Chapter 13
Diagnosis and Improvement of Processes for a Distribution Center in a Mass Production Company

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Abstract The main objective of this work is to diagnose and improve the proposal for a Distribution Center (DC) of a productive Chilean company. This implies recognizing the current state of the DC, analyzing its processes and bottlenecks, and obtaining time measurements. The research problem is associated with the current main problems: operation using overtime costs, dispatch delays, and storehouse collapse. The diagnosis stage considers the parameters to be measured, such as time, number of purchase orders, packing, dispatches, and receptions. This diagnosis allows us to understand that aisle operators (pickers) are a critical resource and that the first work processes to improve concern picking and dispatching. Thus, it is possible to improve the operation of the DC to enhance critical resources and processes. It is proposed to use two pickers and invest them in two tablets. It is estimated that this proposal could significantly reduce external storage costs because it implies an increase in the capacity to process orders by 42.5%, equivalent to 145 releases, which is 43 more than today.

Keywords Distribution center · Dispatches · Picking · Diagnosis · Simulation

13.1 Introduction

For some years, a Chilean mass production company has been experiencing increased operating costs in its distribution center (DC) and the value of rents for external warehouses. Concerned about this situation, the operations management department is developing an improvement plan. It is possible to analyze and make decisions based on the details of DC operation, and the first step was to diagnose the current situation of DC.

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J. L. García Alcaraz et al. (eds.), *Supply Chain Management Strategies and Methodologies*, Lecture Notes in Logistics, https://doi.org/10.1007/978-3-031-32032-3_13

From these observations, it is possible to observe the notorious collapse of the two warehouses in the DC. The first warehouse is used for flammable finished products, and the second is used for non-flammable finished products (miscellaneous). Collapse is to such an extent that the first task in the morning is to clear the aisles of the non-flammable warehouse from the pallets that did not reach their location on the racks. Because of the inefficiency of the DC, the excess of overtime has brought not only cost problems but also fatigue to the operational staff whenever they can make it noticeable.

To develop this research, it is necessary to recognize and differentiate the processes developed in the DC, defining the beginning and end. Once the set of processes is clear, it is necessary to determine the bottlenecks. Process mapping and data survey are then required. According to Frazelle (2016), to take any action within a warehouse, it is essential to recognize the state in which it operates, the associated processes, the product flow, and everything related to the most important resources: human, space, and technological. In addition, to carry out this project, we consulted related material in literature such as Ballou (2004) and Carranza (2004), and we studied similar practical cases as developed by Guaita (2008), Cortes (2010), López (2011), Horvat (2012), Pena and Forero (2012), and Milla and Silva (2013)

In short, this research answers how a company's DC works, recognizes its main shortcomings, integrates a comprehensive diagnosis, and recommends an improvement plan. The general objective is to diagnose the current situation of the DC of the company, create a simulation model of the current situation, and identify opportunities to integrate improvement plans. This work was performed using the BPMN language in Bizagi Modeler to describe flowcharts and arena to simulate the use of resources available on the DC. The following specific objectives were proposed to achieve this general objective:

- Recognizing the different processes of the DC and describing them using BPMN
- Obtaining current operating parameters.
- Designing the model in the Arena software using the analysis results
- Obtaining results and proposing improvement plans.

13.2 Diagnosis of the Current Situation

The first step for diagnosis corresponds to recognizing the processes within the company's DC. Once this recognition has been made, and the facilities have been personally toured, a description of the processes is made in terms of their operation and as a whole. When the description was complete, a BPMN model was developed to visualize the operation of the DC. Together with operations management, the most relevant processes for an improvement project are defined. Then, the data on the reception of the finished products, preparation of the orders, and their dispatch were measured. These data must be analyzed and modeled in arena. The results of these models were analyzed to generate improvement plans.

13.2.1 Recognition, Description, and BPMN

To recognize the processes in the company's DC, the DC has been visited and toured multiple times during operation. Many processes have been identified in these tours. To classify them, it has been decided to differentiate the operation into levels according to the complexity that needs to be analyzed. The dispatch manager generally receives the purchase orders (PO), which are transformed into a work order (WO). These WOs are distributed among the aisle workers who carry out picking. Once this is completed, the cranes must take the pallet with the prepared WO and move it to the dispatch area, where a dispatcher will review each WO and define whether it is complete. Otherwise, the dispatcher looks for the responsible picker and notifies him of the fault. The picker must complete the WO and transfer the missing merchandise with a manual pallet truck to the dispatch area. If WO is complete, the crane loads the delivery truck. In parallel, reception is carried out by a receptionist who checks the load that has arrived, defining whether the load is complete. If it is not complete, the load is received, and a notice of the differences is given. If it is complete, it is received only. When the cargo has been received, the cranes must order merchandise by code and store it in the corresponding warehouse. There are two warehouses: one for flammable products and the other for dangerous products (miscellaneous).

Two work schedules are identified. The first one will be called 8 a.m., starting at 8:15 a.m., at 10 a.m., having a 15-min break, at 12:15 a 45-min lunch, and then people will continue working until 6:15 p.m. The second schedule is called 10 a.m., starting at 10:00 a.m., at 12:5, there is a 45-min lunch and then works until 6:00 p.m., with a 15-min break. After recess, work will be performed until 8:00 p.m. It is important to note that from these schedules, the entry is fulfilled but not the exit; this is because, usually, the work has not been finished at the closing time, forcing overtime. Regarding the available resources, there are four tow trucks, nine pickers, two dispatchers, a dispatch manager, and a receptionist.

