Production Management Model Based on Lean Manufacturing and SLP to Optimize Unproductive Times in SMES in the Plastics Industry

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Abstract

In recent years, there has been a considerable increase in the demand of the plastics industry; therefore, many SMEs have not been able to cover their demands due to production problems, since there is a high number of unproductive hours in unnecessary movements, machine stoppage, and poor machinery maintenance planning, among others. The problem that could be identified and that occurs in most SMEs in the plastics sector is low availability due to unproductive times. The purpose of this article is to reduce downtime in production and consequently increase the OEE, since this represents a loss of money for the company, especially in the injection process. Therefore, the idea is to implement the Lean Manufacturing model, which is validated with its TPM, 5s, ErgoSMED and Poka Yoke tools, in addition to the SLP implementation. To validate this improvement proposal, the Arena simulation software was used in a company in the plastics sector, since it will be possible to obtain a reduction of unproductive times by 20%, reduce travel times by 25%, reduce labor disorder in jobs by 15%, and in general increase availability by 12%, thus increasing the OEE indicator by 20%.

Keywords
Lean Manufacturing, 5S, ErgoSMED, TPM, Poka Yoke, SLP

1. Introduction
The world production of plastics has grown significantly in recent years, reaching 8.3 billion tons to date since the beginning of its production of products in 1950, with China being the largest producer in the sector (Greenpeace, 2021). For Peru, the plastic industry represents 4% of the industrial GDP and generates around 200 thousand jobs. In addition to this, the industry contributes 13% of taxes paid by manufacturing (Sociedad Nacional de Industrias, 2019). The production of plastics in Peru grew at an annual average of 4.6% between 2014 and 2019. Likewise, the industry demands a diversity of raw materials from the chemical sector, recycled plastics and synthetic fibers (Dirección de Promoción de las Exportaciones, 2021). In our country every year, companies that are more plastic are founded, but the most predominant are SMEs, in 2020 the number of registered companies was 2425, regardless of whether they manufacture plastic primarily or plastic products (Carhuavilca Bonett, 2021).
The problem identified according to the literature relates the workload of operators, excess transfers, accident risks, machine maintenance, among others. All this is included in the Total Effectiveness of the Equipment, called OEE, a problem that was also presented in Asia, Indonesia, where a company had high downtime, having an OEE of 72.35% and in the investigation the main causes of the problem, through a quantitative and qualitative study (Saputro &

Rimawan, 2021). In another investigation, a study is shown where the availability, performance and quality indices are low and it is sought to establish a schedule and apply improvement tools to have the machines in good working order, and therefore improve the OEE and productivity (Shams, Rabby, & Istiak, 2019). In addition, it was possible to identify the low productive performance in plastic-producing SMEs in Bogotá, taking into account tangible and intangible factors, which end up affecting the OEE (Suarez Gaitán & Calderón Pino, 2021). Therefore, it is evident from what has been shown that the plastics industry presents production problems due to its low availability rate, especially in injection machines, for which this problem should be analyzed with a greater focus.
Under this analysis, companies in the plastic sector have the great task of improving their overall production effectiveness. A case study has been analyzed that also presents these recurring problems in the sector, in order to seek improvements. The problems that arise are mainly the workload, distance for transfers, accident risks, as well as low efficiency in machine maintenance and production of defectives. Based on this, to solve the problems, a set of tools has been developed, part of the Lean Manufacturing and the SLP application. The tools are ErgoSMED, 5S, TPM, Poka Yoke and SLP. These work organization methods allow us to apply, through engineering, solutions that contribute to the continuous improvement of organizations. In this article, the production management model is implemented in order to find solutions. It should be remembered that this case study considers for its production both products by suppliers as raw material, as well as recycling, things that are not very common in a plastics company. The studies carried out contain information about Lean Manufacturing and SLP, however, this work seeks to deepen some of its tools

1.1 Objectives
Applying Lean Manufacturing in this study allows us to reduce unproductive times, thus identifying reprocesses, unproductive times, waste generated in the mold change, in addition, the 5's TPM will be applied on the injection process and finally the technical feasibility of the study is recognized.

2. Literature Review

2.1 Production models of the plastic sector
Small production companies in the plastics industry constantly present problems in the production capacity of their processes, which leads to the generation of unproductive times. That is why planning is sought for continuous improvement and to be able to use its resources in the best way, this also leads to less environmental impact since processes are standardized and that helps to better order the environment and work hand in hand with the environment. Sustainable development (Jadayil, 2017), (Cheung, 2017).

