Implementation of engineering techniques for reducing waste in Warehousing: A case study in a Peruvian Food Company

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***Abstract*– Companies belonging to the food sector are exposed to a problem related to the loss of products during the production and commercialization processes, which mainly causes an increase in the amount of waste generated. The objective of this research is the reduction of waste generated during warehouse operations in a food company, which presents an increase in its waste ratio equivalent to 233% compared to previous years. The implementation of Lean Warehousing tools was developed, specifically Kaizen Teian and Kanban Pull, together with the Slotting warehouse strategy considering the useful life of the products as a criterion. With the development of these tools, the food waste ratio is expected to be reduced to a value close to the industry standard, corresponding to 0.25%.**

***Keywords*-- Food company, Lean Warehousing, Kaizen Teian, Kanban Pull, Slotting.**

I. INTRODUCTION

In food industries around the world, waste represents the irrecoverable loss of products. In fact, it is estimated that those generated in Latin America and the Caribbean represent 11.6% of the world total [1]. In these regions, food waste represents 15% of available food, which could feed up to 30 million people in the Latin American population [2].

It is emphasized that, after the end of 2019, fruits and vegetables accounted for 21.6% of food waste in the world. In addition, the fractions of total losses were determined according to the stages of the food chain, where it was obtained that 29% of waste was produced during warehouse processes [3]. It should be emphasized that the main processes involved in warehouse management are Receiving, Storage, Packaging and Dispatching.

In the national context, excess food product waste has negative impacts, both economically for the organization and on a general scale in Peru. This impact is measured through the wastage ratio, which represents the proportion of food waste respect to the total product sales [4]. It was found that the magnitude of this indicator amounted to 0.60%, in relation to the food sector, in 2021, increasing by 0.42% in the last four years [5]. This problem drives the implementation of alternatives to solve this problem generated during the warehouse processes.

In view of the fluctuations of these processes, the implementation of Lean Warehousing tools is developed, which aim to optimize existing warehouse operations and seek alternatives for waste reduction [6].

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In a study performed in a food company, it was possible to reduce the waste generated for the order preparation process by 17% through the implementation of the Kanban tool [7]. In another case, the concept of Kaizen practices (continuous improvement) was proposed for the dispatch process, which led to a change in the organization by guiding the team to follow a standard process, achieving a 23% reduction in product losses due to errors in the execution of activities [8]. On the other side, studies were analyzed in which an inventory distribution strategy was applied based on the Slotting methodology, which proposes a series of criteria for the intelligent arrangement of products within the warehouse to reduce waste due to low turnover [9].

Based on this, the research focuses on the integration and implementation of Lean Warehousing tools for the reduction of food waste within the supply chain. This is justified through the improvement opportunities identified in the literature. For example, it was identified that the implementation of advanced technological tools generated high unanticipated costs during project progress. Therefore, the authors suggested the application of tools that allow the organization of resources and that are adapted to industrial conditions at the national level [11]. Also, it is suggested that, to maintain the organization of stocks, both in physical and virtual warehouses, products should be allocated according to the criterion that best suits the prevention of expiration dates in the warehouse [12].

The information presented in this article is distributed as follows: Section II contains the literature review, where the contributions of different authors regarding the implementation of engineering techniques for storage management in each of the its components; Section III details the case study, where the analysis of the organization and its current problems in terms of waste generation is carried out; Section IV presents the design of the proposed solution model according to the characteristics of the system; Section V validates the proposed solution by comparing metrics related to each component of the process; Section VI presents the results obtained during the pilot test carried out in the validation, in which the ratio of waste obtained in terms of the general warehouse system is quantified; finally, Section VII and Section VIII presents the conclusions and recommendations obtained at the end of the investigation.

