14th Annual International Conference on Industrial Engineering and Operations Management
Dubai United Arab Emirates (UAE), February 12-14, 2024

Publisher: IEOM Society International, USA DOI: 10.46254/AN14.20240030
Published: February 12, 2024

# Production Model Based on Lean Manufacturing Tools to Reduce Delivery Times in a Small Manufacturing Enterprise

**Mariafe Olenka Francia-Barba**
Faculty of Engineering and Architecture, University of Lima, Perú
20180730@aloe.ulima.edu.pe

**Erick Linder Rosales-Espinoza**
Faculty of Engineering and Architecture, University of Lima, Perú
20184418@aloe.ulima.edu.pe

**Martin Fidel Collao-Díaz**
Research Professors
Faculty of Engineering and Architecture, University of Lima, Perú
mcollao@ulima.edu.pe

## Abstract

The foam furniture paint industry, belonging to the manufacturing sector, has experienced a decline in recent years due to the COVID-19 pandemic. This situation has negatively impacted production capacity and has generated significant challenges. Among them, reprocessing has occurred due to undesired tones in the paints, the presence of residues in the machines, as well as errors in machinery programming and delays in the start of production. These factors have hindered the manufacturing sector from reaching its pre-crisis economic level. Consequently, delays in the delivery of the final product arise, leading to economic losses for the companies, which hinder their development. To address these issues and thereby reduce product delivery times, the production improvement model based on Lean Manufacturing tools is proposed. The model consists of tools such as 5S, Poka-Yoke, and standardized work. The model was validated through the implementation of pilot tests and simulation using Arena software.

## Keywords
Lean Manufacturing, 5S, Poka-Yoke, Standardized work

## 1. Introduction
Small and medium enterprises represent more than 90% of active businesses in Latin America, generating over 60% of employment in the region. Their proper functioning is crucial for the growth of the countries in this region, where they contribute to more than 28% of the average GDP (CAF, 2023). However, these enterprises often face significant challenges, especially concerning the efficiency of their supply chain and product delivery times. Timely delivery of manufactured goods is crucial for customer satisfaction and market competitiveness (Akimov, 2019). Manufacturing SMEs are in a particularly challenging position, as they must meet delivery deadlines despite having limited resources and capabilities compared to larger companies in the sector. Therefore, it is essential to develop specific optimization models that cater to the needs and characteristics of these SMEs (Afflerbach et al., 2020).

The identified problem, according to the literature, can arise from various inefficiencies within the company (Chatzistamoulou et al.,2022). A specific example can be observed in the context of a metal-mechanical company located in the Caribbean region, where only 42% of its production capacity could be utilized due to operational waste, such as low machinery availability and high work-in-process times. These issues hindered the timely delivery of customer orders (Tulabandhula et al., 2022).

In this context, the present research aims to develop an optimization model for delivery times specifically designed for a manufacturing SME, with a focus on understanding and addressing the challenges that the company faces. The model should consider its production capacity, inventory management, and market demand (Gagnin et al., 2022).

The relevance of this study lies in its practical application in the manufacturing sector of SMEs. It is expected that the results can be implemented by these companies, providing them with a competitive advantage by improving their ability to meet delivery deadlines, optimizing resources, and enhancing customer satisfaction. The present scientific article is divided into seven parts, which are Introduction, State of the Art, Methodology, Contribution, Validation, Acknowledgments, and Bibliography.

### 1.1 Objectives

The objective of this study is to demonstrate the operation of the Lean Manufacturing methodology in reducing production delays in small companies. The efficiency of using various improvement tools such as 5S, Poka Yoke and work standardization will be validated. Finally, their operation will be measured by reducing the percentage of delays.

