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Service enhancement in the hardware sector by Lean, MRP, and SLP tools

Asley Martinez-Palacios, BSc[1], Hernan Barron-Vasquez, BSc[1] and Juan Carlos Quiroz-Flores, Ph.D.[1]
[1]*Engineering Faculty, Industrial Engineering Career, Universidad de Lima, Perú*
20163291@aloe.ulima.edu.pe, *20152748@aloe.ulima.edu.pe* and *jcquiroz@ulima.edu.pe*

Abstract– In Peru, by 2020, SMEs will represent 95% of the companies and employ 26% of the EAP; however, it is known that SMEs have some problems that limit their sustainability. According to the literature, this results from situations such as being unable to maintain an adequate level of service, a non-existent organization in the warehouse, lack of knowledge of product locations, errors in picking, and uncertain availability and reliability of information in real-time, procurement is not based on any guidelines, stock breakage, and human error. Consequently, there is a low level of service in the companies. This problem has been evidenced in other investigations. For this reason, in the present investigation, a solution is proposed through the application of an improvement model using mixed tools implementing SLP, VRP, MRP 5S, and POKA YOKE to increase the current service level of 68% derived from the poor organization of the warehouse and processes, deficient manpower and poor inventory prevention. A model with three components is proposed: data collection, 5S implementation at all levels, route design, warehouse redesign, and demand forecasts to be validated and compared with their respective indicators.

Keywords– Lean Manufacturing, 5S, MRP, VRP, SLP, Poka-Yoke, Service Level

I. INTRODUCTION

PYMES are vital for Latin America and the Caribbean since they represent 99.5% of all companies and generate around 60% of employment, thus contributing approximately 25% of the Gross Domestic Product (GDP) [1]. In Peru, by 2020, PYMES will represent 95% of the companies and employ 26% of the PEA, thus having 21.2% less compared to 2019. Likewise, within the PYMES is the hardware sector that contributes greatly to the Peruvian economy. According to World Bank data, this sector has an economic presence of 32% and a representation of 56% of the PBI. This is better than Argentina at 33%, Brazil at 39%, and Colombia at 41% [2]. It is important to mention that this sector was severely affected because of the sanitary crisis since it had to suspend all its activities until the government authorized it. One of the most important functions of this sector is imports, which according to Adex, had a drop of 18% during 2020. But after the pandemic, the sector was able to reinvent itself and adapt to the new challenges, showing an increase and a 9.5% contribution to GDP in 2022, according to the World Bank.

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On the other hand, 67% of customers leave because of poor service [3], which affects PYMES since presenting a lower frequency of customers, lower revenues, and lower profits puts the company's sustainability at risk. In addition, according to a study, it is known that 67% have lost business due to poor service quality [4]. This shows that PYMES has some problems that limit its sustainability.

The problem that has been identified, according to the literature, comes from situations such as not being able to maintain an adequate level of service, a non-existent organization in the warehouse, lack of knowledge of product locations, errors in picking, lack of knowledge of inventories, stock breakage and wasted human capital [5]. Consequently, there needs to be a higher level of service in the companies. This problem has been evidenced in another research. For example, a study on customer satisfaction measurement in a retail company with a branch in Lima showed that the company had up to 280 complaints and negative responses in 20 days related to customer service times, delivery times, and staff knowledge [6].

In this context, companies must improve their level of service to improve the quality offered and thus be more competitive in the market. For this purpose, a case study was chosen that reflects the problem of low service level. The problems that were evidenced were: low level of service due to untimely orders, inadequate inventory control, stock breakage, warehouse disorganization, personnel deficiency, and lack of organization for product distribution, which generates 27% of economic impact due to opportunity cost that the company cannot invoice. In this sense, to solve the problems described above, an improvement model was developed by combining the 5S. Poka Yoke, MRP, VRP, and SLP tools. This model was developed based on the success cases that presented similar problems to the one in the study. The present research offers a new storage management model to increase the level of service in an SME in the hardware commercial sector.