2.2 Lean Manufacturing applications in the plastic sector – 5S and ErgoSMED
The companies in the plastic sector have a low percentage of use of resources; in addition, there are unproductive times, which is why it is important for correct planning. On the other hand, companies in this sector do not have a plan to have a clean and orderly workplace; this would bring low production (Arroyo-Huayta, 2021). Given this situation, it is important for companies to have a production model that obtains information on unproductive times in order to increase productivity and improve quality, as well as having a program that helps promote a clean and orderly workplace (Ribeiro, 2019) (Resende, 2014).
Good management has a positive impact on production and dimensions are considered as a good management of delivery times, low percentage of defective products, an ordering work environment and low unproductive or dead time (Makwana, 2019).

2.3 SLP applications in the plastic sector
Systematic Layout Planning (SLP) is a tool that organizes the workspace, its implementation improves the distribution of all material flows between departments and is put into practice together with tools such as Relational Diagram of Activities, Guerchet Analysis, among others (Nagi, 2017). In addition, the SLP helps us to improve other aspects such as hygiene, noise emissions and the safety of all workers in the organization, and all this with the same purpose that is to optimize the design of the plant, improving the efficiency and sustainability of the plastic industry (Gómez, 2018). It is relevant to apply audits periodically to confirm the implementation of PFS, and in case it is not adequately complied with, always seek, and analyze other design plans for continuous improvement (Liu H, 2020).

2.4 TPM and standardization of work with Poka Yoke

Some companies in the plastic sector don't have a good maintenance program such as the TPM, this brings high downtime or unproductive, so they generate high production costs and high delays in orders (Elwardi, 2019). Given this position, it is necessary that organizations have a model or program that collects production information to create more good quality quantity (Mielczarek, 2018).

In addition, Poka Yoke is a method of error testing, it helps us prevent defects, identify them and act on them. The standardization of processes is the key to being able to creatways to prevent errors from occurring, since what is always sought is the complete elimination of failures in the production process (Kogawa, 2017). There are many studies that seek to fully define the concept of Poka Yoke in order to implement its application in its entirety, however, the objective sought is to standardize processes to increase efficiency and improve the use of resources such as operator movements, time, design and machines that are fundamental elements in organizations, since with high technology they help us to speed up processes (Lazarevic, 2019).

3. Methods

Our proposed model was defined by the approach carried out in the state of the art, where for our case study to be optimized, Lean Manufacturing and SLP were chosen as work philosophy. The tools proposed according to the problem tree made in the diagnosis, where the objectives met were then outlined and therefore the choice of tools to be used where the most relevant for their implementation are 5S and ErgoSMED, which seek to standardize processes in order to minimize losses. On the other hand, it seeks to improve maintenance efficiency in which autonomous, planned (TPM) will use, and to increase the quantity of well-made and good-quality products, Work Standardization (Poka Yoke) will use. In addition, to reduce the distance of transfers and improve the plant layout in general, Systematic Layout Planning shall be implemented.

The components of the model will be divided into three parts, the first component is a study of the plastics industry to identify the most significant KPI's and problems of the sector, then a value stream map (VSM) will be made to record and identify the waste in each activity and thus be able to observe where the biggest problems are generated.

The second component is the intervention, which begins with the implementation of the Systematic Layout Planning (SLP) to be able to carry out a correct plant distribution and after this, apply the following tools once the plant design is optimal. This is because from the SLP other improvements can be applied, but without affecting the distribution of resources, or in any case, the least.

The SLP guides us towards the design of an optimal distribution of all the company's resources and is the first thing to define. After the implementation of this tool, the other models can be applied without any problems. Subsequently, the 5S and its principles were used for better organization. Also, to improve time and reduce waste in the production system, ErgoSMED is used, which reduces downtime and optimizes processes, making it faster, but without affecting other variables such as quality, characteristics, among others. Then, for maintenance, specifically in plastic injection molding machines, TPM will be used, focused on autonomous and planned maintenance, since our case study presents several problems per machine downtime and this model guarantees a better maintenance management. Finally, the Poka Yoke is used, being the Standardization of Work our main objective. All this is presented in the company, as there are many defects in their processes, so we seek to mitigate this problem.

