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Improving efficiency in a hybrid warehouse: a case study

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Abstract

Logistics has assumed a determining position in the supply chain of each organization. This paper concerns the work carried out in a bus manufacturing organization with the aim of improving efficiency in its hybrid warehouse. A hybrid warehouse could be considered as one that mixes several different activities (reception, storage area, picking, shipping, supply to production lines and production preparation tasks) and brings together many different materials or raw materials and components. This factor led to the appearance of innumerable management methods to improve employee performance. These are intended to meet the needs of their customers, from the motto "do more with less". The work developed in a hybrid warehouse allows to detect logistic complaints related to communication failures between employees, the reduced efficiency in the activities like the check of raw materials or components and respective picking, the lack of space for their reception and storage, and the non-compliance of the FIFO stock management system. It is imperative that organizations can redefine internal spaces and flows, generating a more efficient and intuitive work and admit an opportunity for improvements in terms of space and content management, and hence, cost savings for an organization. The combination of Lean tools was implemented, and the results have been checked, showing a significant impact in the hybrid warehouse, with annual gains through the optimization of several activities: employee turnover (decrease by 50%), check and picking times (decrease about 75 minutes/picking) and better working conditions for employees.

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1. Introduction

Land transportation continues to be a widely used means of transporting people between different locations. The production of buses is quite common, meeting very strict rules on safety issues [1]. But beyond these standards, there is a huge diversity of requirements, which vary greatly depending on the customer. Each market has a different concept regarding the convenience, access to the bus, luggage space, onboard entertainment, etc., depending on the length of the routes, the type of travellers, the comfort level to be offered, among others. This explains the existence of a huge diversity of bus types, which implies an increased effort in their production.

This paper aims to describe a process of improvement applied in the logistics of a warehouse of a bus manufacturer where the problems of material flow and picking management were in place. The problems detected were essentially related to warehouse operation logistics, inbound flows, and outbound flows. The operation was completely out of step with the required flows due to the various growth stages to which it had been subjected. A careful analysis of the initially established processes was carried out, and brainstorming was elaborated to improve these processes, facilitating the work of the operators and reducing the labour aggregate to the picking process. In the initial analysis, layout problems were detected, which had to be solved in order to facilitate further actions to improve the processes.

