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*Original Article*

# A Proposed Model for Inventory Management to Minimize the Rate of Raw Materials Tied up of Textile Industry with Lean Engineering Tools

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***Abstract*** *- This research focuses on improving the stock rotation of the raw materials warehouse of a sheep wool yarn production plant. The objective is to reduce excessive operating costs, the misuse of resources and improve the distribution of materials in the warehouse. This article develops an innovative solution, where the 7S, Poka-yoke, Slotting, and Kardex tools were used to improve the deficiencies in the inventory management systems and the storage conditions of the materials, as well as errors in the stock register. The case study is divided into four stages analysis of the problems and causes, improvement of inventory management activities and tools, evaluation of the impacts generated, and validation of the proposed model. This was carried out in the simulation software Arena, where an increase from 0.83 to 2.4 in raw material turnover, reduced errors in inventory control, and an improvement in the efficiency of inventory management were observed. This case study provides a foundation for other lines of investigation and the model's use by businesses with comparable traits.*

***Keywords*** *- Inventory, Textile industry, 7S, Poka-yoke, Kardex, Slotting, Lean warehousing.*

## 1. Introduction

According to the BCRP, in Peru, the manufacturing sector accounted for 13.2% of the Gross Domestic Product (GDP) in 2021; within this sector, textile production is one of the most important and essential because its income is equivalent to US$151,248.82 million, which represents 3.5% of the national GDP [1].

However, according to reference [2], during the last few years, its representativeness has decreased considerably, which is explained by the increase in foreign producer markets. This has been reflected in the 20.8% increase in imports in the last quarter of 2022 compared to 2021. This, in turn, is explained by the reduction of retail stores and, therefore, the decrease in sales of the national manufacturing industry [3]. Thus, foreign markets have increased, specifically Asian and Central American markets internationally. For this reason, domestic companies seek to efficiently use all their resources through new and more tools and methods that contribute to improving decision-making.

Likewise, one of the main objectives of the industries must be to respond quickly to the needs of the clients since it is fundamental to achieve permanence in such a dynamic and volatile market [4].

Since it is evident that textile companies have failures in their operations, several studies have recently focused on the problems in the industry. Consequently, it is vital to analyze and provide an effective remedy for this crucial industry [5]. These problems within the industry arise from the beginning of the raw material purchasing processes; because having a deficiency in inventory management, in turn, can cause an inconsistency between the actual inventory and the recorded inventory, which leads to a purchase of surplus and existing materials, and what produces both an increase in costs and disorder in the work area; generating setbacks in the entire production chain.

As mentioned in reference [6], companies in Peru have specific problems in managing their inventories and warehouses, mainly related to inadequate demand planning, inefficient physical distribution of the warehouse, and lack of stock control. In addition, these sector problems were evaluated in several studies, finding various causes such as inadequate flow of materials, defective products, high cycle times in the production chain, and delays in order delivery [7].

These problems in the supply chain affect the company's sustainability; this is not only an external standard to meet stakeholders' requirements (Effectiveness) but must also consider compliance with internal standards to ensure profitability and business continuity (efficiency). This situation evidences the problems faced by both the sector and the work area to be studied, so it is pertinent to seek possible solutions to the problem described [8].

Companies in the textile sector, in general, have as a problem the low productivity of their processes, which generates low competitiveness compared to other companies in the industry [9-11]. In addition, according to the points mentioned above, such as the relevance of this sector, the market in which it operates, and the low performance of the production process, the need arises to investigate tools that contribute to raising its operational quality while monitoring and evaluating its key strategies [12].

Therefore, including Lean Warehousing tools is a viable option for the reduction of excess inventory in the production of yarns in a medium-sized textile company since the objective is to identify, analyze and seek an improvement of the indicator to reduce operating costs, add value to the production process, improve the company's operability and eliminate bottlenecks. It can be applied in any company with similar problems. Likewise, a problem is solved in an area where the entire production process begins and which is directly related to the rest of the value chain.

In this context, although there is a wide variety of studies that seek to solve this problem, this research has an innovative and differential approach, making a model based on Lean tools, which will be used in the storage of raw materials, which is where the production process begins in a sector that has many deficiencies and global relevance, so it seeks to generate an improvement and optimize the raw materials with which the organization already has, before investing its liquidity in the purchase of resources for production.