Concerning the availability of cranes, there is one for the internal movements of the flammable warehouse, another for the internal movements of the miscellaneous warehouse, and two for reception cranes. The crane for internal movements of the flammable warehouse is dedicated to movements within the warehouse, the transfer of the finished WO and the storage of the cargo received corresponding to the same warehouse. It is important to note that this crane does not load dispatch vehicles. The internal movement crane of the various warehouse is also dedicated to moving the WOs that the aisles have prepared and helps with unloading, loading, and storage. Unloading cranes are also dedicated to transferring the prepared WO to store the received cargo and load the orders. It is important to know that the warehouse for flammable products cannot enter a crane other than the one corresponding to that warehouse because of the technical restrictions implied by the storage of products with these characteristics.

There are nine pickers, among which there is a supervisor who, in addition to preparing their assigned WOs, is dedicated to supporting other pickers. The dispatch manager oversees the entire line that involves dispatching, and in this case, his main function is to distribute the PO in the WO to the pickers. There are two dispatchers whose mission is to check that the orders are complete, without surpluses or shortages, for which they review each WO that arrives at the dispatch area, managing the completion of the WO if needed. The receptionist oversees whether the cargo brought by the carrier corresponds to what appears in the dispatch guide. This system was modeled in the BPMN, as shown in Fig. 13.1.

13.2.2 Obtaining and Analyzing the Parameters

From the previous BPMN analysis, the key dispatch processes were defined as the picking carried out in the aisles of the DC, the transfer carried out by the cranes, the review carried out by the dispatchers, and the loading carried out by the cranes. The key process for reception is unloading conducted by the cranes. The parameters to be measured are as follows:

- *Picking*: Time and number of boxes. This process has been measured in two ways: how long the picker takes in its WO, called time *T*, and how long the picker takes specifically to place the boxes of a line on the pallet, called *the picking time*. This is because much time is wasted looking for the product, walking to the product, ordering, and cleaning where the product is located. Additionally, this process was performed independently for each warehouse.
- *Transfer*: time by WO. It measures how long it takes a crane to move a WO from the warehouse where it is located to the dispatch area
- *Review*: Time for WO. It measures how long it takes for a dispatcher to review a WO.
- *Loading*: time per loaded vehicle. It measures how long it takes for a route to be loaded.
- *Unloading*: time per unloaded vehicle. It measures how long it takes for a vehicle to be unloaded.

Each of these processes was followed and recorded 45 times. To determine the available capacity, it is also necessary to know how many POs are processed on a business day and how many pallets are received in each warehouse. These parameters are presented and discussed below.

13.2.2.1 Picking

It should be noted that this process is carried out in two warehouses, one for miscellaneous products and the other for flammable products. It is presumed that the latter operation is faster; thus, they will be reviewed independently.

- **Warehouse of flammable products**

The following results were obtained in a miscellaneous warehouse (Table 13.1).

