Improvements of cross-docking operations at Worten's warehouse

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Abstract: The challenge of being the fastest player in a sustainable way, delivering the right product, at the right time, to the right place, is the greatest challenge of the decade presented to consumer electronics retailers. To respond to this challenge, supply chains are forced to be more efficient. This requires drastic reductions in delivery times while saving costs throughout the entire supply chain. This work aimed to improve the cross-docking process of an electronic retail company warehouse, involving the supply of 140 stores present in Portugal. Factors such as the constant increase in demand, the expansion of the range of items, and the increase in the number of stores resulted in the need to redesign how items are sorted and sent to stores. This led to the design of a solution that guarantees sustainability in the medium-long term, is highly expandable, and significantly increases productivity without compromising the logistical cost and quality. To frame the case study, the characterization of the retail industry and the role of supply chains is made, followed by a brief introduction to the company and a detailed description of the processes involved. Then the problem to be addressed is described, and a literature review is carried out with a focus on the concepts of logistics, warehouse management, lean and its tools. Application cases are also presented in order to support the methodology to be used. After performing this characterization, the current situation is typified using lean tools and opportunities for improvement are identified. These opportunities are then addressed by developing and implementing initiatives involving changing processes, layout, and using new equipment. Finally, after developing the key performance indicator's analysis, it is concluded that these improvements allowed to reduce the cycle time of processes in this operation by 45%, reduce the time in queues by 90% and increase productivity by 52%.

Keywords: Cross-docking, Warehouse Management, Lean, Process Improvement, Retail, Sorting

1. Introduction

By definition, retail sells tangible goods to the final consumer, not for resale but for the purchaser's consumption. Retail involves selling merchandise directly to a customer through a point of sale, be it a physical store, a catalog, or a website (Kotler 2001).

The retail industry has evolved in the last 30 years mainly due to globalization. Until the end of the 1980s, the market was composed of many competitors – characterized as almost perfect competition – that held a very low market share.

Nowadays, the global retail market is characterized by fierce competition and is constantly evolving, especially in recent decades due to the proliferation of the internet, reaching most of the world population. These advances have opened doors to new business ways, presenting new challenges for large retailers (Turban et al. 2017).

In Portugal, the history of this market is marked by the abandonment of a large part of the small-scale competitors who were unable to adapt to this new reality, leaving those who, due to their strong financial power and capable management, dominated the market. Therefore, it is essential that retailers can reinvent themselves and continually improve their operations to survive (Farhangmehr et al. 2000).

Worten is the market leader in consumer electronics, home appliances, and entertainment in Portugal and differentiates itself from its competitors by offering the best value for money proposal, both in products they sell and services associated with them. To maintain the competitive advantage, the company is required to innovate and renew the method as it manages its business and operations day after day (Sonae 2017, Worten 2017).

This work aims to look for new solutions to improve Worten's cross-docking operation, more precisely an article sorting operation, reducing operating costs and delivery times and increasing installed capacity.

The main objective of this work is to make the cross-docking operation carried out at Worten's warehouse more efficient, agile and ergonomic, by changing processes and layout, as well as by using new equipment.

2. Case Study

2.1. The Worten company

Worten is a Sonae group company dedicated to retail consumer electronics, home appliances, and entertainment. It currently has 175 stores in mainland Portugal and islands, 35 of which are dedicated exclusively to selling consumer electronics and telecommunications services.

Worten was created in 1986, headquartered in Matosinhos, as part of the Continente supermarket chain, the food retail brand of the Sonae group. In 1998, Worten left Sonae MC (the company that owns Continente Modelo), and Sonae SR – specialized retail was created. In 2016, the brand's turnover justified the separation of Sonae SR, and today it is an independent company, even though it is owned by the holding Sonae SGPS (Sonae 2017).

In Portugal, the company is the market leader in the three sectors mentioned above, asserting itself year after year as an omni-channel competitor, i.e., the company is a competitor that stands out for its ability to integrate the various points of sale, eliminating barriers existing among them and offering its customer a unique shopping experience, regardless of the chosen sales channel (Verhoee et al. 2015).