Finally, in the third component, a verification will be carried out where the model and indicators will be presented together with the objectives to improve our proposed model.

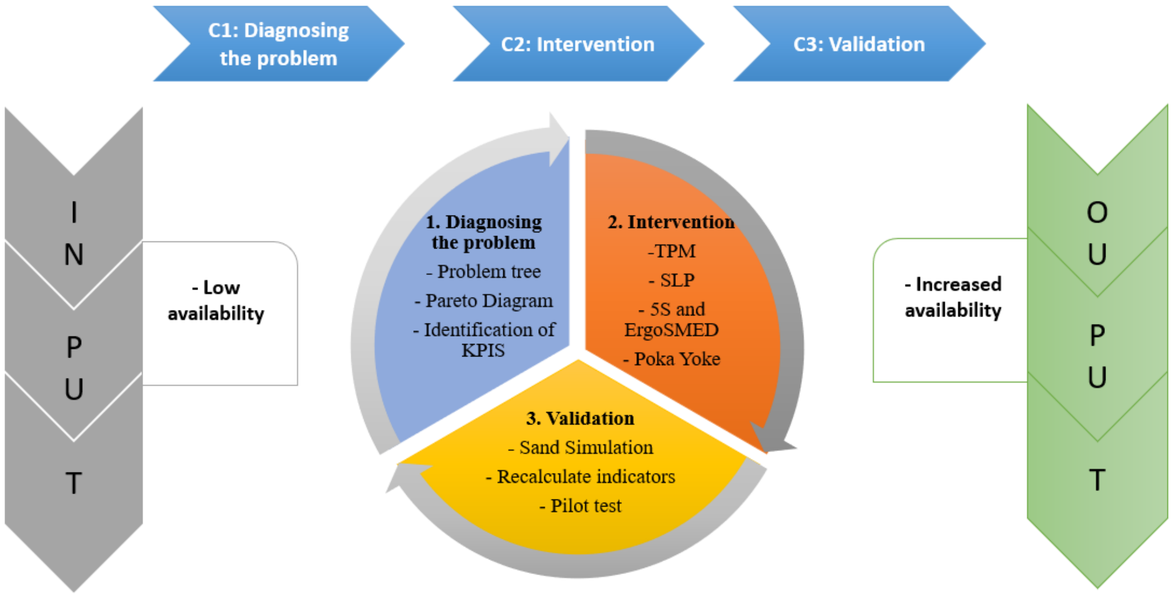

Figure 1. Proposed model

4. Data Collection

In the initial stage of all the activities it was possible to identify some latent problems in the case study, for this an analysis of the situation of the company could be carried out, so a VSM was carried out to determine and see the process where the indicator could be known the percentage of the OEE, therefore, to calculate this indicator the historical data of the company was used, such as production times, machine downtimes, among other data. Likewise, a comparison was made between the world sector and the company with the OEE, a low level of this indicator was found in the company, then, it was deepened to be able to identify the engineering tools to raise the indicator. Finally, using the Pareto chart it was possible to identify the reasons for the unproductive times.
In addition, the distance for mold change was reduced from 44 meters to 30 meters, the initial percentage of work environment clutter of 40% was reduced to 20%, and the MTBF increased from 29.08 hours to 35 hours. These numbers are positive for the second month of simulation.

Table 1: Indicators

Indicator	Current status	Improved situation	Scenario
Availability	70%	78%	98.98%
Mold change distance	44 m	30 m	91.32%
Environment disorder	40%	20%	21.02%
Maintenance efficiency (MTBF)	29.08 h	35 h	18.30%

5. Results and discussion

In the second stage, some Lean Manufacturing tools are implemented to improve the initial situation of the company. First, the SLP tool is implemented which aims to relocate the distribution of the plant in the plastics sector, this tool consists of the following phases, so mention will be made:

ABC diagram analysis, secondly, route analysis of inputs, thirdly, the relationships of the activities are analyzed and carried out in a relational table, fourthly, a relational diagram of spaces is developed. Finally, the best alternative solution is evaluated.