The research has the following structure: Section II contains the State of the Art divided into four typologies. Section III includes the research contribution, and then, in Section IV, the validation of the proposed model is presented. Finally, Section V explains the conclusions of the article.

## 2. Literature Review

### *2.1. Application of 7S*

The 7S model of Lean Manufacturing should be synchronized to improve overall performance. Although the 5S methodology contributed to improving efficiency and productivity in operations, including safety and spirit at work emphasizes utilising human resources as a critical factor in the continuous improvement of organizations [13]. Also, the implementation of safety as a principle in the methodology is due to the need to include the requirement in reducing and eliminating occupational hazards [14]. In addition, this implementation is mainly based on the commitment and discipline of the participants to work constantly under the established protocols [15].

Therefore, the application of the last S plays a vital role in the previous steps, as well as in the role of top management and collaborators to promote the improvement of the six phases, and this is because if the organization has leaders involved in the knowledge and cultivation of the methodology, it tends to be more relevant to the whole team and its proper functioning [16].

Using the case study on the application of the 7S methodology as a guide, it had a positive effect in 100% of the implementation workshops, creating a calm environment and improving the working environment, ensuring the prevention of accidents and the reduction of time spent looking for tools, materials, among other things. Also, although the implementation was carried out in a company dedicated to the manufacture of buckets, the main finding of the research is that the application can be carried out in any sector [17].

### *2.2. Application of Poka-Yoke*

Poka-yoke is a tool that Shigeo developed after World War II, which was designed to focus on the search for quality and possible defects that may occur in operations [18]. Also, this Japanese term refers to "error-proof", so it is a technique that focuses on using methodologies in procedures to avoid inaccuracies in the system.

Therefore, it is proposed as a solution to prevent and reduce human errors through restrictions in the process of products and services but is characterized by a low implementation cost; also, these intelligent tools can achieve a reduction of up to 33% of human controls, which in many cases tend to be repetitive [19].

For example, Lean Manufacturing tools and a socio-technical strategy that employs tools like Kanban and Poka-Yoke to remove excess inventory enhanced productivity indicators in the textile industry. These tools, as well as the use of 5S and preventive maintenance, resulted in a 20% decrease in the execution time of the sewing and finishing processes [20].

### *2.3. Application of Slotting*

Slotting is an activity within the logistics area that focuses on distributing items between warehouses. The main objective of this system is to make better use of warehouse space and reduce transit times. For this reason, it has tools, techniques, and methods to optimize and improve internal operations. However, it is necessary to consider the cost overruns assigned to improvements in warehouse sizing [21, 22].

In the case study corresponding to the implementation of Lean principles to reduce nonconformities in a warehouse of the metal-mechanical industry, which was characterized by incorrect product deliveries, inadequate space segmentation, and lack of a product identification system, the Slotting tool was used to improve stock management, since it has a positive impact on storage, location and order preparation; this is because it establishes the place of products, mainly taking into account the demand for them [23-25].

Likewise, in the case study corresponding to reference [26, 27], in which an implementation of the Slotting methodology was carried out for eight weeks to correctly relocate a group of items, with which it was possible to reduce efforts during production, as well as to guarantee a more significant rotation in the warehouse, and above all to ensure the sale of these products, which, if the allocation were not carried out, would be classified as immobilized.

### *2.4. Application of Kardex*

The use of the Kardex tool in inventory management contributes to inventory control, and this is because the system considers the inputs and outputs of materials and products, so its main feature is the improvement in the circulation of inventory and its storage, which leads to avoiding operational and economic losses [28]. Likewise, it is essential to consider the business variables to allow greater access to information and to achieve a follow-up of this [29].

Due to the implementation carried out, which helped the management of the inventory plan, often non-existent, the Kardex tool was used to improve stock coverage from 43% to 100% in the realization of the warehouse management model integrating BPM Lean Warehousing to increase order fulfilment in SMEs distributors [30]. Thus, a table water bottling company used the Kardex tool to develop and execute a materials requirements plan, Kardex, and a preventive maintenance plan to save operating costs. In this scenario, it was necessary to keep a comprehensive inventory record due to the loss of materials and increased operating costs. As a result, material loss decreased from 33% to 9% at the end of the implementation.

