Waste Elimination Model Based on Lean Manufacturing and Lean Maintenance to Increase Efficiency in the Manufacturing Industry

P Aucasime-Gonzales¹, S Tremolada-Cruz¹, P Chavez-Soriano¹, F Dominguez² and C Raymundo³

¹Ingenieria Industrial, Universidad Peruana de Ciencias Aplicadas, Lima, Peru.
²Escuela Superior de Ingenieria Informatica, Universidad Rey Juan Carlos, Madrid, Spain.
³Direccion de Investigacion, Universidad Peruana de Ciencias Aplicadas, Lima, Peru.

Email: U201512412@upc.edu.pe; U201511694@upc.edu.pe; pedro.chavez@upc.edu.pe; carlos.raymundo@upc.edu.pe

Abstract. This article focuses on the low efficiency of a production process in a manufacturing company. The study aims to integrate and model different tools with greater efficiency to avoid high maintenance costs of production equipment and high implementation costs. Thus, this article presents a waste reduction model intended to reduce setup time and develop an efficient maintenance management system to increase overall equipment effectiveness (OEE). We validated the model in a Peruvian tire manufacturing company and achieved positive outcomes such as a 13% increase in the OEE score and a 22.5% setup time reduction. All this entailed an increase in the component changeover capacity, the outsourcing of 37 activities, and an 80% increase in the knowledge index of the operators involved in the proposal.

1. Introduction
The rubber and plastic sector in Peru record a negative production volume variance, while other sectors present a positive production volume variance [1]. Therefore, we analysed the tire manufacturing process, where we found various issues such as low productivity, quality problems, and production machine downtime; the latter has the greatest impact because it affects equipment performance [2].

The most critical process of the tire industry is vulcanization due to the curing press defects, which makes the process inefficient because the press efficiency is directly affected. In several cases, this results in failure to produce more than 10% of the daily production plan [2].

Competitive advantage is a crucial factor for survival in the Peruvian manufacturing industry. Thus, we intended to integrate various engineering tools in a model that is more efficient than earlier ones, to avoid high implementation and maintenance costs. For this reason, and given the research motivation, we proposed a waste reduction model based on lean manufacturing and lean maintenance to increase efficiency in the manufacturing industry.

2. State of the Art

2.1. Lean manufacturing implemented in manufacturing industries
The authors state that companies implement lean manufacturing techniques to reduce production process waste such as changeover time. In several cases, successful tool implementation improved the
overall equipment effectiveness (OEE) score by approximately 4%; in one case, the changeover time was reduced by 40%, while in another case, a 87% reduction of setup time was achieved in a manufacturing process [3][4]. Other success stories related to setup time reduction show decreases of 50% and 64% as a result of task outsourcing, such that work is done based on the early preparation principle. [5][6].

2.2. Lean maintenance implemented in manufacturing industries

Another lean philosophy tool is lean maintenance, referring to the implementation of lean tools for maintenance management, in manufacturing machinery that presents high levels of waste, such as machine stoppages. For example, the implementation of lean maintenance in textile production resulted in a downtime reduction by 26% and an increase in machine availability by 1.7%. In other scenarios, the positive impact is also shown by an improved OEE indicator, which increased by 5%–7% [7][8][9]. Similarly, the implementation results show an increase in the number of products that can be manufactured (by approximately 31%), a 30% reduction in machine downtime, an average operational efficiency of 67.1%, and an increase in equipment availability by up to 78.9%. Moreover, as mentioned above, the greatest benefit in operational performance indicators translates into an improved OEE score, which in a couple of scenarios could be increased from 45.36% to 60.38% and which averaged 51.5% [2].

3. Contribution

3.1. Proposed Model

As part of the contribution, figure 1 presents a waste reduction model based on lean manufacturing and lean maintenance. It integrates several components that have been comprehensively implemented in the scenario. The model has four phases. The first component is staff because the first phase focuses on its training and education in relation to the methodology and benefits of the whole model. The staff component plays a crucial role because based on their experience and continuous learning, workers will manage to use various tools to improve their current work method and achieve their goals [10].