## 2. Literature Review

### 2.1. Poka Yoke

Poka-Yoke is a relevant approach within the Lean Manufacturing methodology, as it focuses on the prevention and elimination of errors of human origin (De Pie et al., 2023). This methodology has demonstrated its effectiveness in improving product quality and optimizing workflow in many business cases (Summit et al., 2022). Various studies have addressed its applications in industrial contexts, providing evidence of its positive impact. For instance, (Peña et al., 2020) examined the implementation of Lean practices in the water heater manufacturing industry, highlighting the effectiveness of these methodologies in enhancing efficiency and reducing production times. Similarly, it investigated the application of Lean Manufacturing in a cable production process, emphasizing how this methodology contributed to workflow optimization and the reduction of defects in products (Shah et al., 2022).

### 2.2. 5S

With the aim of enhancing cleanliness and efficiency within the company, the 5S methodology was employed. Widely recognized as a Lean Manufacturing tool, it has been successfully used in numerous organizations to improve efficiency and productivity, as explained by (Barot et al., 2020). In this context, the 5S methodology emerges as a crucial tool for addressing challenges related to reducing final product delivery times. Through a comprehensive literature review, a systematic examination of its application in similar companies and contexts was conducted (Cuggia et al., 2021). These converging findings substantiate the application of the 5S methodology in our research, as analogous contexts have tackled various aspects. For instance, they focused on the organization of workspace, which involves eliminating elements from the production process that are unnecessary (Gallo, 2020). Additionally, they emphasized storage optimization. For example, one of the reviewed articles mentioned that barrels used to occupy more space than the company required due to a less efficiently distributed allocation. This resulted in time losses during the search for materials. In this regard, (Zamalloa et al., 2021) have developed approaches to implement this method in small and medium-sized Peruvian enterprises.

Furthermore, the conducted studies not only focus on implementing the conventional 5S method but also propose the 7S approach.

### 2.3. Application of Standardization Work

The effective implementation of work standardization requires the participation of all members of the organization, as it ensures the uniformity of all tasks, reducing variations and errors in the results of operations. Additionally, it facilitates the onboarding of new employees by providing clear and properly documented guidelines. The importance of flexibility and adaptability in implementing work standardization, as it allows for rapid responses to market demands and the ability to adjust to unforeseen events that may occur in a changing context, such as agile organizations (Lee et al., 2019). Organizational culture characterized by adaptability promotes a mindset of continuous improvement among employees, as they will be willing to change and progressively enhance standardized processes based on the learning and feedback obtained from their daily work (Singh et al., 2022).

# 3. Methods

For the development of this research, three phases were conducted, focusing on a diagnosis to understand the problem, the development of Lean Manufacturing tools, and finally, the analysis of the results (Figure 1).