## 3. Method

### *3.1. Rationale for the Proposed Model*

The model proposed in this research is the lean methodology, which includes tools that reduce excesses and achieve better management and operation of a warehouse in a company that produces and markets sheep wool yarn.

This model shows the tools that will be useful to solve a low inventory turnover, such as Poka-yoke and 7S; likewise, tools such as Slotting and Kardex are applied for inventory management. Table 1 shows the comparative matrix of the studies contributing to the research.

### *3.2. Proposed Model*

As part of the proposed model, articles based on lean methodologies have been found to explain the mentioned tools' use. However, they focus on something other than directly applying to companies that produce and supply sheep wool yarns. In other words, the application of these tools still needs to be improved in the textile industry.

Similarly, these articles provide the necessary and reliable information on using these tools but must have defined models for managing warehouses in the textile sector. To show the value of the approach and the tools used, this study contributes by creating a warehouse management model for textile industries and putting the model into practice. The outcomes will be evaluated using indicators and compared to the sector average.

An issue tree, a Pareto diagram, a SIPOC, a process diagram, and indicators were used to examine the company's status to determine the instruments required to produce improvement. To build an acceptable storage method, decrease chaos and disarray, and enhance safety measures inside the warehouse, the 7S gadget was installed in this manner. Secondly, a Kardex inventory management system was used for inventory control and location. This system allows us to have a starting point for identifying and recording inventories. This tool will enable us to speed up the purchasing area's inventory consultations and allow us to consider the material available for production.

Finally, using a figure visual classification system, the poka-yoke tool was applied to classify the type of wool without error. This tool is one of the most valuable systems for minimizing mistakes in warehouse management. Likewise, the Slotting tool was implemented to optimize the location of materials within the warehouse. This allows having a more agile system in the storage process since the material movement flow is considered.

It was determined throughout the creation of the suggested model, as seen in Figure 1, that poor inventory turnover is the primary issue. This made it feasible to investigate the causes and fundamental causes of the issue thoroughly. As a result, technologies that may be adopted via a simulation or pilot are picked while considering the company's actual status.

### *3.3. Model Components*

The model is divided into three components:

#### *3.3.1. Component I: Analysis of the Current Situation*

In this phase, we started by examining the processes that are performed in the company to find the root causes of the problems. In this way, they can be solved using the tools in the next phase.

**Table 1. Comparative matrix of state of the art vs The causes of the research problem**

| Causes / Articles | Inadequate Method of Inventory Control | Warehouse Disorganization | No Inventory Records of Raw Materials |
|---|---|---|---|
| [14] | | | Kardex |
| [6] | | 7S | |
| [9] | Poka-yoke | | |
| [12] | Slotting | 5S | |
| [15] | | 5S | Kardex |
| [10] | Poka-yoke | 5S | |
| [16] | | | Kardex |
| **Proposal** | **Poka-Yoke / Slotting** | **7S** | **Kardex** |

