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Service Model to Increase the Fulfillment of Complete Orders in a Warehouse Based on SLP, Poka Yoke and Time Study in a Textile MSE

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Abstract

Efficient warehouse management in the textile sector is crucial for optimizing material flow and reducing production errors. However, many companies face challenges related to space utilization, material identification, and process standardization, which impact operational efficiency. This research applies Lean Manufacturing tools to improve raw material warehouse management, aiming to increase service levels and optimize operational processes. Systematic Layout Planning (SLP), Poka Yoke, and Time Study were implemented to reorganize material flow, reduce errors, and minimize idle times. As a result, the average time between batch outputs was reduced from 3.3 to 2.8 hours, while the number of defect-free batches increased from 3 to 5 per day, representing a 33.33% improvement. These tools enabled process optimization, improved inventory management, and reduced operational variability. The findings highlight the importance of adapting Lean Manufacturing methodologies to the specific characteristics of the textile sector, enhancing competitiveness and sustainability. This study provides an improvement model applicable to other companies facing similar warehouse management challenges.

Keywords
Manufacture, Textile sector, Level service, Mype and Warehouse.

1. Introduction
The textile sector is one of the most significant industries in emerging economies, contributing approximately 7% of global manufacturing GDP and generating employment for more than 75 million workers worldwide (Alcazar-Quispe et al. 2024). In Peru, this sector plays a crucial role, accounting for 7.6% of the national manufacturing GDP and providing approximately 398,000 jobs. However, despite its economic importance, textile SMEs face significant operational challenges, such as high defect rates (above 10%), inefficient material handling, and long production times, which directly affect their competitiveness and profitability (Ortiz Porras et al. 2022; Trojanowska et al. 2023).

One of the key issues in these companies is the lack of standardization in production processes, leading to high levels of rework, waste, and increased costs. Studies indicate that the absence of proper quality control mechanisms can cause up to 15% of production losses due to defects, while inefficient time management creates bottlenecks that reduce productivity by 20% or more (Yashini, 2020). Additionally, poor facility layout design results in unnecessary worker movement and ineffective material flow, which can increase operational costs by 10-15% (Lista et al. 2021).

Given these challenges, the implementation of continuous improvement tools is essential to optimize processes and minimize errors. In this context, methodologies such as Poka Yoke, Time Study, and Systematic Layout Planning (SLP) have proven effective in reducing defects, optimizing production time, and improving space utilization in manufacturing plants. However, while these tools have been widely studied individually, there is limited research on their combined application in the textile sector, creating an opportunity to explore their integrated impact on Peruvian SMEs.Therefore, this study aims to develop an improvement model integrating these three tools to enhance productivity and reduce operational inefficiencies in textile SMEs. This article is structured as follows: Section 2 presents the literature review, Section 3 describes the methodology, Section 4 discusses the results, and finally, Section 5 outlines the conclusions and recommendations.

1.1 Objectives

This study aims to demonstrate that applying a model based on Poka-Yoke, Time and Motion Study, and Systematic Layout Planning (SLP) enhances order fulfillment levels in textile MSMEs. Specifically, Poka-Yoke will be implemented to minimize human errors in material handling, Time and Motion Study will be applied to standardize processes and improve efficiency, and SLP will be used to optimize warehouse space and workflow.

2. Literature Review

2.1 Service Level in Textile MSME Warehouses

The service level in textile MSME warehouses is a key factor in ensuring operational efficiency and customer satisfaction. According to Dahiwale and Sangode (2019), the implementation of inventory management tools improves product availability and reduces storage costs in textile companies. Similarly, Silva-Treviño et al. (2021) found a significant correlation between service quality and customer loyalty in commercial enterprises, suggesting that efficient warehouse management can positively influence customer retention. Furthermore, Iacocca and Mahar (2018) highlight that establishing cooperative partnerships in the supply chain can enhance delivery times and reduce variability in product availability in MSMEs.