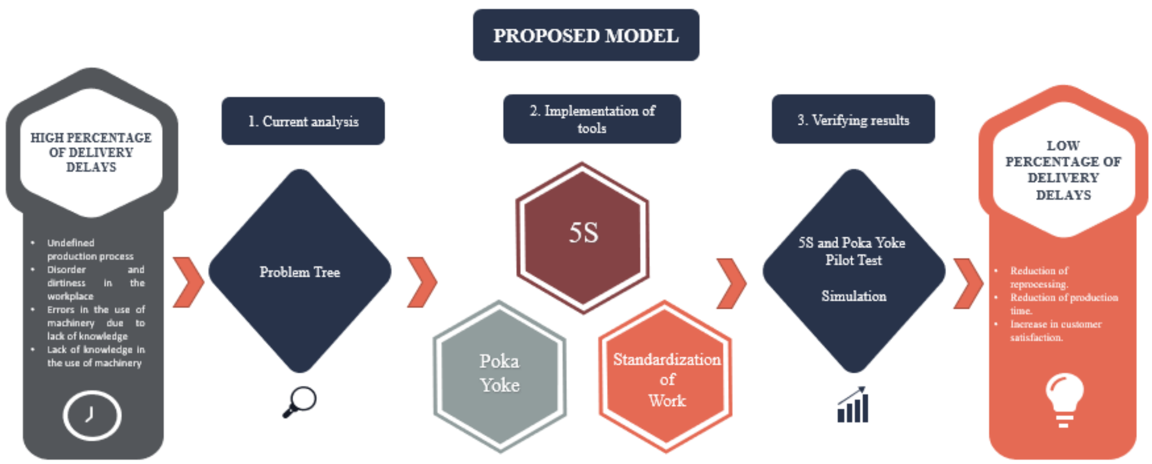


Figure 1. Proposed model

## 3.1. Model components

### 3.1.1 Current Analysis

This phase aims to analyze the current situation of the company and diagnose the state of the issues. Considering that the company lacks documentation detailing the processes, we will apply the Gemba tool, which involved visiting the workplace, conducting interviews with the operator in charge of production management, and learning more about the current product quality. Based on the gathered information, in addition to previous interviews with the company's manager, we will use the Ishikawa diagram to delve deeper into the problems mentioned. Based on all the collected and identified information, we organized the reasons, causes, and potential solutions in a problem tree, which served as a guide to arrange the main causes of delivery delays.

### 3.1.2 Implementation of the tools

The first tool implemented was Poka-Yoke for information in the mixing process. In these operations, visible printed guides have been placed at machinery stations so that the operator has a reference about their use in case of doubts. This was done to improve the machinery usage more quickly, precisely, and reduce time between operations. Additionally, posters about proper mixing were created, as well as a color palette manual to provide the operator with guidance and prevent potential errors in mixing colors.

The second tool to be applied is 5S with the aim of maintaining a clean and organized workplace. The manager and the operator were trained, and together, a resource organization system and a cleaning plan were implemented. These steps helped optimize the time between one process and another, as currently, a significant amount of time is wasted due to the disorder of the tools to be used, resulting in reprocessing due to paint stains from other colors and foreign residues on the final product.

The final tool implemented was work standardization. This tool was applied throughout the production process of the company. Together with the manager and the operator, a flowchart was created that includes the processes to be carried out during production. This includes quality controls that will be documented and reviewed to prevent future errors, and it should be present in the work area, available and visible to all those present in the production area. Quality parameters, methods, reports, specifications, and responsible parties within the production processes will be defined. Additionally, the results and/or applied changes will be documented to have historical data available for future use.

### 3.1.3 Verify the results

In this phase, the results were evaluated after implementing the improvement tools. This phase was crucial to determine the success of the proposed model. The variation in indicators was assessed at the conclusion of the defined period and compared to the initial state. For the evaluation of 5S and Poka-Yoke, a pilot test was conducted over a 3-month period with bi-weekly visits. At this point, discussions were held with the manager about enhancing the implementation of 5S and Poka-Yoke throughout the production process on a broader scale. Finally, feedback was provided to both the operator and the company's manager. To validate the results of work standardization, along with the overall process time, a simulation was conducted using Arena 16.1 Software.

To validate the desired results, we have proposed the following indicators (Table 1):

Table 1. Indicators

| Indicators | Formula | Unit |
|---|---|---|
| On time deliveries | $\frac{Liters\ produced\ within\ the\ standard\ time}{Total\ requested\ liters}\ x\ 100\%$ | Liters |
| Delays in production start | $\sum Time\ to\ initiate\ the\ production\ process$ | Hours |
| Undesired paint tones | $\frac{Liters\ of\ paint\ remixed\ due\ to\ a\ color\ mismatch\ error}{Total\ liters\ mixed}\ x\ 100\%$ | Liters |
| Paint imperfections | $\frac{Liters\ of\ paint\ reprocessed\ due\ to\ paint\ imperfections}{Total\ liters\ of\ homogenized\ paint} x100\%$ | Liters |
| Grinding calibration | $\sum Average\ grinding\ calibration\ time$ | Hours |
| 5S Audit | $\sum Implementation\ of\ 5S$ | % |
| Poka-Yoke Audit | $\sum Implementation\ of\ Poka\ Yoke$ | % |

