Lean production model to increase the level of service in a rubber industry SME

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Abstract— Companies in the rubber sector face a high rate of non-delivery of complete and on-time orders, even earlier, which intensified with the pandemic. This research aims to propose a model that applies Lean tools to increase the fulfillment of the delivery of complete orders on time in a company in the rubber sector. The need for more resources such as rubber, kaolin, or sulfur, which are essential for the production process, leads to a supply of raw materials with inadequate inventory and production management. Given the high rate of non-delivery of complete and on-time orders and the increasing competition in the plastics and rubber sector, companies must improve their service level to meet customers' expectations. This research proposes the application of Lean tools such as Autonomous Maintenance, Standardized Work, Kanban, and Heijunka in a case study to achieve this objective. The implementation of the proposed model resulted in a 16.94% increase in the availability of the extruders, an EPEC of less than three days, and an inventory index of raw material on hand of more than six days. As a crucial result, the OTIF increased by 20.51%.

Keywords— OTIF, Lean Manufacturing, Heijunka, Kanban, Standardized work, Autonomous Maintenance.

I. INTRODUCTION

The SARS-CoV-2 pandemic has had significant commercial consequences, with one of them being the shortage of essential commodities for supply chains, including both raw materials obtained from nature, such as coffee, and processed raw materials like charcoal and rubber [1]. As a crucial raw material [2], rubber has been particularly affected by the pandemic, with experts pointing out a mismatch between demand and production and waiting times ranging from two to three months to obtain imported rubber or finding it at twice the retail price [3]. This has created an obligation for companies in the plastics and rubber sector to serve their customers correctly while maintaining high service quality margins.

According to INEI data, the number of companies in the plastics and rubber sector registered with SUNAT increased by 31.5% from 2015 to 2020 [4]. This gives rise to the obligation to serve customers correctly and not to opt for alternatives, in other words, to keep service quality margins high. The importance of the customer lies in the likelihood of the customer making a future purchase and in customer loyalty to the company. Research by Richa Sharma, Jagtar Singh, and Vikas Rostagi found an answer to reducing efficiency in downtime failures, which led to the implementation of a Total Productive Maintenance strategy to save money, and time and reduce response time to customers [5]. Ma, Massehi, and Snider observed this issue in 2019 in a manufacturing company where they implemented an appropriate dispatching model to improve performance against targets within the control environment [6]. In 2021, Nallusamy focused on integrating and implementing production systems using information systems to optimize raw material flow in a quality-of-service approach [7].

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Based on the literature reviewed, organizations need to fully design or transform production systems leading to extended downtime and low on-time production rates [8]. This motivates research to generate an approach on how to design and develop production and maintenance systems to achieve success in all possible scenarios considering company areas, customer needs, and supplier conditions using a model that employs Lean tools. The research proposes increasing machine availability and matching demand with production to increase the service level under time, quantity, quality, and location by employing autonomous maintenance, a standardized job board, production leveling, and Kanban cards.

The structure of this project is organized as follows: in section 2, a review and analysis of the literature are carried out; in section 3, the contribution of the case study of this research is presented; in section 4, the validation of the proposal is detailed; in section 5, the conclusions are developed, and finally the references are presented.

II. LITERATURE REVIEW

A. Improvement in order fulfillment

In the category of improving order fulfillment, companies in the metal-mechanic, plastic, and rubber sectors were evaluated for their production management problems that negatively affect order fulfillment. The investigations, which are part of the order fulfillment improvement typology, propose a set of tools that enable a correct identification phase, including time study, value flow map, and OEE calculation. Although these tools were implemented in companies with various activities, the research showed that the improvement model efficiently enhanced their production processes. Moreover, the identification phase of the analyzed cases demonstrates how solutions are sought through experience. It is worth highlighting that human talent is crucial in each of these articles, and the implemented models make it an integral part of the application process. Therefore, the investigations propose a set of tools that allow a correct identification phase, which includes time study, value flow map, and OEE calculation [9],[10],[10],[11],[12],[13].

B. Lean Manufacturing

To successfully implement lean practices, each organization should research and identify the best practices within its industry. Although there may be unique lean implementation paths, every company must adapt and redesign the lean framework to its specific needs. Management should have a thorough understanding of the organization's waste and be familiar with lean tools to ensure a successful implementation. One of the benefits of this approach is its flexibility; instead of providing a rigid system at the end of a long transformation process, smaller quality parameters are implemented sequentially at each stage or phase of the transformation system [14][15].

In the metalworking sector, operational efficiency losses significantly impact OEE, followed by availability losses [16]. However, implementing lean techniques has resulted in a substantial improvement in various performance indicators in companies [17]. Furthermore, management commitment is crucial to the process of implementing lean tools. Managers determine supplier relationships, integrate human resources, and approve lean manufacturing techniques and tools that support the implementation [18].