2. Literature review

Supply chain management, also known as the value chain, consists of advancing the strategic positioning of a company, trying to optimize its operational efficiency [2,3]. On the other hand, supply chains cover the activities of companies that need to design, create, deliver and use a product or service to their customers. Thus, some authors claim that firms depend on their supply chains to serve their customers [4]. Nowadays, logistics is an important pillar of the supply chain. Logistics has the function of moving materials, representing the “set of activities that guarantee the availability of the right product, in the right place, at the right time, in the right conditions, in the right quantities, at the right price, to the right customer" [5]. Supply chain management can take different management ways, such as centralized, decentralized or hybrid management. Centralized management usually follows the Nash Bargaining model, decentralized management usually tails the Stackelberg Game model, while hybrid management converges the two models [6]. In the Nash Bargaining model, the supplier and the customer cooperate in order to make decisions together, determining the quantity as well as the optimal price of the materials. The price depends on the quantity supplied to the customer. In the Stackelberg Game model, the supplier chooses the optimum sales price to the retailer, while the customer chooses the optimal order quantity, not cooperating with each other. A number of other models have also been proposed and studied in order to enable proper management of the supply chain [6-10]. In the context of a global economy characterized by increased competition between companies, they aim to improve their service levels by expanding means of implementation and distribution, such as transport and warehousing [11]. The increasing tendency for product variability and even shorter response times have become decisive factors in the ability to establish efficient logistics operations within a company as logistical costs constitute an important part of total production costs. Thus, it is perceived that the efficiency and effectiveness in any distribution network is largely determinant in all warehouse operations [12]. Warehouses can be defined as material handling stations, dedicated to the reception of raw materials, semi-finished or finished products, as well as their storage and preservation, the preparation of material picking and shipment. The role of warehouses in modern logistics becomes more and more expressive due to several factors such as the rapid increase in e-commerce transactions and the desirable values of reduced stock as well as the fast response time to the customer [13]. Just in Time (JIT) is a production management system that dictates that everything must be purchased, transported and produced at the exact time, according to the customer's needs, improving competitiveness and market participation [14]. This was introduced as a substitute for traditional stock management systems, being increasingly used in the manufacturing and service industries [15]. Thus, the JIT aims to reduce waste, from the elimination of activities of no added value, refer the same authors. Regarding the warehouses, one of the most important decisions to make is about their layout. It describes the physical arrangement of the loading and unloading areas, the reception of materials and their storage, as well as equipment, offices and other facilities [5]. Some authors approach different procedures for three types of layout, having been proposed [16]: fixed layout, flexible layout, and category-based layout. However, in some situations, the layout of the warehouse ends up being designed according to the number of movements to which these products are subject, by storage or handling method, by the characteristics of the product/material, by the characteristics of the order, or even by supplier or customer [17]. In this way, other proposals for the organization of industrial warehouse layouts have also appeared, which include: (a) the fixed position layout, which is essentially suited to sectors that deal with large pieces where workers move around these parts; (b) layout by products, more suitable for mass production, and (c) process layout, more suitable when there is a very large diversity of part types [18]. However, there are still other forms of organization of industrial warehouse layout, such as [16,19]: (a) layout based on block stacking and pallet racking system; (b) the layout should focus on the total distance traveled between the picking operations and the shipping operations and, consequently, reflect the minimization of the distances traveled by the employees. With the adoption of methodologies based on Toyota System Production, commonly referred to as Lean methodologies, warehouses are also in the sights of managers because they are a fundamental part of the value chain, being integrated into the processes of continuous improvement [20,21]. The activities included in the warehouses include receiving materials, storing, picking, shipping and customer service [22]. Since always the picking is identified as the activity that requires more work and also the one that is more expensive in most of the warehouses [23], being able to be executed manually, or in an automated way [24]. The main suggestion given by several authors has been to minimize the travelling distances, in order to optimize the total time of separation and preparation of orders [24]. The existence of several optimization algorithms is a good solution to solve the problem of picking route selection. Algorithms, as a rule, are not easy to understand or implement, so that, as an alternative, Heuristic Methods are presented, although they do not present the best solutions, they indicate plausible proposals, easy to implement and memorize. Several picking models have been suggested, which integrate the following methods: (a) discrete picking, where the products are allocated in shelves or racks. The employee collects and separates the materials to the unit until the request is complete. For small orders, it is not advantageous for the excessive time spent on the picking paths [25]; (b) batch picking, in which the employee goes through the various areas and collects the materials to complete multiple requests at the same time. It is especially used for small orders, saving time due to reduced travel distances. However, in the end, the materials have to be separated by customer request [26]; (c) zone picking, in which the employees are divided by the different defined areas, where the requests are collected. Each employee performs the picking, moving only in a small area (reducing traffic congestion) [23]; (d) wave picking, where each employee is responsible for picking a single product type, and the collection is scheduled and done in all areas at the same time, and then the items are separated to create the individual orders [26]. Other authors [27] have addressed some heuristics, which may improve picking efficiency, such as: (a) Nearest neighbor, which consists of an algorithm used to determine a solution to the problem of the vendor; (b) the Shortest arc, where iteratively selects the shortest arcs between the nodes in a graph, where later a final network is constructed from these arcs; (c) Randomized construction, which aims to minimize total costs, in the sense that the choice of arcs that incur slightly higher costs at the beginning of the heuristic can yield a more attractive set of arcs available at the end of the heuristic; (d) Tabu search, which uses a local or neighbor search procedure to iteratively move from a potential solution X to an optimized solution X '. In order to obtain a better management of warehouses, several techniques commonly used in other management problems have been used by several authors, such as Brainstorming [28], Ishikawa diagram [29], Spaghetti diagram [30], SWOT analysis [31] and the 5W2H tool [32].

The present work aims to significantly improve the functioning of a hybrid warehouse, where products and raw materials are received, which are stored there, but also where product preparation operations are carried out before being collected to go to the lines mounting. After an initial analysis, problems of layout, an organization of products and picking sequence were detected. Thus, some of the aforementioned tools were used in a sequential and crossed way, in order to solve this problem, which is presented as a case study. This work intends to present as scientific contribution a set of solutions that can help future researchers and practitioners in the improvement of warehouses that congregate different tasks.