II. LITERATURE REVIEW

The review of the state of the art is carried out to determine the set of proposals that are focused on the implementation of storage engineering techniques. These can show their link with tools that give solution to the identified causes and with it the solution to the waste problem. Given this, the search for such information was classified into the following typologies:

A. Process based on the standardization of product reception

To obtain a better standardization among the product reception processes, one must start from the recognition of the optimal input quantities, so that the quantities that are entered in each component of the warehouse would represent their exact quantity in terms of compliance with the forecasted demand [13]. However, there is the scenario where the existence of a demand pattern is unknown, i.e., the products follow a stochastic trend [14]. If this is the case, it is proposed to recognize the products at the entrance of the warehouse and evaluate them through the stock levels. This is achieved through the application of different tools. Among these we highlight the participation of a computational simulator that integrates the "Dynamic Buffer Management" (DBM) method that works independently of the variable demand [15]. On the other hand, two main tools focused on the standardization process were the Six Sigma model - DMAIC [16] and the Kaizen Teian method.

The group of authors that implemented the Six Sigma model managed to improve the level of performance for the processes under study by 29.8% while maintaining control and follow-up of the improvements obtained [17]. On the other hand, the authors who implemented the Kaizen Teian system obtained the assurance that the personnel assigned to the development of activities in each process is monitored, allowing the standardization of the activities that presented the most failures [18]. Likewise, through the application of this tool, the percentage of damaged boxes was reduced by 27.2%, reducing the waste generated to 18.9% [19].

B. Process focused on optimizing inventory turnover

In the literature, it is stated that the storage component is the one that contributes most to the generation of waste. One of the main reasons is that perishable products expire at this stage. This factor can be treated at the beginning with methods or strategies that intervene from the modification in the management and arrangement of locations for the products in this process [20]. To maintain control prior to establishing possible changes to the allocation of locations, periodic reviews, the configuration of warehouses to guarantee product sales before perishing or the modeling of algorithms that provide the best alternative for minimizing costs incurred [21] are supported.

According to the literature, one of the solution tools is the Slotting method and its adaptation according to the storage classification criteria required by the industry [22]. Likewise, a differentiation is highlighted for perishable products, because in these it is necessary to distinguish between those that follow a high demand and the shelf life they have. In this way, the FEFO classification is prioritized, thus achieving a priority impact for their rotation and greater visibility in the storage area [23]. It was demonstrated that its application in food products has an impact on the reduction of reports of the quantities of immobilized and expired products by 17.3%. In addition, it was shown that wastage was reduced by 22.1% impact on inventory turnover, amounting to 28% with respect to its revenue [24]. On the other hand, two additional tools were identified that can generate similar impacts, among which the application of the nonlinear programming algorithm stands out, which managed to increase product turnover by 21% and reduced the waste generated by it by 15.2% [25]. However, its application was determined in perishable products that were inventoried according to demand criteria. The third tool is also an algorithm focused on the creation of management policy scenarios. With its application, it was possible to increase inventory turnover by 19.7% with respect to sales.

C. Management of shelves for order extraction

The literature details that, within the order preparation process, the waste generated is related to the activities of movement in the aisles and the extraction of products. In these sections, obstacles may appear from the resources used by the company to carry out the activities, among which are forklifts, pallets and ladders [26]. The solution for this management focuses on the organization of these resources and that the personnel is responsible in the use of these [27]. To this end, three tools were identified to contribute to this organization. To facilitate logistics within the order preparation process, a board based on the Kanban Pull system was developed, which showed the information of the resource that was being used and was communicated to all personnel [28]. In this way, the incidents that occurred in transportation due to machinery handling decreased by 20.4%, reducing the waste generated by 19.9% due to damage to the boxes [29]. On the other hand, the implementation of the Extreme Programming tool resulted in a 15.3% reduction in waste generated by the proximity of orders leaving the warehouse [30]. A similar result was obtained with the implementation of the Scrum tool, which performed a continuous evaluation of the tasks performed and optimized communication between areas, reducing handling errors by 16.8% and waste by 14% [31].