II. LITERATURE REVIEW

The articles selected for state of the art are the result of a systematic review of the literature together and classified according to the deficiencies of the hardware sector and the tools used for such problems in five typologies presented below:

A. VRP:

Hardware companies (B2C) must deliver products to customers with varied characteristics like small batches, remote locations, and products. Due to this, logistics costs have increased [7]. In addition, the promise of faster and more efficient deliveries means a challenge for companies because they must deal with more pressure on warehouse operations, create and maintain an efficient distribution network to deliver their products [8]. In a case study of a courier company whose backbone must be on-time deliveries, the company had many incidents, delays, and deficiencies. After implementing a new route design, an 18.5% reduction in delays was achieved [9].

According to what has been mentioned, to avoid vehicle routing problems, generate late deliveries, produce a low level of service and have high logistics costs, implementing the VRP is important so that the company can improve its efficiency.[10]

B. SLP

This category addresses the importance of optimal warehouse design to increase logistics efficiency, because recent practices in this industry focus on speed of response, such as just-in-time delivery to stores and warehouses so that be efficient, so this type of warehouses have to be optimally designed [11]. In addition, a correct warehouse design can increase the productivity of certain processes such as picking and packing [12]. In a case study in China, in the city of Zhengzhou, an international logistics distribution center was designed through SLP to innovate the operation and management mode of the logistics service industry and promote cost reduction and increased efficiency of the logistics. as a result, it was possible to reduce the cost and improve competitiveness. [13].

Likewise, idle space is known to increase operating costs and decrease the profitability of companies and the implementation of SLP was able to reduce storage costs by up to 50% [14].

C. POKA YOKE AND 5S

There is a considerable number of SMEs presenting economic losses due to stock breaks and incorrect stock management that are caused by inefficient supply methods, little order within their warehouses and non-standardization [15]; that is why it is urgent to apply warehouse management tools that are effective to maximize service levels and minimize waste in companies. Under this criterion, various authors agree and implement Lean Warehouse that includes 5S and Poka Yoke to combat deficiencies and non-compliance in deliveries, companies that used "artisanal" methods for the organization of work areas and products but were not favorable in absolute [16]. There are case studies whereby implementing the 5S, the inventory was redistributed, the available storage area was optimized, and the picking time was reduced by 75 minutes [17].

According to the research, to increase the level of service, we must optimize the processes, and for this, it is necessary, correct storage management [18]. Thus, the retail hardware companies will notice increased customer satisfaction since Poka Yoke prevents them from committing process errors.[19]

D. MRP

The use of MRP in the storage management of the hardware sector is still very scarce; however, risk factors appear frequently and it is necessary to have contingency plans to be able to withstand problems in the supply chain, especially when they appear simultaneously due to the uncertainty of demand and the economy; and since there is little information on the reduction of risk in supply chains based on MRP theory and these approaches do not consider the behavior of companies connected in a total supply chain in a stressed environment such as liquidity crisis [20] . Due to the scarce information, we consider that our model can contribute to the scientific community with a novel implementation of the MRP tool in the supply chain of the hardware sector.

III. CONTRIBUTION

Next, Table 1, will compare the literature mapping based on the root causes identified in the diagnosis and determine the tools for the proposed model.

TABLE 1
COMPARATIVE MATRIX OF SELED LITERATURE

Goals / **References**	**Non-existent route plan**	**Lack of organization for distribution**	**delivery errors**	**out of stock**	**warehouse disorganization**
[9,24]	VRP				
[22,31]		5S			SLP
[15]			Poka Yoke		
[20]				MRP	
[14]					SLP
Proposed model	**VRP**	**5S**	**Poka Yoke**	**MRP**	**SLP**

