

Productivity Improvement in a Toilet Paper Processing Company Applying SLP, Standardization and Planned Maintenance

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Abstract

This study addresses a current low productivity problem in the paper processing sector among the Small and Medium-sized Enterprises in Peru. This indicator measured in rolls per machine-hour may improve 16.29% according with other companies of the industry. The diagnostic identified the causes of low productivity as the high level of waste generated, excessive internal transport times, and a high frequency of unscheduled stoppages from machines. The contribution of this research is that to address the issues, an integrated model was implemented, combining Lean Manufacturing tools: Systematic Layout Planning, Standard Work, and Total Productive Maintenance adapted to a context with multiple barriers. The validation was carried out through a pilot test and a simulation software. The functional results showed a significant improvement in the measured Key Performance Indicators, confirming the effectiveness of the proposed model. A 5.48% increase in overall productivity in rolls per machine-hour was achieved, a 24.98% reduction in waste generation, a 33.53% decrease in material handling times, and a 2.53pp increase in machine availability. The combined application of SLP, TPM, and SW techniques allowed for a comprehensive improvement in productivity and efficiency of the production process, validating the initial hypothesis.

Keywords

Toilet paper, Productivity, Standard work, Maintenance and Plant distribution.

1. Introduction

Paper processing companies in Peru belong to the manufacturing sector, specifically to the paper and paper products industry. This segment plays an important role in the national economy, having shown sustained growth in recent years driven by a high demand. In 2022, total production reached 143,560, 21,505 and 7221 tons of toilet paper, towel and napkins, respectively (Instituto Nacional de Estadística e Informática 2024). According to Instituto Nacional de Estadística e Informática (2025), in November 2024 the national production increased by 3.93%, and within this the manufacturing sector grew by 6.67%; this is particularly relevant since manufacturing contributes to almost 13% of the national Gross Domestic Product (GDP).

Alarcón and Castaño (2024) showed that in the transformation of paper rolls into reams, high levels of waste are generated in the form of defects, talent waste, transportation and rework, which negatively affect productivity. These reprocesses generate wrapping waste and reduce the available time efficiency to 67.50%. Castro (2023) reports low

productivity in toilet paper producers due to constant and unplanned machine failures, which cause equipment availability to fall below 90%.

The same problems of machine stoppages, poor utilization of available time and low productivity were found in the company under study. However, as being a Small and Medium-sized Enterprise (SME), there are associated risks that need to be recognized in order to anticipate corrective actions. The main risk is operators' resistance to change, which can lead to non-compliance, demotivation, or even loss of initial productivity and quality. To mitigate this, a progressive implementation of tools approach was proposed, including a direct on-the-job support and feedback sessions to resolve doubts in real time during intensive training periods.

The paper is structured as follows: Section 2 presents a literature review, while Section 3 describes the methodology used in the research. Section 4 explains the data collection and treatment, while Section 5 presents the numerical and graphical results obtained with the validation methods and discusses them in comparison with the literature. Finally, Section 6 presents the conclusions of the research, answering the objectives and proposing recommendations for future researches on the topic under study.

1.1 Objectives

In line with the main problem identified, the overall objective of the research is: To increase productivity in the double-ly toilet paper production line of a paper processing company by 16.29% applying Lean Manufacturing tools.

From this, the following specific objectives were defined:

- To reduce the level of waste in the process by 25%.
- To reduce non-productive times by 34% by avoiding excessive internal transport.

2. Literature Review

The literature on engineering tools to improve processes in manufacturing companies reveals a growing need to employ techniques such as Standard Work (SW), Systematic Layout Planning (SLP) and Total Productive Maintenance (TPM). These tools seek to increase company productivity and make them more competitive in dynamic markets, where SMEs face more implementation barriers than large companies.

The evidence suggests that combining SW, SLP and TPM can simultaneously improve productivity, reduce waste, shorten internal transport times and increase equipment availability, precisely the dimensions targeted in this research.