D. Process for defining standardized procedures in product dispatching

The activities of the last component of the warehouse process are usually like the first one since they are the entry and exit of products [32]. Thus, the activities that make up these processes are similar but not the same, in fact, it was identified that the common problem was the handling of the machinery, since not all personnel consider relevant the development of guides or instructions in their use [33].

Therefore, the tools used for this process must ensure the standardization of the activity that presents the most failures and ensure that the operators follow them. As defined in typology 1, the tools best suited for this adaptation are the Kaizen Teian methodology and the Six Sigma system. However, as determined between these two applications, the Kaizen tool showed a greater reduction in metrics, being this the tool to follow.

The authors that implemented the Six Sigma model managed to improve the performance level of the processes under study by 25.2%, maintaining the control and follow-up of the improvements obtained [17]. On the other hand, the authors who implemented the Kaizen Teian system obtained the assurance that the personnel assigned to the activities of the assembly line are developed in a standardized way due to the monitoring of the activity [18]. Likewise, through the application of this tool, the percentage of damaged boxes was reduced by 29.8%, reducing the waste generated to 17.5% [19].

III. CASE STUDY

A. *Organization description*

An in-depth study was conducted on the ABC food company, which is experiencing a problem due to the amounts obtained from the increase in the generation of waste in its warehouse operations. These operations are divided into four processes: Receiving, Storage, Packaging and Dispatching.

TABLE I
WAREHOUSE PROCESSES

	Receiving	Storage	Packaging	Dispatching
FINISHED PRODUCTS	Unloading Activities	Location Assignment	Picking	Loading Activities
		Maintenance		
	Control of Products Received	Inventory Management	Packing	Distribution
		Waste Management		

B. *Object of investigation*

The ABC food company has a wide variety of products, so the object of research was limited to finished products (TP) belonging to the Mass Consumption business in Peru (CMP). Thus, the categories of food products belonging to the company's Distribution Center 1019 (DC 1019) were analyzed. Through a comparison between the amounts generated by each type of product, it was obtained that those belonging to the "sauces" category generated higher expenses for waste after the closing of the first quartile of the year 2022. Based on this, it was decided to work with the items that had the highest participation in the category, these being the hot sauces products. Among these, the study focused on the five hot sauces with the highest expenditures. It should be noted that the finished products to be analyzed are presented in doypacks of 400 grams, which are packed in boxes of 24 units, to be finally stacked on pallets of 35 boxes.

C. *Waste of the select product generated in the warehouse*

Once the object of research has been defined, the waste generated by each stage of the warehouse is presented. This shows the amount of waste generated after the close of the month of March 2022.

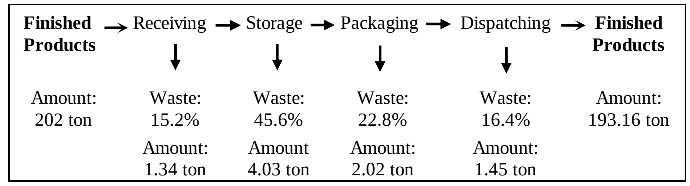

Fig. 1 Waste of the select product

According to the figure 1, it is determined that each process represents a fraction of the problem, so they can be treated as components of the warehouse process. With this, the main causes of each component were identified along with the amount generated.

TABLE II
MAIN CAUSES BY COMPONENT

Process	Main Cause	Waste (ton)	Waste (S/)
Receiving	Difference in the performance of personnel activities in the unloading activity	1.06	S/ 2,533.75
Storage	Consideration of a single criterion for product location assignment	2.28	S/ 5,472.00
Packaging	Disorganization in the use of resources during product picking	1.37	S/ 3,289.33
Dispatching	Difference in forklift handling during product loading	1.04	S/ 2,489.18

IV. CONTRIBUTION

A. *Linking cause and solution*

Through the literature review, the possible potential solutions to the prioritized causes that were determined for each warehouse process were determined.