C. Total Productive Maintenance

The TPM philosophy is a widely adopted tool in modern-day companies due to its ability to enhance the production process and bring about unexpected changes. However, the success of its implementation depends on the procedure and commitment adopted by the company's staff and management [19].

Although machine stoppages due to breakdowns in the production area are commonplace, it is not acceptable for them to be frequent and negatively impact the quality of the product or service. Implementing the TPM philosophy in the metal-mechanical sector, specifically in forging, cutting, and punching areas, has resulted in significant improvements. These include an average increase in production of 15.63%, an average reduction in breakdown time of 23.14%, an average reduction in scrap rate of 17.94%, and an average increase in OEE of 17.08%. Additionally, the results of parameter improvements are validated using multi-criteria decision-making approaches [10].

One of the pillars of Total Productive Maintenance is Autonomous Maintenance (AM), which enables rapid interventions to increase equipment success rates, reduce production line downtime, and improve processes by increasing the availability of machines [20]. Furthermore, reducing the number and duration of equipment failures, and addressing equipment conditions that indirectly affect them, can reduce breakdowns [21].

D. Continuous production flow

Production leveling enables production management to adapt to demand by maintaining a consistent level of raw materials, in-process products, and finished products. Many companies use this tool to identify key problems, reduce waste, and simplify processes [22]. Heijunka is a key component in achieving this goal, as it makes the operating system more efficient by accepting the CPS-Heijunka system and E-Kanban as part of the recommended method [23].

Kanban is an information system that enables the harmonious production of products at the correct time and quantity. Implementation of Kanban cards in low productivity companies, such as an automotive company in 2020, resulted in an 11% decrease in weighted errors and a 21% increase in productivity for the implemented features [24]. When combined with other tools like VSM, 5s, and process standardization, Kanban can improve service quality by reducing cycle times by up to 16% [25].

When applied to production, Heijunka is used to match production with demand, resulting in on-time production. The implementation of this tool has resulted in significant achievements in space saving and improved productivity. The use of visual management care tools in Heijunka is also encouraged as they can increase operational efficiency by reducing inventory and installation [26].

III. Contribution

A. Basis:

Based on the literature reviewed, organizations need to design or completely transform production systems. The reasons lie in conflicts of interest between production and maintenance, and time discrepancies between their activities and organizational structure, leading to long downtimes and low percentages of on-time production [8]. The contribution of the proposed model was to generate a design and development of production and maintenance systems to achieve success in all possible scenarios that consider areas of rubber and plastic companies, customer needs and supplier conditions through a model that uses Lean tools. In addition, methodologies such as TPM and Just in Time are combined to produce excellent results. The model proposed below was based on the maintenance models developed by [27].

B. Proposed model

Based on previous research and a review of scientific articles, a production model based on maintenance and production was proposed to increase the order fulfillment rate in the rubber and plastics sector. The model consists of 2 components, which are as follows: Machine Layout and Production Leveling.

The components mentioned above are born from an analysis of the current situation of the companies in the search for a solution to the problem of low order fulfillment rate, achieving a correct relationship between the interests of maintenance and production.

C. Design of the proposed model:

The model (fig. 1) is made up of two components. Component 1 started with the Total Productive Maintenance methodology applying one of its pillars, Autonomous Maintenance, and continues the component with the Standardised Work tool, which seeks to reduce operator errors. Component 2 introduced a change in the production system by seeking continuous flow employing two tools: Heijunka and Kanban.

The first component was aimed at keeping the extrusion process machines available, which refers to the operators being able to carry out corrective and preventive maintenance activities on these machines. Also, the operators reduce the errors that lead to machine downtime by following a correct extrusion process.

For the first component, on the one hand, various instruments such as checklists were implemented to evaluate attitudes, aptitudes, and absenteeism control corresponding to the first stage of previous activities, and optical instruments such as flyers were also used to keep the company's workers informed about the Immersion stage. In addition, use was made of records completed by the operators during the Autonomous Maintenance development stage. However, on the other hand, instruments such as information boards were used to carry out the Standardised Work tool, where the correct way the process should be carried out was shown on the board.

Thus, the instruments used in component 1 were:

- Checklist: assess attitudes, skills, and absenteeism.
- Flyers for dissemination of the methodology.
- Lubrication, cleaning, and improvement records.
- Machine operation and maintenance manuals.
- Procedure to develop an audit of Autonomous Maintenance.
- Information board on the extrusion

The second component is Production Levelling which aims at a continuous production flow based on a Pull system.