2.1 Systematic Layout Planning

Several studies report that many manufacturing companies fail to satisfy demand and deliver orders on time due to poor supply chain planning and inadequate production systems. To address these problems, Carhuayano-Paucar et al. (2022) applied SLP to improve the work environment and reduce the takt-time of the process, eliminating non-value-added activities and redesigning the plant layout. As a result, they reduced production lead time by 25% in a simulation with the proposal compared to the current situation.

Badharinath et al. (2024) analyzed the implementation of SLP in a manufacturing company and managed to reduce the distances traveled by materials to reach each station in the production process, thereby reducing cycle time. Production was doubled by eliminating a large amount of idle time. Their approach included relationship analysis among areas and several layout alternatives. Similarly, Lista et al. (2021) redesigned the layout applying SLP and Lean Manufacturing principles; by grouping product families and analyzing flow through Value Stream Mapping (VSM) and affinity diagrams, they reduced material travel distance by 48%. In the same way, Salins et al. (2024) applied SLP in a manufacturing company and, after verifying the optimal sequence of areas according to the production process and simulating different layout alternatives, were able to reduce material flow by 34% and improve space utilization by 26%.

2.2 Standardized Work

In organizations with poor communication, limited employee training and resistance to change, these become barriers to implementing tools such as standardization. Once implemented, however, machine set-up times, material search

times and defective products are significantly reduced (Silva-Castro et al. 2022). Lean Manufacturing tools such as Standard Work, 5S, TPM and Kanban have been shown to be beneficial and to improve common problems in the sector such as quality, customer satisfaction, waste elimination and process time reduction, thus increasing competitiveness in the manufacturing sector (Marinelli et al. 2021).

The implementation of 5S and standardization in a manufacturing company has been shown to reduce non-productive times and unnecessary movements. Shahriar et al. (2022) showed that Standard Work increased overall efficiency, reduced waste, improved product quality and enhanced customer satisfaction. These practices produced an 8% decrease in time in several activities and eliminated non-value-added tasks such as searching for inputs.

2.3 Total Productive Maintenance

Regarding TPM, Mares Castro and Ramírez Pérez (2024) applied TPM under a DMAIC approach in a packaging manufacturing plant. They increased machine effectiveness and reduced non-productive times such as repair time. Singh et al. (2022) also reported an increase in efficiency from 16.17% to 19.64% after implementing TPM through machine maintenance and personnel training. Their approach focused on eliminating unplanned stops and establishing simple preventive routines managed directly by operators.

Avilés et al. (2023) implemented a planned maintenance schedule, which eliminated sudden machine failures and unexpected production stoppages characteristic of reactive maintenance. Likewise, Alcazar-Zamora et al. (2023) developed a continuous-improvement model using Lean and TPM on rewinding machines in a textile company. As result, they obtained a 42% increase in efficiency and a 73.81% reduction in non-productive times and non-value-added activities. Additionally, the implementation of Standard Work contributed to waste reduction and improved plant efficiency.

Also, León-Ludeña et al. (2023) proposed a combined SLP and TPM and approach to reduce cycle times and gain competitive advantage. After performing VSM analysis and validating the model in ARENA simulation software, they reduced cycle time from 12 to 7 days and increased OEE by 30%.

3. Methods

In the company studied, several problems were identified. These include large quantities of paper waste after the rewinding and cutting processes due to the lack of machine calibration caused by the absence of work and operation standards, long internal travel distances associated with poor workplace organization, and frequent machine stoppages due to failures. To solve the critical problems identified, technical indicators of the current process were determined and engineering tools were selected to improve operations. Based on the work of Alarcón and Castaño (2024), who achieved a 16.29% increase in productivity in a paper company, the technical gap between the company's current productivity and this benchmark was established.

The implementation of engineering tools to improve operations aligns with the company's strategic objective of handling a higher volume of institutional orders without increasing the number of shifts or expanding the physical plant. The gap affects not only the efficiency of operating time, but also the capacity to respond to demand increases and to avoid work overload caused by order accumulation. This gap demonstrates that the current process operates under its potential and that several operating conditions can be optimized.

