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Reverse Logistics Optimization Model Applying Process Simulation in a Carbonated Beverage Distribution Centre in Perú

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Abstract **-** The main objective in this paper is to analyze the reverse logistics process of a distribution center to propose an optimization model. For this, the case study of a carbonated beverage distribution center in Perú was used, where high waiting times of trucks due to problems in verification of payment and classification of bottles were found. The optimization model included the usage of automation and digitalization of processes. To verify the results, simulation was used in the ARENA software, making the proposal visible and determining its impact on the service process of trucks that return daily with empty, broken or dissatisfied bottles with the client. With the following research, positive results were obtained, demonstrating the effectiveness of the application and the potential of engineering and statistical analysis tools, being able to observe an improvement in the classification area and in the number of trucks served in one day of operation, with an improvement of 59.29% and 36.17% respectively.

***Keywords*:** Reverse logistics, simulation, digitalization, automation

1. Introduction

The distribution industry, as part of the development of their activities, present situations in which dispatches, supply and/or customer satisfaction do not meet expectations and, therefore, they must resort to administration, reception and handling of non-conforming or discarded elements. Among the main models used in reverse logistics are mixed integer linear programming [1], simulation using the ARENA software [2], system dynamics [3] and analytical hierarchical analysis [4]. As in any simulation project, it requires planning, coordinating and understanding the requirements of each task involved; for this, engineering tools will be used to apply reverse logistics in a distribution centre in the beverage sector [5]. Specifically, the problem in question can be specified and defined in the following terms: Is it possible to model reverse logistics, in a distribution centre of a company in the beverage sector in which trucks return every day with boxes of empty containers, products rejected and losses (expired and damaged), using Simulation?

[6] In a furniture company in Valencia, they determine that reverse logistics is a key competence to manage the disposal of products, to recover value and improve sustainability results by helping companies comply with the government regulations on reducing the use of materials, waste and improving its image before the client and society in general. Using the reverse logistics methodology, they determined the total duration of the process, the response time to the customer, and the perceived autonomy and trust of the participating workers, which positively impacted the sustainability of the supply chain.

[1] presents the results of an investigation in the Usochicamocha irrigation district of the Department of Boyacá - Colombia, which faces a problem due to the non-return and collection of all the empty containers and packaging of pesticides that generate the farmers. Due to the above, the research proposes a configuration and operation of the reverse logistics (LI) network for the collection, storage and final disposal of pesticide waste in said area, for which an integer linear programming model is developed. mixed to define both the quantities to be collected and transported to final disposal and to evaluate the possibility of opening new collection centers. The results of the mathematical model show that, on average, 5 kg of waste are collected on each farm and that 1106.58 kg are sent for disposal.

This research seeks to use reverse logistics in a distribution centre in the beverage sector, specifically in trucks that return daily with boxes of empty containers, rejected products and waste (expired and damaged) using engineering tools such as reverse logistics, digitalization, simulation, among others, so that companies in the sector take advantage of opportunities to improve the supply chain in order to generate greater economic, social and environmental value, using a model that incorporates uncertainty and randomness of the data. “In the value chain, reverse logistics management allows closing the global cycle of an economic and environmental system” [7].

2. Methodology

2.1. Problem definition and requirements

A drink distribution centre that supplies the eastern area of Lima sends 100 trucks loaded with products in the morning to make deliveries according to customer orders. In the afternoon they return loaded with boxes with empty containers, rejects, and waste (expired and damaged). 40% of trucks return only with empty containers, in a quantity of 1 to 5 pallets per truck, with the same probability. The other trucks contain the 3 types of cargo, distributed as follows is show in the Table 1.

Table 1: Distribution of cargo trucks.

Type of cargo	**Quantity**
Containers	From 1 to 5 pallets with the same probability.
Rejects	From 2 to 3 pallets with the same probability.
Waste	Only 10% of these trucks contain 1 pallet of waste

The trucks arrive starting at 2 pm with exponential distribution according to the time provided in the Table 2.

Table 2: Schedule range.

Time	**Mean (minutes)**
2 pm – 4 pm	12
4 pm – 6 pm	7
6 pm – 9 pm	3
9 pm – 10 pm	8

Upon entering, they park at one of the 9 available docks in a uniform time between 1 and 2 minutes, the driver gets out and goes to one of the 7 available screens to carry out their settlement, which consists in confirming the products delivered and recording what is being returned, taking between 1 and 2 minutes with uniform distribution per pallet.