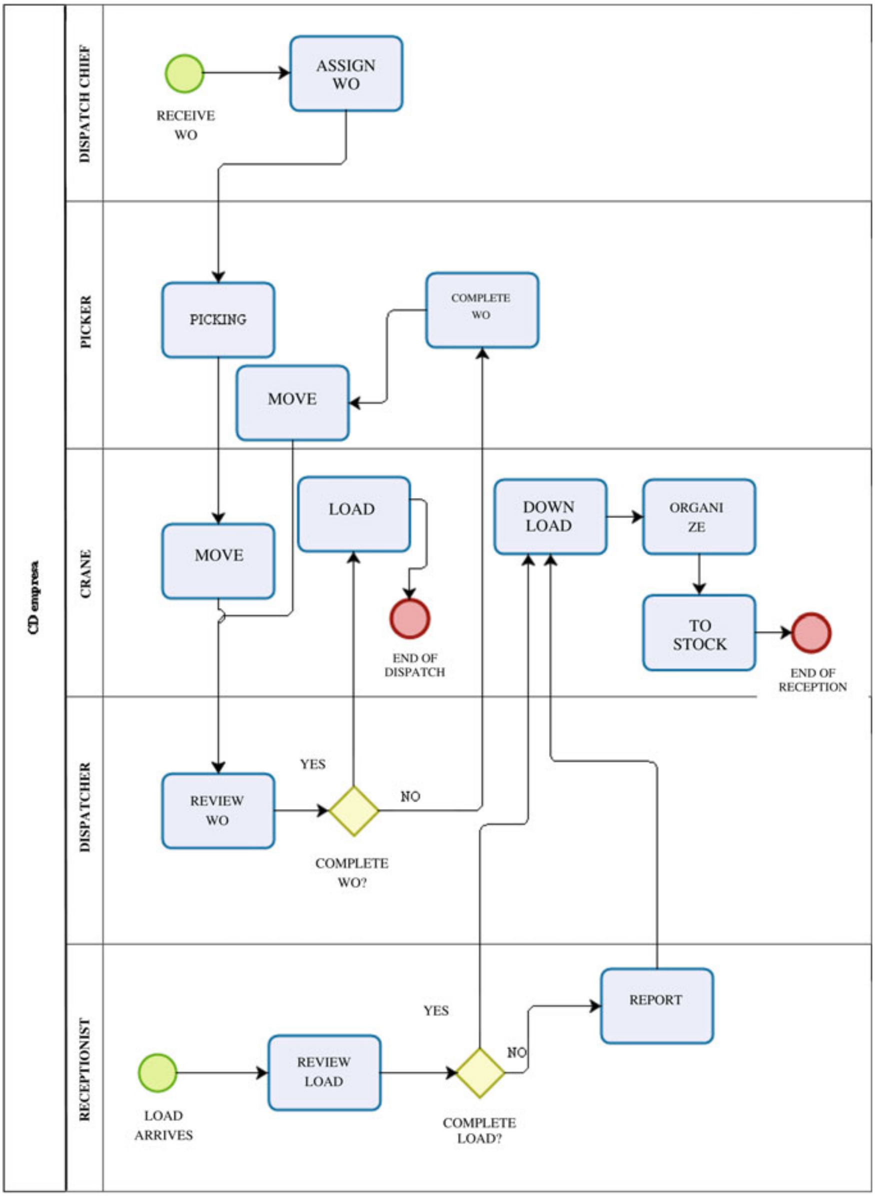

Fig. 13.1 BPMN of the DC

Table 13.1 Summary of the results in the flammable warehouse

Observation	T [min]	Picking [min]	Boxes
Total	315	161	1,289
Average	16	8	64
Deviation	24	19	103

These values corresponded to 20 observations. *Time T* is the time taken by the picker to pick up the pallet on the manual pallet truck, going through the search for each line of products, walking in each attempt to find it, and requesting that the crane came down the pallet if it was in height, ordering, and cleaning the area if it was messy and dirty, also considering the picking time. Picking time is the time the picker takes to pick up and place each box of a line on the pallet of the WO in preparation. It can be noted that the deviation is greater than the average; this is mainly due to abrupt differences in the time-box relationships that exist in some measurements. For example, one observation recorded the data of 10 boxes in 53 s, another recorded eight boxes in 22 s, and a third observation recorded three boxes in 22 s. It is possible to realize that the behavior is inexplicable mathematically because, in some observations, the picker presented more difficulties than others in handling the boxes, mainly because of the differences in the sizes of the boxes of the different products, some even reaching double, triple, and bigger than others.

It can also be said that the picking time for a box, on average, is 7.5 s, while its T time is 14.6 s. If the values of both times are compared line by line, it is obtained that Table 13.2 indicates.

The total efficiency is defined as the average ratio between the *picking time* and the time T of each line. That is, how much of the total time, in %, has been used for picking up the boxes and leaving them on the corresponding pallet. In this case, it corresponds to 39%; that is to say, 61% of the time is wasted in actions such as looking for the position in which the product to be picked up is located, walking more than necessary due to lack of concentration of the picker, or in ordering and cleaning the place where the picking will take place. The search is mainly based on how the products are stored, with a chaotic and random system, with the criterion that the arrangement is made by placing together the greatest possible number of equal products, regardless of whether there are locations with the same product currently in use. This results in a kind of rotation of positions as warehouse locations are released and occupied, generating a product search conflict.

It can also be verified from the recorded data that there is an approximately linear relationship between picking time and the number of boxes. See Fig. 13.2.

Equation 13.1, obtained from Fig. 13.2, has a box offset of 173.3/10.2 = 17 because the data dispersion is very high. This equation can explain the linear relationship

Table 13.2 Comparison of T with picking

Observation	The difference [min]	Efficiency
Total	154	39%

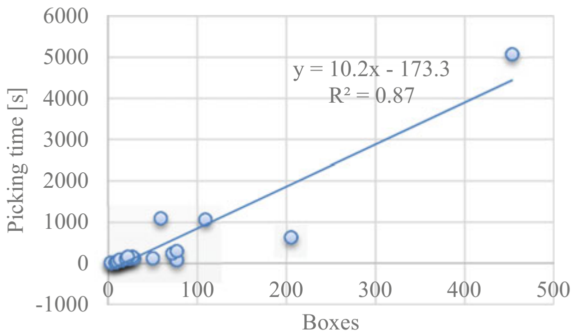

Fig. 13.2 Relationship between the number of boxes and picking time for flammable warehouse

between the number of boxes prepared and the time is taken to pick them, which was 87%.

$$y = 10.2x - 173.3 \tag{13.1}$$

where "*y*" is the picking time in seconds and "*x*" is the number of boxes.

- **Warehouse of miscellaneous products**

The following results were obtained for the warehouse of miscellaneous products. See Table 13.3.

These values correspond to 25 observations. Additionally, it is obtained that the total time to prepare a box is 13.8 s while putting it on a pallet takes an average of 7.1 s. As in the flammable warehouse, the deviation is close to the average, and the explanation is the same: there are differences in the sizes of the boxes of different products.

The following table can be obtained by comparing T time with the effective picking time. See Table 13.4.

Tables 13.3 and 13.4 follow that after 583 min (9.7 h), a picker inside the warehouse used 284 min (4.7 h, for operations other than obtaining efficiency. This is 42% on average per line.