Despite these benefits, implementing advanced warehouse management methodologies faces multiple challenges in textile MSMEs. Perlaza (2022) argues that many small businesses lack the financial and technological resources to adopt sophisticated inventory control tools, affecting their ability to maintain optimal service levels. However, there is a consensus that digitization and workflow optimization in warehouses can significantly enhance operational efficiency. Kumar and Rodrigues (2018) demonstrated that integrating Lean and sustainable strategies in warehouse management not only optimizes storage but also fosters innovation in the textile sector. Nevertheless, further research is needed on the long-term impact of these strategies in textile MSMEs, as most studies focus on short-term effects and large enterprises.

2.2 Warehouse Management and its Impact on Productivity

Efficient warehouse management plays a crucial role in increasing productivity in textile SMEs. The implementation of Systematic Layout Planning (SLP), Poka Yoke, and Lean Manufacturing tools has demonstrated improvements in inventory control, workflow efficiency, and waste reduction. According to Roncal et al. (2023), applying multicriteria ABC classification and standardized work methodologies led to a 43.9% reduction in product return rates in a textile SME, significantly optimizing warehouse processes. Similarly, Canales et al. (2022) found that integrating Just-In-Time (JIT), Kanban, and Standardized Work improved warehouse operations, reducing material handling times and enhancing production continuity. Additionally, Santiago et al. (2024) highlight the benefits of SLP in warehouse layout optimization, leading to more efficient space utilization and minimizing unnecessary movements. However, despite these advantages, warehouse optimization in SMEs faces challenges. Romero et al. (2020) argue that the lack of employee training and resistance to change are common obstacles in small businesses, making it difficult to fully integrate advanced warehouse management techniques.

Despite these barriers, there is a consensus that the digitalization of inventory management significantly improves warehouse performance. Roncal et al. (2023) emphasize that automated inventory control systems, when combined with SLP, optimize material flow and reduce warehouse transit times. Moreover, Canales et al. (2022) demonstrated that Lean methodologies adapted to SMEs can generate sustainable productivity improvements. However, most existing research focuses on large enterprises, often overlooking the unique constraints of textile SMEs. Romero et al. (2020) stress the need for more targeted studies on small businesses to develop strategies adapted to their limited resources and operational capabilities. Furthermore, Santiago et al. (2024) note that the implementation of SLP and Lean Manufacturing tools must align with a company's organizational culture and operational structure to ensure sustainable warehouse management improvements.

2.3 Application of Lean Manufacturing in Warehouse Optimization

Lean Manufacturing has been widely implemented in warehouse optimization to reduce waste and improve operational efficiency. Previous studies have shown that the application of the Systematic Layout Planning (SLP) method enables better space distribution, facilitating the reduction of search times and improving warehouse organization (Cao, Li & Wang 2022). Likewise, the implementation of Poka-Yoke has shown positive results in reducing defects in processes, ensuring a more reliable workflow (Hernadewita et al. 2019). In this regard, the textile industry has adopted these approaches to enhance inventory management and minimize errors in material handling, resulting in a more efficient process and lower risk of product loss (Yadav et al. 2019).

On the other hand, it has been evidenced that the application of Lean methodologies not only optimizes warehouses but also directly influences the financial and operational performance of companies. The combination of Lean Manufacturing with agile manufacturing practices enables greater responsiveness to demand changes and reduces storage costs (Khalfallah & Lakhal 2020). Additionally, the implementation of Poka-Yoke in assembly lines has demonstrated an improvement in operational performance by significantly reducing the product rejection rate, which directly impacts productivity and final product quality (Dabi et al. 2023). These results reinforce the importance of adopting Lean strategies in warehouse management as a key approach for business sustainability and competitiveness.

3. Methods

The design of the research follows an applied approach, as it focuses on improving order fulfillment efficiency in a warehouse through the implementation of engineering tools. The proposed model has INPUT (input) the low fulfillment of complete orders in a warehouse with the expectation that the OUTPUT (output) will result in a significant improvement in this indicator. For this purpose, it has been divided into three components: analysis, improvement tools and validation, as can be seen in Figure 1.

The first component aims to analyze the current state of the textile company, where data will be collected to identify existing problems. This can be done with the assistance of collecting data using the Pareto Diagram which serves to quantify and rank the main sources of inefficiencies, and the problem tree which outlines the relationship between problems and their root causes. The second component involves the implementation of improvement tools discussed earlier, including Systematic Layout Planning (SLP), Poka-Yoke and Time Study. Finally, the third component focuses on the validation of the proposed model, the effectiveness of the implemented tools is analyzed through the assessment of the key performance indicators (KPIs). The AS-IS (current state) and To-Be (optimized state) scenarios using Arena Simulator. Figure 1 illustrates the proposed model to achieve the results of this research.