The component comprised two techniques that are related to each other to achieve a leveling of production with demand. These techniques are Heijunka and Kanban. The objective of component 2 was to ensure the on-time and quantity of raw materials and finished products. For the second component, for the first phase corresponding to the Kanban tool, visual instruments such as colored Kanban cards were used to guide the operators on the status of the container supply. In the second phase, which corresponds to the Heijunka tool, a study of demand was carried out using demand forecasting instruments or methods, which resulted in the production plan in hours and quantities. This production plan was reflected on a Heijunka board, a visual tool that allowed the operators to be aware of the production plan.

Thus, the instruments used in component 2 were:

- Kanban cards
- Demand forecasting methods
- Heijunka board

D. *Indicators*

<u>On-Time In Full</u>

Nallusamy mentions that the OTIF, which details that it must be higher than 97%, guarantees the customer's reliability with the company and ensures the customer's return. [7].

$$OTIF = \frac{Orders\ fulfilled\ in\ time, and\ quantity}{orders\ received}$$

<u>Availability of machinery</u>

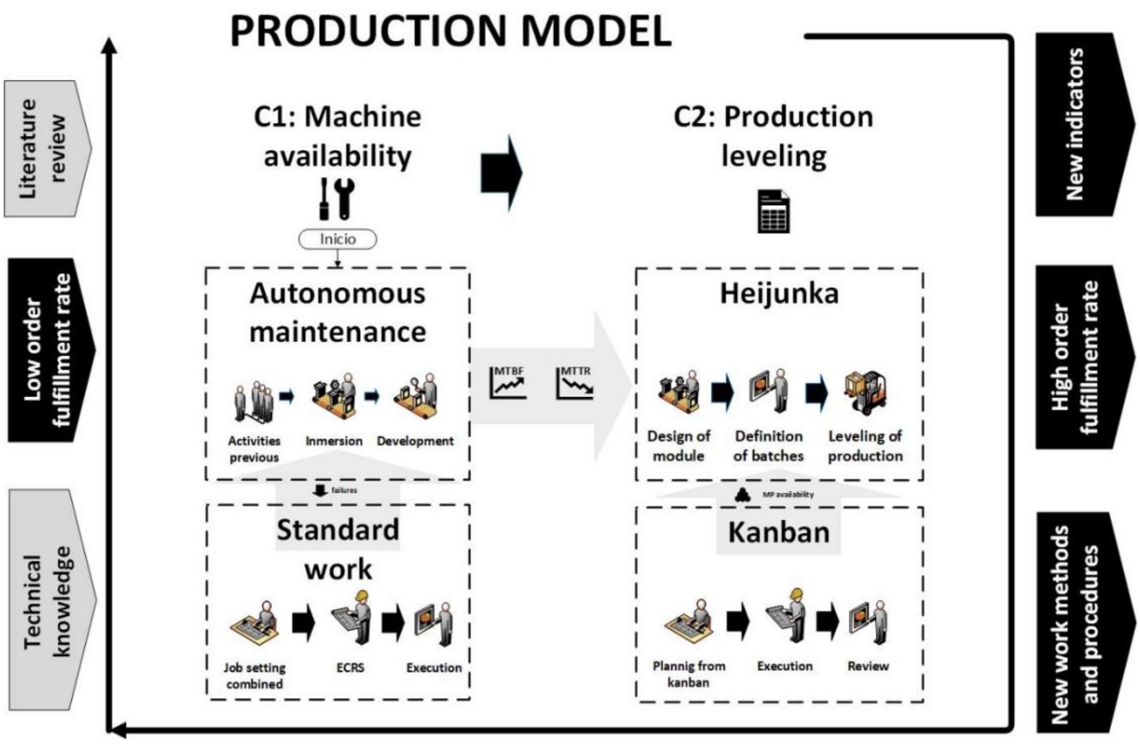

Fig. 1. Proposed production model. Source: Adapted from [27],[29],[30].

Several studies indicate that the proposed model can increase the availability of extruders by 19%. [17]

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

EPIC

EPEC refers to how many days the same product will be produced again. Steinhoff notes that the model can reduce EPEC to 3 days. [28]

Inventory on hand

For several authors, the availability of raw material on hand must be greater than the Lead Time of the main raw material supplier. This model ensures the availability of raw materials in such a period, according to [26].

$$Inventory\ on\ hand = \frac{Evaluation\ days}{inventory\ turns.}$$

IV. Validation

A. Description of the scenario

The development of the pilot plan for each of the tools proposed as part of the proposal was carried out in an SME in the rubber sector to verify the proposal results in a real scenario. In the case study, three production lines manufacture the following products: 3S 200mm rings, 3S 160mm rings, and 250mm rings. The most important product line is the 3S 200mm ring, which was the focus of the research. It has an OTIF of 73.49%, and compared to the industry indicator, which currently has a value of 97%, it can be seen that there is a high percentage difference.