![Figure 1. Waste reduction model](image)

The second component is waste; production equipment downtime, which directly affects the manufacturing company products, causes various problems such as production noncompliance, defects, and loss of man-hours and machine-hours. Thus, companies seek to minimize or, at best, eliminate
waste by using lean manufacturing techniques. The third and last component consists of the waste lean defects, involving production machines and their maintenance. This is an important factor for the elimination of this type of waste, from evaluation to building a maintenance plan, focusing on lean maintenance. Another goal is to sustain the model over time and continuously improve it to achieve better performance.

3.2. Proposed method
The waste elimination model was implemented using the Single Minute Exchange of Dies (SMED) and autonomous maintenance pillar of total productive maintenance. Methodology is shown in figure 2.

![Implementation flowchart of the proposal](image)

3.3. Indicators.
Below are the main metrics related to the primary model goal.

3.3.1. Set-up time reduction. Goal is to reduce setup times by at least 11% and its interpretation is to show the changeover time reduction in a process.

\[
\frac{(End\ time - Initial\ time)}{Initial\ time} \times 100\% \quad (1)
\]

3.3.2. Overall equipment effectiveness (OEE). The indicators presented will be used to measure the proposed model performance and show the achievement percentage of the proposed goals. Goal is to increase efficiency by at least 4% and its interpretation is to increase overall equipment performance.

\[
Availability\% \times Performance\% \times Quality\% \quad (2)
\]
4. Validation

4.1. Case study
The proposed model was implemented and validated in a tire manufacturing company in Lima, Peru, specifically for the vulcanization process, that is, the last process of tire manufacturing and in a radial tire vulcanizing press. Figure 3 shows one of the vulcanizing presses as part of the scenario where the case study has been carried out.

![Vulcanization press](image)

**Figure 3.** Vulcanization press

4.2. Initial diagnosis
Regarding the initial diagnosis of the case study, we obtained the following results for the vulcanizing press used for the pilot plan.

- The current changeover time is 37.8 min. for moulds and 27.4 min. for bladders.
- 37 activities were carried out in a wrong manner in the mould and bladder changeover activity.
- The initial OEE score in the pilot press was 55.7%

The press in question had an OEE score of 55.7%, which is well below the world-class OEE. Further, a time study showed that the press bladder and mould changeover times exceed, on average, 33 minutes. The time taken is very long; thus, the process is inefficient and entails a current changeover capacity of 4 moulds and 6 bladders per day, that is, only 57% of the operator workload.

4.3. Contribution to the scenario
We developed the implementation method for the waste elimination model starting from the ongoing training stage given to the pilot press operators and then implemented SMED in the bladder and mould
changeover activities to achieve a work method that enhances the vulcanization process efficiency. Finally, we implemented autonomous maintenance to improve machine operation by reducing downtime.

All the changeover activities to be performed must be mapped along with their execution time, to analyse them and to choose the activities to be outsourced, as implemented in the tool shown in table 1. The goal is to reduce high setup times, performing some of the activities while the press continues to operate, without the need to stop it, which wastes tire vulcanization time.

Table 1. Classification of activities

| Activity          | Task                        | Duration (min.) | Activity | Duration (min.) | Type       | Proposal |
|-------------------|-----------------------------|-----------------|----------|-----------------|------------|----------|
| Mould Change      | Loosen bolts of the previous mould | 2.70            |          |                 | Internal   |          |
|                   | Bring the crane with tools to press | 1.32            |          | 36.81           | Internal   | External |
|                   | Lift the press head         | 0.64            |          |                 | Internal   |          |

Likewise, because of the constant and prolonged press stoppages in the tool shown in table 2, we presented the autonomous maintenance standards to achieve effective maintenance management.

Table 2. Autonomous maintenance standards

| Inspection / Lubrication / Cleaning Standards Area: Vulcanization |
|---------------------------------------------------------------|
| Activity                        | Method   | Time (min) | Frequency (weeks) |
| Sean check and cleaning         | Cleaning | 5          | 3                 |
| Safety bar check                | Inspection | 3.5       | 4                 |
| Main gear oil change            | Lubrication | 8         | 12                |

Thus, using the proposed tools and based on the initial press diagnosis indicators and the outcomes achieved, we made a comparison, as shown in table 3.