Table 13.3 Summary of the results of the miscellaneous warehouse

Observation	T [min]	Picking [min]	Boxes
Total	583	298	2,535
Average	23	12	101
Deviation	21	16	121

Table 13.4 Comparison of *T* with picking

Observation	The difference [min]	Efficiency
Total	284	42%

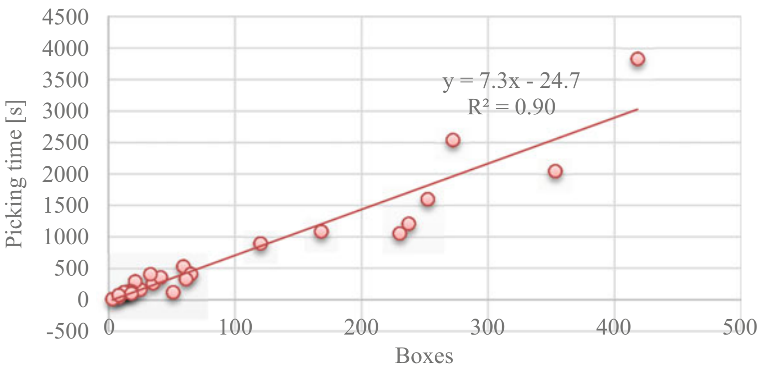

Fig. 13.3 Relationship between the number of boxes and picking time for miscellaneous warehouse

As in the other warehouses, the relationship between the number of boxes and the time spent preparing them is approximately linear. See Fig. 13.3.

Equation 13.2 in Fig. 13.3 shows a lag of 24.7/7.3 = 3.4 boxes, and the number of boxes explains 90% of the picking time.

$$y = 7.3x - 24.7 \tag{13.2}$$

In comparative terms between warehouses, it can be said that the amount of WOs in the miscellaneous warehouse is approximately 1.57 times larger. See Eq. 13.3.

$$\frac{2.535}{1.289} \times \frac{20}{25} = 1.57 \tag{13.3}$$

In Eq. 13.3, the first factor corresponds to the proportion of boxes prepared in the miscellaneous warehouse concerning the flammable warehouse. The second factor is the proportion of the number of observations.

In both cases (flammable and miscellaneous), the T time for a box was close to 14 s. The picking time for a box was close to 7 s, and the efficiency in the two warehouses was close to 40%. With this information, it can be said that the preparation of orders must be determined by the number of boxes and not by the warehouse type.

13.2.2.2 Transfer

All available cranes transfer WOs to their corresponding dispatch areas. This is measured when the crane selects a WO, moves it, and returns to the warehouse. Table 13.5 shows the results obtained for the transfer of the 45 WOs.

Table 13.5 shows that the transfer of 45 WO took 182 min; on average, it took 4 min, with a standard deviation of 1 min. This is complemented by the fact that the standard deviations of the boxes are 121 for miscellaneous warehouses and 103 for

Table 13.5 Summary of transfer results

Observation	Transfer [min]
Total	182
Average	4
Deviation	1

flammables. Thus, it can be understood that the transfer time does not depend on the boxes contained in the WO, but rather on the obstacles that appear on the path, such as other cranes, trucks, pickers, pallets, and garbage.

13.2.2.3 Review

Two dispatchers reviewed the transferred WOs, verifying that the transferred WO was the same as that in the PO. Table 13.6 shows the results obtained for the review of the 45 WOs.

It can be seen that the total review time of the 45 WOs is 149 min (2.5 h), which means an average of 3 min per WO, with a standard deviation of 2 min. This deviation is due to the review time depending on the number of boxes and, in part, the number of different products on the pallet. There are also delays when the WO is incomplete.

A major problem is generated during this process related to the time required to complete a delivery route. A route is composed of one or more POs, which in turn is composed of one or more WOs. Therefore, a route will not be available for loading if it has not been reviewed until the last WO of the route. It would be logical to think that the preparation of WOs has the same order in which they will be dispatched. However, there are currently no defined criteria for granting a preparation order (only the most important clients are given urgent dispatch). For example, the first WO of a route could have been prepared and moved at 8:30 a.m.; however, the route could have been completed at 05:00 p.m. Table 13.7 below shows the results of the parameters of this time window:

Table 13.6 Summary of review results

Observation	Review [min]
Total	149
Average	3
Deviation	2

Table 13.7 Summary of the time window results

Observation	Window [h]	PO	WO
Total	120	325	1,195
Average	2.7	7	25
Deviation	1.2	4	10

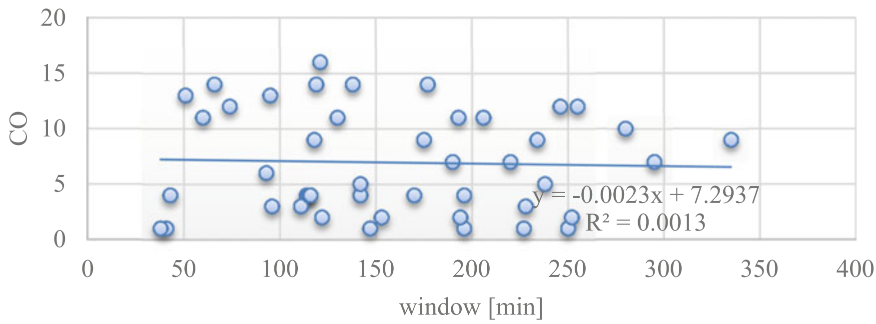

Fig. 13.4 Relationship of the time window with the amount of PO

In summary, 45 routes were followed, and the time window was extended by 120 h, with an average of 2.7 h per prepared route and a standard deviation of 1.2 h.