In parallel, a forklift operator unloads only what corresponds to rejections and losses, taking a uniform time between 0.5 and 1 minute per pallet. Next, only when the driver has finished recording his settlement and is next to his corresponding load does an inspector approach with a tablet, where the information is updated and proceeds to verify that what was recorded by the driver corresponds to what he has observed physically, this is done in a time with uniform distribution between 5 and 7 minutes per pallet. Then, a count of the containers that are in the truck is also carried out in a time with uniform distribution between 3 and 4 minutes per pallet, this activity has 6 inspectors. After this verification, it is observed that 5% are not satisfied, so the drivers must make observations with the shift supervisor.

Continuing with the process, once the load is verified, the rejects are taken by a forklift to their corresponding location in the picking fields in a uniform time between 2 and 3 minutes per pallet. The waste is taken to a waiting area and then transported at the end of the shift to the waste warehouse in a uniform time between 1 and 2 minutes per pallet.

Next, one of the 3 available “mobilizers” boards the truck loaded with containers and takes them to the “sorting” area in a uniform time between 3 and 4 minutes, parking in a uniform time between 0.5 and 1 minute in one of the 4 available docks where you wait for a forklift to unload the pallets from the floor in a uniform time between 1 and 2 minutes per pallet. Once unloaded, the mobilizer takes the truck to the garage in a uniform time between 3 and 4 minutes. Finally, the pallets are “classified”, that is, pallets are formed with a single type of container. For this, there are 4 operators who carry out this activity in a uniform distribution time between 5 and 8 minutes. The sorted pallets are carried by a forklift to the packaging warehouse in a uniform time between 2 and 3 minutes. In this second zone, 3 forklifts operate (different from the previous ones), where the download was the priority activity. Finally, it is known that half of the inspectors take a break at 6 pm for 50 minutes and the other half do so when the first group returns.

2.2. Improvement Proposal

A solution for bottle classification is the automation of processes using machines with recognition sensors, programmed using the Ladder program for quick and efficient classification. [8] indicate that the classification activity continues to involve a large amount of human labour, whose performance is directly linked to quality, therefore, subject to human errors. To carry out the process, [9] indicate that it is necessary to locate a differentiating variable that allows recognizing the differences of each object, in this case, volume is observed as the main differentiating attribute. Given the investment cost implications for implementation, simulation is presented as a solution for verifying the benefits of the implementation project.

[10] show that the use of automation for the classification of asparagus using a computer vision system, given the type of material to be classified, manages to increase the productivity of the production line by 100%, going from 5 kg/h to 10 kg/h. Regarding the effectiveness of the use of this process, [11] indicate that this system has a percentage of effectiveness greater than 97%, based on a cardboard classification system based on image comparison.

On the other hand, as a solution to the second improvement point, the digitalization of the payment process is proposed. [12], mention that the implementation of a payment process through digital channels generates a win-win situation for both the producer and the consumer since it reduces payment time and allows control of company finances in real time. [13] develop a comparative study about the implementation of a digital system for the payment system in the banking area where an improvement in times is shown, going from 15 minutes per payment to an interval of [0.34 - 3] minutes per payment. The improvement proposal diagram is shown in Fig.1.

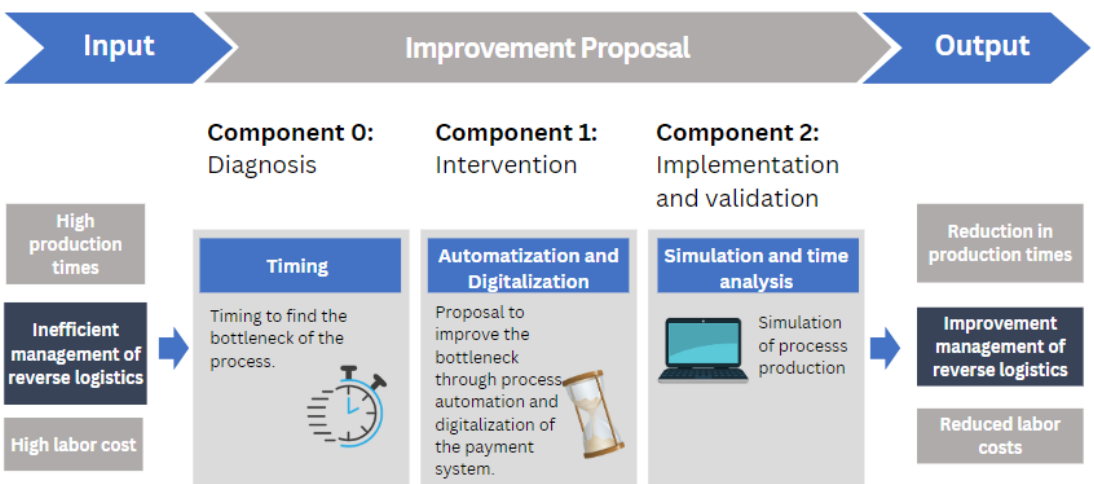

Fig. 1: Improvement Proposal.