B. Initial diagnosis

After analyzing the inefficiencies in the production process, it was concluded that implementing the company's strategic objectives is most affected by issues related mainly to the non-fulfillment of orders. All this inefficiency affected the company monetarily in the amount of PEN 77,000, which means 7.65% of the annual turnover. A detailed analysis of the leading causes of the problem was carried out, for which they were divided into two main reasons because each has different causes: machine stoppage, shortage of raw materials, and others.

The first cause identified was machine downtime: The metric related to machine downtime was the availability of the extruder machine. To calculate availability, it was essential to know the mean time between failures and the mean time to repair. One of the root causes that led to machine stoppages was the number of breakdowns, which showed a value of approximately 160 breakdowns from the diagnosis.[17]

The second cause was the incorrect use of the machines, an issue related to maintenance, production, and operation methods. It was observed that the operators were unaware of the extruders' calibration, repair, or maintenance methods. This was evidenced by the number of times the machine had to be cleaned daily.

C. Validation design and results

To develop the model proposal, pilot plans for each tool were implemented to improve the initial indicators. First, the optimal number of samples needed to demonstrate the reliability and consistency of the application was determined, and the sample size formula for the final population was used, determining two and a half months for the implementation of the pilots.

Autonomous maintenance:

The methodology was developed in the company's main plant following the 11 steps described in the plan. The area considered for the development of Autonomous Maintenance was the extrusion area, which was diagnosed as having a high rate of stoppages in the extruders.

As shown in Table I, the implementation of Autonomous Maintenance in the established period resulted in an increase of 16.94% in machine availability.

TABLE I. RESULTS OF AUTONOMOUS MAINTENANCE

	Diagnosis	**Pilot Plan**	**Expected**
Machine availability	79.06%	96%	98%

Source: Author's own elaboration.

Standardized work:

To carry out the standardized work, studies were carried out in the plant, such as the route of the operators utilizing a spaghetti diagram, a time study to calculate the capacity and define the balance of the activities concerning take time, and a standardized workboard was established. Subsequently, the operators were trained and audited, and the results were evaluated.

When analyzing the data obtained during the eight weeks, it was observed that 25% of the stoppages were caused by the operators, thus reducing the percentage with the diagnosis, as shown in Table II

.

TABLE II. RESULTS OF STANDARDIZED WORK

	Diagnosis	**Pilot Plan**	**Expected**
Operator errors	40.06%	25%	0%

Source: Author's own elaboration.

Heijunka:

The implementation of Heijunka included weekly production planning. To start the pilot plan, it was essential to train the production manager who gives the production orders in hours. The training explained to the production manager how to find the number of hours using Excel software. In the same way, the operators were trained to become familiar with the change. This allowed the EPEC to be reduced to 3 days.

TABLE III. HEIJUNKA RESULTS

	Diagnosis	Pilot Plan	Expected
EPEC	4.72 days	3 days	3 days

Source: Author's own elaboration.

Kanban:

The area where the containers in which the rubber strips are transported were placed. Later, the operators were trained and audited in the use of Kanban cards.

The average MP on hand during the eight weeks of the pilot plan was 6.9 days. This translates into enough MP to fulfill the week's production orders. As a result, the available inventory time on hand became more extended than the purchase cycle, as shown in table IV.

TABLE IV. KANBAN RESULTS

	Diagnosis	Pilot Plan	Expected
Inventory on hand	5.25 days	6.9 days	>= 6 days

Source: Author's own elaboration.

V. CONCLUSIONS

The production model applied in a manufacturing company in the plastics and rubber sector increased the order fulfillment rate by 20.51% of the case study. In addition, it increased machine availability by 16.94% and reduced raw material shortages by 22.77%.

On the one hand, thanks to the satisfactory results obtained, the present research demonstrated the effectiveness of the production model in one sector of the literature, plastics, and rubber. On the other hand, thanks to the research and the literature reviewed, the proposed production model can be applied to various items with encouraging results, which shows its high scope, efficiency, and quality.

In addition, this study allows us to expand the literature on improving the level of service in manufacturing companies and customer satisfaction by using tools such as Autonomous Maintenance, Standardized Work, Heijunka, and Kanban in the production process.

Finally, in the future, the possibility of expanding the application of the model to other sectors is considered, thus reaffirming its flexibility and viability, as well as continuing to explore new research related to the sector and problems and evaluating other forms of solution.

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