Table 3. Comparing initial vs final outcomes

| Title                                      | Outcomes before implementation | Outcomes after implementation |
|--------------------------------------------|--------------------------------|-------------------------------|
| Set-up time                                | 64 min                         | 50 min                        |
| Number of activities performed in a wrong manner | All the activities were carried out internally | 37 outsourced activities |
| New pilot press OEE indicator              | 55.70%                         | 68.8%                         |
| Previous Knowledge index                   | 1/4                            | 4/4                           |

As shown in table 3, the setup time of the bladder and mould components was reduced by 14 minutes, which increased the component changeover capacity by 7 bladders and 2 moulds per day. This resulted from SMED implementation and a work method improvement based on the tools used to
outsource 37 activities that could be carried out when the press is in operation. Likewise, the press OEE indicator was increased by 13%, mainly using autonomous maintenance based on tools such as the cleaning, inspection, and lubrication register, which detailed the related activities, as well as the manner and frequency in which they must be carried out.

5. Conclusions
By implementing the improvement model, we achieved an OEE increase of 13%, a 22.5% reduction in setup times, an increase in the component changeover capacity by 7 bladders and 2 moulds and an 80% increase in the knowledge index.

The tools play a significant role in the proposal implementation because they are used to conduct the proposal components step-by-step, and they support all stakeholders in the efficient development of the proposal.

The commitment of the company’s employees, from top management to operators, is of great importance, because they are the ones to develop the proposal and have great influence on the techniques used.

References
[1] SNI, “Importancia de la Industria”, 2018
[2] F. Saleem, S. Nisar, M. A. Khan, S. Z. Khan, and M. A. Sheikh, “Overall equipment effectiveness of tyre curing press: A case study”, J. Qual. Maint. Eng., 2017
[3] J. Singh, H. Singh, and I. Singh, “SMED for quick changeover in manufacturing industry – a case study”, Benchmarking, vol. 25, no. 7, pp. 2065–2088, Oct. 2018
[4] M. Braglia, M. Frosolini, and M. Gallo, “Enhancing SMED: Changeover out of Machine Evaluation Technique to implement the duplication strategy”, Prod. Plan. Control, vol. 27, no. 4, pp. 328–342, 2016
[5] Karwasz and P. Chabowski, “Productivity increase through reduced changeover time”, J. Mach. Eng., vol. 16, no. 2, 2016
[6] K. Antosz and A. Pacana, “Comparative analysis of the implementation of the SMED method on selected production stands”, Teh. Vjesn., vol. 25, pp. 276–282, 2018
[7] Thawkar, V. Deshpande, and P. Tambe, “A reliability centred maintenance approach for assessing the impact of maintenance for availability improvement of carding machine”, Int. J. Process Manag. Benchmarking, vol. 8, no. 3, p. 318, May 2018
[8] Henríquez-Alvarado, F., Luque-Ojeda, V., Macassi-Jauregui, I., Alvarez, J. M., & Raymundo-Ibañez, C. (2019). Process optimization using lean manufacturing to reduce downtime: Case study of a manufacturing SME in peru. Paper presented at the ACM International Conference Proceeding Series, 261-265. doi:10.1145/3364335.3364383
[9] T. Ylipää, A. Skoogh, J. Bokrantz, and M. Gopalakrishnan, “Identification of maintenance improvement potential using OEE assessment”, Int. J. Product. Perform. Manag., 2017
[10] Y. Cano, G. Quispe, H. Chavez, N. Mamani-Macedo, C. Raymundo-Ibañez, F. Dominguez (2020) Occupational Health and Safety Management Model for Mining Contracts. Human Interaction, Emerging Technologies and Future Applications II. IHIE 2020. Advances in Intelligent Systems and Computing, vol 1152. Springer, Cham. DOI: https://doi.org/10.1007/978-3-030-44267-5_74