2.3. Statical Analysis of data

In this stage, the probability distributions associated with the time between arrivals and each of the random durations necessary for the simulation are determined. To do this, after recording the times and eliminating the peaks, the Chi-square test and the Smirnov-Kolmogorov test were made to determine the probability distribution and its corresponding parameters by using the input analyzer. Firstly, the time between arrivals of the entities was determined, obtaining an exponential distribution with an average of 7 minutes during the first 2 hours, 3 minutes during the next 3 hours and 8 minutes for the rest of the simulation. This is verified with the distribution-fit test, which indicates that the result is significant given that the p-value of both tests are close to 1. In this same way, the time distributions of the activities of the current process were determined, as shown in Table 3. The bottlenecks have a uniform time, where classification activity is in the range [5,8] minutes and the verification process are in range [5,7] minutes.

Table 3: Activity time.

Process	Distribution	Time	Unit
Park	Unif	1-2 min	min/truck
Settlement	Unif	1-2 min	min/pallet
Download	Unif	0.5 - 1 min	min/pallet
Verification	Unif	5 - 7 min	min/pallet
Count of bottles	Unif	3-4 min	min/pallet
Picking	Unif	2-3 min	min/pallet
Transport to sorting area	Unif	0.5 - 1 min	min/pallet
Download	Unif	1-2 min	min/pallet
Classification	Unif	5-8 min	min/pallet
Transport to warehouse	Unif	2-3 min	min/pallet

2.4. Simulation Model

In order to model the attention of the trucks that return every day with boxes of empty containers, rejected products and losses (expired and damaged), the following indicators have been determined.

- Average size of the queue of trucks that arrive every day with boxes of empty containers, rejected products and waste (expired and damaged).
- Average classification queue size.
- Average process time.
  - Average service time of all arriving trucks from 2.00 p.m until 10 p.m.

The following diagram of the actual process is shown in Fig.2. since the arriving of the truck till the transportation to the warehouse.