The tools selected to address these causes were Standard Work (SW), Systematic Layout Planning (SLP) and Planned Maintenance as a pillar of TPM. Each tool has a particular philosophy and essence that is leveraged to solve the root causes of the company under study. The lack of standardization can cause waste, rework and increase manufacturing times. Standardization enables a defined and safe process, and its correct application can reduce organizational costs. Implementing standards and procedures reduces defects and prevents new errors that could affect production; making standardization highly recommended in the manufacturing sector (Silva-Castro et al. 2022). According to León-Ludeña et al. (2023), SLP seeks a more efficient plant layout. Its quantitative perspective minimizes distances between stations to reduce costs, while the qualitative perspective maximizes proximity between related areas. Combining both perspectives leads to new plant layouts that increase productivity and reduce production times. TPM, in turn, aims to

optimize workflow by increasing the performance of production equipment through preventive maintenance and early detection of failures (León-Ludeña et al. 2023).

Figure 1 shows the macro design of the proposed model. The model is based on the approaches found in the reviewed literature, adapting techniques and components to the main problem, its causes, and the desired objectives.

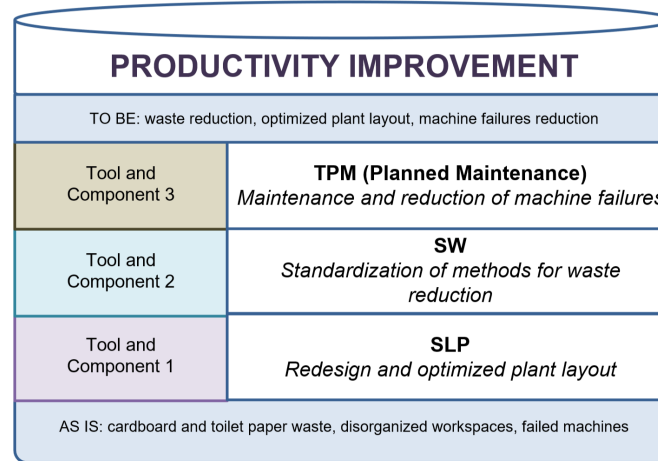


Figure 1. Macro design of the proposed model

Silva-Castro et al. (2022) propose a standardization model to reduce defects in clothing manufacturing. As in this study, their case lacked standard work methods, which caused waste and rework. León-Ludeña et al. (2023) follow a model composed of sequential phases that begin with a problem definition, data collection and root causes identification; subsequently, they redesign the plant layout using SLP, resulting in a reduction in cycle time. These models were adapted to solve the low-productivity problem in the double-ply toilet paper line.

For this purpose, three components were defined: an optimized plant layout using SLP, standardized methods to reduce waste through Standard Work, and Planned Maintenance to reduce machine stoppages as a TPM pillar. The components of the model interact systematically and support the objective of improving the indicators described in Table 1.

Table 1. Key Performance Indicators

Component	Indicator	Unit
Global	Productivity	Rolls per machine-hour
	Cycle time	Seconds per pack
C1: SLP	Travel time	Seconds per roll
C2: SW	Waste	Kilograms per batch
C3: TPM	OEE	%

3.1 Component 1

The current physical arrangement of machines reveals a reactive and unplanned design, generating unnecessary paths and backtracking of flow. To overcome this, a layout reconfiguration was developed using SLP, approaching the problem from the spatial foundation of the production process. The new design starts by classifying relationships between areas using the AEIOU-X method shown in Table 2, prioritizing functional proximity among cutting, rewinding and sealing operations, and eliminating crossings between operator and material flows.

Table 2. Scores based on reasons and proximity value

Letter	Name
A	Absolutely necessary
E	Especially important
I	Important
O	Ordinary
U	Unimportant
X	Undesirable

Number	Reason
1	Use the same inputs
2	Share the same space
3	Workflow sequence
4	Nuisance caused by noise

Based on the proximity scores and reasons, a relationship chart was constructed indicating the proximity value and the number of the reason behind the chosen value. This to finally develop the activity relationship diagram shown in Figure 2.