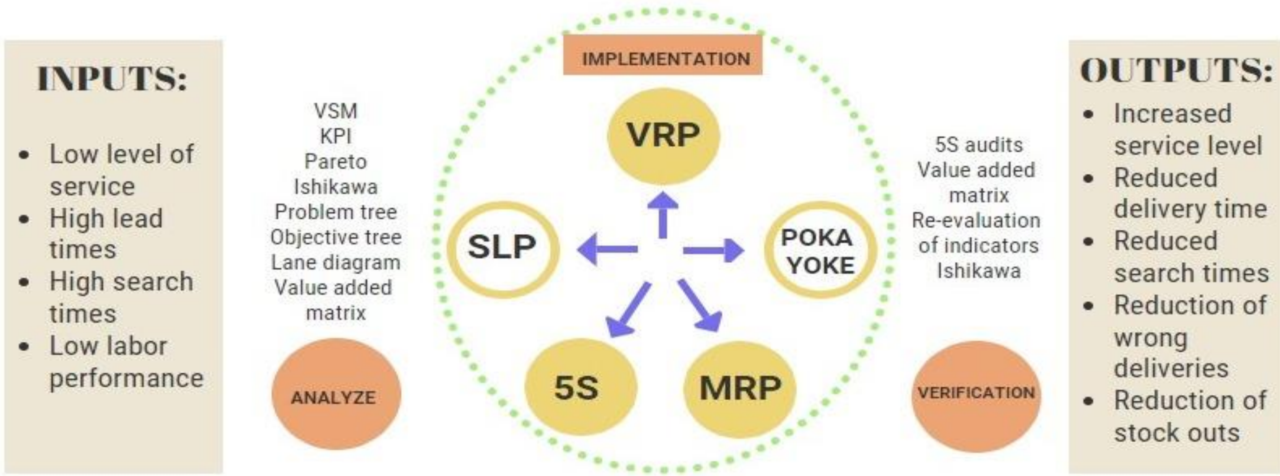

Figure 1. Proposed Model

A. Model Basis

Recent practices in this sector point to speed of response, such as just-in-time delivery to stores to be efficient, but SMEs need to apply tools or methodologies that allow them to improve their processes due to ignorance of all the possibilities they offer [21].

B. Proposed model

As shown in Figure 1, the design of the proposed model focuses on a continuous improvement system through implementing a mix of tools in a company in the hardware sector. Said methodology allows to improve in the organization for the distribution of products, the non-existent plan of transport routes, the deficient delivery personnel, the stock breakage, and the disorganization of the warehouse.

C. Model Components

To develop the proposed model, three components have been used as indicated in Figure 1. Therefore, each component of the model will be explained in detail.

Phase 1 is analyze the data collection, to begin with this phase, each of the important KPIs was analyzed. The VSM is used to assess and recognize problems in the different processes. Once this was finished, the Pareto and Ishikawa tools were used to recognize the root causes of the problems and in the same way, a lane diagram was made to demonstrate them in a better way. Finally, the problem and objective tree are made to show the causes and propose the tools for their respective solutions.

In phase 2, the tools selected review of the problem and objective tree are implemented.

VRP

The routes that generate longer delivery times or greater problems and costs for the company are identified. It is proposed to organize the routes by coordinating the locations, the distance, and the vehicles. It is intended to have a single start and end for deliveries, which will be coordinated with customers providing a range of hours.

POKA YOKE

Errors are detected, the places where they occur are identified, the causes are recognized, the conditions are evaluated, it is determined that the informative Poka Yoke is the one that will provide a better solution to the problems (deficient product, inadequate product, high lead times). delivery) with which through the Pick to Light (software that will provide the operator with the details and the quantity of the merchandise that must be removed for the respective packing), the assigned is tested, and the operation is reviewed.

SLP

The use of the SLP within the warehouse will begin with the location within the area, followed by the distribution planning in relation to the activities and the respective areas. Likewise, a preparation of distribution plans for the products or equipment will be carried out. With this, the optimization of the areas within the warehouse will be achieved.

5S

An evaluation of the warehouse and its different processes is carried out for the proper implementation of the tool. This is how waste is identified and the application of all its phases (Classification, order, cleaning, standardization, and discipline) is considered. However, the main phase for the company is order. Therefore, in the first place, a classification of the area is carried out through photographs and the implementation of red cards that will allow the identification of deficient material for the warehouse. Once this is finished, it will proceed with its order, and it will be possible to get the most out of the respective area by rotating the family of products (the products with the most rotation will be placed in a better view). Therefore, Cleaning is carried out, which is essential in all work activities, and a weekly cleaning program is proposed. For standardization, patterns that maintain the assigned organization will be ensured. And finally, discipline will be provided through regular auditing to encourage operator collaboration.

MRP

For this tool, you will start with the list of products; Following this, the amount of available inventory will be accommodated, and the net requirements will be offset. It is necessary to constantly calculate the need and the rotation of materials, having actual knowledge of the adequate supply terms. This to avoid stock breaks and non-compliance with the respective already coordinated deliveries.