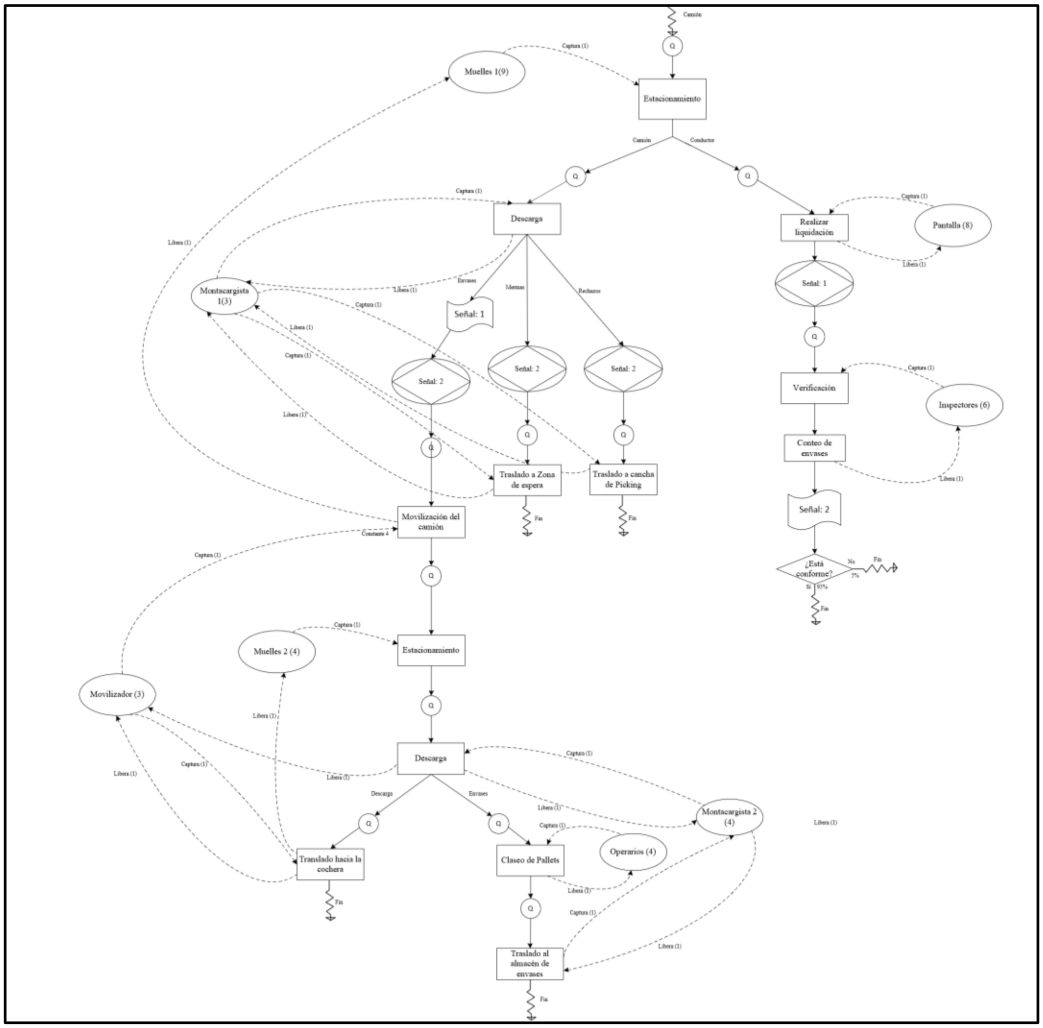

Fig. 2: Process Diagram.

2.5. Simulation experiment design and execution

To obtain the level of precision desired, the following formula was used to determine the number of replications.

$$N = N_0 \left(\frac{h_0}{h}\right)^2 \qquad (1)$$

Where:

h_0 represents the initial amplitude
h represents the desired amplitude
N_0 represents the initial number of replicas

Based on the process described in point 2.1, the following simulation model shown in the Fig. 3. was developed.

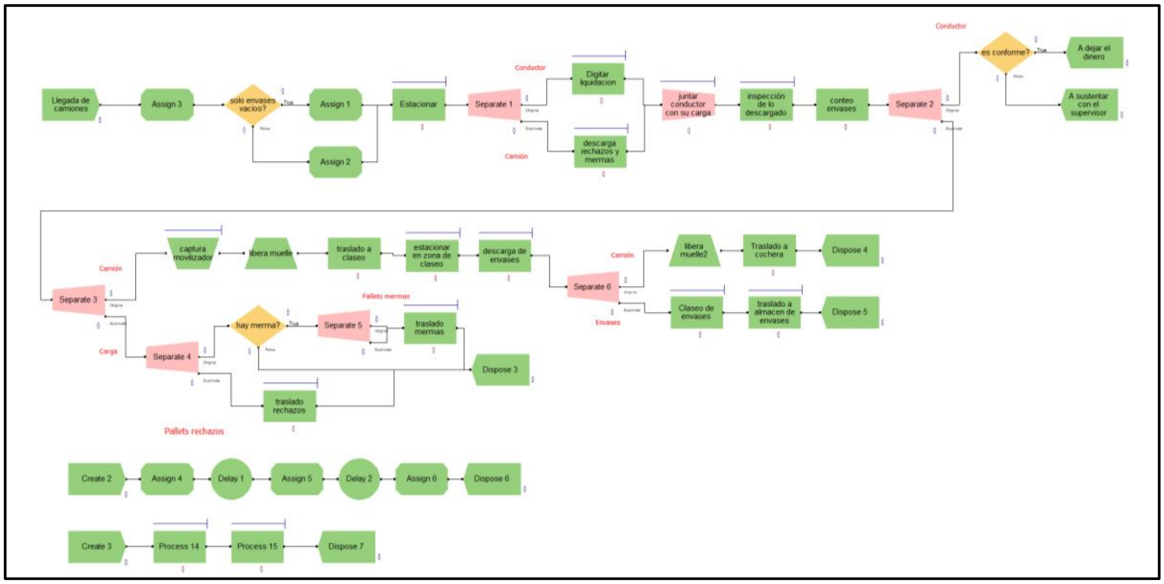

Fig. 3: Arena Model of actual process.

The model was first run with 30 replications and the initial value of h_0 was 0.74. To obtain the desired precision, N = 65.12 will be considered, therefore, the result was that we needed to perform 66 replications. The following indicators were obtained with a 95% confidence level:

- It was possible to determine the average size of the parking queue is in the interval of [4.3299, 5.4099] trucks. The main queue is at dock 1, this is due to the high frequency of truck arrivals at rush hour, with only 3 mobilizers available to move the trucks. This is an important aspect because there are peaks where the maximum size of the queue is on average 10.3767 trucks, causing workers to wait outside the Distribution Center, which can be dangerous since the drivers return with the money collected for the delivery of the product. In addition, drivers complain about staying until late hours knowing that the next day, they must come in at 7 am to leave for delivery. Likewise, if it is considered to increase the number of mobilizers, the queue moves to the inspection process since the inspectors go out for refreshments at rush hour.
- It was also possible to show the average size of the queue of packaging pallets in the process of classification, which is in the interval [5.108, 6.168]. This happens because there is no order or method in the classification process and there are a lot of inexperienced workers due to staff rotation.
- The average service time per truck is in the interval [19.3173, 20.8173] minutes, but it should also be noted that the maximum average service time is 26.7286 minutes.
- The average number of trucks in the system is in the interval [30.4613, 32.3613] trucks and the maximum average number is 39.1965 trucks.