In relation to the difference in personnel development in the unloading activity for the product receiving process, two possible solution tools were highlighted for the standardization of activities [34]. Among these, the Kaizen Teian methodology was selected given the focus it promotes for continuous improvement and the benefits that its implementation brings with respect to the waste generated.

In relation to the consideration of a single criterion for product location assignment in the storage process, three solution tools were identified. Of these, the Slotting model strategy was chosen under the FEFO criterion, since foods are perishable products that maintain an expiration and immobilization rate, so they must be stored according to their useful life [35].

Regarding the disorganization in the use of resources during product picking, three tools were identified that allow an organization in the management of resources within the company. Among these, the Kanban Pull tool was chosen, since it successfully integrates a visual support using identification cards, as well as the implementation of a control panel that integrates these cards and communicates the necessary information to the personnel. This would reduce the accounting waste generated by the resource obstacles encountered in the identified sections.

In reference to the difference in forklift handling during product loading in the dispatching process, two tools were located. These tools were defined in the first cause, since it is necessary to standardize the activity identified as critical. In this case, the tool to be used will be the Kaizen Teian since it ensures continuous improvement in the performance of the activity.

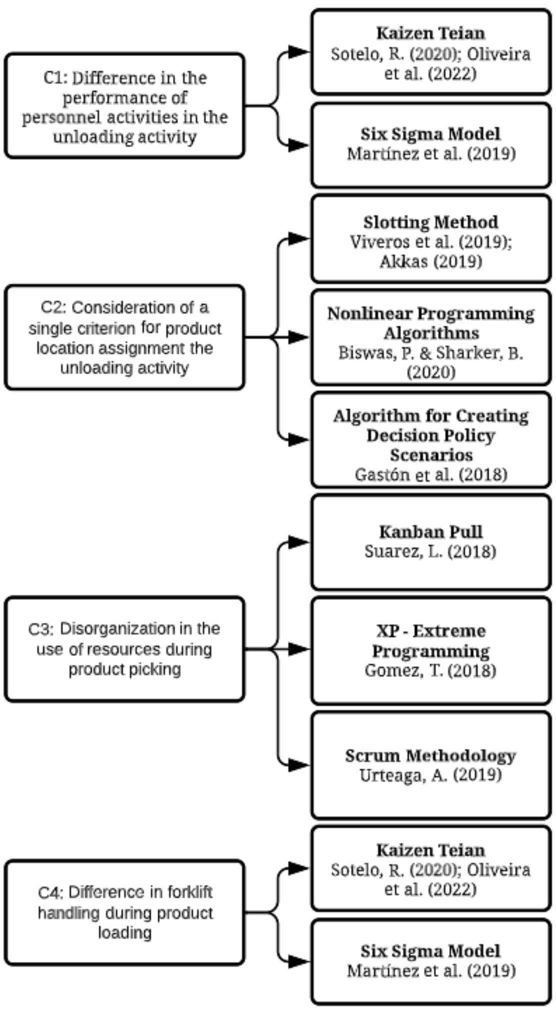

Fig. 2 Linking cause and solution

B. *Design of the proposed solution model*

The proposed model is based on the techniques of warehousing tools, it focuses on the Lean Warehousing methodology which provides a horizontal solution orientation, that is, it integrates the four main processes of the warehouse and provides the application of a different tool per process. Unlike other existing solution models, the proposed model focuses on the integration of these three tools. Likewise, the specific use of Lean tools is identified for the reduction of waste in the defined processes, including Kanban Pull and Kaizen Teian.

As part of the solution model, given that there will be changes in the activities to be developed by the personnel and the implementation of formats and records, they must show acceptance of the change, to implement strategies to achieve modifications with respect to the objectives, processes, and technologies. For this reason, change management is proposed, an application that sensitizes and raises awareness among the personnel about the changes that are developed within their activities function and obtain a better career plan. This implementation is the preliminary phase.