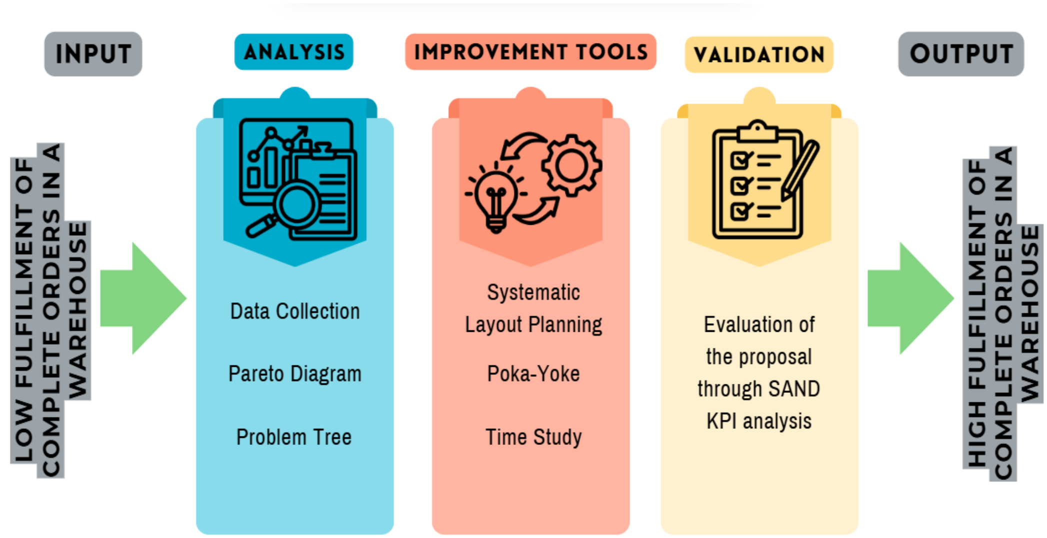


Figure 1. Proposed Model

4. Data Collection

The data collection for this research was based on information provided by the textile sector company through interviews, surveys, and sales reports during the research period. Additionally, information from multiple bibliographic sources (articles, books, interviews, etc) was included for a more comprehensive evaluation. As a part of the analysis, tolls such as the Pareto Diagram and the Problem tree were used, as mentioned earlier, to identify the main issues faced by the company and investigate their underlying causes. Table 2 shows the process of the tools.