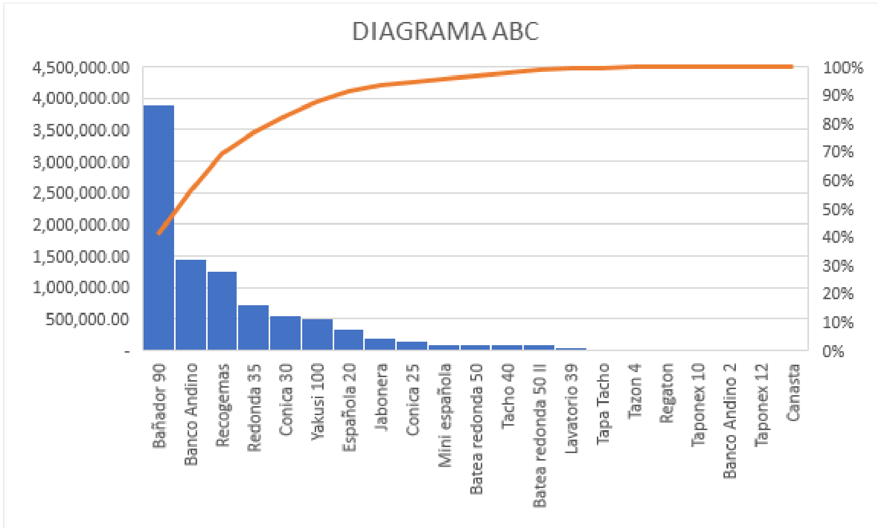

Figure 2. Diagram ABC

In the implementation of the 5S, ErgoSMED and TPM, the first tool helps to improve the workplace of the operators, since the workstations are kept clean and tidy, on the other hand, the second tool (ErgoSMED) aims to reduce downtime and the elimination of activities that are not necessary, Therefore, by using these tools, the objective is to reduce unproductive times and improve production, for this the activities to be performed will be mentioned, finally, the TPM aims to reduce machinery breakdowns, thus avoiding unproductive times.
Form teams to support, communicate and constantly train the personnel in the 5S and TPM topics, as well as to record the control of cleaning, order the work stations and perform 5S audits.
Finally, the Poka Yoke tool will be implemented to standardize processes.

5.1 Verification

In this stage it will be verified and evaluated if the objectives are met in the implementation stage, these fulfillments are made through indicators, since the correct verification of the improvement model can be ensured.
Applying the 5S tool, the audits will have to be implemented, which will be able to verify the compliance of the activities that are proposed. Likewise, applying the TPM tool, constant training will be applied to the staff for the correct monitoring of the proposed activities.

Indicators

The following indicators have been used to analyze the impact of each of them with respect to the objectives. Below are each of them and the initially set goal.

- **Availability**: This is the main indicator in which we will measure the improvement of downtime.

% Availability = (Total Hours - Stopped Hours) / Total Hours

- Interpretation: It is the amount in which you have participated in the processing of the product with the number of total hours that must be worked in a certain period.

- **Transfer index:** Evaluates the route that resources make to reach their goal.

% Transfer = (Initial transfer sum in meters / Final transfer sum in meters) x100

- Interpretation: It is the relationship between the initial and final transfer made by the resources once the improvement model has been used.