2.2. Worten's supply chain

In the last decade, due to the digital and global world in which we live, the frontiers of consumer goods markets in developed countries disappeared. In a short space of time, we went from a market where the end consumer had little to no information to a market where you can virtually order any good, from anywhere on the planet using your smartphone from the comfort of your home (Verhoee et al. 2015).

In order to keep up with market requirements and the company's omnichannel strategy, Worten's supply chain has undergone structural changes over the past few years. It moved from a linear supply chain to a web-based supply chain, involving a higher level of complexity. To this end, Worten was forced to change a large part of its logistic flows and information systems (Worten 2017).

2.3. Cross-docking at Worten

As explained before, this work focuses on improving the process of cross-docking based on sorting by destination zone process. This process is defined as the separation of aggregated units of one or more references by destination zone, which means by store or external customer in Worten's reality.

The cross-docking operation is composed of two main processes, the first is sorting by destination zone, and the second is sorting by destination. Each zone represents a group of stores. Both processes are now explained.

Once the reception ends, the first process begins. The operator goes to the input buffer; transports a pallet to the sorting by destination zone area, then scans the barcode of any item that is on the pallet with the aid of a pulse barcode reader, and the system returns the units that must be separated for each of the distribution zones.

The operator reads the information received and places the respective units on the workbench of each zone and repeats the process for all items on that pallet. When it is finished, the operator returns to the reception area to restart the pre-sorting process for another pallet.

Lastly, the operator moves to the bench of a given zone removes, if necessary, the cardboard packaging where supplier groups the items, places them inside a transport cart and takes it to the respective zone, finishing the process (Worten 2017).

The next step in this operation is the second process called sorting by destination that is assisted by a Put-to-Light (PTL) technology. Upon receiving the transport car with items coming from the sorting by zone area, the operator reads the barcode of any item using the barcode ring scanner. Then, the PTL system activates the displays for that zone only, turning on a LED on a display so that the operator can quickly identify the box of destination where he must put the items. The system also indicates the number of units to put in each box. The operator repeats this process until all items are distributed. When a box is full, a label is attached to the box, and the box is pushed back through a roller track, allowing the operator to place an empty box in that position (Worten 2017).

3. Literature Review

3.1. Supply chain and logistics

In the existing literature, we can find several definitions of supply chain management. The Council of Supply Chain Management Professionals (CSCMP) - recognized as the official entity of professionals and academics in the field, defined that supply chain management encompasses the planning and management of all activities involved such as purchasing, acquisition, conversion, production and all logistics management activities. It also includes coordination and collaboration with external partners, service providers, and customers. Essentially, supply chain management integrates the management between demand and supply within and between companies. The same entity defined in 1998 logistics as the part of the supply chain that plans, implements, and controls the efficiency, effectiveness, reverse flows, and storage of goods, services, and related information between the point of origin and the point of consumption to satisfy customer requirements.

Years later, Guedes et al. (2000) defined the supply chain as the network of entities involved in interconnected processes and activities, both upstream and downstream, that create value for the user in the form of services or goods. It defined logistics as the system that encompasses processes, activities, and logistical resources necessary for the supply chain thus is often defined as a logistical pipeline. Last decade (Gaspar 2014) defined that the big difference is that supply chain management encompasses the infrastructure network including warehouses, factories, ports, transport, and information systems that connect suppliers to the customer, while logistics is the activity that develops within the supply chain.

According to Chandra & Fisher (1994), to improve consumer satisfaction, the three fundamental components to achieve better performance in a supply chain are forecasting demand, correct inventory management, and responding to constant challenges. The management of a supply chain can also be defined by the sum of techniques created to efficiently interconnect suppliers, producers, warehouses and retailers, so that the products are shipped in the correct quantity, in the correct place and at the correct time. The continuous objective is to reduce the global costs of the chain while the needs of the consumers are satisfied (Simchi-Levi et al. 2003).