TABLE III
DESIGN OF SOLUTION MODEL

PHASE 0 Change Management			**PHASE 5** Validation
Identification of the current problem			Pilot Test
PHASE 1 Receiving	**PHASE 2** Storage	**PHASE 3** Packaging	**PHASE 4** Dispatching
Continuous Improvement	Waste Management	Flow Management	Continuous Improvement
Kaizen Teian	Slotting	Kanban Pull	Kaizen Teian

C. *Proposal Specific Model*

Change Management

First, it is proposed to implement a change management model focused on the understanding and comprehension of the personnel about the Lean Warehousing tools to be integrated. The beginning of this component is given with the development of process flows, highlighting the critical activities of each warehouse process. Based on this, we propose the development of training workshops on the models to be implemented and the standardized processes to reduce the criticality in the development of the activities that generate waste.

Receiving

On the part of product reception, it is proposed to conduct an initial audit focused on measuring critical activities to evaluate the current situation. Based on the results of the study, a standard process is established, which aims to reduce the difference in the development of activities by the personnel. Once defined, a continuous improvement follow-up format based on the Kaizen Teian model is established to ensure compliance with the defined process.

Storage

Regarding the storage process, it is proposed to consider the shelf life of the hot sauces as a criterion for their location in the warehouse. Thus, in a first stage, the effort made by the operators in a current situation where the product is stored according to demand is evaluated. Through an audit, it became evident that the low product turnover is related to the ease with which the operators can locate the product. Therefore, a sample of a new location was made following an allocation of locations by shelf life. Through this, the same effort analysis was carried out, which proved that this criterion is beneficial for increasing the rotation of hot sauces.

Packaging

For the order preparation process, the resources that generated obstructions during the trips to the packing area were analyzed. Once identified, a flow diagram of materials and information was drawn up, which provided a visualization of the current situation regarding unused or unreturned resources. Therefore, the implementation of Kanban cards was proposed, which will allow the identification of resources and their location through the integration of a GPS system. In addition, these cards will be integrated into a control panel, which will allow operators to recognize the availability of the resource and ensure its return to avoid interruption in the transfers.

Dispatching

Finally, in the dispatch process, an audit was conducted to show the conflicts during the loading activity, which was determined to be the critical activity of the process. This audit mainly revealed failures in the handling of forklifts. In view of this, a standard process was established, highlighting the handling to be performed by forklift operators. Once defined, a continuous improvement follow-up format based on the Kaizen Teian model was established to ensure optimum compliance with forklift handling.

TABLE IV
DETAILED IMPLEMENTATION PROPOSAL

Implementation of engineering techniques for reducing waste in Warehousing: A case study in a Peruvian Food Company.				
Base Component Change Management	**First Component** Receiving	**Second Component** Storage	**Third Component** Packaging	**Fourth Component** Dispatching
Stage 1: Layout of actual activities	**Stage 1:** Solution objectives	**Stage 1:** Solution objectives	**Stage 1:** Solution objectives	**Stage 1:** Solution objectives
Stage 2: Identification of critical activities	**Stage 2:** Training Planning	**Stage 2:** Training Planning	**Stage 2:** Training Planning	**Stage 2:** Training Planning
Stage 3: Training Planning	**Stage 3:** Validation of the model	**Stage 3:** Actual situation with the demand criteria	**Stage 3:** Standardization of picking activity	**Stage 3:** Validation of the model
	Stage 4: Implementation of standardization	**Stage 4:** Standardization according to FEFO criteria	**Stage 4:** Validation of the model and evaluation	**Stage 4:** Implementation of standardization
		Stage 5: Validation of the model		

V. VALIDATION PROPOSAL

A. *Validation metric*

In relation to the table IV, a scheme of metrics is presented to validate the implementation of the tools in terms of the solution of the identified prioritized causes. In this way, the values of the indicators obtained in the current situation are presented through the results of the reports obtained in the last week of March 2022. In addition, the expected results that can be achieved with the implementation of the proposed model and the support adapted to the solution literature are presented.