Phase 3 is the verification of the application. In this phase, an evaluation is carried out to verify the fulfillment of the objectives so that the proposed model's adequate development is consolidated. Likewise, a value-added matrix will be made; monthly audits will be carried out to ensure added improvements.

a) Proposed Process Design

Figure 2 shows the application process of the proposed model in detail. It shows the three components that make it up: (1) Analyze the data collection (2) Implement the tools and (3) Verify the application.

b) Indicators

To ensure the functionality of the proposal, relevant indicators will be used to measure and compare before and after the implementation of the proposal.

- **Out of stock:** Objective is Reduce stock out from 11.90 to 8%, differentiation of 3.90%

$$OOS = \frac{\text{Quantity of product not supplied}}{\text{Total quantity required}} \; x\,100$$

.

- **Average picking time:** Objective is Reduce the average picking time from 198 to 65 minutes, differentiation of 133 minutes.

$$Picking\ Time = \frac{\text{Total picking time in a shift}}{\text{No. of order preparations in a shift}}$$

- **OTIF:** It allows measuring the percentage of times the order has arrived on time and is complete. Objective: Increase the OTIF level from 82.60% to 90%

$$OTIF\!: \frac{\text{Total Complete and On} - \text{Time Orders}}{\text{Total Orders}} \text{x100}$$

- **Forecast error:** It allows to measure the accuracy of the forecast and to know if products need to be ordered from suppliers.

$$FE = \text{Products Sold} - \text{Projected Demand}$$

- **5S:** Objective is Reduce from 23 to a range of 5 to 10.

$$Audit\ 5S = \sum(score\ score\ obtained\ in\ each\ \text{“}S\text{”})$$

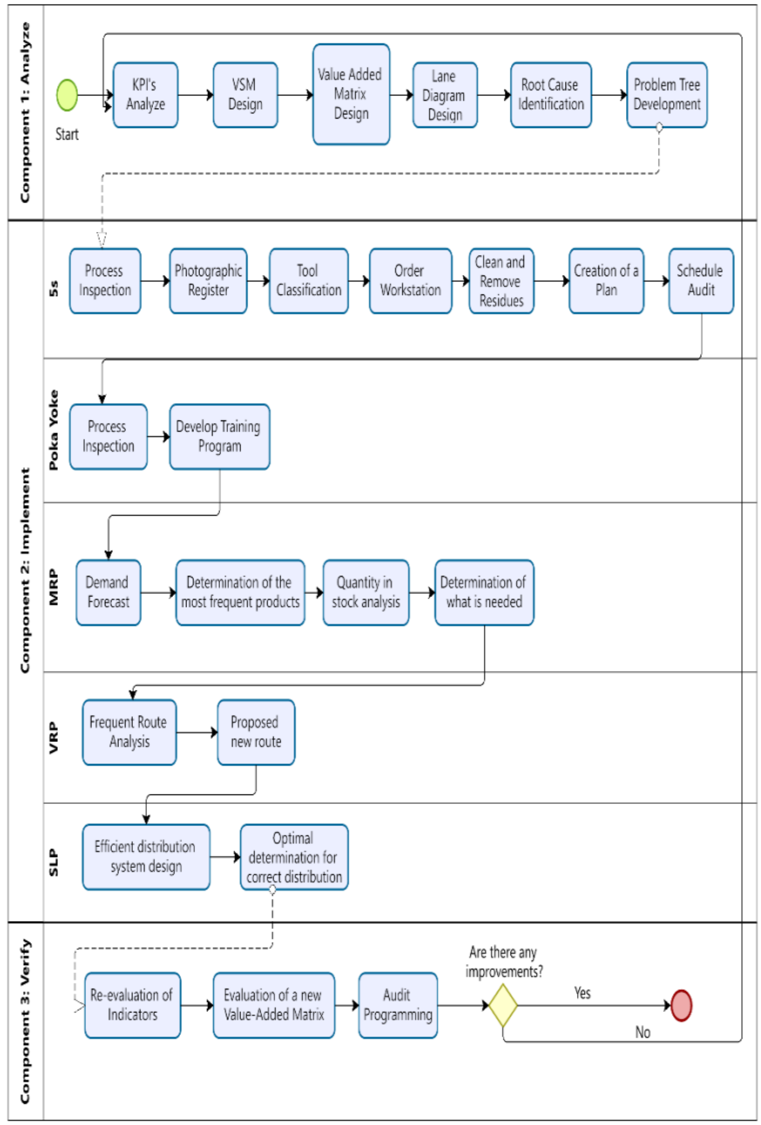

Figure 2. Steps for the construction of the contribution.