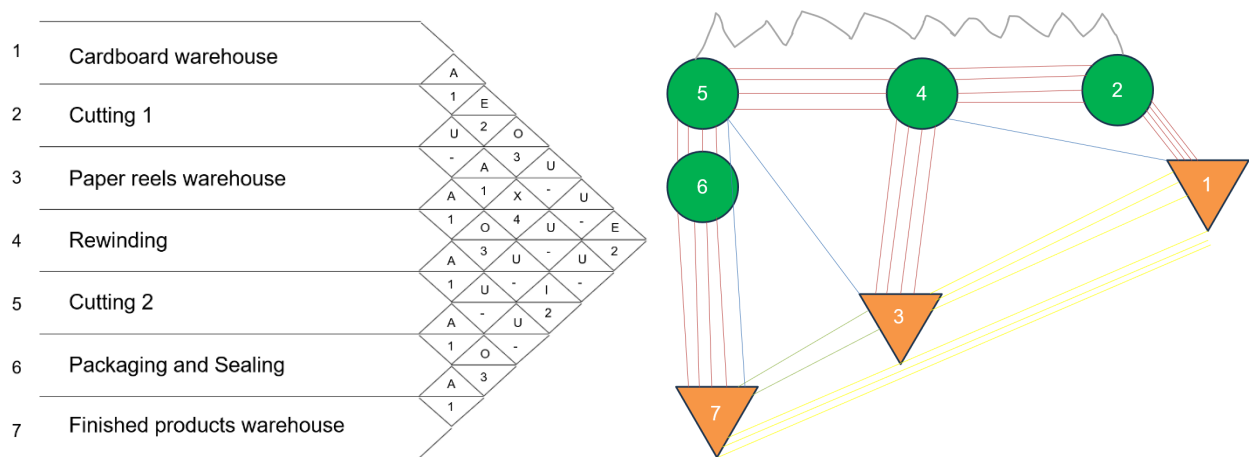


Figure 2. Relational table and diagram of activities

Lastly, layout proposals were generated according to the relational diagram in order to improve plant distribution and reduce crossings and non-productive times.

3.2 Component 2

Moreover, current operations exhibit high variability between shifts, which directly affects efficiency and product quality. A critical factor is the lack of machine calibration at the beginning of each workday. To counter this, operating standards were designed for each stage: rewinder operator, cutting assistant and packing operator, to define and control technical and sequential parameters. Each standard includes:

- The optimal work sequence (based on direct observation and time analysis)
- Standard times per task
- Minimum quality requirements
- Safety and ergonomic handling conditions

Also, equipment calibration, identified as a major cause of waste, is standardized through daily start-up procedures with fixed technical parameters to ensure correct operation from the beginning of each shift. A daily operational checklist is also designed for supervisors to validate compliance with key activities. This system allows structured monitoring of operators and ensures that all personnel adhere to standards.

Figure 3 shows the step-by-step standardization plan.