3.2. Warehouse management

Warehouses, when they exist, are a fundamental part of a company's logistics network (Koster et al. 2007). According to the authors, warehouses are used as an intermediate point between the starting point of the supply chain and the point of consumption. These products can be raw materials, products in the process of being manufactured or finished products. De Koster et al. (2007) further explain the difference between a production warehouse and a warehouse. In a warehouse, the main objective should be to function as an intermediate storage point for goods that will later be distributed to other geographies, while the basic role of a production warehouse is to support it, both providing raw material and collecting the product in transit. Gu et al. (2007) add that warehouse management is an integral part of supply chain management and that it contributes decisively to the effective delivery of products to customers. The authors also express that the main functions of warehouses are to store products from various suppliers to satisfy customer orders and create value through special operations such as product customization, pricing, labeling, and creation of kits, opening the possibility of creating scope economies.

Increased competition in the retail market forces companies to continuously improve the design of their processes in their distribution network (Gu et al. 2010). This point raised by the authors is highly relevant because it was the reason that led to the development of this work. Mishra et al. (2011) express that an effective and efficient warehouse management contributes drastically to the reduction of inventory costs and its delivery time to customers. This could lead you to wonder if a warehouse is needed. Ramos et al. (2010) carried out a study in which they concluded that storage at intermediate points reduces the overall costs of the supply chain, i.e., the transport costs that would be added to the distribution chain if the goods were delivered directly from the point of production.

Finally, it is necessary to quantify the productivity of a warehouse. Using the information extracted by the warehouse management systems, it is possible to extract analytical data in order to be able to identify any waste later. In addition to the analytical models of productivity assessment, another widely used method is benchmarking, which consists of analysing the average productivity of the market so that the company knows its position and so that it can combat any points of disadvantage or weakness (Gu et al. 2010).

3.3. Cross-docking

"Cross-docking is a relatively recent technique used in supply chain management that consists of transferring goods directly from trucks arriving at a given warehouse to trucks that take them to another destination without the goods being stored" (Shuib & Fatthi 2012). Also, Belle et al. (2012) defined cross-docking as a logistical concept that connects intermediate points in the transport network. It is exposed as the operation of consolidating merchandise coming from several different geographies to a given endpoint, with the least possible handling and no storage between loading and unloading of merchandise.

The main advantages of implementing cross-docking are inventory reduction as the time that the goods remain in the warehouse for this operation does not exceed 24 hours (Belle et al. 2012); reduced warehouse costs as the supply and picking flow are substantially reduced, and these are a large part of the total costs of a warehouse (Ray 2010); improved transport network, the average occupation of trucks increases substantially (Vasiljevic et al. 2013) and finally supply cycle reduction because if there is no stopped inventory, the time it takes for an item to be delivered after the order is placed with the supplier, substantially decreases (Belle et al. 2012).

However, for this system to work, it is necessary that all members of the supply chain are coordinated (CSCMP 2013). If they aren't, the probability of an inventory break increases as there is less merchandise in the entire chain. Therefore, it is essential to have a thorough stock management to reduce the risk of stockouts (Belle et al. 2012).

In short, the use of cross-docking in oiled supply chains can be a good strategy that can bring competitive advantages to companies if it is well used (Belle et al. 2012).

3.4. Lean

There are several definitions of lean accepted by the scientific community. However, three stood out during the research carried out. Ohno (1982) expressed that Lean is based on the Just-in-Time (JIT) method, always trying to focus on the reduction of product throughout the distribution system, with the objective of harmonizing production and avoiding excesses of manufacture.

Shah & Ward (2007) defined lean as a socio-technological system that aims to eliminate waste, minimizing the impact of volatility between demand and supply from the beginning to the end of the supply chain.

Finally, Melton (2005) defines the lean methodology as a revolution that changes how business is done, transforming how the supply chain operates, impacting strategic, functional, and operational management. According to the author, to practice a lean culture, it is necessary to approach the problem using the following steps. 1) Collect data;2) Analyse data; 3) Develop improvements; 4) Implement improvements; 5) Measure and analyse benefits. This is the method used in this work.

In order to implement the lean philosophy, the tools considered relevant to identify or eliminate/reduce waste in a process are described.

<u>Value Stream Mapping (VSM)</u>

The definition of VSM according to Chera et al. (2012) is a lean management method to visually analyse the current state of all activities in each process, analysing the flow, discrepancies, ambiguities and errors that together create waste that by definition are activities that do not add value to the process. This visual tool was created in the Toyota

Production System (TPS), but given its value, it is implemented in most organizations that apply lean culture (Teichgräber & de Bucourt 2012).