Figure 13.4 shows that the relationship between the window length and PO amount is not linear, which makes sense given that one route might have fewer orders than another, but the orders can be much larger.

Regarding the relationship between the time window and the number of WOs, it can be said that it has similar behavior and makes sense since there are orders with many or few WOs. This means that this time window is mainly due to planning, which the Logistics Manager validated.

13.2.2.4 Load

The loading process is performed when the dispatcher authorizes a route. Unloading cranes and miscellaneous warehouse cranes can perform this operation. A flammable warehouse crane is not used for this process because it is very specific and expensive equipment and is preferred to optimize its useful life. Table 13.8 presents the results of the upload process.

It can be seen that from a total of 45 observations, the total time has been 80 min, with an average of 1.8 min per pallet with a deviation of 0.6 min. The main difficulties observed in this process are the chaos generated by loading all routes simultaneously, accommodating the pallets in the tightest vehicles, and the limited space available for transit.

Table 13.8 Summary of load results

Observation	Load [min]
Total	80
Average	1.8
Deviation	0.6

Table 13.9 Summary of unloading results

Observation	Discharge [min]
Total	98
Average	2.2
Deviation	1.0

13.2.2.5 Download

The unloading process is carried out when the receptionist reviews the truck with merchandise and authorizes the reception. The time is measured when the crane picks up a pallet, unloads it, and accommodates it in the available area outside each warehouse until the crane returns to the truck. For this process, there are two cranes, called unloading cranes, and the results are listed in Table 13.9.

In the unloading of the 45 pallets, the time was 98 min, with an average of 2.2 min for each pallet and a deviation of one minute. The difficulties in this process are how the merchandise arrives inside the truck; sometimes, the same product arrives at different positions of the truck, which makes orderly arrangement difficult and generates unnecessary movements.

13.2.2.6 Entry and Exit

For the correct functioning of the model to be simulated, it is necessary to know how many POs are processed in a day, how many correspond to which warehouse and how many products are received in each warehouse.

It has already been seen that the workload is not proportional in each PO, so the intention of generating a standard load has been adopted, maintaining that a WO must be composed of 110 boxes. In the picking observations, it was possible to verify, through a histogram analysis, that the largest number of boxes was in the range of 100–120 boxes; 110 boxes per WO satisfy the requirements. Figures 13.5 and 13.6 show that the largest number of boxes prepared by the picker is close to 109 for miscellaneous and 116 for flammable. It aims to generate the WO with some boxes today that the pickers handle, reflecting a large part of their work.

Analyzing the databases, it is possible to define that during 2016, work was carried out in 244 days, processing 5,006,535 boxes in dispatch, equivalent to 45,514 WO. This implies that there are 187 WOs per day, and if the average number of POs processed in a day is 62, one PO must be related to three WOs on average. Additionally, it can be deduced that 33% of the POs correspond to flammable products and 67% to miscellaneous products. It is also known that 33,700 full pallets of finished products were received that year. On average, the pallets contained 220 boxes. Merchandise arrives daily for four reasons: returns, imports, transfers between warehouses, and transfers from the production plant. Table 13.10 summarizes this information.

A value of 0.33 means that imports are received every three days, approximately once a week. On average, 115 pallets were received daily.

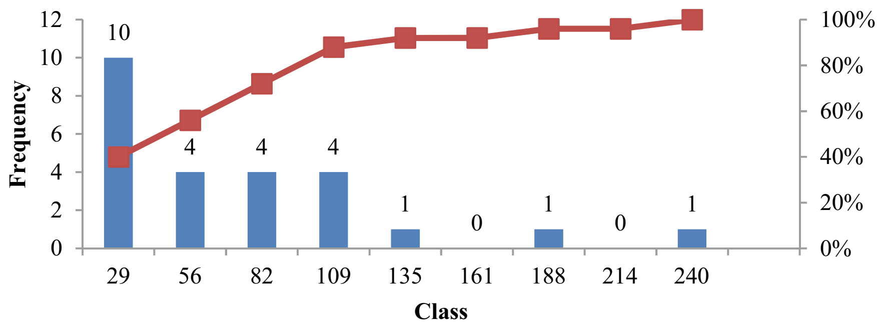

Fig. 13.5 Histogram of the number of boxes in the miscellaneous warehouse

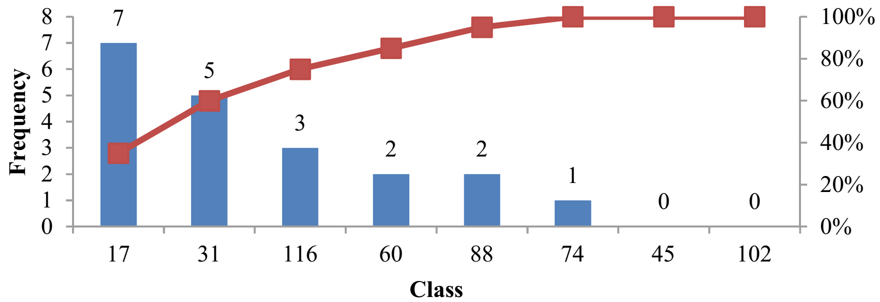

Fig. 13.6 Histogram of the number of boxes in the flammable warehouse

Table 13.10 Summary of merchandise arrival

Arrivals	Return	Import	Transfer	Plant
Times per day	3	0.33	1	5
Pallets at a time	2	32	14	19