TABLE V
INDICATORS AS IS – TO BE

Receiving	**Storage**	**Packaging**	**Dispatching**
Number of cases damaged in the unloading activity ("box/pallet") Actual value: 1.45 box/pallet Proposal Value: 0.36 box/pallet	Rate of personnel effort during the trip to the product location of the product Actual value: 3.59% Proposal Value: -16.87%	Number of cases damaged during the movement ("box/pallet") Actual value: 1.09 box/pallet Proposal Value: 0.27 box/pallet	Number of cases damaged in the loading activity ("box/pallet") Actual value: 1.27 box/pallet Proposal Value: 0.45 box/pallet
Error rate in the execution of critical activities Actual value: 27.27% Proposal Value: 9.09%		Rate of forklifts not returned Actual value: 20.00% Proposal Value: 5.00%	Forklift handling error rate Actual value: 36.36% Proposal Value: 9.09%

B. Validation component

Once the situation of the ABC food company is presented, we proceed to implement a sampling with the critical variables to be considered by process. This will be implemented for an estimated 6 weeks, approximately. With this it will be possible to validate the obtaining of the expected metrics.

TABLE VI
PILOT TEST DURATION

PILOT TEST			
Component	**Proposal**	**Validation Method**	**Duration**
Receiving	Kaizen Teian	Pilot Test	4 weeks
Storage	Slotting - FEFO		8 weeks
Packaging	Kanban Pull		5 weeks
Dispatching	Kaizen Teian		4 weeks

Receiving

For the validation of the Kaizen Teian tool in the product receiving process, a follow-up format of the new standardized activity flow was presented, where the new position of forklift assistant is also evident. A record was developed on a sample of 23 unloading activities to evaluate the reduction of boxes affected in the process due to the implementation of the tool. In addition, a continuous improvement supervision report is presented. This evaluation will be done after 4 weeks of implementation.

Storage

Regarding the validation of the Slotting methodology and the useful life allocation criteria, a location close to the warehouse packaging area was assigned for a total of 90 boxes of products with expiration in December 2022. It was verified that this new location represented less effort during product location activities to ensure increased rotation in the warehouse. In addition, the sale of the products close to being classified as immobilized through a trade operator was ensured. The results will be presented through the number of immobilized and expired products that were able to leave the warehouse with the new location of hot sauces in the warehouse. The test of this implementation will run for 8 weeks, to study the desired approach.

Packaging

The validation of the Kanban Pull tool for the preparation process consists of a record of the report of resources that have not been returned. To do this, a sample of each resource was recorded through Kanban cards, which were supervised during the development of 12 picking activities. Said evaluation was carried out with the incorporation of a supervisor in charge of the resource availability control panels that were incorporated in the warehouse. Likewise, the assignment of functions of the resource control panel supervisors is presented, who will assume a new position in the process. These records will be evaluated at the end of week 5.

Dispatching

For the validation of the Kaizen Teian tool in the order dispatch process, a follow-up format was presented with the activities, indicating the optimal handling of the forklift and the parameters to be followed during operations within the warehouse. Also, a record of functions assigned to a new position was presented, being represented by the forklift assistant. With this, the improvement in the development of 12 order loading activities was evaluated. In addition, a continuous improvement tracking report was developed to monitor standardized forklift handling. This evaluation will be done after 4 weeks of implementation.

VI. Results

Receiving

After the standardization of the product unloading activity, reports were made to evaluate the new improved situation and analyze if there are certain improvements during the activity, after the application of the Kaizen Teian tool. In this case, the parameters of the affected boxes (representing the waste generated in this process) and the error rate during the execution of the unloading activity were measured. As main results, the reduced number of affected boxes stands out, being the improved value 0.30 box per pallet. On the other hand, the error rate during execution was reduced to 13.04%. Regarding this last value, it should be noted that it did not reach the expected percentage proposed in the literature, but it is nevertheless considerable.