## 4. Validation

The manufacturing sector, particularly micro and small businesses, face various challenges, with one of the primary concerns being inadequate order delivery compliance. Previous research, such as the study conducted by Smith and Johnson, has examined the impact of delivery delays on business performance (García et al., 2022). As a result, the underlying causes of delays were scrutinized, and remedies were suggested to enhance efficiency in the delivery processes. In the specific context of the foam furniture paint industry, it's noteworthy to consider that this sector is relatively unfamiliar in Peru. Therefore, to facilitate proper comparative analysis, a competitor company struggling to improve its delivery compliance was chosen. A comparison of the study company's data with that of the competitor reveals that the competitor company achieves a 73% delivery compliance rate, while the study company attains 69.8% compliance. The latter confronts difficulties with deliveries, failing to meet the set deadlines with customers. The key issue pinpointed in the study company is the deficient delivery compliance, stemming from the lack of standardized production processes, inadequate training, and disorder and untidiness in the workspace. This low compliance bears a negative economic impact, resulting in a 10% refund of the established price due to delays. In the analyzed period, this translated to a loss of $2,934. To discern the root causes of the problem, a causal tree analysis was employed, identifying two primary factors contributing to the subpar delivery compliance (Figure 2).

## 4.1. Poka Yoke Validation

For the validation of this tool, a pilot test was implemented over a designated period of 3 months, encompassing 4 visits. Throughout the test, a form was utilized to measure the observed variables during the process, along with feedback from the operator overseeing production. These values represented an implementation percentage, with the aim of reaching 100% by the end of the fourth visit.

Next, the results obtained during the 4 visits will be displayed, along with their evolution in a graph (Figure 3 and Table 2).