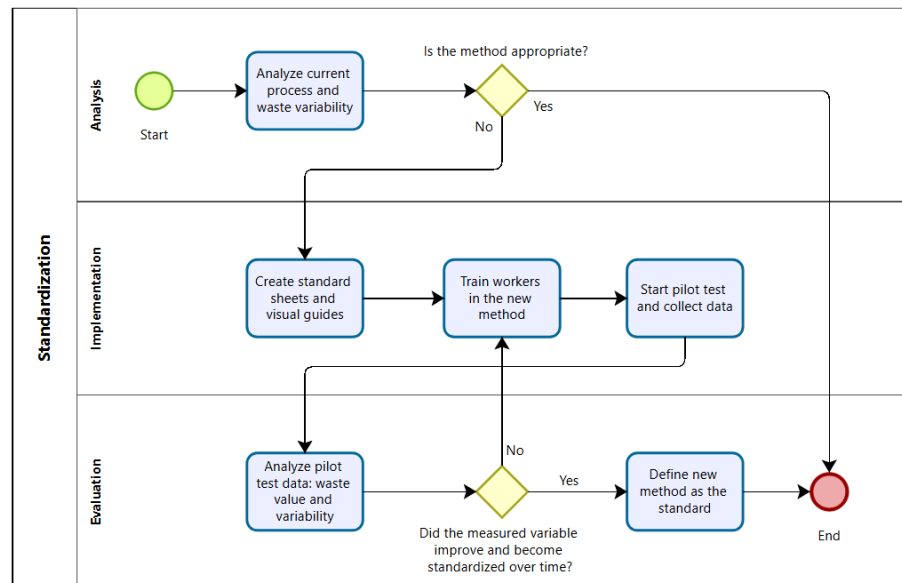


Figure 3. Flowchart of component 2

3.3 Component 3

As a fundamental part of the solution, a structured maintenance system was designed following TPM principles, particularly the “Planned Maintenance” pillar to increase technical availability of the machines involved in the toilet paper line by regularly scheduling inspection, lubrication, and minor adjustment activities. The bottleneck in the operation was found in the rewinding machine, so this critical system is the one that will be addressed.

The maintenance plan is defined through a schedule by equipment type, based on the manufacturer’s technical recommendations and historical failure analysis. Each intervention is documented through technical reports and maintenance records and the scheduled activities are carried out without interfering with the production cycle.

Table 3 shows the maintenance activities, their frequency, and the spare parts required for their execution.

Table 3. Maintenance table

Activity	Frequency	Resources
General cleaning (removal of paper scraps and dust), lubrication of critical points	Every shift	Compressed air, industrial wipes, specified lubricant, degreaser
Pneumatic system inspection, adjust drive belt tension	Weekly	Teflon seals
Axle and cylinder verification, deep cleaning of the system	Monthly	Brushes
Bearing replacement, shaft and roller alignment	Annually	Precision instruments

4. Data Collection

In this study, the unit of analysis was defined as the processed cardboard core, which represents the physical element that continuously passes through all stages of the production process: rewinding, cutting and packaging. At each stage, the core allows the recording of key variables such as processing time per activity, quantity of inputs used, waste generation and occurrence of operational stoppages.

To obtain the data required for the simulation model validation, a simple random probabilistic sampling approach was used. This method was chosen because it objectively represents the population of cores processed during a standard working day, ensuring that each unit had the same probability of being selected.

The pilot sample consisted of 40 cardboard cores observed directly during normal plant operation to estimate the standard deviation required to calculate the final sample size. Using a 95% confidence level, the study population was established as 600 cardboard cores, corresponding to the total units processed by the production line in a standard day. With the population and after collecting the pilot data, the necessary sample size for the final data set of each variable was calculated to ensure representativeness in the universe and population under study, resulting in 29 observations.

Once the final data were collected for each activity with a representative sample size, a descriptive analysis of each variable was performed regarding the data obtained. Subsequently, goodness-of-fit tests were carried out. A p-value > 0.05 was obtained in both Chi-Square and Kolmogorov–Smirnov tests, indicating insufficient statistical evidence to reject H_0 . Therefore, the data were considered to follow the probability distributions shown in Table 4.

Table 4. Distribution function by activities

Activity	Distribution	Expressions
Cut 1	Normal	NORM (18.2, 2.4)
Rewinding	Normal	NORM (43.9, 0.527)
Cut 2	Triangular	TRIA (28.5, 30.4, 31.5)
Packaging and Sealing	Uniform	UNIF (42.5, 44.5)

High variability was observed in waste values as shown in Figure 4, which was corrected through process standardization.