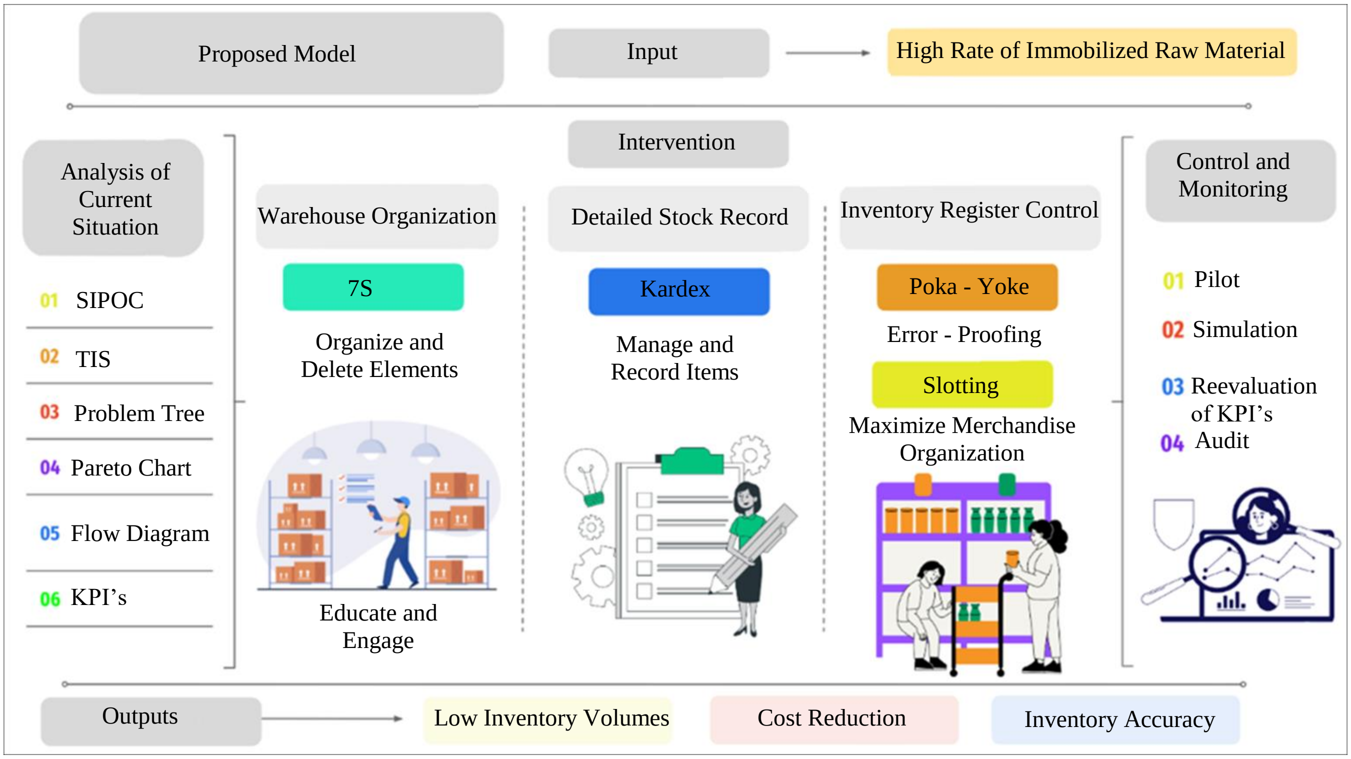


**Fig. 1 Proposed model**

*3.3.2. Component II: Tool Development*

*7S*

- **Classification**: Distinction of the materials according to the characteristics of the sheep fibre.
- **Order**: A specific place was assigned, considering the distinction of characteristics.
- **Cleaning**: Eliminating products that do not meet the corresponding quality specifications through control sheets.
- **Standardization**: Use of manuals for the processes carried out in the warehouse.
- **Discipline**: Durability of the process over time.
- **Safety**: Implementing protective equipment and eliminating items that do not correspond to the workplace.
- **Spirit at work**: Commitment of the participants to comply with the implementation.

*Poka-Yoke*

Before the tool's implementation, we identified the materials in stock in the warehouse. At the same time, we identified the types of materials that have a higher inventory turnover and at the same time, present errors or difficulties in their registration. Likewise, it is necessary to establish the names of the stocks to classify them in the best possible way.

This tool allowed us to visually categorize the different types of stock within the warehouse since this tool will enable us to identify products and allow us to have the scope.

*Slotting*

Before implementing slotting, the flow of incoming and outgoing materials within the raw materials warehouse was identified since this allows analyzing which types of materials are in most significant demand so that, when applying the tool, the types of materials with the highest consumption can be identified.

It was also necessary to analyze the state of the warehouse and the storage order. This tool optimized the location of materials within the warehouse to improve the flow of the process.

*Kardex*

In recording and managing stock within the raw materials warehouse, an estimate was made of the number of raw materials in the warehouse, the number of raw materials that would come in due to planned purchases, and the number of raw materials leaving the warehouse for yarn production. With this estimate, the Kardex tool was implemented to track inventory levels and effective stock control accurately. With this, the relevant information of each material is recorded, such as its quantity, date of receipt, departures, and time in the warehouse.

*3.3.3. Component III: Implementation*

The implementation will be assessed throughout this time to ensure the goals are met, a better model is developed, and the intended indicators will be monitored.