IV. Validation

A. Validation scenario

This research has developed an optimization model for the root causes of increasing the service level. Therefore, a pilot test was implemented to demonstrate the effectiveness of the 5S tool. On the other hand, the simulation for the Poka Yoke, SLP, VRP, and MRP tools was made using Arena software to establish the validity of the proposed model.

B. Initial diagnosis of the company under study

In this research, the storage processes within the company were evaluated. Through a diagnosis, it was determined that the processes have constant deficiencies that affect customers and represent losses to the company and an economic impact of 27%. To determine the reasons and reduce this problem, a Pareto diagram and a problem tree were created, as shown below in Figure 3.

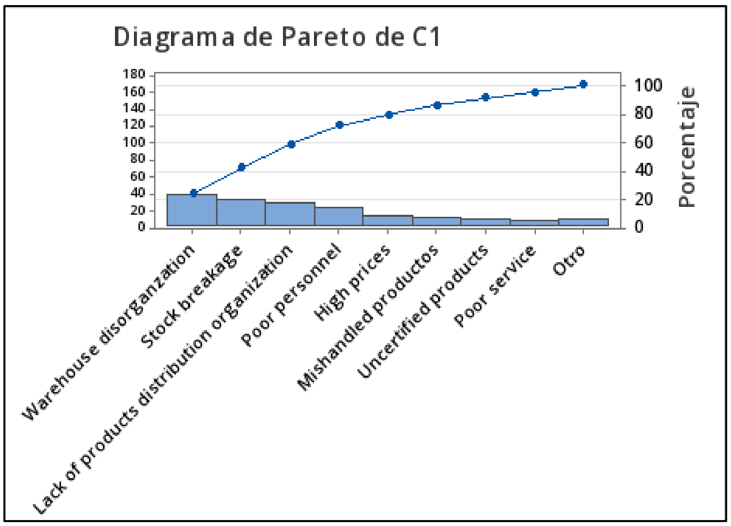

Figure 3. Analysis of causes with Pareto Diagram

C. Validation design

A pilot test for the 5S tool was conducted in the warehouse area to diagnose the company's level and thus identify opportunities for improvement. In addition, training was provided to the company's workers, and a 5S committee was formed to carry out the activities and supervise them for proper execution.

- Stage 1: Seiri (Select)

At this stage, the tools or materials that did not provide value to the activities in the warehouse were purged. A control card was used to keep a record of the materials or tools that were found. As shown in Figure 4, the red cards allowed the proper identification of the tools to be removed.

Figure 4. Use of red cards

- Stage 2: Seiton (Order)

After the selection stage, a visual inspection was carried out with the support of photographic records, and management proceeded to relocate or eliminate the tool or material. Figure 5 shows the area after implementation.

Figure 5. Products are ordered and released.

- Stage 3: Seiso (Cleaning)

After the first two stages, each area was cleaned. To this end, a cleaning schedule was drawn up and the personnel responsible for this action was determined. Figure 6 shows the cleaning schedule and Figure 6 shows the checklist.

CABLES E INSUMOS SAC	CONTACT:					
	AREA:					
ACTIVITY	PLANNING					
	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
	9:00 - 9:30	9:00 - 9:30	9:00 - 9:30	9:00 - 9:30	9:00 - 9:30	9:00 - 9:30
Clean and dry floors						
Clean work tools						
Tools and products located in their respective places						
Free aisles						

Figure 6. Cleaning schedule.

Also, as part of this stage, the following checklist was completed to ensure proper cleanliness within the company.

CABLES E INSUMOS SAC	ORDER AND CLEANLINESS CHECKLIST						
Worker	Date	Clean and dry soils	Hclean working tools	Tools and products located lugares	Free aisles	Observation	Responsible for supervision
Note: *If this form is not signed, the departure card will not be signed and a warning will be issued for non-compliance of order and cleanliness.							