3. Methodology

This project was developed in the company Caetano Bus, a bus manufacturer based in the north of Portugal. The work covered essentially two areas: the material reception area and the storage area of the same materials. To improve the operating conditions of the warehouse under study, techniques such as Brainstorming, Ishikawa's diagram, 5W2H technique, Spaghetti Diagram and 5S were adopted. The study was developed following five main steps. In the first stage, a brief review of the literature was done in order to frame the work to be developed, based essentially on scientific articles. The second stage was the development of the work in the warehouse of raw materials and components, aiming to identify the problems. Then, in the third stage, the theoretical concepts were applied in order to support the practical work. Then in the fourth stage, proposals for solutions were developed, using brainstorming, planning and meetings for decision-making. Finally, in the fifth stage, the results were extracted and the conclusions drawn, as well as proposals for future work.

4. Results

4.1. Problems identification

In the outer zone of the warehouse reception, have been detected a set of problems that make difficult its management. It was verified the existence of two gates that are used for the discharge of the materials by the suppliers, which cause embarrassment in the flows of materials reception. The check operation of the materials received is carried out by the employees in the covered area of the warehouse. There are also in the discharge operations, some lack of definition of zones for discharges of the local/international suppliers, as well as the existence of failures in the temporary windows of discharge. Regarding the park, there is a large area that is not used for the storage of materials due to the existence of disorganization. The outer platform is the suitable place for storing materials with reduced rotation, however, it is not being used in its entirety for this purpose since it is allocated to other materials with medium-high rotation.

Some problems were also identified in the inner receiving area of the warehouse. Material discharged at the reception is checked, but there is no definition of areas specially dedicated to this purpose. In the area concerning materials in transit, there are materials in the vicinity of the gates that are used daily, which hinders traffic. There is uncertainty in the dedicated spaces, namely the existence of materials from local/international suppliers and the existence of different types of materials/products. It is further noted that materials intended to respond to stock ruptures are stored in the same batch of the remaining materials. It was also found that the corridor area was occupied with palleted materials/products. Regarding the shelves devoted to local suppliers, it was verified that their sizing is not enough since there was evidence of materials placed on the floor, in the circulation corridor. The synchronized supply system, which consists of a space where the suppliers themselves place the materials supplied directly in the places where the picking will take place later, shows that there is no stock control. The list of materials and products to be received, called ZMOV, is checked, and the part coding is checked manually, which causes a high checking time. Finally, in the reception, there are orders of a small volume that occupy reception space, usually on the floor, which causes disarrangement and lack of safety.

Regarding the warehouse storage system and its shelves (two floors), the main problems detected have been properly identified and are described as follows. A large amount of packing material was detected (a study conducted between 2 January and 8 May 2018 indicates that 2,756,448 different materials and products were received). As regards the type of material, there is a strong dispersion (eg screws, chassis brackets and outer casings). Regarding the arrangement of the shelves, these are arranged vertically and horizontally, which implies a greater number of movements in the picking process. In some stock places, it can be observed that the shelves are not in the best safety conditions for the employees. The existence of different types of materials on the same shelf and/or rack hinders the activities of the operators. Some materials/products are supplied in the kit for the production sector. These kits contain several codes, however, sometimes they are not stored in the same place. The storage area is not proportionally distributed depending on the different models produced, ie there is a high occupied area for storing materials related to the COBUS bus model (airport bus). There are certain stock locations that are not organized and contain obsolete materials. There is some uncertainty in the areas used for production supply trolleys (there is no identification for each section). In the intermediate trolleys used during the picking, unnecessary movements are observed, as well as the need for space to park them at the end of the day. There is a need for a large space for storage of the buses seats (inadequate storage system). The material is improperly assumed, ie the space is poorly used on the shelves. There are ergonomic failures since considerable volume/weight materials are stored in the upper shelves. In the storage of profiles, it is observed that the stored material is arranged horizontally on pallets, being this an inadequate storage system. A large area occupied by pallets, with stored materials, was identified. There are poorly sized storage locations due to poor planning and/or lack of space. Some material is stacked incorrectly, which makes it difficult for warehouse employees during picking, as well as their safety and of other employees. As regards the packaging of material, it is found that it is not adequately protected with plastic packaging, due to the lack of care from the employees. There is a duplication of codes in the same stock location. There is evidence of material and boxes without identifiable code (loss of information). In Fig. 1, it is possible to see the material flows, reception and after-sales employee movements (dashed coloured lines). There are day-to-day constraints suffered by the warehouse workers, namely:

- The suppliers have two gates in operation (gates G1 and G2), which promote constraints at the level of continuous flow in the reception of materials;
- The reception and after-sales areas are merged (lack of a clear definition). The number of movements by the employees is high, due to the fragmentation of these zones;
- Local suppliers are responsible for allocating material on the shelves (lack of control).