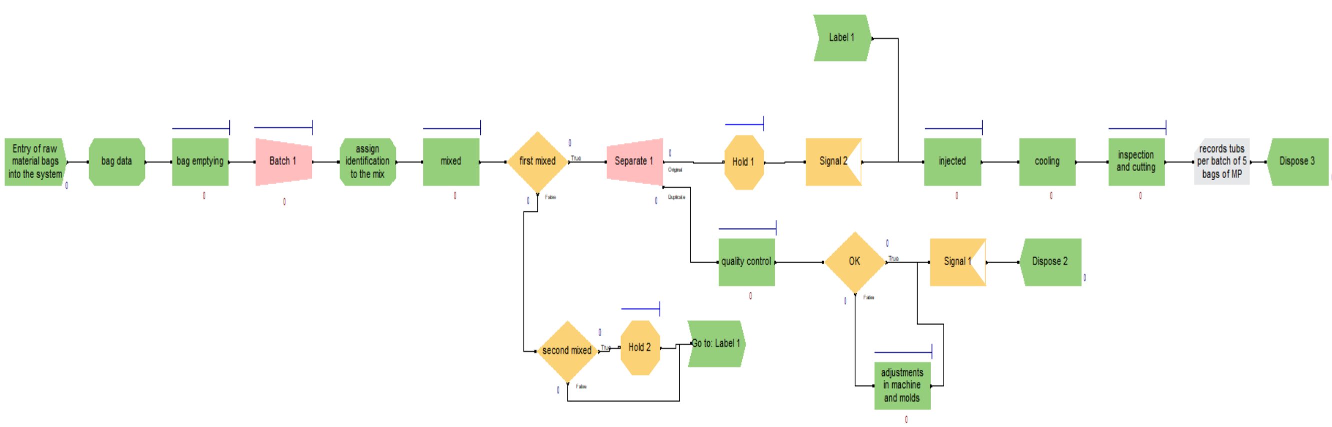

Figure 3. Representation of the current system

• **Order:** Measures the actual distribution of the work environment with respect to what is planned or expected.

% Order = (Actual Search Time / Expected Search Time) x100

- Interpretation: evaluates the order through the actual measurement of the search for a certain resource with respect to what is expected.

• **Efficiency:** measures the performance you have when performing the maintenance of a machine.

% Efficiency = (time stopped due to breakdowns / total production time available) x100

- Interpretation: Measures the performance of the maintenance that is performed on a certain machine.

• **Defective:** Measures the percentage of products that contain a defect and must be separated or reprocessed.

% Defective = (Total defective products / Total production) x100

- Interpretation: evaluates the percentage of defective products in relation to the total produced in a certain time.

5.2 Validation

Initial Diagnostic: The Company is dedicated to the manufacture of a portfolio of plastic products, ranging from the reception of raw material to the final finish of the product. Through the realization of a diagnosis, it was identified that the biggest problem of the company is the low availability especially in the injection process. The availability index of the injector machines is 15% below the industry standard and 5.25% of the impact is due to the change of mold in these machines, generating losses of S/.32.298.23.
Mold change is the main reason for availability problems due to the excess time it takes for such activity. The other problem is the high downtime in machine stop, which includes stops such as breakdowns in the machines, oil change, nozzle change among others.
Validation design and Comparison with the initial Diagnosis: the simulation is developed through the Arena software; therefore, the metrics and results of our initially established objectives will be analyzed. In addition, in the development of the simulation the scope that comprises and the parameters such as the input and output variables are specified, as well as the entities and attributes that the system comprises.
Improvement-Proposal Simulation: The simulation began with the identification of the general problem of low availability, with a value of 70%. Then, the arena software was obtained for the system data input and the generation of the corresponding distributions for each of the processes. The simulation was performed with a Chi-Square Test and for the Erlang, Exponential, Weibull, and Beta distributions with a Kolmogorov-Smirnov Test greater than 0.15.

The following table shows the distributions that occur in the Arena, for each system process.

Table 2. Distribution Values

Process	Adjusted distribution

Input of raw material	EXPO(36.7)
Emptying the sacks	UNIF(1,3)
Mixed	UNIF(5,10)
Quality Control	TRIA(10, 12.2, 14.9)
Verification	>50%
Adjust machine	NORM(17.7, 2.47)
Injected	0.4 + 1.19 * BETA(1.62, 1.58)
Cooled	UNIF(3,5)
Inspection	TRIA(255, 259, 265)

Based on what was simulated, an improvement in times was obtained in the plastic production processes: the availability of the company was 70%, with the validation and improvements of the system, this indicator improved to 86%, very close to of the industry standard which value is 95%. In addition, all this also leads to the improvement of the OEE.

Table 3. Current Situation and Results for Simulation

Problem	As Is	To Be	Results
Low availability	70%	95%	86%

6. Conclusions

The purpose of this research guides us to have a greater knowledge of the context in SMEs in the plastic sector in Peru. The specific indicators that were improved by this study are mentioned below.
The improvement in the plant distribution guaranteed a better movement of resources within it, and with the implementation of SLP the other tools were implemented in the most appropriate way because with the SLP the order of all the elements that are in the plant was optimized.

Autonomous and planned maintenance is relevant for the optimization of processes in machines and could be evidenced in a significant way: the average MTTR went from 0.7 hours to 0.58, while the MTBF before had an average of 29.08 hours, and now 51 hours.

About defective products, the processing of the raw material in the machines, especially in the injected, has been improved through the Poka Yoke through continuous improvement devices.

The application of the 5s and ErgoSMED helped to have a better production, since the spaces were better ordered, better distribution of the tools, the disorder of the environment low from 40% to 24%

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