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Warehouse Management Model Based on Lean Manufacturing to Reduce the Incidence of Ceramic Tiles Breakage in the Retail Sector

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Abstract

This research analyzed the problem of broken products that negatively affect retail construction finishing companies. For this reason, the study was conducted in a retail company in the mentioned sector. The main problem is broken ceramic tiles found throughout the logistics process. This company has a rate of product breakage of 2.15%, equivalent to 707,704.58 PEN in total cost and costs involved. The leading causes of this problem are poor storage and transportation of products 26.32% and inadequate control and handling of products 27. 03% and poor handling with the forklift 25.97%. A model was formulated under the Lean Manufacturing and warehouse management methodology divided into three stages for the implementation of the tools: "Order and Stability," which consists of the performance of the 5S combined with warehouse management tools, and "Planned Flow," which focuses on the implementation of SLP, and the last phase is called "Make Kaizen Flow" which focuses on the combination of standard work and the Kaizen Philosophy. Finally, through a simulation, it is determined that the application of this model reduces the main problem to 1.65% and allows standardizing activities and improving the order and distribution of the warehouse. This research will be an example for future implementations for companies in the retail sector of construction finishes.

Keywords
Lean Manufacturing, standard work, ceramic tiles, breakage.

1. Introduction
The retail sector worldwide is marketing millions of products per day, which demands complete care so that these products can arrive intact at their distribution (Barrientos-Ramos et al. 2020). This article highlights the importance of decreasing the number of damaged products in distribution centers and increasing the efficiency and resources needed in the retail sector. With the implementation of a methodological approach, the impact that this generates on a country's economy is made known. For example, in Peru, the retail industry represents 10.7% of the Gross Domestic Product and 25.8% of the national Economically Active Population (El comercio retail representa el 10.7% del PBI del Perú 2019). Within this sector, the ceramic industry grew by 12.36% in 2020 due to the great demand of the construction sector, which requires these products to finish the aesthetics of their projects. On the other hand, research based on statistical data from retail companies engaged in the retail marketing of products manages to receive 1.86% of defective products per year in their establishments (Vásquez Médico et al. 2018). Consequently, this evidences that the retail sector has certain types of limitations with the improvement of this indicator, making its profitability lower than planned.

According to the bibliographic guides, the problem identified is that there is no constant and adequate quality control and a lack of standardized methods in the performance of the tasks. Consequently, the products are damaged in the warehouses. This problem has been identified in other research at a global level, such as in Latin American countries like Argentina, which indicates that in the retail sector of ceramic products, the percentage of defective products exceeds 2.89% in most of the companies in this area. The leading cause is the lack of implementation of tools for quality control management in the delivery process, such as those provided by lean manufacturing. Likewise, in Asian countries such as China, many medium-sized companies in the retail sector receive defective product due to a lack of standardized work for the reception of the merchandise, which involves poor handling of materials in the process of opening containers, transfer to the warehouse, picking process and dispatch process.

In the past few years, retail sector companies have had significant deficiencies in receiving the merchandise. The leading causes that were determined are poor storage and transport of products, inadequate control, and handling of the material, and inadequate handling with the forklift, which cause economic losses. A case study was chosen to show the problems faced by the ceramic tile retail sector due to inefficient merchandise control management. Therefore, to establish a solution, a warehouse management model was implemented under the Lean philosophy, such as work standardization, 5S, visual control, SLP, and Lean Kaizen. This case study was performed with the guidance of successful cases, with a significant similarity concerning the problems found in the literature review, demonstrating the need to propose an improvement in this sector. It should be noted that, in the articles reviewed, there is little information regarding the application of lean tools in the ceramic tile retail sector since it has been little researched.

1.1 Objectives

The main objective of this research is to reduce the percentage of broken ceramic tiles to 1.65% and, in turn, contribute to developing new tools to facilitate the logistics processes of a retail company. In this way, new methods are modeled to guarantee the reduction of broken products, cycle times, handling times, and improved warehouse management indicators, which is reflected in greater profitability for the company. It is also expected that the proposed model will be helpful for the implementation of continuous improvement and lean tools in the retail sector that sells construction finishes.

2. Literature Review

2.1. Lean warehousing (5s)

The application of a Lean system allows for reducing time in some activities, consequently increasing productivity (Zamalloa-Menacho et al. 2022). A 5s methodology is a tool that originated in Japan with a systematic approach that increases efficiency through a set of 5 actions: sort, order, clean, standardize, and self-discipline; aimed at organizing the workplace (Silvério et al. 2020). This lean tool restores order in the arrangement of resources and reduces the degree of defective work. It is necessary to have specific, measurable indicators for the organization. Applying the 5s methodology reduces waste, improves productivity, and shows measurable results in a short time (Maksudul Islam et al. 2015). Applying Lean Warehousing, 5s, FEFO, SLP, OBC, slotting, and picking techniques to develop a model focused on analyzing the problem of non-conforming products in the warehouse, as a result, increased the productivity rate of the storage and picking processes by 33% and 27%, respectively (Figueroa-Rivera et al. 2021; Sanchez et al. 2021).

2.2. System Layout Planning (SLP)

The System Layout Planning (SLP) allows finding a correlation by analyzing the logistical and non-logistical relationship between the operating units of the warehouse; in other words, this tool facilitates a new appropriate distribution for the work area (Baca et al. 2021). The utilization of the SLP tool and Lean tools reduces lead time and distances traveled for worker movements, representing a significant improvement for the overall efficiency of material flow that impacts several aspects, including increased production and cost reduction (Anchayhua et al. 2022; Brás and Moura 2021). In addition, this tool is a viable approach to solving the design problem because SLP seeks to identify the proposed alternative that best fits the institution's strategies and operating procedures (Pan and Yang 2021)

2.3. Lean Kaizen

The Kaizen methodology can be implemented in different sectors and used in improvement projects and performance evaluations (Bufogle 2020). Implementing Lean Kaizen uses Value Stream Mapping (VSM) to identify opportunities for improvement that are not achieved to determine at a glance, ensuring continuous progress in productivity and product quality based on Lean Manufacturing tools to identify and eliminate waste (Kumar et al. 2018). The methodology applied to implement Kaizen, such as Fishbone or Ishikawa diagrams to perform cause and effect analysis, resulted in savings in terms of money and time. A model on the ceramic finishing sector integrating Lean Manufacturing tools: 5'S and Kaizen Standardization; with those of Planning and Inventory Management achieving a

10% reduction in inventory and scraps and increasing the reuse of plates from 51.44% to 60.70% (Machuca et al. 2021).