In this method, Vamsi, Jasti & Sharma (2014) classified the activities in a process in three groups:

• Value Added Activities (AVA) – Activities in which the customer or organization recognizes value.

• Non-Value-Added Activities (ASVA) – Activities that have no value for the customer or the organization and that are wasteful.

• Necessary but non-value-added activities (ANSVA) – Activities that do not add value to the customer but which for some reason, are important to the organization.

Then the implementation team should reduce the execution time of activities with added value without disturbing their proper functioning; eliminate non-value-added activities and, if possible, eliminate necessary activities without added value, without interfering with the smooth running of the organization or process.

PDCA

PDCA (Plan-Do-Check-Act) is a lean tool created to manage an improvement process or project.

According to Imai (2012), this tool is divided into four equally important sequential steps:

1. Plan: In the first step, it is necessary to define the goals and objectives so that the results obtained are in accordance with the expectations of all stakeholders. Next, the procedure that is followed to achieve the desired goals is defined.

2. Develop: The second phase is the execution of the plan defined in the first point, but before doing so, it is essential to ensure the involvement and training of all people connected to the process. As much data as possible should be collected for use in the following steps.

3. Check: This process serves as a step for evaluating the results of the process implemented with the data collected in the previous point to verify if all the steps defined in the first point were followed in detail. The results must be compared with the objectives established in the planning, and if there are differences, the manager must analyse the reason.

4. Act or Adjust: Once the causes of any divergences between the results obtained and the expected results are understood, measures should be taken to correct the failures that occurred both in the planning and implementation phases.

Spaghetti Diagram

The Spaghetti diagram is a visual management tool that allows the identification of all physical flows and movements performed by people, machines, or goods in each process (Melton 2005). By itself, it is not a problem-solving tool but rather a tool that enhances continuous improvement by identifying potential movements that could be a source of waste (Bevilacqua et al. 2015). Despite being a straightforward tool, it is advantageous in factories and warehouses where processes are executed repeatedly.

Five S (5S)

The Five S tool, developed by Toyota when implementing the TPS, was designed to create desirable working conditions, with an immaculate, clean, and efficient working climate. To achieve the objectives described above, it is necessary to remodel the workplace, excluding unnecessary equipment and materials and reorganizing those considered important (Shah & Ward 2007).

According to Manea (2013), the tool's name is based on five Japanese words starting with the letter S, which represent five fundamental tasks to organize a job.

• Seiri (Sort): This is the first pillar of the 5S methodology. Everything that is necessary and what is not should be identified, eliminating everything useless. At the end of this step, the work area should display empty spaces and re-evaluate the layout.

• Seiton (Set in order): The second pillar can only be implemented after the first is completed. This step aims to organize the objects that were identified as necessary in the Seiri step so that they can be easily used and identified. At the end of this step, the work area should be adequately organized and allow you to find everything you are looking for easily.

• Sixo (Shine): The purpose of this third pillar is to remove all dirt, rubbish, and dust from the workplace. It is also necessary to identify the causes of dirt and resolve them. At the end of this step, the work area should be clean and have processes that guarantee it keeps that way.

• Seiketsu (Standardize): The focus of this pillar is standardization. Work rules should be established, and the organization of cleaning tasks formalized. Standardization ensures that the first three pillars are met by making their implementation a daily habit. At the end of this step, the work area should be adequately cared for in terms of disposal, organization and should have all processes properly defined and finally should have rules that define responsibles for maintaining the first three pillars.

• Shitsuke (Sustain): Discipline and educate everyone involved to meet the aforementioned points, creating a culture of efficiency and cleanliness in the work area (Fargher 2006).

In short, it is concluded that the 5S is a simple but also expowerful method of improving the workspace and that it serves as a basis for the implementation of other lean methodologies.

4. Collection, processing e analysis of data

4.1. Process characterization

The first step of the lean methodology defined by Melton (2005) is Data Collection so that lean data analysis tools such as VSM can be used, as described in the literature review chapter.