Figure 7. Cleaning checklist.

- Stage 4: Seiketsu (Standardize)

For this stage, 5S compliance checklists were made to ensure compliance with each task assigned in the different stages and thus be able to manage preventive measures. Figure 8 shows the 5S compliance checklist.

5S COMPLIANCE CHECKLIST		
INSPECTION DATA:		ÁREA OF THE COMPANY
DATE	SUPERVISOR	WAREHOUSE
CRITERIA TO BE EVALUATED		
Attendance report.		
Operators are aware of new merchandise and tooling location.		
The operator complies with the cleaning policy.		
Signs are complied with.		

Figure 8. Compliance Checklist

- Stage 5: Shitsuke (Discipline)

At this stage, knowledge of the implementation is reinforced through audits, and an informative list of the phases and their respective tasks is provided visually. In the same way, four stages are followed: Arrange the monitoring plan, conduct evaluation, review results, and establish improvement plans. Figure 9 shows the informative list.

Phase	Tasks
Planning	Planning work activities
	Manage resources required
	Control costs
Do	Administer the meetings of the 5S committee
	Planning training for partners
	Lead activities in the implementation of the 5S programme
Verify	Follow up on work activities
	Complete internal audits
	Analyse the results of the proposed indicators
Acting	To carry out the corrective actions required
	Register the activities that have occurred
	Distinguish opportunities for improvement

Figure 9. Informative list.

After implementing the 5S, an audit was carried out, which showed optimal results compared to the initial review. Figure 10 shows the comparison of both reviews.

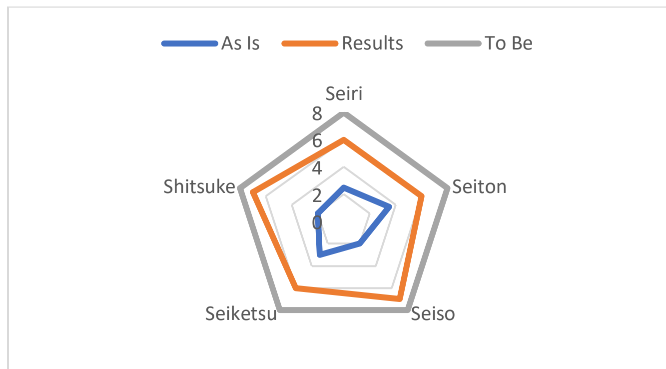

Figure 10. 5S audit result

Likewise, to validate the SLP, VRP, and MRP tools, the Arena software is used to simulate the processes from when a purchase order is received until the product reaches the customer; at the end of the process, the time is calculated to determine if there was an improvement. The process associated with SLP is the picking time, the process associated with VRP is the distribution, and the process associated with MRP is the stock breakage. The simulation result was a 63.8-minute improvement in cycle time, i.e., the entire cycle time was reduced by 63.16%.

The process begins with the arrival of the purchase order from the customer to the warehouse, there is notified how many products will take and verified that there is stock, also every so often the warehouse is replenished according to MRP planning which generates a subprocess consumes time of the operator,