2.4. Standardized work

The implementation of standardized work is based on standardizing movements and actions, considering quality and safety to reduce cycle time and variation (Goshime et al. 2019). Standardized work is a lean tool that helps synchronize processes, reduce defects, and brings efficient methods for each type of operation, in other words specifying standards and establishing better methods and sequences for each process and employee. In conclusion, the standardization of work methods reduces the probability of failures, improves workflow, and motivates to learn from failures to discover alternative work method designs allowing higher productivity (Bragança et al. 2015). Work standardization is a set of actions that helps to analyze, improve, and control the process and leads to continuous improvement; identifying activities that do not add value to eliminate them through work standardization increases productivity by 6.5% (Mor et al. 2019). This tool provides short-term results with improved organizational performance, increased productivity, and reduced delivery times.

3. Methods

A model is developed through the literature review of the chosen scientific articles to improve the ceramic breakage incidence indicator. This model proposal generates value by applying Lean Manufacturing tools to solve the problem present in the case study. Below is the comparison matrix between the causes of the problem developed in the case study and state of the art (Table 1).

Table 1. Comparison matrix of the causes developed in the case of study vs. the state of the art

Causes / Author and ref.	Inadequate handling	Low warehouse availability	Cluttered work area	Unnecessary routing
Sanchez et al. (2021)	Standardized work			
Anchayhua et al. (2022)				System Layout Planning
Goshime et al. (2019)	Standardized work			
Baca et al. (2021)				System Layout Planning
Maksudul Islam et al. (2015)			5'S Methodology	
Pan and Yang (2021)		Warehouse management		System Layout Planning
Figueroa-Rivera et al. (2021)		Warehouse management	5'S Methodology	System Layout Planning
Silvério et al. (2020)			5'S Methodology	
Proposal	Standardized work	Warehouse management	5'S Methodology	System Layout Planning

3.1. Proposed model

The proposed model shown in Figure 1 demonstrates the implementation plan of tools that will improve the broken product indicator. This model uses a methodology that behaves as a process of expected inputs and outputs through lean manufacturing tools to reduce the central problem.

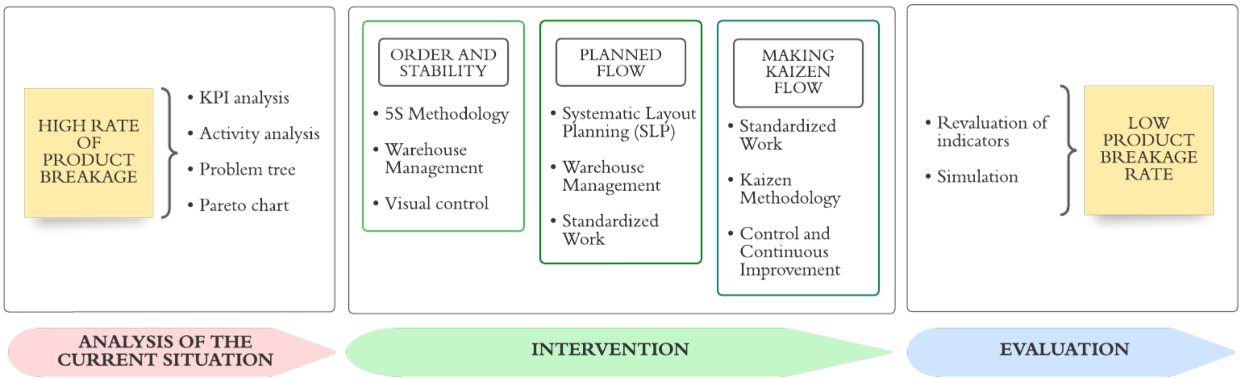


Figure 1. Proposed Model

The model consists of 3 phases. First is the analysis of the current situation, which is based on the detection of the main pain points of the retail company through the development of a VSM diagram that, in turn, will allow a more detailed view of all the activities, times, and resources involved. The second phase is based on implementing the 5S, Standard Work, SLP, and Warehouse Management tools to define a work standard, control defective products, improve distribution and improve order in the warehouse. Finally, the third phase evaluates the tools used and the results that the application of the model will allow to achieve continuous improvement and ensure the reduction of the percentage of broken products, which is evidenced as the main problem of this research.

3.1.1. Analysis of the current situation

In this first phase, a detailed analysis of the current situation and the activities involved in relation to the main problem, which is the incidence of ceramic tiles breakage in the case study. For the analysis of each indicator that supports the problem, first of all, data must be collected throughout the time of operation of the distribution center that involves the mentioned problem, and information must also be gathered from the interview with the managers and heads of each area; then, a problem tree analysis must be carried out to find the causes, sub-causes and root causes that generate this problem. Once these causes have been obtained, a Pareto diagram is made to prioritize the leading causes to be corrected. Then a tree of objectives is made to identify the tools and methodologies to be implemented to develop the solution, the primary diagnostic tool for this study was the value flow map. In addition, the most relevant KPIs were analyzed, and a VSM was built to have a more general view of the logistics process and its relationship with the problem.