After collecting data, VSM is presented to characterize the operation, present the relevant data of each process and visually identify the points to be improved. In each section, key performance indicators that serve to assess the current situation are presented.

During the VSM elaboration, it was calculated that the average cycle time for processing an order is 43.6 minutes, with only 11.5 seconds spent handling the item. The remaining time is spent in queues and transport because the orders are prepared in parallel and not in series, i.e., it is not prepared unit by unit, but item by item.

4.2. Identification of opportunities for improvement

In this section, based on the waste identification exercise carried out using the VSM tool, problems and opportunities for improvement (OI) were be identified for each of the processes and respective activities. Several analyses were carried out to support the opportunities identified based on the records of Worten's information systems and based on measurements. The sample period considered is three consecutive months of data (January 1st, 2018 to March 31st, 2018).

General Waste:

High waiting times (T): It is identified that this process is unbalanced in two correlated aspects that cause high waiting times and bottlenecks. The two aspects are the imbalance of units to be separated by each zone and the allocation of resources to them. During the sample period, zone 1 received only 12% of the workload, zone 2 31%, while zone 3 received 57% of the units to be separated, with the same resources on each zone. Assuming that the effort of separating a unit is equal regardless of the zone, it is concluded that the workload on the zones is not balanced.

By the correlation between both, the following opportunity for improvement was identified:

OI1 – Load imbalance between zones and incorrect allocation of resources

Waste on Process 1 Activity 1 (P1A1): sorting by destination zone

Non-ergonomic work environment (A): This activity consists of removing goods from a pallet, coming from the reception area, and separating them by distribution zone, which is a repetitive process. In this activity, two opportunities for improvement related to ergonomics were identified that may cause work accidents due to the repetition of heavy goods lifting and affect productivity:

OI2 – Manual lifting of merchandise on the ground.

OI3 – High height of the workbenches

Excessive Travel (D): Since the 3 benches will separate 87% of the pallets that are processed by this activity, the distance between benches is unnecessary.

It is calculated that the distance traveled per processed unit is 0.26 meters/unit. The value was calculated as follows:

$$Distance\ P1A1 = \frac{\sum distance\ covered\ in\ P1A1}{\sum Units\ processed}$$

Therefore, it was identified the following OI:

OI4 – Excessive distance between separation benches

Process errors (E): When removing the items from the pallet and placing them on the distribution benches indicated by the system, two types of error in the separation of goods were detected, which will only be cataloged as an opportunity for improvement.

OI 5.1 – Quantity errors, i.e., the operator placed a different number of units than the indicated by the system.

OI 5.2 – Bench errors, i.e., the operator placed the items on a different bench than the indicated by the system.

These two error typologies together represent 0.72% error calculated as follows:

$$\%\ error = \frac{\sum Units\ with\ error}{\sum Units\ processed}$$

Waste on Process 1 Activity 2: Unpacking and placing in tote

Excessive Travel (D): the distance between the separation benches and the recycling area varies between 3.6 meters and 5.4 meters depending on the bench, and this journey must be made, back and forward, for each unpacked pallet. Also, it was measured that, on average, the equivalent distance covered by a prepared unit is 0.43 meters, with bench 2 being further from the recycling zone, presenting a higher covered distance than the other benches. Although it appears to be a small number, as this is a large-scale process, 257 kilometers were covered during the observation period of this activity. Therefore, the following opportunity for improvement was identified:

OI6 - High distance between the separation benches and the recycling zone

Excessive handling (M): as described in activities 1 and 2, the goods are handled twice before until the residues are separated. Therefore, the following opportunity for improvement was identified:

OI7 – Double handling of goods until waste separation.

Waste on Process 2 Activity 1 (P2A1): sorting by destination

Non-ergonomic work environment (A): The top level of distribution boxes is 1.7 meters high, making the distribution of articles and removal of boxes less ergonomic and not very productive. Therefore, the following opportunity for improvement was identified:

OM8 – Excessive height of the top level of distribution boxes and reduced space to introduce items in lower levels.