In the area reserved for the COBUS bus model, several opportunities for improvement were also detected. There is a greater number of pickings made for the COBUS model with respect to the other models, which results in a greater effort on the part of the employees, due to the production rate. The need for large storage space for COBUS materials makes it difficult to locate the material (materials with no assigned stock in some picking lists). There is a high amount of COBUS materials stored and dispersed by the area allocated to this model, which causes excessive employees' travelling distances and time wasted on them. In Fig. 2, it is possible to observe the movements made by the employees in the allocated area, to elaborate different pickings relative to the same production order. Four zones were identified: Zone 1: purple; Zone 2: blue; Zone 3: orange; Zone 4: green. Employees started picking in zone 3 (marked black circle), moved to Zone 4 to collect the empty pickup trolleys and then proceeded according to the order of the picking list to be made; in the end, they returned to zone 4 with the pick trolleys filled in (some employees went through several zones for a single picking).

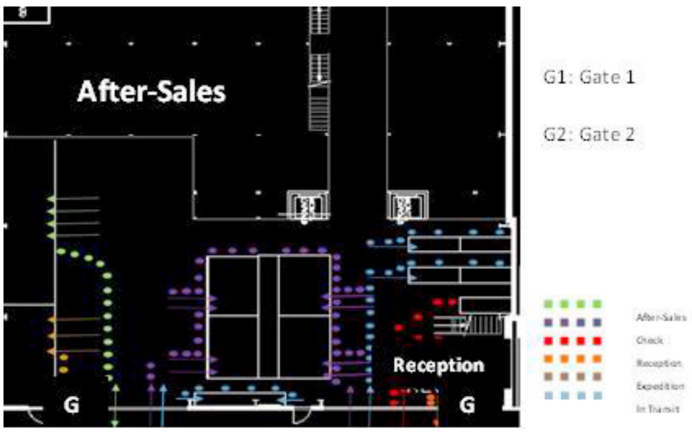

Fig. 1 – Employee movements and material inflows/outflows in the warehouse.

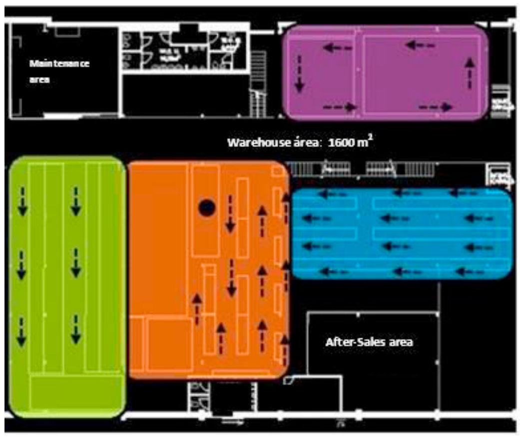

Fig. 2 – Employee displacements in picking activity (Black point in the orange area)

4.2. Project Analysis

With the aid of the Brainstorming technique, the Ishikawa's diagram was developed (Fig. 3) for the identified problem: Warehouse Layout. The concepts in green relate to reception problems, the blue concepts refer to batch problems, and the black concepts relate to problems common to the above areas.