3.1.2. Intervention

The intervention is the second phase, which consists of three elements. The first is called "Order and Stability," which consists of implementing the 5'S methodology combined with warehouse management tools. This tool helps standardize work, eliminate waste and activities that do not generate value, and increase the availability of tools and machinery. Furthermore, the guidelines for order and cleanliness will be established throughout the warehouse, and personnel will be trained on the methodology and the actions to be taken. Also, implementing this tool, combined with inventory management, will reduce the inventory level and maintain an optimal environment for the picking process, avoid incidents, and maintain storage allocation policies. This phase begins by collecting and analyzing data through an audit and recording evidence and photos. Then, the first three S plus the warehouse management tools will allow a complete classification of the warehouse and the products with higher or lower rotation, products in stock and broken ceramic tiles of the picking process. In the same way, the tools to be used in all the processes involved in the warehouse will be classified as the state of the pallets and tools to perform the picking. Then, the products with lower rotation, in bad condition, and unnecessary items will be eliminated from the warehouse to generate more space inside the warehouse. For the last two S, warehouse cleaning policies, picking policies, control records, and routine guidelines will be defined to have an orderly and clean workplace with space for storage and to avoid excessive handling of ceramic tiles. Finally, order and cleanliness will be raised as a habit through constant monitoring through internal audits.

The second element is "Planned Flow," which focuses on implementing Systematic Layout Planning (SLP) tool. This tool allows to have a new planned design of the work areas, has an exact location of the warehouses in transit, and establishes the locations of each process in order to eliminate unnecessary routes, also with the data obtained from the identification of products with higher turnover is performed a redistribution of products in the warehouse. The proposed model focuses on solving distribution problems, reducing the distances traveled by the forklift, defining transit warehouses to avoid excessive handling of ceramic tiles and the efficient use of resources such as defining the ideal locations of the products in the warehouse as well as the optimal design of the warehouse. However, since the current design of the warehouse does not have an optimal storage method, they are only stored according to the criteria of the person in charge of each warehouse, which generated delays in the picking process and possible incidents, delays in carrying out the storage process and increased the use of the warehouse, which generated delays for the entry of the products and excessive handling of the material.

The last element is called "Making Kaizen flow," which is based on the combination of standard work and Kaizen methodology. It can be stated that a good diagnosis, together with the standardization of the work, allows the improvement of processes and the quality of each of the products, as well as reducing the incidents of broken products. It should also be noted that it will reduce the time in each activity, increase quality controls and reduce the rate of non-conforming products. In this phase, an analysis of the activities involved, and the main causes will be carried out through the 5 Whys. After identifying the opportunities for improvement, the procedures will be reviewed. Policies and work methods will be generated to counteract these incidents with good practices and quality control in the activities that need it. A procedures manual will be developed for each deficient activity. Finally, the new procedure will be documented, and training will be provided to operators and personnel involved. Audits, follow-up, and continuous improvement will also be carried out.

3.1.3. Evaluation

The evaluation and validation of compliance with the objectives set out in the implementation were developed. In this phase, the initial and final indicators are evaluated under a simulation model of reality to demonstrate the impact generated by the proposal and ensure the model's current state. Audits will be conducted before and after implementing a pilot test to verify the feasibility and compliance of implementing the 5'S combined with warehouse management and Kaizen standardization. In addition to the pilot test, an analysis was performed using the SLP tool to determine the optimal warehouse area in transit. The indicators and formulas are shown below:

Percentage of ceramic tiles breakage: This indicator is of primary importance to meet the objectives, and through the application of Lean tools, it is desired to reduce. Therefore, this indicator will be evaluated after the reception, after storage, after picking, and after dispatch.

$$\% \frac{Broken\ product\ area\ (m^2)}{Area\ of\ product\ shipped\ (m^2)}$$

Forklift travel time with product: This indicator will allow determining the time in minutes of handling the forklift with the product; reducing this time will improve the leading indicator.

$$\sum Time\ of\ product\ transfer\ by\ forklift\ truck\ (minutes)$$

Picking cycle time: After the implementation of the standard work, this indicator should end the time in which an operator, on average, performs the picking activity, the reduction of this will improve the cycle time and demonstrate the effectiveness of the standard work, in turn, reduce incidents of breakage.

$$\sum Time\ it\ takes\ for\ an\ operator\ to\ pick\ a\ product\ (minutes)$$

5S accomplishment: This indicator represents the percentage of the pilot test where 5S is implemented and its level of accomplishment, considering the average of the 5S. A high level of accomplishment demonstrates the effectiveness of the implementation of this tool. In addition, it will help keep the warehouse tidy and clean and improve the performance of the activities involved.

$$\frac{\%\,Accomplishment\ (1s\ +2s\ +3s\ +4s\ +5s)}{5}$$

Unneeded product in the warehouse: This indicator refers to all products that, through the implementation of 5s and warehouse management, are classified as unnecessary products, such as discontinued products, products with very low turnover, unsold balances, defective products, and unnecessary items. Their classification and subsequent elimination from the warehouse or transfer to another area will improve the utilization of the warehouse and, in turn, improve the performance of related activities and, in the future, reduce unnecessary handling of products.

$$\%\frac{Total\ unneeded\ product\ \ (m^2)}{Total\ products\ in\ warehouse\ (m^2)}$$

Percentage of pallets well-packed: This indicator represents the total number of pallets prepared for the shipment that has been packed correctly. Good product stowage and packaging directly reduce breakage and improve customer satisfaction by reducing the number of broken products shipped to the customer.

$$\%\frac{Number\ of\ well-packed\ pallets}{Number\ of\ pallets\ shipped}$$

In-transit warehouse area: This indicator represents the warehouse area in transit in square meters where the product is moved prior to storage. Increasing the warehouse area in transit will reduce unnecessary transfers both in time and distance and excessive stacking that jeopardizes the integrity of the product. For its calculation, the delimited area is measured, and through the implementation of SLP, it is intended to improve.

$$\sum warehouse\ in\ transit\ area\ (m^2)$$

4. Data Collection

Figure 2 shows the data collection flow and the elements collected, depending on the area involved; the three main areas for analyzing the information on the problem are the commercial area, operations, and warehouse. In addition, historical information, sales documents, sales reports, shrinkage reports, and new documents were collected through interviews with managers and supervisors.