13.2.3 Design and Analysis of the Simulation Model

The simulation model must reflect the operation as closely as possible with the information collected to understand how the processes work with available resources. The arena was used as the simulation software because it allows resource-related operations. The model of the current operation of the entire system is not shown in this document because it is very large, and only the proposed model is presented later in this paper.

The model for the current operation was run 244 times, simulating 2016. The model obtained an average of 203 WOs processed per run, with an average of 112 pallets received per day. Both values follow the reality in the previous section and are listed in Table 13.11. On average, a WO spends 10.6 h in processes until it is dispatched, while a pallet takes an average of 1.82 h to be stored, as Table 13.12 shows. The variability in the entire analysis has not been exposed (but it has been considered) because of the values of all minimum cases.

With the information obtained from Table 13.11, it is possible to project the occupation of the warehouses, intending to determine the capacity that will be required in the coming years. It is known that 112 pallets are received daily, and 203 WO are dispatched daily. In addition, a position within the warehouses stores a pallet with 220 boxes, and the WO of 110 boxes is equivalent to 0.5 pallets. The dispatch of 203 WO was equivalent to the release of 33 daily positions in the flammable warehouse and 68 in the miscellaneous warehouse, while 37 and 75 were received, respectively. Tables 13.13 and 13.14 show the 5-year projection of the occupation with a growth of 7% per year, defined by the demand planning area and the sales manager.

The storage capacity of the miscellaneous warehouse is 2,283 positions, which means that if the initial inventory is zero during the first months of the second year, the warehouses would already have storage problems. This is consistent with external warehouses and is explained by the current use of the warehouse, which does not fall below 80%.

The storage capacity of a flammable warehouse is 1,748 positions; therefore, during the first and second years, in theory, there should be no problems; however, in practice, external warehouses are already being used for accumulated products. This is because the projection considers zero as the initial inventory, which is completely different because its occupation ranges between 70 and 100%.

This is a problem that the company should address because using external warehouses is one of the most important capital leaks. In addition, the time each process takes per entity is analyzed, knowing the average waiting time of an entity. The most time-consuming process is, in the first place, picking 6.82 h to process a WO. According to the data, this is mainly explained by the time a WO must wait to be prepared. Secondly, the unloading took 1.65 h, which is explained by the accumulation of work in the process queue; that is to say, if a pallet took 2 min to be unloaded, it had to wait an average of 1.61 h for its turn. Third, there are time windows with values close to 1 h per WO, which reflect the wait for a route to be loaded owing to the non-planning of the dispatch.

Table 13.11 Average number of OT and pallets per day

Number of	Average
WO	202.64
Pallets	111.65

Table 13.12 Average processing time for OT and pallets per day

Number of	Average
WO	10.6244
Pallet	1.8292

Table 13.13 Projection of the occupation of the miscellaneous warehouse

Year	OT	Released positions	Received pallets	Stored	Accumulated
1	49,532	16,593	18,310	1717	1717
2	52,999	17,754	19,591	1837	3554
3	60,948	18,996	20,962	1966	5520
4	70,090	20,325	22,429	2104	7624
5	80,603	21,747	23,999	2552	9876

Table 13.14 Projection of the occupation of the flammable warehouse

Year	OT	Released positions	Received pallets	Stored	Accumulated
1	49,532	8173	9018	845	845
2	52,999	8744	9649	905	1750
3	60,948	9356	10,324	968	2718
4	70,090	10,010	11,046	1036	3754
5	80,603	10,710	11,819	1109	4863

Subsequently, the scheduled utilization of each resource in the model was analyzed, considering its average, half-width, minimum average, and maximum average data. It can be seen that pickers are a critical resource in this model because their scheduled utilization averages 95% on average, and all pickers have had to work up to 16% more than estimated. This happens because there are days when the workload forces DC operations to close, even after midnight, and they imply a great cost over time.

However, the data show that the efficiency of the pickers ranged from 62 to 78%. The time lost in searching, walking, ordering, and cleaning is considered within this value, so the efficiency of the pickers can be improved without modifying the picking procedure, that is, by managing work planning and using technology.

In any case, if it is decided to store with a methodology that allows knowledge of at least the positions of the products during the day, then the search time and unnecessary walks would be considerably reduced, causing the instantaneous use of the aisle to be reduced or to make it more efficient.