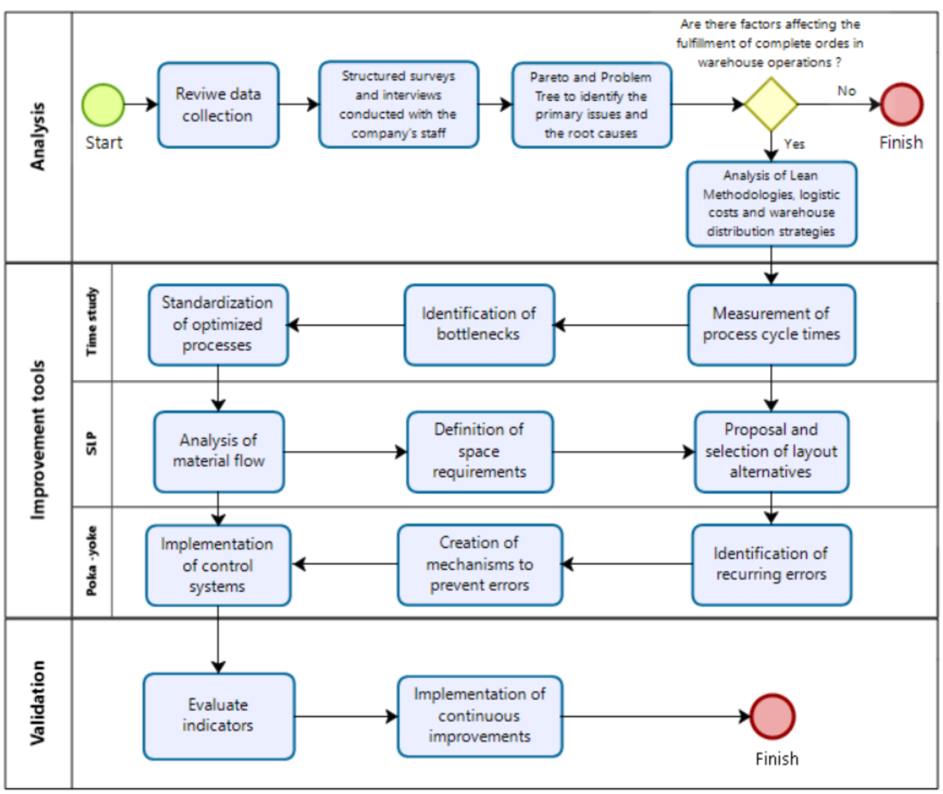


Figure 2. Diagram of the results

4.1 Implementation of SLP, Poka Yoke and Systematic Layout Planning

This phase is focused on the application of the selected tools, according to the main issues identified in the case study. In the case study, the company faces an inventory problem caused by poor space design, inefficiency in material handling, and errors in manual processes, which in turn generates low fulfillment of complete orders in the warehouse.

Therefore, a study was conducted on all processes within the warehouse, which allowed us to analyze the current state of the company. Once the observed times were obtained, the standard time was calculated, considering the allowances and the percentage of supplements applied to each operator. Specific indicators were established to monitor and regulate the current situation of the company. Table 1 presents the initial results.

Table 1. Indicators of the current situation

Indicator	AS-IS (current state)	Unit of measurement
Time Between Departures	3.3	Hours
Warehouse Cycle Time	11.6	Hours
Complete orders	3	Batches
Defective Batches	1	Batches

A visual verification system using Poka Yoke has been implemented in the weighing area. Each type of fabric will have its own average weight noted on the receiving sheet, with an established tolerance range. When an operator weighs a roll, they must verify that the weight is within the expected range, and if not, it will be marked with a red sticker and the observation will be noted. This will ensure that rolls not meeting the required weight are flagged and do not move forward in the next process, preventing errors and enhancing efficiency.

Finally, to implement Systematic Layout Planning (SLP) in the warehouse, the workflow and the current layout of the space were analyzed. Some of the main activity zones included the receiving area, which was located far from high turnover areas, such as the weighting area and the pallet area, which is presented in Figure 3.