None of the resources are working at 100% utilization, which shows that a redistribution of tasks is necessary to reduce the size of the queues.

2.6. Model Validation

In this model, the main data is taken directly from the company's own reverse logistics process. The main existing bottlenecks in the company form the processes of truck parking, inspection and packaging class. It is verified that the model represents reality, since, according to the graphical representation and the results of the Arena software report version 16.10.00003, the waiting times correspond to each process, obtaining the longest waiting times in the identified bottlenecks, as shown in the previous section.

2.7. Model Verification

Using real data, the simulation model was run, and the results were confronted with the real results, analysing the behaviour of the queues, the use of resources and the flow of the entities, observing that the model behaves in a similar way to the real system. For example, the average length of attention during the afternoon is in the interval of [657, 678.58] minutes, equivalent to an interval of [10.95, 11.31] hours, corroborating that the model reflects the overtime of the workers. As a root of this problem, large queues generated during the process were found, including hourly peaks as shown in section 2.5.

2.8. Proposal simulation results

As a result of the improvement model, the following indicators were obtained with a 95% confidence level:

- It was possible to determine the average size of the parking queue is in the interval [2.32, 3.23] trucks. During this process, the maximum number of trucks was 7.72 units.
- It was also evident that the average queue size of the classification process is in the interval [2.28, 2.31] packaging pallets.
- The average service time per truck is in the interval [11.27, 12.19] minutes.
- The average number of trucks in the system is in the interval [19.18, 20.92] trucks.

2.9. Results

For the interpretation and analysis of the output data, the Arena Output Analyzer was used, establishing the intervals for μ with different levels of confidence. It also allowed us to perform the paired analysis (comparison of means) for the comparison of scenarios. Likewise, the 95% confidence level and the number of replications calculated above will be considered. For the total time, we have considered the following statements:

X_A = Indicator of total time, original model
X_B = Indicator of total time, proposed model

To determine if there is a significant difference, 2 hypotheses were used:

$$\text{Ho: } \overline{XA} = \overline{XB} \tag{2}$$

$$\text{Ha } = \overline{XA} \neq \overline{XB} \tag{3}$$

The following results were obtained when running the model in the interface is show in the Fig. 5.

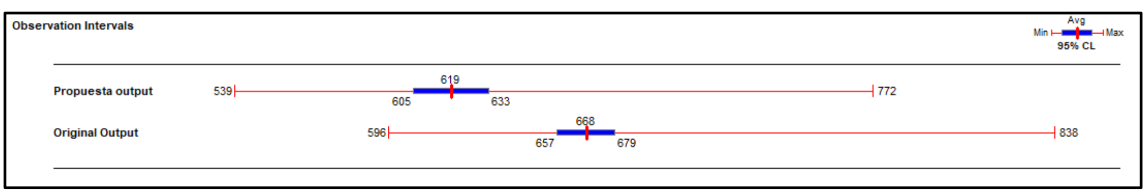

Fig. 5: Output analyzer.

As can be seen, there is a time lag between the confidence intervals of the original model and the improvement proposal. Given that the indicator of interest is the attention time, it can be stated that the improvement proposal model is better than the original model since it generates a reduction in time in the process. Therefore, the null hypothesis is rejected.

4. Conclusion

The new proposal shows a significant improvement in several key aspects of the Distribution Center operation. The reduction in the average size of the parking queue and the pallet sorting process indicates greater efficiency in the management of these processes. In addition, the average service time per truck and the total time to service trucks have decreased, suggesting greater agility in service. However, it is important to add that the maximum number of trucks in the queue and the system is still relatively high, which could indicate the need to continue improving planning and resource allocation. Below is the comparison of the means and the percentage of improvement between both models is shown in the Table 4.

Table 4: Comparison of means and improvement percent.

	Original	**Proposal**	**% Improvement**
Parking queue (trucks)	4.8699	2.775	43.02%
Classification (pallets)	5.638	2.295	59.29%
Total time (min)	667.79	618.6	7.37%
Service time per truck (min)	20.0673	11.73	41.55%
Number of trucks in the system	31.4113	20.05	36.17%

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