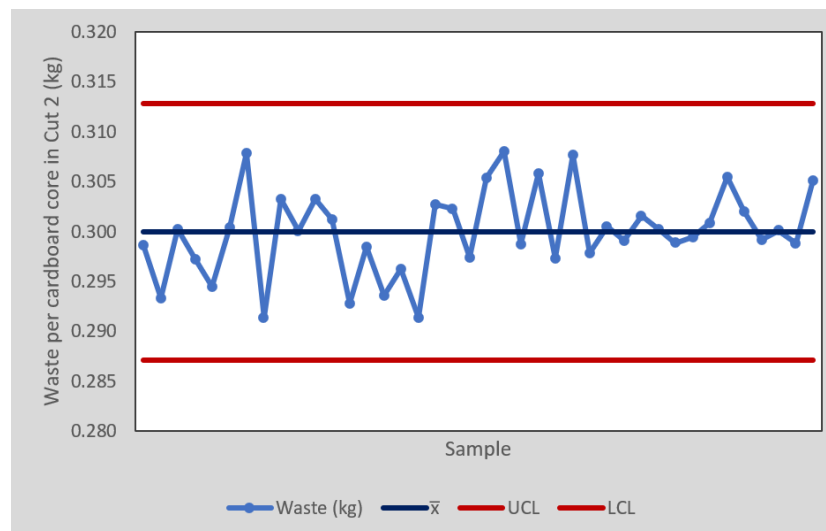


Figure 4. P-chart of waste in kilograms

5. Results and Discussion

5.1 Proposed Improvements

The proposed improvements were based on optimizing the layout of the work area, standardizing processes to reduce the amount and variability of paper waste, and establishing a routine for machine maintenance. Instructions were implemented for each operation, as well as machine calibration at the start of each workday. Checklists were also introduced to verify each maintenance activity. The final plant layout was proposed after developing the selected engineering tool. Figure 5 shows the initial path diagram of the plant, where several crossings obstruct the flow of the production process, and the proposed design, which best complies with the activity relationship diagram and follows

a continuous sequence without crossings within the plant; resulting in a reduction of 54.28 meters of travel, equivalent to a time saving of 31.31% (Figure 5).

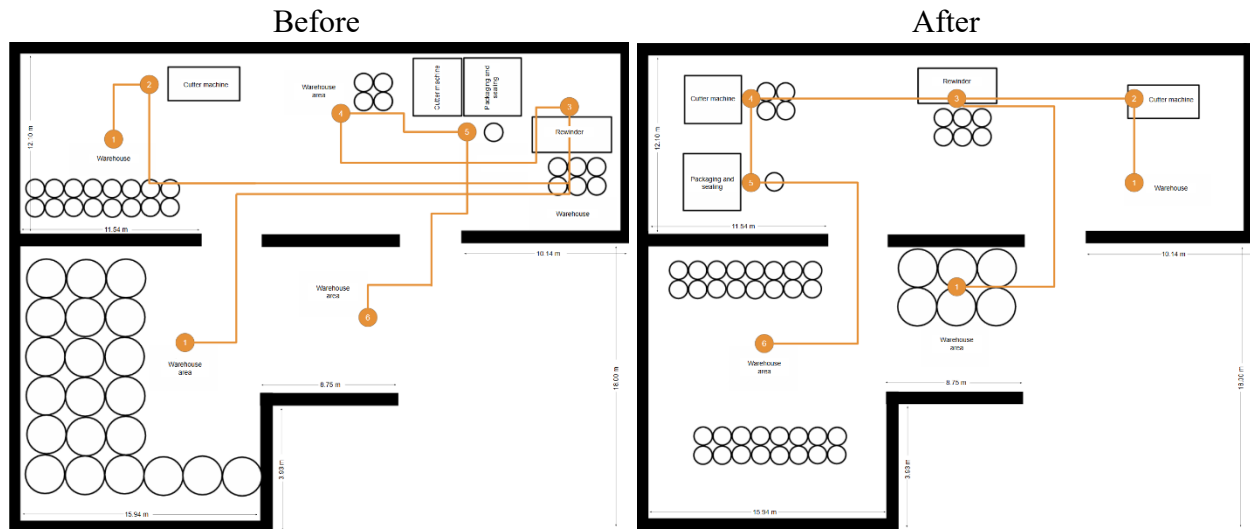


Figure 5. Initial and final path diagram

5.2 Numerical and Graphical Results

Figure 6 shows how waste values are standardized during the pilot test. This will be consistent over time during the company's operations thanks to the standards provided and the training carried out.