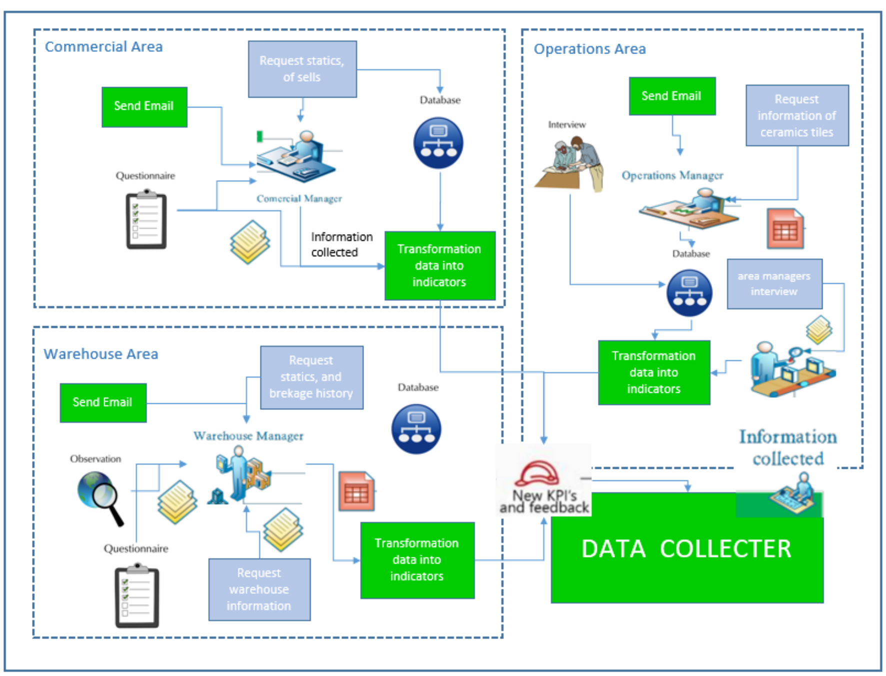


Figure 2. Relationship diagram of the data collection process

5. Results and Discussion

5.1 Numerical Results

This section presents the data obtained from the data collection. First, the percentage of broken products was quantified through the historical data obtained from the product area of the company, which had an annual average value of 2.15% of the broken product in m2 over the total of products shipped in m2. This value is above the average shrinkage value in the retail sector, which is 1.60%, showing a technical gap of 0.55%. In monetary terms, this problem is quantified at approximately 797,704.58 PEN. Through the analysis of the shrinkage report made by the audit area, it is observed that the three leading causes that cause a high percentage of tile breakage incidents are inadequate stowage and transportation of products (26.32%), which includes poor management by the supplier and carrier to ensure the integrity of the load (Figure 3).

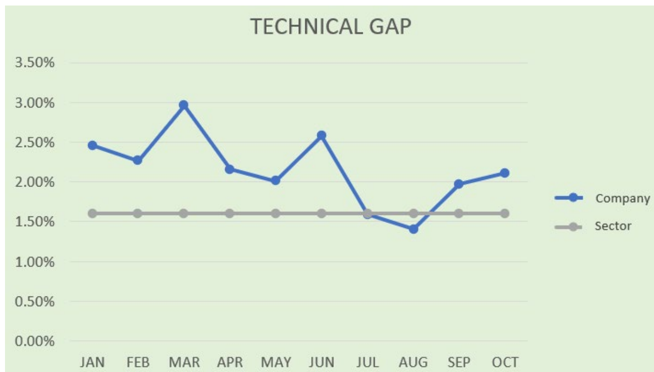


Figure 3. The percentage shrinkage of broken ceramics of the company under study and the percentage shrinkage of the sector from January to October 2021

Furthermore, the inadequate control and handling of the products (27.03%) due to the disorder in the warehouse, the lack of standardization of work when handling the products, and the absence of quality control mainly in the picking process, due to the nature of the product, incidents tend to occur frequently. Finally, it is identified that the excess handling time of the forklift is 15 to 20 minutes on average per purchase order received ready to be stored. The inadequate handling of products with the forklift (25.97%) includes the excessive handling of products, unnecessary loading trips, lack of space, and incorrect handling due to speed.

5.2 Graphical Results

Following are the graphs that are part of the model. These are the results of analyzing the current situation; measuring the results allows improvement. For example, the following graph shows the Value Stream Map of the company in which each activity, resource, time, and the main problem, the breakage of ceramic tiles, can be identified in detail (Figure 4).