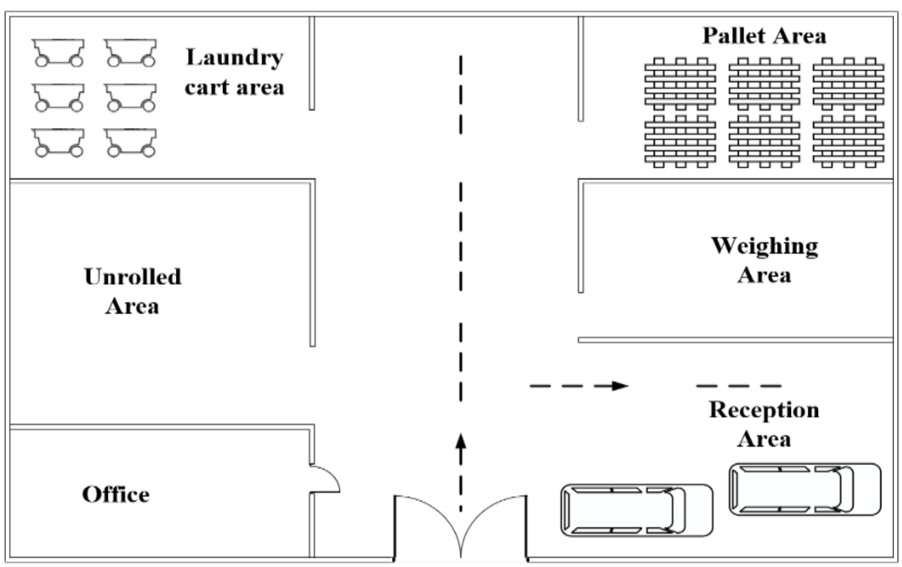


Figure 3. Current Warehouse Layout

5. Results and Discussion

5.1 Numerical Results

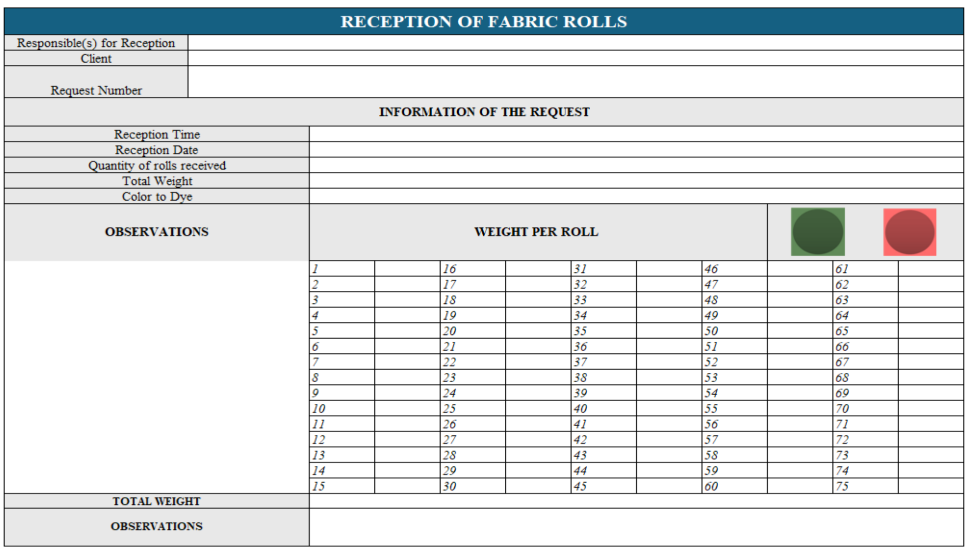
The implementation of the improvement was carried out through a simulation test that used the information from the company within 3 months. During this time, all the proposed improvements and guidelines were applied, yielding the following results of the indicators (Table 2):

Table 2. Indicators of the improved state

Indicator	TO-BE (improved state)	Unit of measurement
Time Between Departures	2.8	Hours
Warehouse Cycle Time	9.6	Hours
Complete orders	5	Batches
Defective Batches	0	Batches

5.2 Graphical Results

The following graphical results are presented based on the implementation of the proposed improvements. First, data regarding the weight of the rolls, along with the corresponding observations, are detailed, allowing for the verification of the effectiveness of the improvement applied to prevent errors in reception area and unrolled area, as shown in Figures 4 and 5.



RECEPTION OF FABRIC ROLLS

Responsible(s) for Reception	
Client	
Request Number	

INFORMATION OF THE REQUEST

Reception Time	
Reception Date	
Quantity of rolls received	
Total Weight	
Color to Dye	

OBSERVATIONS — WEIGHT PER ROLL

1		16		31		46		61	
2		17		32		47		62	
3		18		33		48		63	
4		19		34		49		64	
5		20		35		50		65	
6		21		36		51		66	
7		22		37		52		67	
8		23		38		53		68	
9		24		39		54		69	
10		25		40		55		70	
11		26		41		56		71	
12		27		42		57		72	
13		28		43		58		73	
14		29		44		59		74	
15		30		45		60		75	

TOTAL WEIGHT	
OBSERVATIONS	

Figure 4. Fabric Roll Reception Control with Poka Yoke System

VERIFICATION OF FABRIC ROLLS			
Responsible(s) for Reception			
Client			
Request Number			
Do the rolls have defects? (Mark with an X)			
Yes		No	
If you mark "Yes", please place the corresponding color stickers			
What type of defects?			
Holes, stains, etc. (RED sticker)			
Description			
How many rolls have holes?			
Stains (BROWN sticker)			
Description			
How many rolls have stains?			
Small rolls (BLUE sticker)			
Description			
How many small rolls?			
What other type of defects does it have? (BLACK sticker)			
Description			
How many rolls?			

Figure 5. Fabric Roll Reception Control with Poka Yoke System

For the SLP tool, a relational activity table was created, as shown in Figure 6, which has the following nomenclature between activities: A, absolutely necessary; E, especially important; I, important; O, ordinary proximity; U, unimportant and X as undesirable. This table enabled us to create a proposed plan for the warehouse, which is presented in Figure 7.