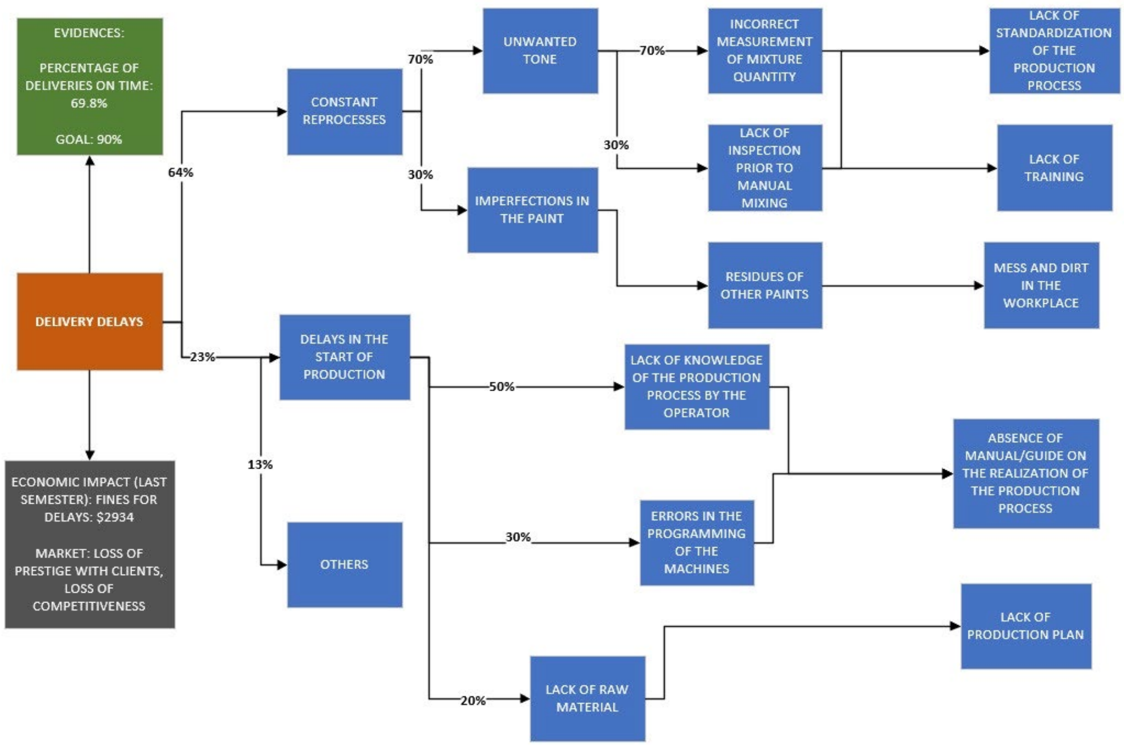


Figure 2. Problem Tree

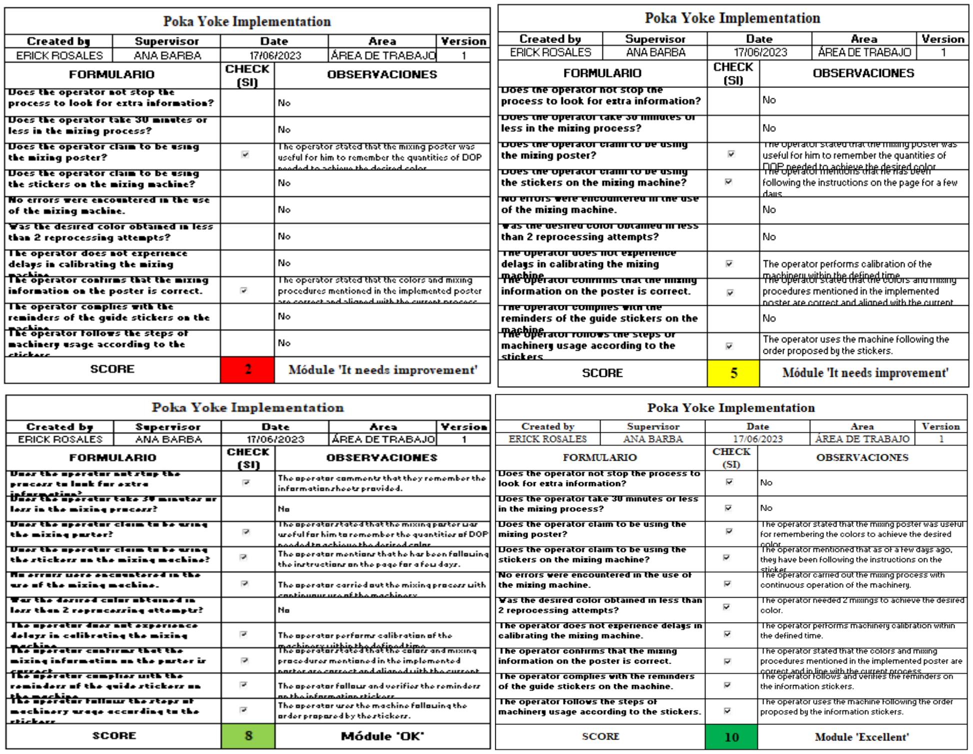


Figure 3. Poka-Yoke Pilot Test

In the following Table (Table 2), we will present the evolutionary results of the Poka-Yoke implementation.

Table 2. Poka-Yoke Implementation

| **Data / Visit** | **Initial View** | **Visit 1** | **Visit 2** | **Visit 3** | **Visit 4** |
|---|---|---|---|---|---|
| Score | 0 | 2 | 5 | 8 | 10 |
| Implementation | 0% | 19.81% | 52.12% | 72.37% | 94.60% |

### 4.2 5S Validation

After implementing the documents and improvements along with the corresponding training, the validation of the 5S implementation was carried out through a pilot test consisting of 6 visits. These visits occurred bi-weekly over a period of 3 months. Here are the initial results of the 5S evaluation and the outcome after the 6 visits to the company's plant (Table 3). The results of the 5S pilot test can be observed in Figure 4.

Table 3. Results of the 5S pilot test

| **Category/Number of visits** | **1** | **2** | **3** | **4** | **5** | **6** |
|---|---|---|---|---|---|---|
| Organize and classify | 5 | 5 | 7 | 8 | 8 | 10 |
| Order | 4 | 4 | 5 | 7 | 9 | 10 |
| Cleaning | 2 | 4 | 5 | 7 | 8 | 9 |
| Keep | 1 | 5 | 5 | 6 | 8 | 10 |
| Discipline | 6 | 6 | 6 | 5 | 7 | 9 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Total Average | 18 | 24 | 28 | 33 | 40 | 48 |
| Implementation rate | 36% | 48% | 56% | 66% | 88% | 96% |