Excessive displacements (D): The distance traveled between the separation benches, and the respective zone is high, having a greater impact when few units are transported at a time. The same applies to the distance traveled during distribution, as there are long distribution zones. Also, because the stores with the most demand are dispersed, there is waste in movement. Therefore, the following opportunities were identified:

OI9 – Excessive distance between separation benches and distribution zones.

OI10 – Excessive distance traveled within distribution zone.

It was calculated that the distance covered in the route described in OM9 is 2.02 meters/unit, which is equivalent to 85% of the total distance covered. In comparison, the distance covered in the route described in OM10 is only 0.36 meters/ unit, equivalent to the remaining 15%.

Waste on Process 2 Activity 2 (P2A1): Closing and completing box replacement

Preparation errors (E): when moving to the printing label area, especially at the end of the preparation cycle when all the boxes are full, errors in labeling were identified, such as labeling the wrong box. Therefore, the following opportunity for improvement was identified:

OI11 - Shipping labeling error.

This error is 1.31% and is calculated as follows:

$$\%\ error = \frac{\sum Units\ in\ boxed\ with\ wrong\ label}{\sum Units\ in\ boxes}$$

Excessive displacements (D) and High waiting times (T): Regarding excessive movements, according to the process described above, two opportunities for improvement are identified, the first concerning the movement between the complete box and the printer and the second associated with the distance traveled to reset the box. Both identified problems and excessive travel also cause high waiting times, as Activity 1 is interrupted until Activity 2 is completed, creating bottlenecks. Therefore, the following wastes were identified:

OI12 – Excessive distance between sorting locations and printer zone.

OI13 – Excessive distance between sorting locations and empty boxes zone.

It was calculated that the distance covered per unit in the described activity is 1.23 m/unit. This value was calculated as follows:

$$Distance\ P2A2 = \frac{\sum distance\ covered\ in\ P2A2}{\sum Units\ processed}$$

4.3. Proposal for improvements to be developed and implemented

In this section, the improvements identified for each opportunity are presented. To facilitate understanding of the area of application of each of the improvements, they were grouped by typology as presented.

Group 1 – Process improvement and layout of the separation benches area (G1): The improvements found in this group are aimed at process 1, carried out in the area surrounding the separation benches through changes to the process and layout.

Improvement 1: Use an electric pallet truck with an elevator (I1) to improve ergonomics and productivity (OI2).

Improvement 2: Redesign of sorting benches (I2): With the redesign of sorting stands, the height of the sorting benches was changed, making these benches more ergonomic (OI3), the distance between each of the stands was reduced (OI4) and finally the separation error was reduced by creating physical barriers between the benches (OI5).

Improvement 3: Change the recycling zone's location (I3) to reduce the distance between this zone and the separation benches (OI6).

Improvement 4: Change in the waste separation process (I4) to eliminate the double handling of the goods (OI7).

Group 2 - Process improvement and sorting zone layout (G2): The improvements found in Group 2 aim to eliminate or mitigate the waste identified in process 2, carried out in the zone surrounding the distribution zones through changes to the process and layout.

Improvement 5: Redesign of the sorting structure (I5) to avoid heavy load lifting (OI8) and reduce the distance covered in replacing empty boxes (OI13).

Improvement 6: Use of portable printers (I6): The use of portable printers was proposed instead of the fixed printers currently used, with two objectives. The first objective is to eliminate the distance traveled between the box to be closed and the printing area, consequently eliminating wasted time (OI12). The second objective is to reduce the labeling error (OI11), as the operator will print the label in front of the box where he will paste it.

Group 3 - Global layout improvement (G3): The improvement presented in Group 3, aims to create a global layout that fits the available space and joins the subsets designed in groups 1 and 2 in order to reduce the greatest distance traveled between the entire process, which, as shown in OI9, is the distance between the separation benches and the distribution zones.

Improvement 7: Redesign of the sorting structures and stands layout (I7) to reduce the distance traveled between the separation stands and the sorting zones (OI9) and to reduce the distance traveled during the distribution in each zone (OI10).

Group 4 – Improvement of the attribution of stores to sorting positions (G4): In this group, after changing the layout and structures of process 2, we intend to improve the attribution of stores to the respective sorting positions.