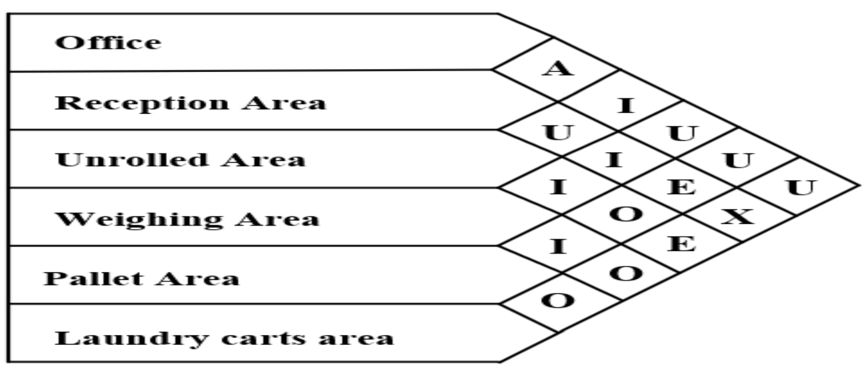


Figure 6. Relation Between Activities

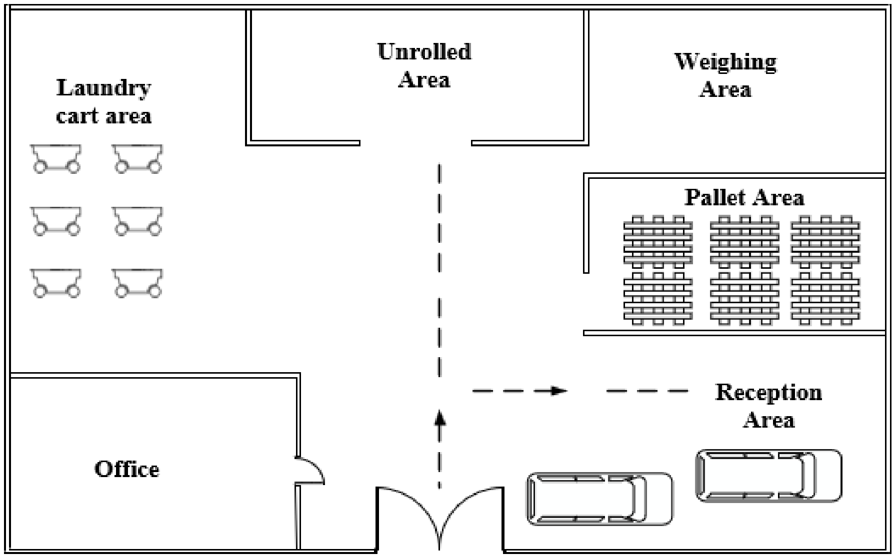


Figure 7. Warehouse Layout after improvements

5.3 Proposed Improvements

The proposed improvement for the textile manufacturing company following the implementation of SLP, Poka Yoke and Time Study are outlined below. See table 3.

Table 3. Comparison of indicators between scenarios

Indicator	AS-IS	TO-BE	Variation
Time Between Departures	3.3	2.8	- 15.15 %
Warehouse Cycle Time	11.6	9.6	- 17.24%
Complete orders	3	5	+ 66.67 %
Defective Batches	1	0	-100 %

5.4 Validation

To validate the proposed improvement model, Arena software was used to simulate the processes within the warehouse area, utilizing a sample size of 131 fabric rolls. The simulation included operations within the warehouse, as well as the number of machines, materials, operators, and associated work times.