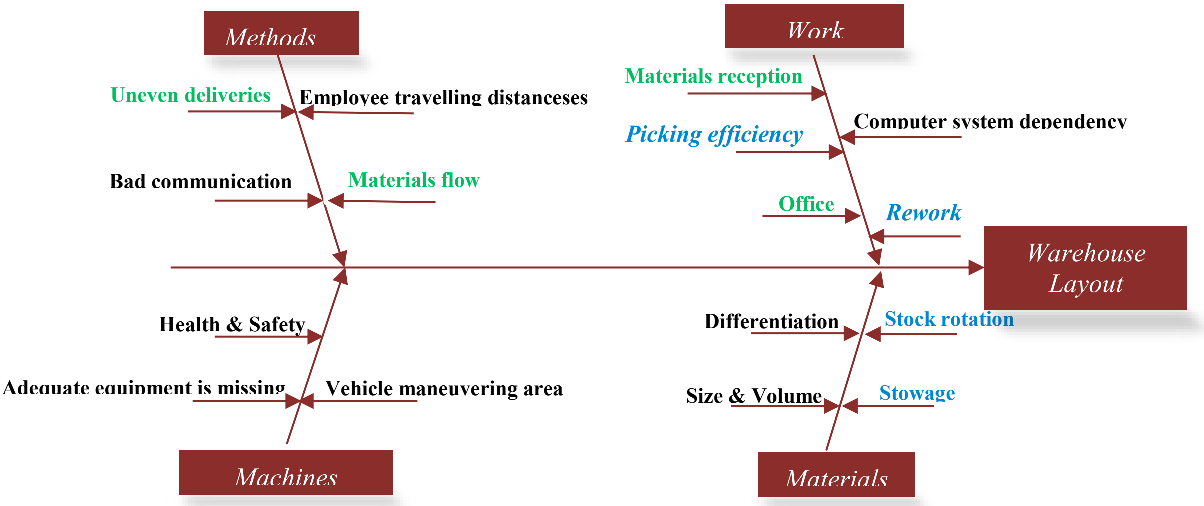

Fig. 3 – Ishikawa's diagram performed using a Brainstorming technique

As regards the problem related to the layout of the warehouse reception, two solution proposals were developed, based on the concepts of fixed layout and layout by categories, based on a possible redefinition of the reception layout. Fig. 4 illustrates the proposal that was presented, among others, and was chosen as the most appropriate by the team that developed the initial Brainstorming. Regarding the problems related to the implantation of the shelves in the warehouse and picking system, three proposals were elaborated, and the proposal indicated in Fig. 5 was selected.

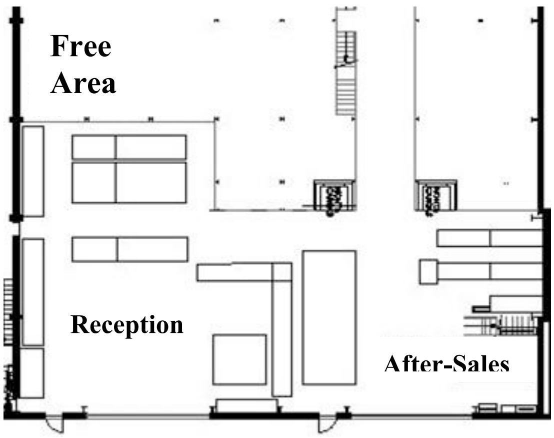

Fig. 4 – Proposal of the warehouse layout reception presented and understood as more appropriate

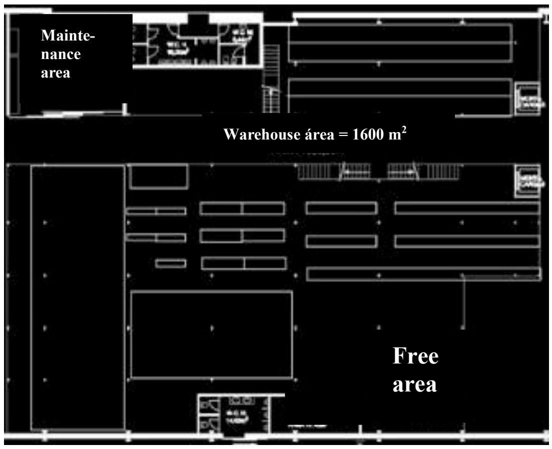

Fig. 5 – Selected warehouse layout proposal

The selection of the proposal presented in Fig. 5 was based on the fulfilment of the following requirements: (a) the shelves are orientated in a way that facilitates the access of the employees that perform the picking operation, minimizing the distances covered; (b) the size of the shelves and corridors shows to be adequate to the size and volume of the materials moved; (c) implies a redefinition of the stock sites, which is favorable to the elimination of some detected problems; (d) requires the acquisition of adequate handling systems and the implementation of a warehouse management system, which is equally positive, modernizing the warehouse management system.

Afterwards, critical analysis was made of the proposed solution, regarding changes in the warehouse layout, with an impact on the picking of the COBUS model. In Table 1, the 5W2H analysis of the proposal that was approved for implementation is presented.