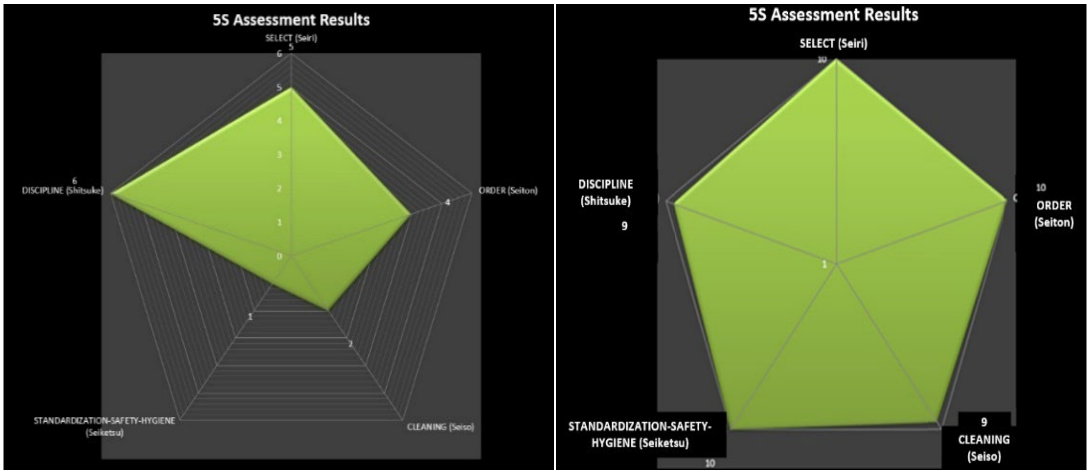


Figure 4. Initial Review vs. Final Review

## 4.3 Validation of the Standardized Work

The scope of the system encompasses from the weighing stage to the packaging of the finished product, as the operation time is influenced by order demand, and it includes the production area where the improvements were applied. The Input Analyzer software of the Arena program was used to determine the most appropriate distribution at each stage of the process. It is important to highlight that the simulated process only changes in times (Table 4).

Table 4. Distributions adjusted for each activity

| Activity | Adjusted Distribution | Units |
|---|---|---|
| Weighing | Unif (60;120) | Minutes |
| Mixing | Unif (60;120) | Minutes |
| Moistening | Unif (90;210) | Minutes |
| Homogenization | Unif (120;180) | Minutes |
| Grinding | Unif (60;150) | Minutes |
| Matting | Unif (72;100) | Minutes |
| Packaging | Unif (25;35) | Minutes |

Next, the company's initial and final systems are visualized, as the work standardization applied in the simulation only affected the operation times (Figure 5).

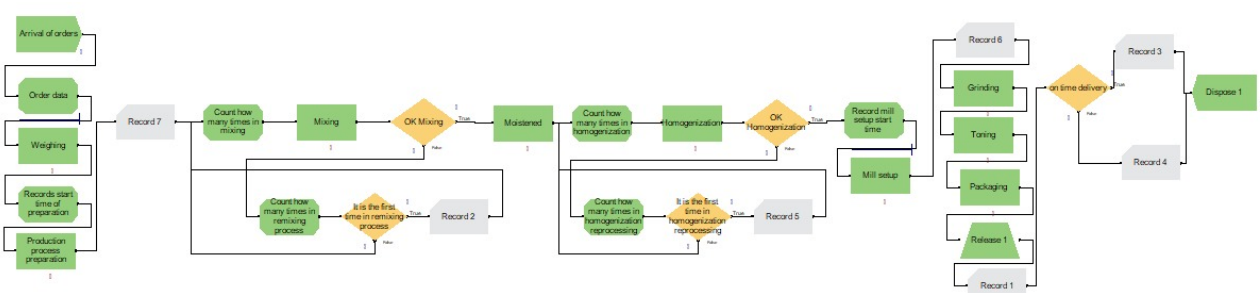


Figure 5. Representation of the current system

The implementation of simulation using the Arena program has had a significant impact on improving on-time deliveries at the company. Before the simulation, only 69.8% of the orders were fulfilled on the scheduled date, but after the implementation, delivery efficiency increased dramatically, reaching a fulfillment rate of 91.8%, considering that the standard time per order to produce was equal to or less than 20 hours.