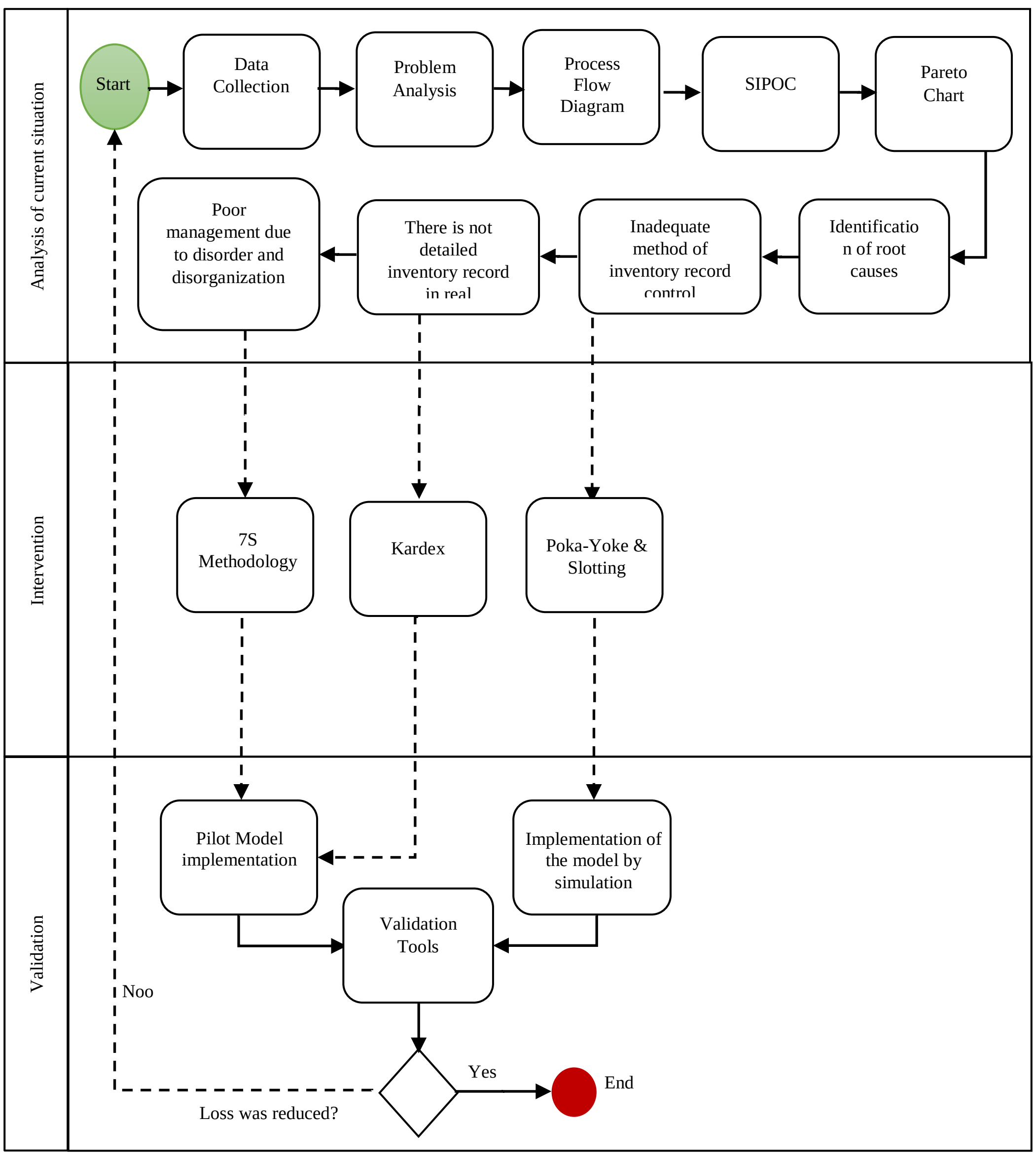


**Fig. 2 Proposed method**

### *3.4. Model Indicators*

*3.4.1. Raw Material Inventory Turnover*

This indicator expresses the frequency with which raw material inventory is renewed or used in each period.