Table 1. 5W2H analysis of the selected proposal

5W	What?	Creation of a continuous flow of materials, from production to assembly line (JIT).
	Why?	Production and delivery based on demand and exact quantity required: reduction of stocks and space occupied.
	Where?	Production – Assembly line.
	When?	February 2018 – June 2018.
	Who?	Suppliers + Team of the Logistics department + Andreia Freitas.
2H	How?	Industrial awareness (suppliers and collaborators); 5S; create productive flow; Heijunka; standardize the work.
	How much?	Preparation of the assembly line for JIT production system; acquisition of equipment and human resources.

In the storage and glasses preparation cell, the Jishuken technique was performed, which lasted for fifteen days. This activity intended to introduce Lean practices, having as main objectives the optimization of the storage space, the improvement in the preparation process of the glasses and their flows. The current layout was designed and the material flows were identified. The different tasks regarding the glasses preparation were then balanced and the waste of time identified using Value Stream Mapping (VSM) (Fig. 6).

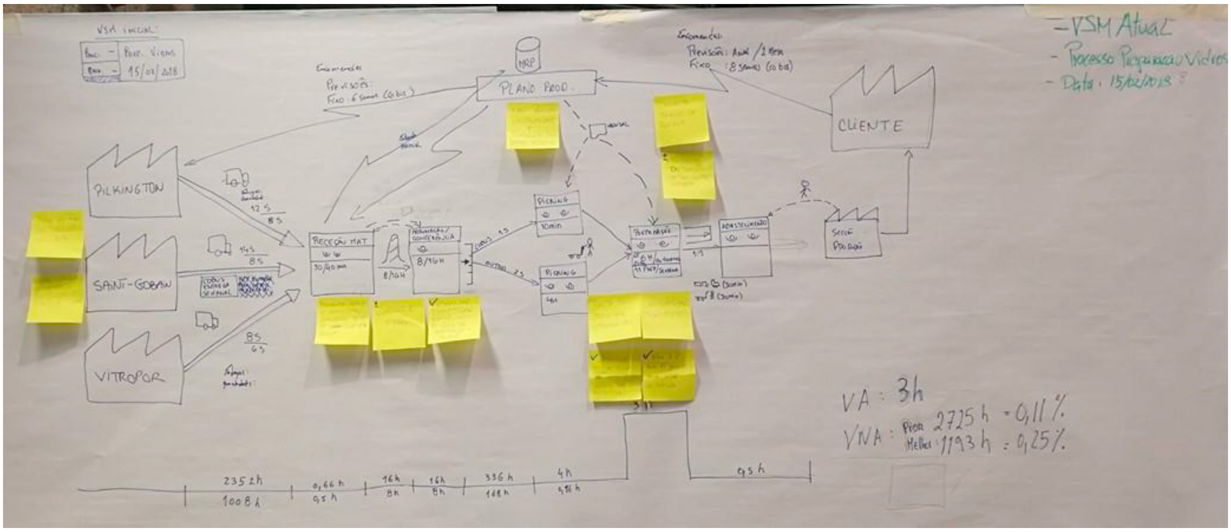

Fig. 6 – VSM of the buses' glasses warehouse area

From the VSM drawn up, proposals were made for improvements in layout and material flows, with optimization of the storage and the glass preparation cell. Subsequently, the activities were represented by the description of the previous process. Then, the main changes and benefits brought by this new layout were highlighted, and a plan of action for possible future improvements was drawn up.

In short, after a careful analysis of the problems and formulation of different solutions, the following actions were implemented in the receiving area of the warehouse, and the succeeding results were obtained:

- The layout of the warehouse was modified, and Gate 1 was allocated to suppliers, and Gate 2 was free for warehouse activities;
- The areas allocated to the reception of goods, verification and storage of materials became well defined, and a new space was allocated to the storage of parts for the after-sales service;
- The managers were sensitized to use the outer space of the warehouse rationally, making the employees respect the established guidelines;
- The suppliers were sensitized to use rationally the spaces allocated to them and to comply with the imposed rules, as well as the time interval that they have for the discharges.