Table 5. Results of the indicators

| Problem | Main Indicator | As Is | Objective | To Be | Variation | Indicator | As Is | Objective | To Be | Variation |
|---|---|---|---|---|---|---|---|---|---|---|
| Constant delivery delays | On time deliveries | 69.8% | 90% | 91.8% | +22% | Delays in production start | 3.81 H | 1 H | 0.42 H | -3.39 H |
| | | | | | | Undesired paint tones | 70.20% | 30% | 35.46% | -34.74% |
| | | | | | | Paint imperfections | 28.60% | 5% | 4.90% | -23.7% |
| | | | | | | Grinding calibration | 0.75 H | 0.5 H | 0.14 H | -0.61 H |
| | | | | | | 5S Audit | 36% | 85% | 96% | +60% |
| | | | | | | Poka-Yoke Audit | 19.81% | 90% | 94.60% | +74.79% |

The use of simulation allowed for identifying the outcomes of the implemented Lean Manufacturing tools. For instance, the mixing operation experienced a reduction from 36.5 to 18.5 hours in processing times, enabling the completion of more orders in less time, thanks to the implementation of Poka-Yoke. Additionally, the homogenization operation saw a decrease from 14.9 to 2.6 hours, due to the implementation of the 5S methodology.

These tangible results support the effectiveness of simulation with the Arena program in enhancing on-time deliveries. The company will continue to utilize this powerful tool to further optimize production, ensuring that customers receive their orders as agreed upon and strengthening their reputation as reliable suppliers in the furniture foam paint market (Table 5).

## 5. Discussion

Two scenarios were validated, comparing the current scenario with the improved scenario after the implementation of the pilot tests and simulation. It's worth noting that the implementation of the tools had a designated duration of 3 months.

## 6. Conclusions

In conclusion, the implementation of the 5S tool has been pivotal in reducing delivery times, leading to a significant improvement, and positioning the company competitively in the market. The positive transformation in space and resource management has boosted productivity and adherence to agreed-upon customer deadlines. Likewise, the use of Poka-Yoke has proven effective in preventing errors and defects in the process, with employees showing commitment to identifying sources of error and proposing solutions, fostering a culture of continuous improvement within the company.

Furthermore, through flowcharts and detailed documentation, rigorous sales control has been achieved, resulting in a substantial reduction in fines due to delivery delays. This has minimized errors and ensured consistent and high-quality production. Work standardization has had a positive impact, providing greater consistency in the company's results. In summary, the implementation of these three tools has generated a positive impact on Onyx International, leading to efficiency, quality, and profitability. The waste reduction from 5S, the use of Poka-Yoke to prevent errors, and the work standardization with detailed documents have been key in satisfying the company's customers.

## References

Afflerbach, P., Kastner, G., Krause, F., & Röglinger, M., *The business value of process flexibility: An optimization model and its application in the service sector.* Building Research and Information, 48(8), 839-855, 2020.

Akimov, S.S., *Optimization of production processes when building a value flow map. Journal of Physics*: Conference Series, 5(Q1), 13, 2019.

Barot, R. S., Raval, K., Berawala, H. S., & Patel, A., *Implementation of lean practices in water heater manufacturing industry*. Materials Today Proceedings, 2020.

CA F: Banco de Desarrollo de América Latina., *El Caribe se integra en el ADN de CAF, 2023*. Recuperado de https://www.caf.com/es/actualidad/noticias/2023/07/el-caribe-se-integra-en-el-adn-de-caf/.

Cagnin, M. I., & Nakagawa, E. Y., M-PoP: *Leveraging the systematic modeling of processes-of-business processes.* Business Process Management Journal, 28(1), 265-285, 2022.

Chatzistamoulou, N., & Tyllianakis, E., *Improvement Model Based on Four Lean Manufacturing Techniques to Increase Productivity in a Metalworking Company*. ACM International Conference Proceeding Series, 2022.