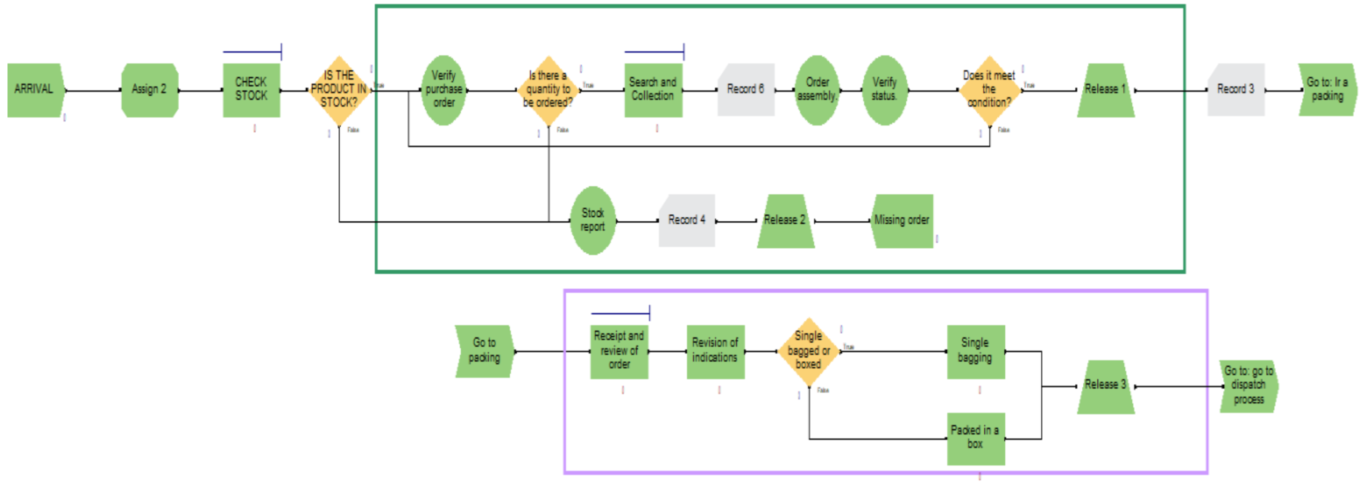

Figure 11. Proposed model in Arena

then begins the picking process in which the operator goes in search of products and collects them in a cart and then take it to the packing area as shown in Figure 11.

In this part is where the Systematic Layout Planning and 5S tools were applied to reduce the effort and time of the process, in the packing area there are two types of packing, the simple and boxed, the times vary depending on which one is ordered. Finally, the product can follow 2 options depending on the customer, the first one if the customer wants to pick up the order in the store which the scope of the model ends there and the second one in which the customer wants it to be shipped to his home or some specific address. For the latter option the optimal route is calculated to minimize the travel time using VRP, these sub-processes are shown in Figure 12.

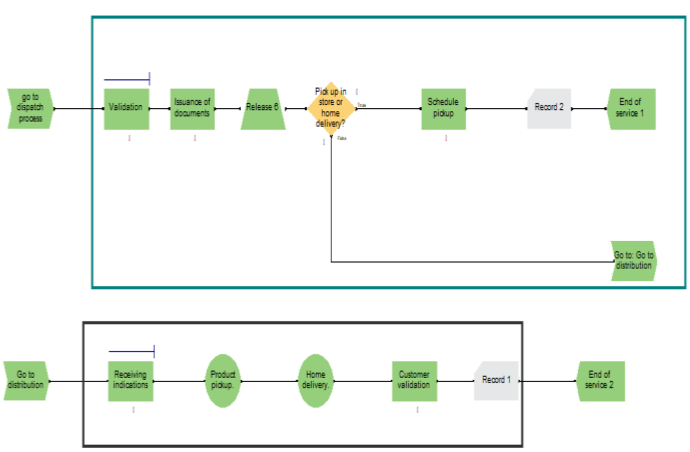

Figure 12. Sub process distribution.

After the implementation of the model and tools in the pilot test, the times are recalculated 30 times to have a significant sample and that new information is entered into the Input Analyzer to obtain the simulation input data and 120 repetitions are done with 95% confidence to evaluate the new results and measure the validity of our proposed model.

Finally, important results are extracted from the model to be able to compare times, generate new indicators, draw conclusions, and generate discussion in future research that seeks to implement in companies' models that improve indicators like ours and improve their effectiveness.
The table below shows a comparison between the results of the initial model and the simulation where the results after the implementation of the model are shown, these are the results of 120 replications.

TABLE 2
RESULTS OF SIMULATION ON ARENA SOFTWARE

Components	Current Situation	Improved situation
Cycle Time	101	53.6
Picking Time	119	37.2
Number of times out of stock	88	81

V. Discussion

A. *Segmentation*

For product segmentation, a study of the standard product and ABC analysis was carried out to find the products that could have the greatest impact on the study; this analysis is important for future research since the scenarios to be studied will differ. In addition, two scenarios have been compared in the model to determine the significant changes. For our case, after having done the analysis, three products were selected: Ropes, Winches, and Slings, since they are the ones that contribute the most to the company.