13.2.4 Improved Process Proposal

Because bottlenecks are generated during picking and dispatching, it was decided to design a model that shows and confirms this situation and serves as a proposal. The chosen strategy allows for improvements in the equipment investment by only two tablets. In this case, it is proposed that work orders be received at 8:15 and 14:15, corresponding to the load scheduled by the logistics planner. These are called cut-off hours. After each cut-off hour, the dispatch chief must deliver the work plan in a form to each crane. This form contains products and quantities that must be transferred from the racks to the consolidation area. In the consolidation area, at 10 a.m., all available pickers must carry out picking, leaving each finished WO in a finished WO area, which will be transferred to the dispatching area for review and subsequent loading.

Regarding consolidation, it is necessary to open a process that allows us to determine the location of each product just before starting consolidation. This process is called product recognition and takes an average of 30 min per warehouse. A picker will carry it out, and the information will be written on a tablet in an orderly and precise manner and sent to the planner. Reconnaissance must be performed in each warehouse independently, and two pickers are required in parallel.

This improvement makes it possible to eliminate the search time of each picker and the time associated with walking around, ordering and cleaning the area, and waiting for the crane to bring down a pallet, among others. It should be noted that the average preparation time of a WO is 12 min, and the average picking efficiency is 40%, which implies that the WO is ready for transfer in 30 min. It is estimated that at least 80% of the time wasted picking is explained by the search for products and associates, equivalent to 14.4 min. Therefore, the picking efficiency would increase by 44%, allowing a WO to be ready for transfer by an average of 13.6 min.

The planner must assign dispatch times for each day and arrange transport to comply with the schedule. This would facilitate complete scheduling, clarifying the priorities and achieving an early dispatch, avoiding the time window currently to carry out the load, and dissolving the problem of accumulation of work at the end of the day.

Planning would eliminate the 1 h on average time window generated today after having a route ready for the load. In this way, the consolidation strategy and use of two tablets would allow the optimization of these two processes by planning the work.

It is important to mention that this project does not propose changes in the reception of products; however, it would be very convenient to generate a reception plan because it would allow the warehouse to be organized promptly to eliminate the product recognition process. The BPMN model for the proposed method is illustrated in Fig. 13.7.

The ARENA model was run 244 times to obtain results comparable to the base model. In addition, the model presents the following considerations.

- The 10 a.m. schedule is modified by 9 a.m., maintaining the recess and lunch schedule and entering and leaving one hour earlier. This will allow the cranes a time window for free consolidation in the morning.
- The number of pickers decreases from 9 to 7. Due to the improvement, the number of pickers for this model is estimated to be 7.
- The work is divided into two batches, at 8:15 and 12:45. In the first schedule, the aim is to optimize consolidation, leaving the cranes free to carry out the consolidation without having obstacles from aisles, allowing merchandise to be