Cuggia-Jiménez, C., Orozco-Acosta, E., & Mendoza-Galvis, D., *Lean manufacturing: a systematic review in the food industry*. Información Tecnológica, 21(5), 624-632, 2020.

De Pie, B., & Lamari, F., *Reducing Construction Execution Conflict while Increasing Productivity: The link between Internal Integration and Financial Performance.* Journal of Legal Affairs and Dispute Resolution in Engineering and Construction, 15(1), 04020002, 2023.

Gallo, T., Industry 4.0 tools in lean production*: A systematic literature review*. Procedia Computer Science, 2020.

García, J., *Improvement Model Based on Four Lean Manufacturing Techniques to Increase Productivity in a Metalworking Company.* Proceedings of the LACCEI International Multi-Conference for Engineering, Education, and Technology,2022.

Lee, S., & Park, J. , *Effects of work standardization on labor productivity: Evidence from the semiconductor industry.* International Journal of Industrial Ergonomics, 69, 132-138, 2019.

Pena, R., Ferreira, L. P., Silva, F. J. G., Fernandes, N. O., & Pereira, T., *Lean manufacturing applied to a wiring production process.* Procedia Manufacturing, 47, 441-446, 2020.

Shah, S. H., Atweh, L. A., Thompson, C. A., Carzoo, S., Krishnamurthy, R., & Zumberge, N. A., *Workflow interruptions and effect on study interpretation efficiency. Journal of the American College of Radiology*. Advance online publication, 2022. doi:10.1016/j.jacr.2021.12.098

Singh, R. K., & Gurtu, A, *Prioritizing success factors for implementing total productive maintenance* (TPM). Journal of Quality in Maintenance Engineering, 28(3), 474-492, 2022.

Summit H. Shah, MDa, Lamya A. Atweh, MDa, Corey A. Thompson, MDb, Stephanie Carzoo, MSa, Rajesh Krishnamurthy, MDa, & Nicholas A. Zumberge, MD., *Workflow Interruptions and Effect on Study Interpretation Efficiency, 2022*. doi: 10.1016/j.jacr.2021.12.098.

Tulabandhula, T., Sinha, D., & Karra, S., *Optimizing revenue while showing relevant assortments at scale*. European Journal of Operational Research, 2022.

Zamalloa Menacho, A., Mamani Rojas, R., Flores Pérez, A., & Collao Díaz, M., *Propuesta de modelo productivo basado en Lean y Mejora Continua para mejorar la productividad en pymes de panadería*. IEIM, 7(2), 45-53, 2021.

Zhang, Q., et al. , *Customizing work standardization for small and medium-sized enterprises*: A case study in the food processing industry. Journal of Cleaner Production, 277, 124061, 2020.

## Biographies

**Mariafe Olenka Francia Barba** Mariafe Olenka Francia Barba is a Bachelor of Industrial Engineering from the University of Lima, with specializations in Project Management and Business Engineering. She currently holds the position of Project Manager at an investment company.

**Erick Linder Rosales Espinoza** is an Industrial Engineering student from the University of Lima with experience in quality, commercial and human resources areas, with a specialization in Lean Manufacturing, quality, projects and is currently working as a pre professional practitioner in a renowned company in the financial sector.

**Martín Collao-Diaz** at ESAN University and Industrial Engineer from Universidad de Lima specialized in supply chain management and operations. A leader with more than 25 years of local and international experience in national and multinational companies in industrial, hydrocarbon, and mass consumption sectors. Broad experience in supply chain management (purchasing, inventory, suppliers and supply sources management, logistics: transport, distribution and warehouse management), operations (planning and control of production and maintenance), and integrated system management (ISO 9001, ISO 14001, and OHSAS 18001). Business alignment based on sales and operations planning (S&OP). Besides, continuous search for improvements in profitability based on process optimization and saving projects using tools such as Six Sigma methodology, among others, focused on being a High-performance Organization (HPO). Development of a high-performance team. Member of IEEE and CIP (College of Engineers of Peru).