtained with the 5 whys tool. In addition, with the objectives tree it was possible to have a broader view and thus, a better analysis of the information.

3.3.2 Component 2: Proposal

The second phase, called Proposal, was based on the tools chosen to be implemented. With the literature review, it was possible to decide which tools were the most appropriate for the case of study. It was determined the use of 5S to reduce the number of defective products, Autonomous Maintenance to reduce failures in the company's machines and SMED to reduce downtime.

3.3.3 Component 3: Implementation

- 5S implementation

For the 5S application, it was divided into the stages the Seiri (Sorting), Seiton (Organizing), Seiso (Cleaning), Seiketsu (Standardize) and Shitsuke (Discipline) to reduce the number of defective products.

- Autonomous Maintenance implementation

The autonomous maintenance application was used to reduce failures in the blow molding machine, establishing schedules and training plans so that operators act with knowledge in case of problems and avoid unnecessary downtime.

- SMED implementation

To reduce the downtime due to low productivity, SMED was applied. By following the seven steps of this methodology, times could be reduced, as well as increasing the process efficiency and reducing lead times.

Finally with the use of the Arena software the simulation of the implementation was carried out. The results were evaluated by indicators.

3.4 Indicators

To measure the impact caused by the improvement tools, four indicators were used to analyze the results. They are detailed below.

3.4.1 Order Fulfillment

This is used to measure the number of orders delivered in relation with the agreed date.

$$\frac{order\ delivered\ on\ time(u)}{Total\ order\ (u)} * 100 \tag{1}$$

3.4.2 Overall Equipment Effectiveness

Provides insight of the machine efficiency

$$Availability * Performance * Quality \quad (2)$$

3.4.3 Productivity

It allows to measure how productive a process is in accordance with time.

$$\frac{actual\ quantity\ produced\ (u)}{estimated\ quantity\ produced\ (u)} * 100 \quad (3)$$

3.4.4 Rework Level

It allows to know the number of reprocessed units produced.

$$\frac{amount\ of\ waste\ (u)}{quantity\ produced\ (u)} * 100 \quad (4)$$

4 VALIDATION

4.1 Initial Diagnosis

It was determined in the initial diagnosis that there is a technical gap in the order fulfillment. Currently, the company under study complies with 70% of its orders, compared to the general index of the industry that represents 85% compliance. Therefore, in order to increase productivity and the percentage of order fulfillment, the main causes of the problem were addressed: (a) insufficient maintenance, (b) output of defective products, (c) inefficient employee. The following are the results of the data obtained from the current model and what we wanted to achieve with the application of the proposed model.

Table 2: Average values of the indicators.

Indicators	Current	Objective
Order Fulfillment	70 %	85%
Overall Equipment Effectiveness (OEE)	68.24 %	85%
Productivity	69.05%	85%
Rework Level	9.81 %	6%

4.2 Validation Design and Comparison with the Initial Diagnosis

For the validation design and comparison with the initial diagnosis, two schemes were made. One of the current model that represented the output process of the bottles from the blow molding machine and its output from the process as packages containing 300 bottles ready to continue to the next process. And another off the proposed model containing the implementation of 5S tools to reduce the number of defective products, SMED to reduce downtime and Autonomous Maintenance to reduce machine failures. With the application of these tools, it was also possible to reduce the number of processes and resources compared to the current model.

4.3 Simulation of the Proposal

The model simulation was developed in Arena software to validate the results and corroborate the performance. The number of replicates was determined in 330 times with the Input Analyzer software wand the collected data. The proposed model simulation is presented in Figure 2 below.

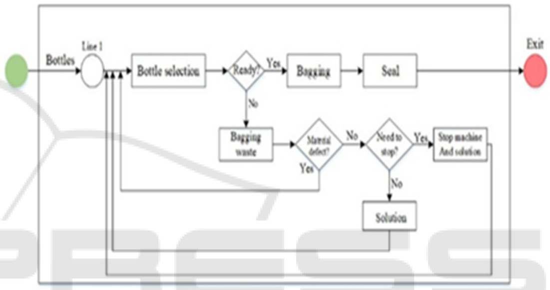

Figure 2: Diagram of the proposed model.

The simulation diagram shows the elimination of activities that did not add value. At the same time, the production work is only centered on the operator due to Autonomous Maintenance and SMED.

Table 3: Actual indicators vs Improved situation.

Indicators	Current	Improvement
Order Fulfillment	70 %	88%
Overall Equipment Effectiveness (OEE)	68.24 %	86.33%
Productivity	69.05%	86.83%
Rework Level	9.81 %	6.74%

The results obtained showed an 88% in the order fulfillment percentage, verifying the effectiveness of the 5S tools, Autonomous Maintenance and Single Minute Exchange of Die implementation and demonstrating the improvement of all the indicators when applying them.

5 CONCLUSION

The implementation of the model that applies the Lean Manufacturing methodology allowed to improve the productivity index by 17.78% and thus an 18% increase in the order fulfillment on time. Therefore, demonstrating the viability of the improvement proposal and its possible application in companies of the same industry.

In turn, it was found that the application of these tools managed to exclude activities that did not generate value, eliminate waste, and reduce time.

In the future, it is recommended to carry out a good diagnosis and data collection to be able to determine more easily the problem and its main causes, and thus obtain more accurate results. Likewise, to validate the improvement of process optimization with the use of Lean Manufacturing tools in different scenarios using other equipment such as the injection molding machine.

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