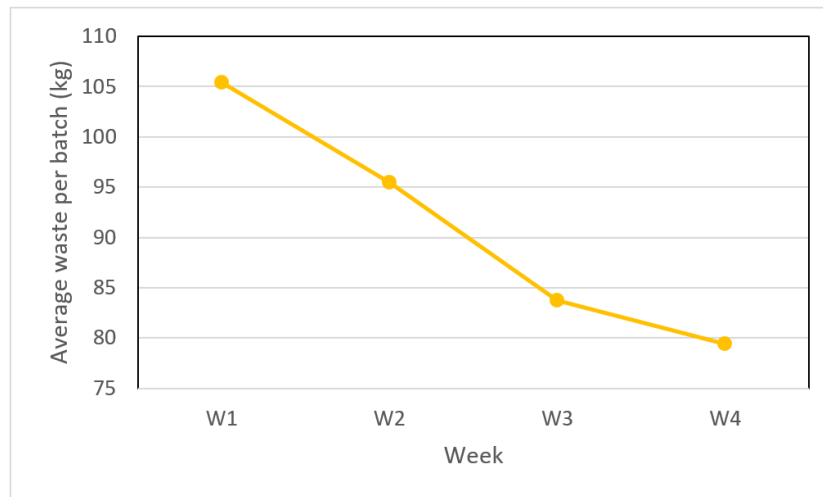


Figure 6. Weekly waste evolution in kilograms

For the ARENA simulation, to statistically verify the difference between scenarios, 95% confidence intervals were calculated for the analyzed indicators and compared following the validation methodology. The results show overall improvement in the main process indicators, reflecting greater operational efficiency and more stable production conditions. The simulations evidence a reduction in non-productive times, lower waste generation, and higher equipment availability, confirming that the improvements implemented in the model optimize system performance in an integrated manner, as shown in Table 5.

Table 5. Results of validation of the proposed model

Indicator	As-is	Achieved	Variation
Productivity (rolls/machine-hour)	420.43	443.48	+5.48%
Cycle time (seconds/pack)	54.81	51.45	-6.13%
Waste (kg/batch)	98.36	73.79	-24.98%
Travel time (seconds)	323.57	215.07	-33.53%
Machine availability (%)	93.57	96.10	+2.53pp

5.3 Validation

Standard Work component was initially validated through a pilot test where time and waste data were collected after implementing the new practices in one production line. The resulting data were then validated via ARENA simulation software together with the SLP and TPM components taking into account the new travel times derived from the proposed layout, as well as maintenance times and machine failures.

To obtain statistically valid results from the simulation, the required number of replications was calculated using the confidence interval approach based on the t-distribution. An initial pilot run with 10 replications, following a normal distribution, was conducted to estimate the standard deviation and determine the corresponding t-value with (n-1) degrees of freedom. Considering a maximum relative error of 5% with a 95% confidence level, the required number of replications was determined to be 226. This result is explained by the variability observed in the pilot run. The simulation model of the proposed scenario is presented in Figure 7.