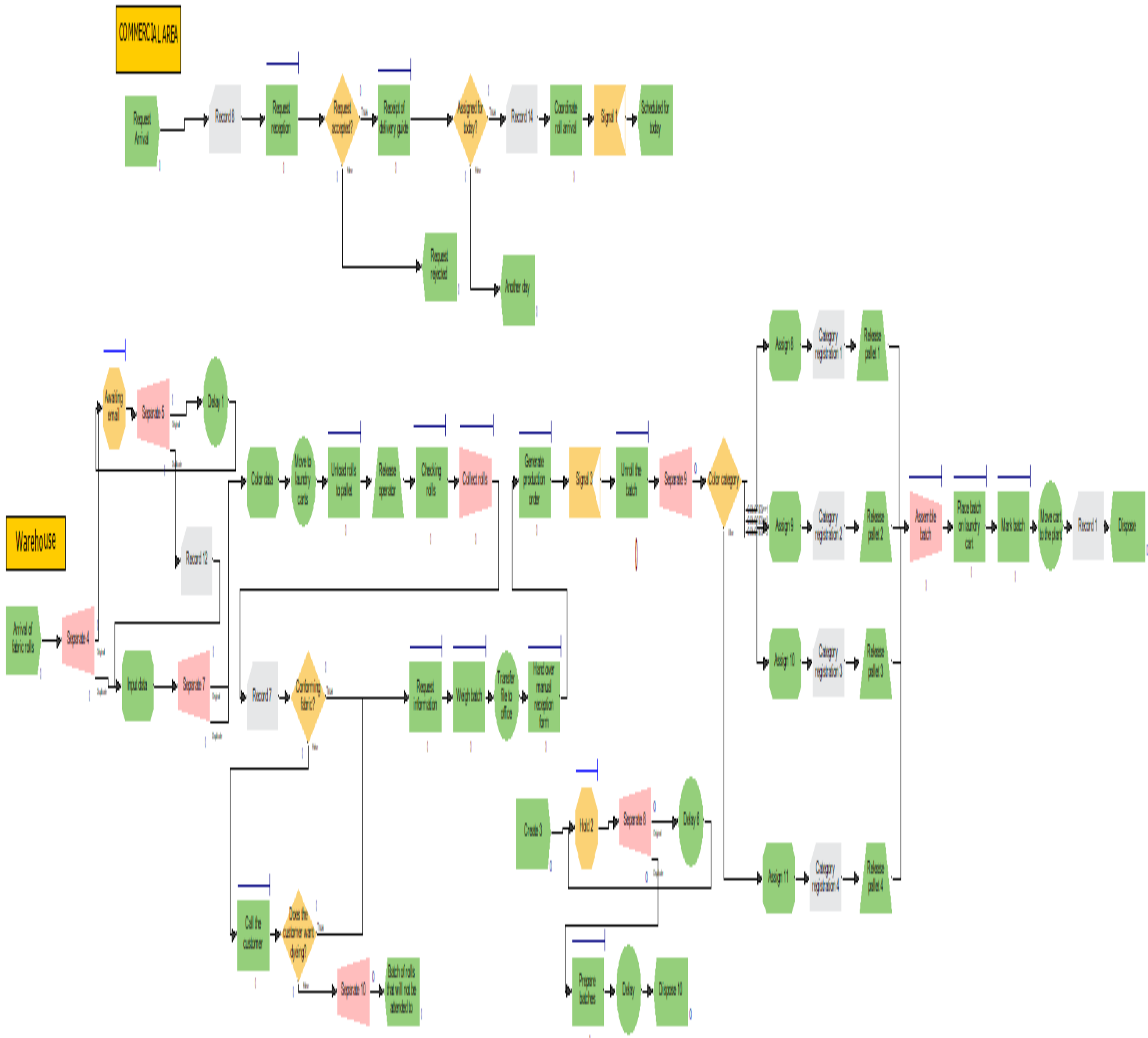


Figure 8. Simulation of the proposed improvement in the Software Arena

6. Conclusion

In conclusion, the integration of System Layout Planning (SLP), Poka Yoke and Time Study contributed to increase the fulfillment of complete orders in the warehouse of the studied company, increasing the number of batches from 3 to 5, demonstrating the effectiveness of the model proposed. Time Study played a vital role in obtaining standard times for each activity conducted in the study area. Through Poka Yoke, using stickers to mark defects and controlling the average weight of rolls of fabric received, allowed a reduction from 1 to 0 defective batches. Finaly, SLP technique for better distribution of work areas, reducing the cycle time in the warehouse from 11.6 to 9.6 hours and the time between departures from 3.3 to 2.8 hours. This approach can be highly beneficial for future studies focused on improving organization and inventory operations as it offers adaptable and efficient solutions tailored to specific challenges.

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