*Rotation of Raw Materials*

This indicator measures the average time raw materials remain in inventory before use.

$$\text{Rotation of raw materials} = \frac{(\text{Daily cost of raw materials})}{(\text{Average inventory value of raw materials})} \quad (1)$$

*Inventory Accuracy*

This indicator measures the accuracy and reliability of physical inventory records compared to book inventory.

$$\text{Inventory accuracy} = \frac{(\text{Theoretical inventory value} - \text{Value of physical inventory}) \times 100\%}{(\text{Value of book inventory})} \quad (2)$$

*Immobilized Raw Materials*

This indicator measures the number of raw materials stored in a company's inventory for an extended period without being used in production.

$$\text{Immobilized Raw Materials} = \frac{(\text{Value of raw materials tied up}) \times 100\%}{(\text{Total value of raw materials in inventory})} \quad (3)$$

## 4. Results

### *4.1. Initial Diagnosis*

The process begins with the arrival of the material at the plant, where according to company policy and strategy, each material must be inspected and reviewed. As part of the first diagnostic, an inspection was also conducted, and it was discovered that the company's primary issue was the poor inventory turnover of raw materials, which was 0.83, indicating that the inventory takes longer than a month to deplete and be replenished.

This had a yearly economic effect of 79,555 PEN in inventory expenses or 12.03 percent of sales. In addition, the inventoried raw material needed to be more orderly and organized in the warehouse. This directly impacted the number of purchases made by the designated area since the quantity did not match what was recorded.

### *4.2. Validation Diagnosis*

Two simulation techniques were implemented utilizing Arena software to reflect the company's current situation and future development.

The information utilized in this comparison was gathered, including corporate background information, the number of bales that entered the warehouse, storage time, waiting time, and other information. Therefore, it was discovered via statistical analysis that the sample determines the distribution of the data. Additionally, using the software's Input Analyzer extension, producing the proper distribution to finish the model was essential. For the validation of the pilot, photographic evidence is attached (Figure 3), where the situation of the raw materials warehouse before the improvement is presented. Photographic evidence (Figure 4) is attached below after implementing the tools.

**Fig. 3 Initial situation**

**Fig. 4 After implementation**

### *4.3. Simulation*

Two process simulations using Arena software were run to depict the existing state of the company's process flow and the suggested change. The firms gathered the information that was utilized in this simulation. The model considers past information, such as the number of bales entering the warehouse, storage, and waiting durations.

Additionally, statistical computations discovered the sample to establish the data distribution. To complete the model, it was also essential to determine the optimum distributions using the Arena software's Input Analyzer extension. Allotted distributions of simulation model activities in the Arena Simulator are shown in Table 2.

The process's scope begins with the wool bales' arrival at the plant. Once the product is in the plant, it goes through several activities, ending with storing the bales. Table 3 shows the entities, attributes, and activities of the simulation system performed. Finally, Figure 5 shows the representation of the improved process in the simulation software Arena Simulator. The model was run for seven days to evaluate the indicators, considering 9.5 hours of daily work. Table 4 shows the improvements obtained.

Inventory turnover was 0.83 times; after the improvement, it was obtained that the raw material has a turnover of 2.41 times since a better demand forecast and inventory control were implemented. In addition, the amount of immobilized stock in the warehouse was reduced, resulting in an improvement of 9.32%. In addition, the accuracy of raw materials was increased by 0.99%.

### *4.4. Future Work*

Some limitations and areas for improvement were identified that could be addressed in future research. Some possible areas for future research include:

- We comprehensively analyse variables that facilitate implementing or adapting Lean methodology in different sectors and specific areas.
- Investigate using Lean tools in other supply chain processes, such as production planning and inventory management.
- Evaluate the impact of implementing Lean tools on key performance indicators such as productivity, quality, and customer satisfaction.
- Conduct comparative studies between companies or sectors to identify best practices and lessons learned in implementing Lean tools.
- Investigate the application of emerging technologies, such as artificial intelligence and the Internet of Things, in combination with Lean tools to improve efficiency and decision-making in warehouse and supply chain management.