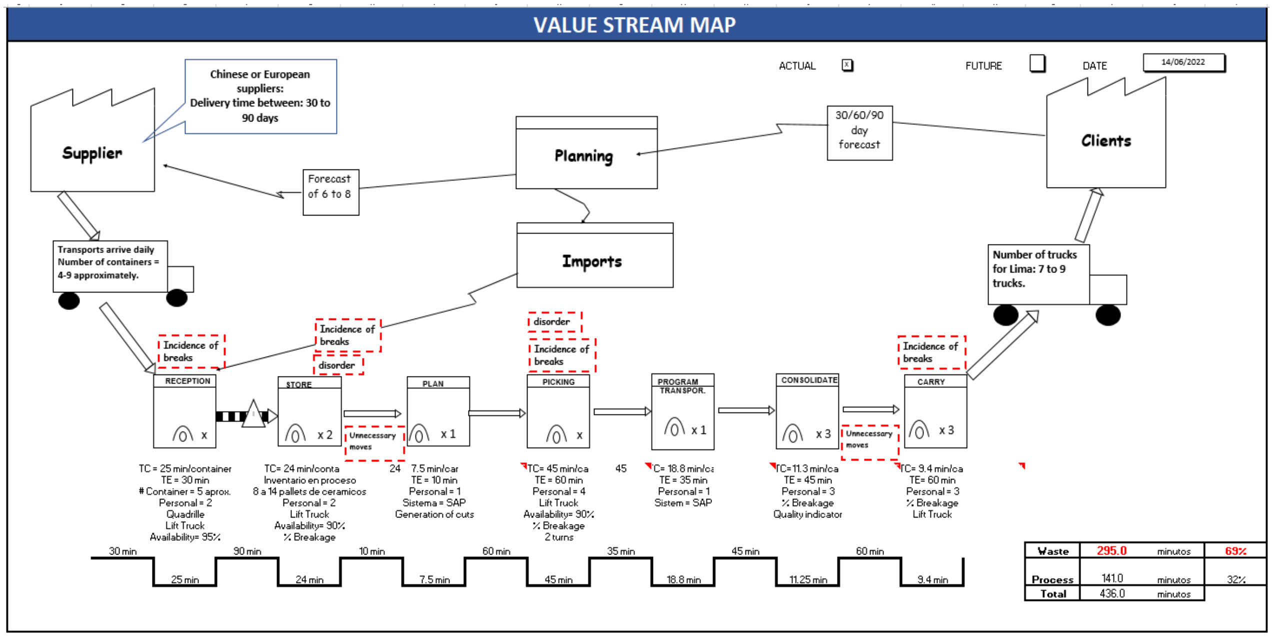


Figure 4. Value Stream Map for the retail company

Also shown are the graphs for the quantitative analysis of the problem, which is the economic impact in the company from January to October 2021 (Figure 5).

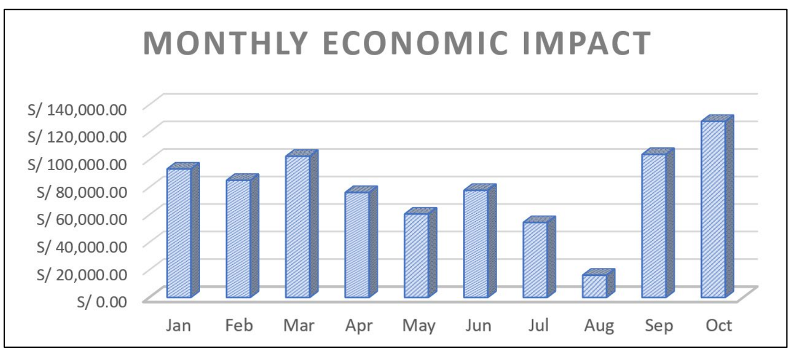


Figure 5. Monthly economic impact

5.3 Proposed Improvements

The proposed improvements are better evidenced through the flow diagram of the proposed model. These allow achieving the desired objective of reducing the percentage of ceramic tiles breakage.

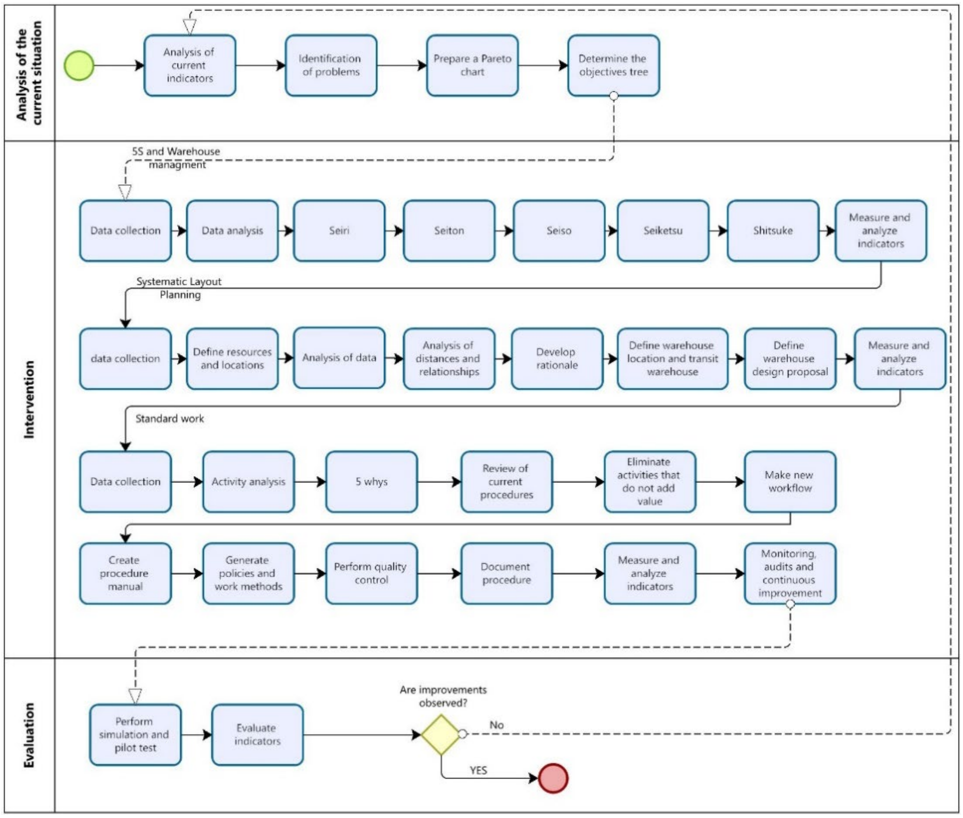
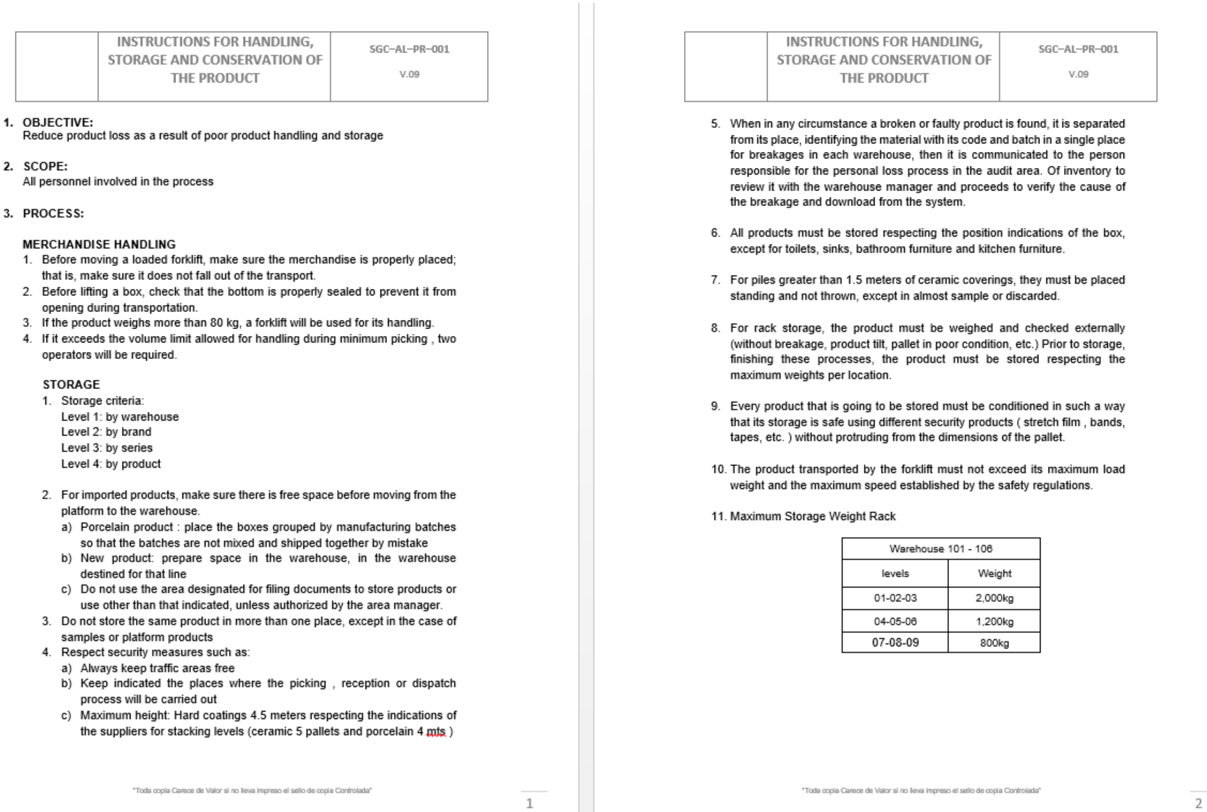