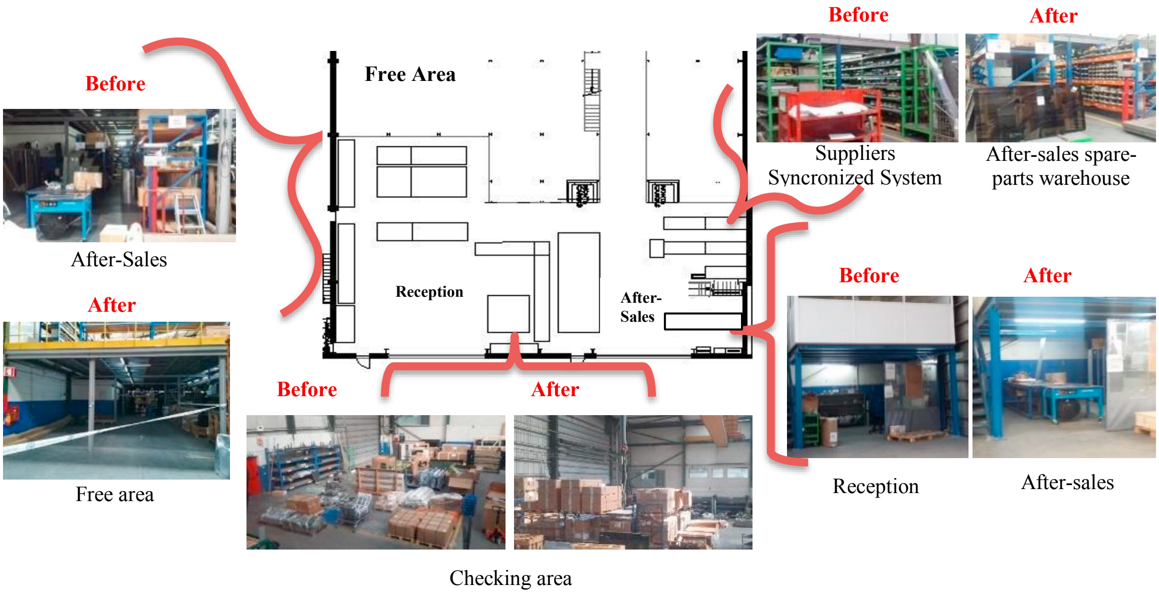

Fig. 7 - Implementations made on the warehouse reception, reflecting key layout changes

With the implementation of the mentioned improvement actions, several benefits were obtained in the intervened areas. Regarding the area occupied, it was verified that the area used for the material used by the after-sales sector decreased by approximately 12.5% and that the reception area was increased by 43%, making it possible to better organize the warehouse and the activities taking place around it. Fig. 7 intends to describe graphically and with real pictures, the transformations made through this work in the warehouse under study. With the use of suitable storage systems in height (racking systems), it was possible to create better conditions of packaging of the material received and to use more floor space in the materials' reception area: 62.16 m^2 (Fig. 8).

Fig. 8 - Perceptioned benefits: inventory redistribution and space optimization

With regard to employee movements, these have decreased by around 50%, as well as the time associated with the performance of their activities. This time saving refers to the time spent on receiving the material, checking and storing it (Fig. 9).

The layouts of floors 0 and 1 were redefined, with the glasses with greater stock activity stored in the lower area, and the remaining ones were placed on floor 1, using adequate storage systems, optimizing the area available in 57,6 m^2 (Fig. 10).

Fig. 9 - Received benefits: decreased movement

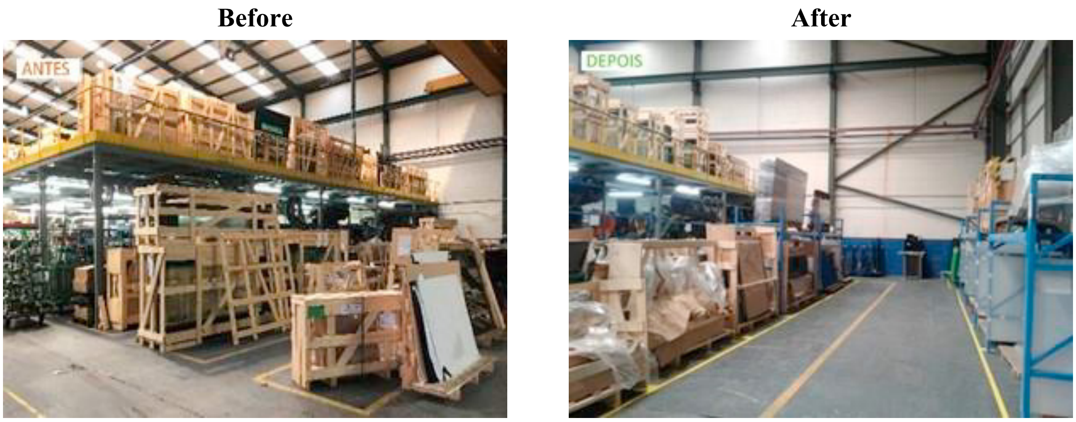

Fig. 10 - Partial implementation in storage and glass preparation cell

In short, after a careful analysis of the problems and formulation of different solutions, the following actions were implemented in the receiving area of the warehouse, and the succeeding results were obtained:

- Redistribution of inventory, optimizing the area available at the reception, in the storage area of materials for after-sales and storage area for supply to production lines (glass storage), through 5S tool;
- Decrease in employee movement times (around 50%), through Spaghetti diagram analysis;
- Decrease in check and picking time (about 75 minutes/picking), through Spaghetti diagram and 5S tools;
- Better working and safety conditions for warehouse employees, through 5S tool.

Considering the area made available due to the redefinition of spaces and housekeeping previously described, it was possible to allocate an area of 20 m^2 for fast checking operations of materials received, an activity that was previously performed outside the warehouse.

5. Discussion

The implemented changes allowed CaetanoBus to obtain real benefits, through the several improvements implemented. The relocation of spaces, as well as greater organization in the activities of unloading and verification of the raw materials, allowed a gain of space of 62.16 m^2 in the reception of raw materials. This warehouse reception area had been identified as critical due to the agglomeration of materials for verification, the existence of materials that are supplied through a system synchronized with the suppliers, and due to the delivery of materials by the suppliers outside the time interval previously established. The increase in space achieved benefited all activities developed in the warehouse, from the reception to the final storage of materials. The space allocated to the after-sales service was reduced, since the reorganization allowed to realize that it could be optimized, without prejudice to its operation. The *Jishuken* methodology brought several improvements to the storage and glass preparation cell, which were quite interesting. The adoption of a shorter time in the verification and picking operations, allowed to improve in 2 minutes per code the time spent in this operation. The reduction in employee travelling distance was also an important achievement. With regard to the redistribution of the inventory (available volume), the space occupied in floor 0 was reduced by 31.8 m^2. The creation of better moving means adapted for the glass brought higher safety to the operation with these materials allowed better working conditions, which showed the corresponding reflexes in the well-being of the workers and greater availability to work. The work began to be carried out with greater assertiveness, which was reflected in a higher quality of the work done. The implementation of the 5S has created greater employee involvement and a sense of responsibility, increasing their motivation in the workplace. By doing a work area analysis, a reduction of 62.16 m^2 was achieved in the reception, 31.3 m^2 were saved in the space dedicated to general storage and 31.8 m^2 were keep back in the glass storage, which totalled 125.26 m^2. Regarding the reduction of labour time, a reduction of 128.3 h/month was achieved in the reception operations and a reduction of 25.65 h/month in the formation of a kit of materials for a COBUS bus was reached. Moreover, in the picking and handling of glasses, a reduction of 11 h/month was also achieved. Taking into account that the current cost of labour is 25 €/h, at the end of the year, the savings reaches a value of 49,485.00 €. In total, the COBUS model picking time has been reduced 00:35:51/picking, making more agile the process.

6. Conclusions

The project aimed to improve the efficiency of the hybrid warehouse (storage and preparation), in order to redefine internal logistics spaces and flows, making the work more efficient and intuitive. Brainstorming sessions allowed problems to be inventoried and suggested solutions, regarding the use of Ishikawa's diagram. Spaghetti diagram was used to define the routes usually done in the picking process, helping to minimize them. Different opportunities for improvement were considered at the level of space management and time management using 5S tool, with the consequent reduction of costs. It was possible to verify that the low investment required can be completely returned 2.9 months later, a short period of time. This project allowed the organization to have a net profit of € 43,285.69 at the end of the first year after implementation, with subsequent annual savings estimated at around € 50,000/year. Workers' satisfaction was much higher due to the elimination of constraints related to lack of space. The picking process started to be about 35 minutes faster, which represents a reduction of about 25% of the time initially consumed by the workers in this task. This paper makes it clear that the application of Lean methodologies to companies continues to be a priority, as significant productivity gains can be achieved through investments that are practically irrelevant to companies. Given the better organization of the spaces achieved, the accumulation of waste and the transport of waste to the appropriate places also brought benefits to the environment, improving waste management into the company warehouse.

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