**Table 2. Activity-adjusted distributions**

| Activity | Adjusted Distributions | Unit of Measure |
|---|---|---|
| Quantity of bales arriving in the system | NORM (6.6, 1.85) | Units |
| Weighing time of incoming material (per unit) | TRIA (167, 197,266) | Seconds |
| Bale inspection (per unit) | NORM (53.5,7.23) | Seconds |
| Classification of materials (per unit) | NORM (48.7,3.87) | Seconds |
| Material storage (per unit) | NORM (407,30.7) | Seconds |
| Warehouse inspection | TRIA (790,877,887) | Seconds |

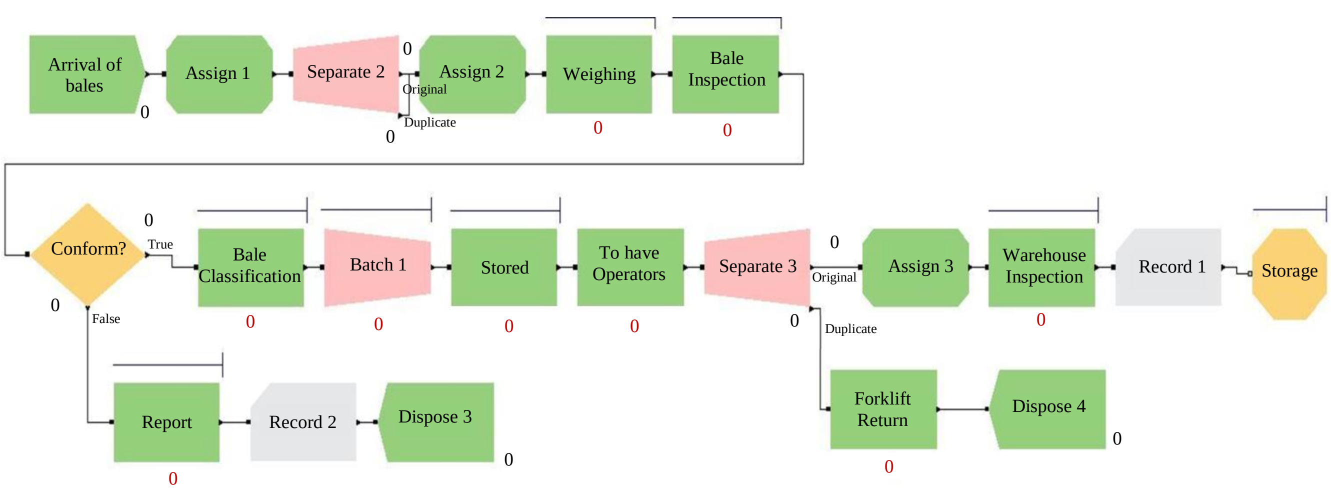


**Fig. 5 Improved situation simulation in arena simulator software**

**Table 3. System entities, attributes, and activities**

| Entities | Attributes | Activities |
|---|---|---|
| Bard | Arrival time | Arrival |
| | Weight | Weighing |
| | Type of material | Inspection |
| | | Sorting |
| | | Storage |

**Table 4. Results of indicators studied**

| | Indicators | Present | Objectives | Upgraded |
|---|---|---|---|---|
| Kardex | Rotation of raw materials | 0.83 | 4 | 2.41 |
| | Immobilized Raw Materials | 54.10% | 43.81% | 44.78% |
| 7S | Inventory accuracy | 97.9% | 99.30% | 98.89% |
| Slotting | | | | |
| Poka-Yoke | | | | |
| Slotting | | | | |
| Poka-Yoke | | | | |

## 5. Conclusion

The tools and the use of the lean methodology approach of the inventory management model led to practical outcomes, which helped enhance the current system. The inventory turnover could be increased from 0.83 to 2.41, which caused the company to have a higher frequency of raw materials and to have material available monthly. On the other hand, it was possible to improve the amount of stock immobilized in the raw materials warehouse by 9.32%, which was perceived as a reduction in monthly storage costs. Finally, the precision or accuracy of raw materials registered increased by 98.89%, which allows for greater control of available raw materials and better management of purchases.

The tools simulated were the Poka-yoke and Slotting in the Arena Simulation program. On the other hand, the 7s and Kardex tools were implemented through a pilot with the warehouse operators and supervisors.

The results of this research were positive. However, the values of the indicators of the sector still need to be reached. This is because limitations were found. Therefore, an exhaustive analysis of variables that facilitate the application or adaptation of the lean methodology is required to conduct further research. Also, this research can be used as a basis for future research in different sectors, considering the characteristics of each area to be studied.

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