Improvement 8: Cross-zone load balancing (I8) to reduce waiting queues and improve resource utilization (OI1)

Improvement 9: Change the stores' assignment to sorting positions (I9) to reduce the distance travelled within each zone (OI10).

Group 5 – Improvement of the Visual Management of the system under study (G5): Finally, in group 5, it is intended to improve the visual management of the operation under-study, to standardize the places where each component must be placed and reduce the processing error through identification of key locations.

Improvement 10: Pavement Identifications (I10) stabilize each activity's cycle times by reducing wait times (OI1).

Improvement 11: Identification of separation benches (I11) to eliminate or reduce the separation error (OI5).

Improvement 12: Identification of stores in sorting positions (I12) to eliminate or reduce the label pasting error (OI11).

5. Development and implementation of improvements

5.1. Development of improvements

The first step of this phase is to do a chronological plan for the development of improvements. For each improvement it was adapted the lean methodology proposed by Melton (2005) that was presented earlier in this document, using the following steps:

- Step 1 – Requirements gathering.
- Step 2 – Development of improved solutions
- Step 3 – Procurement
- Step 4 – Benefit Estimation
- Step 5 – Validation in Gemba

After approval of the plan by the management team, each of the improvement groups was developed.

Group 1 - Process improvement and layout of the separation benches area

Improvement 1 – Use of electric pallet truck with elevator (I1): after gathering the requirements and making the procurement, an electric pallet truck was purchased and tested for this activity.

Improvement 2 – Redesign of sorting benches: after studying the requirements, it was concluded that the best structure to carry out this process would be similar to the structure of process 2, with the particularity that it would have only two levels, the lower level being for the separation of goods by destination zone and the upper level for replenishment of empty boxes. After the solution was designed, the supplier was asked to design a prototype, so that the solution could be tested in a controlled environment before being implemented.

Improvement 3 – Change in the location of the recycling zone: to reduce the distance travelled between the recycling zone and the sorting benches, the recycling zone was placed next to them, and it was estimated that the average distance travelled per unit will reduce from 0.43 meters/unit to 0.15 meters/unit.

Improvement 4 – Change in the waste separation process: This improvement intends to anticipate the unpacking of the goods by eliminating the step of placing the packed goods on the workbenches. For this purpose, the new process was designed and tested in a controlled environment.

Group 2 – Process improvement and sorting zone layout (G2):

Improvement 5 – Redesign of the sorting structure: In this improvement, the new sorting structures were dimensioned to improve the ergonomics and productivity of the operation. It was defined that the two lower levels are used for sorting by destination and the upper level for replenishment of boxes.

Improvement 6 – Use of portable printers: With the objective explained above, the requirements for the new printers were raised, and the procurement carried out. After performing the tests, it was concluded that they satisfied the intended purpose.

Group 3 – Global layout improvement

Improvement 7 – Redesign of the layout of sorting structures and stands: In this improvement, the overall layout of the operation was designed. To this end, it is defined the number of sorting benches and sorting zones and the connection between them. With this configuration, it was estimated that the distance traveled between the benches and the zones is reduced from 17.35 meters to 1.35 meters. In addition, the network and energy points were defined and the other equipment necessary for the operation to be carried out.

Group 4 – Improvement of the attribution of stores to sorting positions

Improvement 8 & 9 – Cross-zone load balancing and change in the assignment of stores to sorting positions: This improvement group was worked on together and, consequently, presented as one. As explained above, it is necessary to re-assign stores to sorting zones, ensuring the balance between zones and reducing the distance traveled within each one. In addition, it is necessary to ensure that all 140 stores have a sorting position. To this end, meetings were scheduled with the sales teams to raise the sales forecast for each store and with this information the stores were divided by each zone, ensuring that it was expected to send the same quantity of units to each area. Then, within each zone, the stores were distributed in descending order from the beginning to the end of the zone, ensuring that the distance traveled is as short as possible. It is estimated that with this setting, the distance traveled will decrease from 2.38 meters/unit to 0.57 meters/unit.

5.2. Implementation of improvements

In order to implement the proposed improvements, it was made a detailed implementation plan focused on purchase and delivery of equipment and materials; layout preparation; preparation of computer systems; preparation of the process's changes; start-up phase; and finally, monitoring and stabilization of the operation.