Figure 6. Flow diagram of the proposed model

The company under study presented an initial situation with several opportunities for improvement. For example, applying the 5'S methodology improves order within the warehouse, eliminates unnecessary items, and, combined with warehouse management, generates space by sorting slow-moving products for transfer to another area. The application of SLP will generate warehouse space in transit, reducing excess product handling by having a delimited area for transfer after receiving. It will also allow the correct distribution of the warehouse to reduce product transfer distances with the forklift, which, in turn, will reduce product handling time. Finally, applying the standard work will directly impact the reduction of tile breakage incidents by generating a standard for the product reception procedure, the picking procedure, and the dispatch procedure for the correct packaging and storage of the products to be shipped. Figure 6 shows the work instructions for handling, storage, and conservation of products developed to reduce and comply with a work standard for the reception, picking, and dispatch process. Creating and implementing the Instructions for handling, storage, and conservation of the product have a more significant impact on the picking process since there were no instructions for those activities. In addition, following the instructions reduces the percentage of broken products when handling ceramic tiles correctly (Figure 7).



	INSTRUCTIONS FOR HANDLING, STORAGE AND CONSERVATION OF THE PRODUCT	SGC–AL–PR–001 V.09

1. **OBJECTIVE:**
Reduce product loss as a result of poor product handling and storage

2. **SCOPE:**
All personnel involved in the process

3. **PROCESS:**

MERCHANDISE HANDLING
1. Before moving a loaded forklift, make sure the merchandise is properly placed; that is, make sure it does not fall out of the transport.
2. Before lifting a box, check that the bottom is properly sealed to prevent it from opening during transportation.
3. If the product weighs more than 80 kg, a forklift will be used for its handling.
4. If it exceeds the volume limit allowed for handling during minimum picking , two operators will be required.

STORAGE
1. Storage criteria:
Level 1: by warehouse
Level 2: by brand
Level 3: by series
Level 4: by product

2. For imported products, make sure there is free space before moving from the platform to the warehouse.
   a) Porcelain product : place the boxes grouped by manufacturing batches so that the batches are not mixed and shipped together by mistake
   b) New product: prepare space in the warehouse, in the warehouse destined for that line
   c) Do not use the area designated for filing documents to store products or use other than that indicated, unless authorized by the area manager.
3. Do not store the same product in more than one place, except in the case of samples or platform products
4. Respect security measures such as:
   a) Always keep traffic areas free
   b) Keep indicated the places where the picking , reception or dispatch process will be carried out
   c) Maximum height: Hard coatings 4.5 meters respecting the indications of the suppliers for stacking levels (ceramic 5 pallets and porcelain 4 mts)

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	INSTRUCTIONS FOR HANDLING, STORAGE AND CONSERVATION OF THE PRODUCT	SGC–AL–PR–001 V.09

5. When in any circumstance a broken or faulty product is found, it is separated from its place, identifying the material with its code and batch in a single place for breakages in each warehouse, then it is communicated to the person responsible for the personal loss process in the audit area. Of inventory to review it with the warehouse manager and proceeds to verify the cause of the breakage and download from the system.

6. All products must be stored respecting the position indications of the box, except for toilets, sinks, bathroom furniture and kitchen furniture.

7. For piles greater than 1.5 meters of ceramic coverings, they must be placed standing and not thrown, except in almost sample or discarded.

8. For rack storage, the product must be weighed and checked externally (without breakage, product tilt, pallet in poor condition, etc.) Prior to storage, finishing these processes, the product must be stored respecting the maximum weights per location.

9. Every product that is going to be stored must be conditioned in such a way that its storage is safe using different security products (stretch film , bands, tapes, etc.) without protruding from the dimensions of the pallet.

10. The product transported by the forklift must not exceed its maximum load weight and the maximum speed established by the safety regulations.