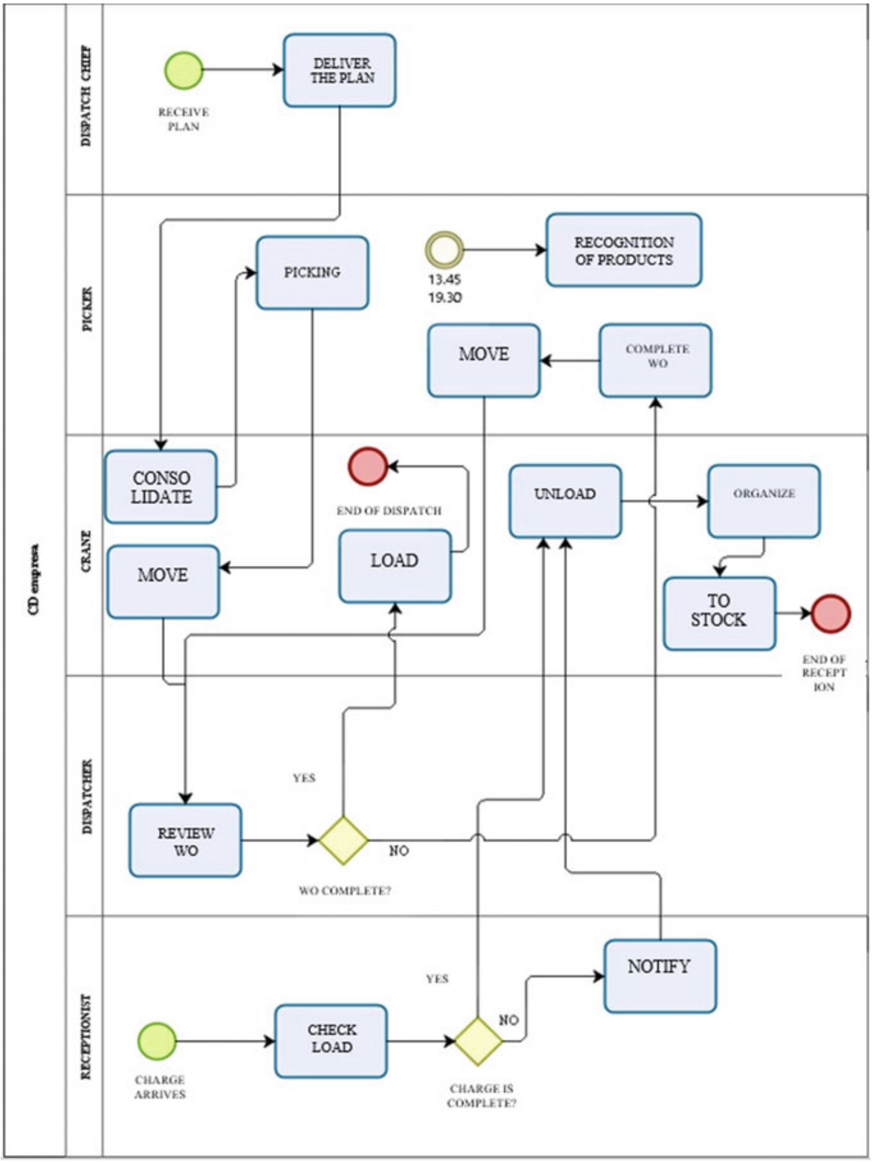

Fig. 13.7 BPMN of the proposed model

received without inconveniences. In the second round, consolidation and picking are carried out in parallel.

In the following Tables 13.15 and 13.16, you can see the results of the proposed model designed using Arena software and their corresponding analyses.

Table 13.15 New average number of OT and pallets per day

Number of	Average
WO	184.68
Pallets	109.00

Table 13.16 New average processing time for OT and pallets per day

Number of	Average
WO	6.0689
Pallet	1.8309

From Table 13.15, the amount of 185 WO is within the real, approaching the 187 registered during 2016, and the value of 109 pallets is similar to that of the original model (Table 13.11).

Comparing Table 13.16 with Table 13.12, it can be seen that the total average time that a WO takes to be ready for dispatch drops from 10.6 h to 6.1 h, that is, 4.5 h. This means that, with the proposal, a route could effectively be dispatched in 4.5 h less, estimating that the operating capacity of the DC would increase by 42.5%, thus being able to process 290 WOs per day with the same resources as the original model.

After evaluating and comparing the results of process time and waiting times of every task (loading, consolidating, downloading, flammable, miscellaneous, picking, checking, and moving) with the real operation of the system made in the former model, it can be seen the following; since the preparation now is focused on firstly dispatching a single route, the loading process is no longer divided into six routes, but instead becomes a single loading process. This increases the time in storing the merchandise in the miscellaneous warehouse. In turn, picking decreases to 28.8%.

The processes of storing miscellaneous and transferring increase their average time processing a WO due to the increase in their waiting queue. Queue time for the miscellaneous storage process skyrockets because the warehouse crane has loading, unloading, storage, and transfer functions.

Also, it was found that crane resources are the most likely to extend their working hours, becoming the new critical resource and turning the focus to optimizing crane-related processes. In addition, the number of pickers has been reduced to 7, increasing its scheduled use.

Regarding the analysis of utilization, the use of pickers decreases, and the use of cranes increases, making it clear that if the proposal is adopted, the new focus should be the resource of cranes.

13.3 Conclusion and Recommendations

Under the analysis presented, it can be said that the processes in which the bottlenecks are generated are mainly two: picking and unloading. Picking presents an average time of 6.83 h per WO and unloading 1.65 h, but the waiting explains the high time in both cases. In conclusion, the problem can be solved by generating a work plan so that all the WOs that are being prepared correspond to the route closest to the dispatch. It only needs planning so that the processes will continue to be carried out with the same current speed, but the waiting time will be reduced. However, this is not enough to eliminate overtime, so it is necessary to intervene in the processes.

On the other hand, it would be possible to obtain a notorious improvement in the use of resources, such as reducing from 9 to 7 pickers or significantly increasing the use of cranes. The planning would eliminate time losses generated by the disorder and chaos today, improving the average time in which a WO would be dispatched in 4.5 h, thereby affirming that the routes to be dispatched can be dispatched more quickly. To apply this proposal, acquiring two tablets for those who carry out the recognition of products in the warehouses and developing a plan that allows maintaining a criterion in pursuit of prompt dispatch. It is contemplated that once implemented this proposal, it is most likely that the new bottleneck will be generated by the processes related to the cranes, recommending then to carry out a new study in this regard.

In terms of cost–benefit, it can be said that the monetary costs correspond to two tablets, approximately 70,000 Chilean pesos. It should also be considered that implementing a new procedure can bring other complications that end in economic costs. In terms of benefits, in resources, it is estimated that two pickers would be expendable, equivalent to two salaries of $310,000, that is, 620,000 Chilean pesos per month. Additionally, the benefits must include the new operating capacity, corresponding to 42.5% more, equivalent to processing 290 WO, which would, in turn, imply an aid to the problem of occupation of the warehouses since 145 positions would be released each day, 43 more than in the original model.

It is also recommended to generate a merchandise reception plan according to the production and sales plans to maintain an orderly organization within the warehouses. This would help improve the efficiency of the picking process by eliminating the associated time losses, even eliminating the proposed recognition process.

Regarding the warehouse occupation, it is recommended to analyze the construction of new warehouses, according to the storage projection, reducing the cost of external warehouses and optimizing economic resources.

For those who carry out a similar study, it is recommended to recognize the operation in the plant since it provides information that allows interpreting some of the analysis results. In addition, it is recommended to investigate if there are databases with relevant information according to the investigation. All the necessary to complete a final aim: to remain competitive, especially in the current global environment plagued by the pandemic and the subsequent global inflation.

Acknowledgements This research chapter was sponsored by the FONDECYT Grant No. 11180964.

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