The construction logic of this plan followed, in a first phase, a top-down approach to creating the tree of activities to be carried out and, in a second phase, a bottom-up approach to define the time of each activity. Activities were scheduled so that implementation was completed two months before the yearly period of greatest load.

The entire plan was followed, and it was not necessary to activate the contingency plan thanks to the effort of the entire team and suppliers in planning and executing.

6. Analysis and discussion of results

In this chapter, the actual results attained after implementing the improved solutions through data collection and observation of the operation under study are evaluated. In order to define the positive impact of the implemented improvements, the improved solution will be compared to the baseline and benefit estimate (the latter, when possible). Since the operation under study is marked by strong seasonality, there is a need to compare the results obtained in similar periods. For the initial situation, data from January to March 2018 continued to be used and for the improved solutions data from January to March 2019. Although all the intermediate KPIs of each stage of the process were calculated, this extended abstract only presents the global results of the operation under study. The following table summarizes the results obtained.

Table 1 – Results obtained

Key Performance Indicator	Unit of Measure	Before	After	Var (%)
Distance Covered	meter/unit	4,3	0,96	-77%
Preparation Error	wrong units / total units	2,02%	0,29%	-86%
Process Cycle Time	second	11,5	6,5	-45%
Waiting Queues Cycle Time	second	694	63	-90%
Productivity	unit/hour/ person	329	501	52%

Distance covered: The average distance traveled during the entire operation was reduced from 4.3 meters per unit to 0.96 meters per unit (77%). This result was obtained mainly by reducing the distance covered during activity P2.

Preparation error: The overall operation error, reduced from 2.02% wrong/processed units to 0.29%, (86% reduction). This benefit was obtained by the alteration of the separation benches, the use of portable printers, and the identification of the places where to place the goods.

Process Cycle Time: The average cycle time of the processes went from 11.5 seconds per unit to 6.3 seconds per unit (45% reduction).

Waiting queues cycle time: In this step, the cycle time variation of the Q1 and Q2 queues is presented. The average cycle time for the queues went from 694 seconds (11.5 minutes) per unit to 63 seconds per unit (90% reduction). This reduction is due to the procedural elimination of Q1 by improving the waste separation process and balancing the workload between zones.

Cross-zone workload balancing: This improvement enabled an 83% reduction in the average Q2 queue cycle time. As explained before, the load imbalance between zones means that there was an excess of merchandise to separate in a particular zone (in this case, zone 3). In contrast, in the other zones, everything that was delivered to them has already been separated. This results in a very high waiting time in zone 3, thus increasing overall waiting time. When distributing the load evenly among the zone, this phenomenon no longer happens.

Productivity: Finally, the productivity measured in units per hour per person of the operation as a whole is presented. The overall productivity went from 329 units/hour/person to 501 units/hour/person (an increase of 52%). This increase is due to the same factors that were presented in the indicators above.

7. Conclusions and future developments

The work developed focuses on improving the cross-docking process for supplying the stores of a consumer electronics retailer (Worten), which takes place at the company's central warehouse. To this end, lean methodologies were used to improve processes, layout, and the work tools used.

To characterize and analyse the initial situation of the process, the VSM tool is used to collect and analyse the KPIs of this operation and identify opportunities for improvement, cataloging them by their type of waste, following the principles of lean methodology. After identifying the waste in operation, improvement solutions are proposed, developed, and implemented based on changing the layout of the operation; improving workplace ergonomics; changing the structures and machinery to be used, and improving sorting processes so that this operation is more productive and with higher quality.

After implementing the improved solutions, the results obtained are analyzed and discussed based on the identified KPIs. It was demonstrated that the average distance traveled per processed unit was reduced by 77%, the preparation error was reduced by 86%, the cycle time of the processes and queues decreased by 45% and 90%, respectively, and finally, that productivity increased by 52%. Based on the results obtained, it is proven that the lean methodology is applicable to this case study.

As future work, it is recommended to study the possibility of automating this operation, both in the aspect of transporting goods between the separation benches and the distribution zones and the separation of items by the stores.

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