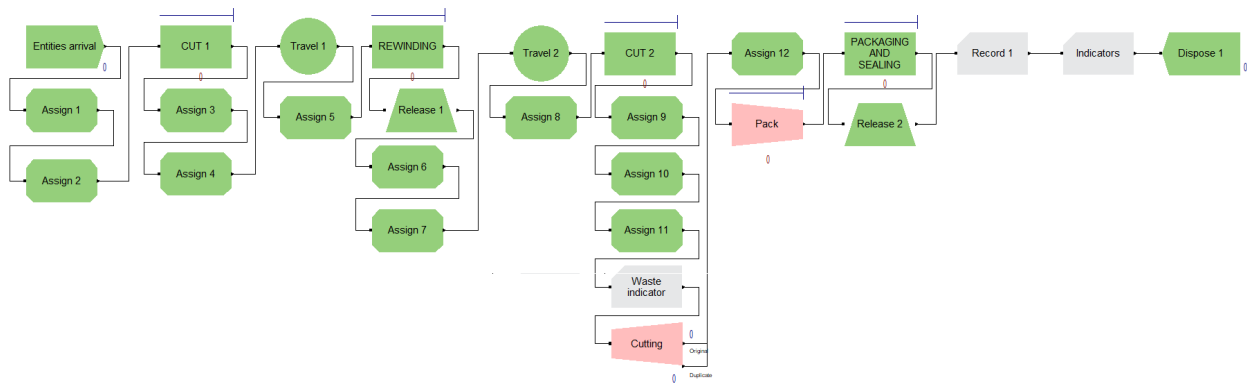


Figure 7. Proposed scenario simulation model

Regarding the analyzed indicators, in all cases, there was no overlap between the confidence intervals of the As-Is and improved scenarios, which indicates statistically significant differences between them. Consequently, a paired test was not required, since the separation of intervals itself confirms improved performance in the proposed scenario. The confidence-interval plots obtained from the Output Analyzer are shown in Figure 8.



Figure 8. Confidence intervals of indicators

5.4 Discussion

The analysis of results shows that the improvement model based on SLP, SW and TPM (through planned maintenance) increases the overall productivity of the double-ply toilet paper line in the paper processing company. While the desired scenario, according to Alarcón and Castaño (2024), was a 16.29% increase, the case study achieved a 5.48% improvement.

Seminario-Mestanza et al. (2023) developed a production model using TPM and SLP and increased productivity in a manufacturing company by 7.69%, similar to this study, also validated through simulation and showing fewer machine stoppages. Combining these tools with 5S Leon-Ludeña et al. (2023) increased production capacity by 27% in a Peruvian textile SME and drastically reduced cycle time. Likewise, Salins et al. (2023) reduced material flow by 34% through SLP-based layout redesign, optimizing flow and space utilization.

Regarding Standard Work, Kawakami-Arévalo et al. (2022) implemented SW together with 5S and SLP and achieved an 11.82% productivity increase in a Peruvian manufacturing company. Carhuayano-Paucar et al. (2022) also applied SW and SLP to reduce production times by 25% in a medium-sized company in Peru.

Finally, the model presents a positive impact in terms of replicability. The methodology can be adapted to other production lines in the same plant (such as paper towels or napkins) or to other companies in the sector with similar conditions, making it a scalable technical solution that can contribute in the long term to strengthening small paper-processing companies in the country.

6. Conclusion

The productivity of the double-ply toilet paper production line was increased by 5.48% through the application of a model combining SLP, TPM and SW, thereby confirming Lean Manufacturing principles in a paper processing company. Simulation made possible to evaluate an improved scenario incorporating the effects of these tools, which optimized flow and reduced stoppages and waste.

Waste per batch, measured in kilograms, was reduced mainly in the cutting stages as a result of standardized working procedures that included machine calibration and better operational practices. Solid waste from the operation decreased by 24.98%. Non-productive times such as internal transport and machine stoppages due to failures were reduced. The new layout developed through SLP eliminated crossings and interferences in material flow, reducing travel time by 33.53%. Planned Maintenance increased rewinder availability by 2.53pp.

The contribution of this research, in comparison with the analyzed literature, lies in confirming that structured application of Lean Manufacturing tools in paper and cardboard SMEs, taking into account all implementation barriers, can generate positive and beneficial impacts for organizations, enhancing productivity and increasing sales in a sustainable manner.

Future work is recommended on automating failure detection through sensors to further optimize maintenance scheduling and increase availability, as well as carrying out extended pilot tests to validate the assumptions defined in the model and adjust them to real operating parameters. To replicate the model in other production lines or paper-processing companies, adjustments must be made to reflect each line's specific context and constraints.

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