B. Scenario vs Result

In scenario one, the process of the three main products was evaluated through the processes and activities used by the company at that time in the warehouse. The input data was collected directly measured in the field and with historical information from the company to determine the significant times to study and improve. It is worth mentioning that at that time, the main OTIF indicator was 82.6%, the average picking time was 198 minutes, the audit score was 23 and out-of-stock was 11.9%. Here we highlight that the main indicator is below the standard of the optimal value.

In scenario 2 consists of proposing an improvement in the activities, specifically in picking where the sequence of activities was not optimal, in this process a filter was added to improve the stock review and the activity of "taking product" was moved after the new filter.

Also, in this scenario the tools of the proposed model have been applied and the new results have been simulated with Arena, which after being measured are presented in the table below.

Now that both scenarios are available, a comparison is made between the initial situation and the improved situation in the following table.

TABLE 3
COMPARISION OF SCENARIOS

Indicators	Scenario 1	Scenario 2	Variation
OTIF	82.6%	91.2%	8.6%
Out of Stock	11.9%	6.1%	5.8
Average Picking Time	198 minutes	53.6 minutes	144.4
5S-Audits	23	10	13
Forecast error	62.5%	42.8%	19.7%

C. Analysis of results

As mentioned in section IV, it was possible to validate the effectiveness of the improvement model proposed through Arena, so that the objectives set in stock breakage, picking time optimization, 5S audit, forecast error and on-time and complete deliveries were met.

Likewise, it is essential to evaluate and validate the impact of this project in economic terms to know the monetary benefits that the project will have and the repercussions for the case study company.

TABLE 4
ECONOMIC IMPACT

Economic losses	Scenario 1	Scenario 2
Unrealized sales (PEN)	149,256.35	102,210.74
Cost of returns (PEN)	242,186.26	191,327.14
Total	**391,442.61**	**293,537.88**
%	27%	20.24%

Regarding the economic impact of the scenarios, as seen in the table above, there is a significant improvement in financial losses. The table above shows there is a substantial improvement in terms of economic losses. In the proposed scenario, better results are obtained faster than in the initial case. This amount decreased in less than a year means a lot for the company in the case study due to its size and competitiveness in the market.

Finally, these indicators and economic results are enough to support our scenario as valid.

D. Future works

It is necessary to specify that the Arena software has been used to validate the proposal in the present work. In the future, if you want to validate works inspired by this software, you must consider the use of authorized software that can perform simulations with a confidence of at least 95% and that, in addition, must be the updated version to obtain reliable results on which to validate the results.

It should also be noted that depending on the characteristics of the company, the results may vary, as well as the indicators, since each company presents different diagnoses, and the indicators should be presented in such a way that they serve to measure the improvement to be validated in that company.

In this case study, the data from the intervening company were taken during recovery from the Covid-19 pandemic. Contains data taken during a period of recovery from the Covid-19 pandemic. Therefore, factors such as reduced demand may affect the inputs and outputs of the model.

Finally, it is recommended to apply these tools in other areas to expand the knowledge as a whole; that is, to diagnose, propose, implement, and validate the tools, and to integrate other tools to see the compatibility and reach new conclusions in different industries, both large and small or medium-sized companies.

VI. CONCLUSIONS

This research was able to diagnose the main problems of the case study using a Pareto diagram and analysis of causes where it became evident that the poor organization and poor design of the warehouse generated a high picking process time (198 min.) and a bad forecast generated stock breakage, which caused a high economic impact (27%).

After carrying out the study, we can conclude that the application of mixed tools in micro and small enterprises in the hardware sector can lead to increased efficiency and generate an economic impact, which has been evidenced in the comparison of results.

Unlike previous studies that focus on large companies and the use of 2 or less tools, ours benefits hundreds of companies with the use of Lean landed in a scenario similar to theirs.

When applying the tools, it became evident that the most important was the 5S and SLP since it was possible to improve the flow of activities by freeing and redesigning the space, which generated an effort reduction of 32.14%.

With respect to the economic impact, the company benefited by reducing its losses due to untimely orders and improving customer satisfaction by reducing the time of its processes, which ensures customer loyalty and generates more future income.

Finally, the simulation model was validated from 120 replications; the results were favorable; therefore, it is considered a viable project for the future.

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