Storage

In the storage process, the rate of effort of the personnel during the entire route to the product location was measured according to the demand-driven location criterion. Through the implementation of the slotting tool, which includes the useful life criterion as the main factor for the location of perishable products, it was promoted that these are close to the packing process and thus the new overexertion was calculated. The result obtained was -14.61%, indicating that the operators would not overexert themselves, which would serve as an incentive to carry out this proposal and obtain results in inventory turnover.

Packaging

Given the implementation of the Kanban Pull panels and their integration with the pull cards, an improvement was achieved in the organization of the resources distributed during product picking. For this, audits were recorded based on the panel supervisor, who was responsible for accounting for the number of resources that were not returned, becoming an obstacle and generating waste in the process. Given this, the report was quantified and showed a reduction to 0.42 cases per pallet. On the other hand, the rate of the most frequent resource (forklift) not returned decreased by 10%, being a value close to the ideal, i.e., that proposed by the literature.

Dispatching

After the standardization of the product loading activity, reports were made to evaluate the new improved situation and to analyze if there are certain improvements after the application of the Kaizen Teian tool. In this case, the parameters of the affected boxes and the error rate during the execution of the loading activity were measured. The main results were the reduction in the number of boxes affected, the improved value being 0.33 box per pallet. On the other hand, the error rate during execution was reduced to 16.67%. Regarding this last value, it should be noted that it did not reach the expected percentage proposed in the literature, in fact, it is still far from the ideal, resulting in a point of improvement for future development in the dispatch process.

Results in the Warehouse System

In a synthesized manner, the general warehouse system was integrated, including the amount of waste generated by the implementation of the tools. The table VII shows the economic amount that this waste reduction would represent.

TABLE VII
ANNUAL ECONOMIC RESULTS

DETAIL	AMOUNT	
Benefit for soon to expire products sold	S/	2,149,476.10
Savings for maintaining products in the warehouse	S/	75,725.28
Savings for non-discarded products	S/	1,064,541.83

As show in the table VII, two main benefits are obtained, which integrate the amounts presented. These are directed to sales and the total amount of waste. These amounts contribute to the calculation of the system's metric of waste to revenue ratio as projected.

TABLE VIII
WASTE RATIO RESULT

	Actual	Economic Benefit	Proposed
Amount for waste	S/ 3,193,655.87	- S/ 75,725.28 - S/ 1,064,541.83	S/ 2,053,388.75
Sales income	S/ 532,275,977.73	+ S/ 2,149,476.10	S/ 534,425,453.82
Ratio	0.60%		0.38%

According to the table VIII, it is observed that by implementing the tools in the different processes that make up the overall system, the benefits that would be the representatives for the calculation of the waste ratio are obtained, thus obtaining the value of 0.38% of waste in the overall system through the implementation of the tools.

VII. CONCLUSIONS

As a result of the validation of the tools, the final result of the warehouse system for the company under study is emphasized, which identifies the achievement of a waste ratio of 0.38%. However, the intention of this research was focused on achieving a percentage of 0.25, in order to achieve a penetration over the gap identified for this problem. Therefore, it is concluded that the integration of the tools and their application in this system did not give the expected scope in order to obtain an ideal model, however, an improvement is identified regarding the current situation, since this ratio presented a reduction of 0.22%. Likewise, the importance of the choice of the tools to be applied to the processes present in the system is highlighted, since, if more tools had been integrated, the proposed goal might have been met.

VIII. RECOMMENDATIONS

Emphasizing the realization of the pilot test during the storage process, other types of tools are recommended apart from the Slotting strategy. This is because the proposal involves a general change in warehouse locations, which implies costs for redistribution, this being a conflict in large companies. During the development of the validation, it was possible to obtain a warehouse space to carry out the tests and obtain results with the Slotting method. However, the pilot test was limited to a small number of hot sauce products. For this reason, it is suggested to develop simulations instead of pilot tests for similar case studies, given that more accurate results can be obtained on a larger scale.

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