11. Maximum Storage Weight Rack

Warehouse 101 - 106	
levels	Weight
01-02-03	2,000kg
04-05-06	1,200kg
07-08-09	800kg

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Figure 7. Instructions for handling, storage, and conservation of the product

5.4 Validation

5.4.1. Validation design and comparison with initial diagnosis

For the 5'S pilot test combined with warehouse management and kaizen standardization, the validation method will be performed by comparing initial and final indicators obtained at the end of the implementation period. An analysis will also be performed to determine the optimal area for the warehouse in transit. The Arena software will be used as a validation method for the other tools in the model. However, being a simulation software, it has some limitations, such as the accuracy of the data obtained and collected. In addition, it does not consider external factors that may affect the duration of each activity and the implementation of the model. The controlled variables of the system (number of operators, number of forklifts, working hours, HH cost) and the uncontrolled variables (time of activities, percentage of defective products, the time between arrival and departure, and work order arrivals) were identified and defined.). Likewise, all the elements belonging to the model, such as entities, attributes, and activities, must be defined. The results of the pilot test validation are presented in the following table 2.

Table 2. Results of the indicators in the pilot test

Indicators	Current	Expected	Obtained
5S accomplishment	0%	100%	90%
Unneeded product in the warehouse	15%	0%	0%
In-transit werahouse area	80 m^2	200 m^2	200 m^2
% Pallets well-packed	75%	100%	100%

5.4.2. Simulation of improvement proposal

The current situation and the proposed improvement were simulated in the Arena software. For calculating the samples, a confidence level of 95% and an average error percentage of 10% were considered. A total of 77 runs of the current situation and the proposed improvement of the whole logistic process were carried out: reception, storage, picking, and dispatch. After taking the times, the optimal distribution for each activity was defined through the input analyzer, Lean Manufacturing tools were implemented in the improvement proposal, and an additional activity was added for the proper storage of products. As a result, the model shows the improvement of product integrity and reduced time and distances for the forklift transfer processes, which involves less time for handling the products. Quality control and work standards were also implemented for the reception and dispatch activity, evidenced in less standard time at the simulation's time. In addition, the leading indicator, the percentage of ceramic tiles breakage, decreased to 1.65%.

Table 3. Results of the indicators in the pilot test

Indicator	I.C Original model			I.C Improve model			Variation (%)
	Average	Minimum Value	Maximum Value	Average	Minimum Value	Maximum Value	
Picking cycle time	6.07 min	5.3 min	7.73 min	4.41 min	4.12 min	4.67 min	27.3%
Forklift travel time with product	18.5 min	16.2 min	23 min	12.1 min	10.5 min	13.7 min	34.6%
Percentage of ceramic tiles breakage	2.15%	0.0%	15.7%	1.65%	0.0%	12.9%	23.3%

The Table 3 shows that with a 95% confidence level, the improved indicator of picking time and forklift transport time with product show a significant difference in the current model, so positive results are expected. However, for the primary indicator of breakage percentage, there is an overlapping of the minimum with the maximum, so it is necessary to compare the means. Furthermore, the output analyzer report obtained that for this indicator, the null hypothesis is rejected, so there is a significant difference. In other words, this indicator is reduced for the improved model. Through the statistical validation, it is evident that applying the tools under the improvement model helps improve the indicators related to the problem and reduces the percentage of breakage of ceramic tiles (Figure 8 and Figure 9).

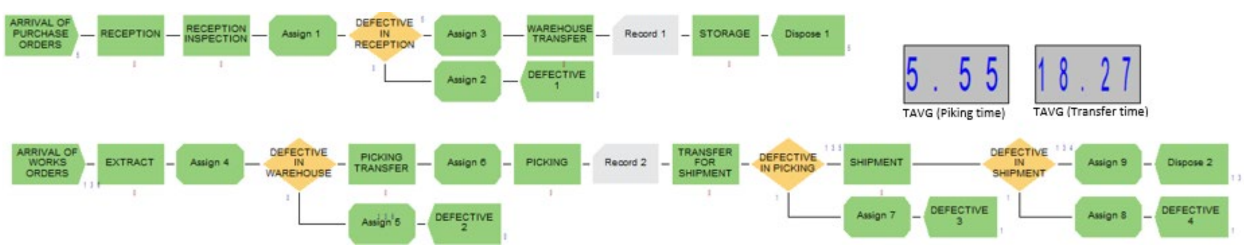

Figure 8. Simulation of the current situation

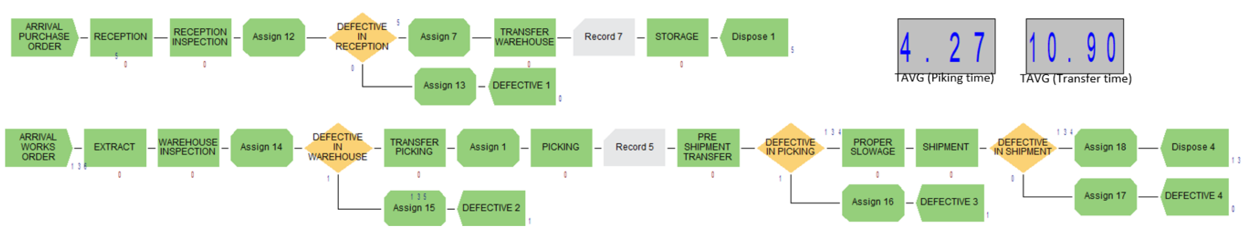

Figure 9. Simulation of the proposed model

6. Conclusion

Implementing Lean manufacturing and Lean Kaizen methodology tools such as 5S, SLP, and Standard Work in conjunction with warehouse management allows positive results in a retail sector company that sells construction finishing products. After setting up the model and performing the simulation, the tile breakage indicator improves to 1.65% of the total area of products sold, and the improvement of each indicator is related to the problem. This optimization translates into higher profitability for the company. In conclusion, the present research's objective was to improve the indicator of ceramic tile breakage, which is presented as the company's main problem under study.

References

Anchayhua, G., Cevallos, S., Peñafiel, J. and Raymundo, C., Production Management Model Based on Lean Manufacturing and SLP to Increase Efficiency in the Tapestry Manufacturing Process in Lima Manufacturing SMEs. Lecture Notes in Networks and *Systems*, vol. 319, 2022.

Baca, J., Sánchez, F., Castro, P., Marcelo, E. and Alvarez, J. C., Productivity improvement in companies of a wooden furniture cluster in Peru. *International Journal of Engineering Trends and Technology*, vol. 69, no. 10, pp. 97–107, 2021.

Barrientos-Ramos, N., Tapia-Cayetano, L., Maradiegue-Tuesta, F. and Raymundo, C., Lean Manufacturing Model of Waste Reduction Using Standardized Work to Reduce the Defect Rate in Textile MSEs, 2020.

Bragança, S. and Costa, E., An application of the lean production tool standard work, *Jurnal Teknologi*, vol. 76, 2015.

Brás, M. and Moura, A., Facility Layout Design Tools Comparison: A Case Study of a SME in Electronic Industry. *Proceedings of the 4 th European International Conference on Industrial Engineering and Operations Management*, pp. 933–947, Rome, Italy, August 2-5, 2021.

Bufogle, L. R., Maintenance and operations improvement process. *AISTech - Iron and Steel Technology Conference Proceedings*, pp. 2208–2213, Cleveland, Ohio, USA, August 31 – September 3, 2020.

El comercio retail representa el 10.7% del PBI del Perú, Available: https://andina.pe/agencia/noticia-el-comercio-retail-representa-107-del-pbi-del-peru-765384.aspx, September 2, 2019.

Figueroa-Rivera, E., Bautista-Gonzales, A. and Quiroz-Flores, J., Increased productivity of storage and picking processes in a mass-consumption warehouse applying Lean Warehousing tools: A Research in Peru, 2021.

Goshime, Y., Kitaw, D. and Jilcha, K., Lean manufacturing as a vehicle for improving productivity and customer satisfaction: A literature review on metals and engineering industries. *International Journal of Lean Six Sigma*, vol. 10, no. 2, pp. 691–714, 2019.

Kumar, S., Dhingra, A. and Singh, B., Lean-Kaizen implementation: A roadmap for identifying continuous improvement opportunities in Indian small and medium sized enterprise. *Journal of Engineering, Design and Technology*, vol. 16, no. 1, pp. 143–160, 2018.

Machuca, S., Alexandra, A., Salinas, Z. and Junior, G., Modelo integrado de Lean Manufacturing con Gestión de Inventarios para reducir el inventario y scrap generado en el sector de acabados de construcción, Available: http://hdl.handle.net/10757/654544, 2021.

Maksudul Islam, M., SajibulAlam Bhuyan, M. and Seyam, A., Implementation of 5S in a Plastic Manufacturing Company wth Fuzzy Logic. *International Journal of Research (IJR),* vol. 2, no. 1, pp. 649–658, 2015.

Mor, R. S., Bhardwaj, A., Singh, S. and Sachdeva, A., Productivity gains through standardization-of-work in a manufacturing company. *Journal of Manufacturing Technology Management*, vol. 30, no. 6, pp. 899–919, 2019.

Pan, X. and Yang, J., Warehousing Layout Optimization on Logistics System of Fresh Products. *3rd International Academic Exchange Conference on Science and Technology Innovation*, pp. 1241–1246, Guangzhou, China, December 10-12, 2021.

Sanchez, N. Y. E., Santos, P. Y. S., Lastra, G. E. M., Flores, J. C. Q. and Merino, J. C. A., Implementation of Lean and Logistics Principles to Reduce Non-conformities of a Warehouse in the Metalworking Industry. *Proceedings - 2021 10th International Conference on Industrial Technology and Management*, pp. 89–93, Cambridge, UK, March 26-28, 2021.

Silvério, L., Gonzaga Trabasso, L. and Vinicius Pereira Pessôa -, M., Lean manufacturing-a method of managing a manufacturing enterprise. *IOP Conference Series: Materials Science and Engineering*, 2020.

Vásquez Médico, J., Rojas Polo, J. E. and Cáceres Casanya, A., Improved productivity indicators in a textile company through the synergy of Lean Manufacturing tools and socio-technical approach. *16 Th LACCEI International Multi-Conference for Engineering, Education, and Technology: "Innovation in Education AndInclusion."*, Lima, Peru, July 19-21, 2018.

Zamalloa-Menacho, A., Manani-Rojas, R., Flores-Perez, A. and Collao-Diaz, M., Proposal of production model based on Lean and Continuous Improvement to improve the productivity in SMEs of baking: an empirical investigation in Peru. *2022 The 3rd International Conference on Industrial Engineering and Industrial Management*, pp. 66–71, Barcelona, Spain, January 12-14, 2022.

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Juan Carlos Quiroz-Flores holds an MBA from Universidad ESAN. Industrial Engineer from Universidad de Lima. Ph.D. in Industrial Engineering from Universidad Nacional Mayor de San Marcos, Black Belt in Lean Six Sigma. He is currently an undergraduate professor and researcher at the University of Lima. Expert in Lean Supply Chain and Operations with more than 20 years of professional experience in the direction and management of operations, process improvement, and productivity; specialist in implementing Continuous Improvement Projects, PDCA, TOC, and Lean Six Sigma. Leader of the transformation, productivity, and change generation projects. Able to form high-performance teams aligned with the company's "Continuous Improvement" strategies and programs. He has published articles in journals and conferences indexed in Scopus and Web of Science. His research interests include supply chain and logistics management, lean manufacturing, lean six sigma, business process management, agribusiness, design work, facility layout design, systematic distribution planning, quality management, Industry 4.0, Digital Transformation, and Lean Manufacturing. He is a classified researcher by the National Council of Science, Technology and Technological Innovation of Peru (CONCYTEC), as well as a member of IEOM, IISE, ASQ, IEEE, and CIP (College of Engineers of Peru).