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Automated warehouse implementation study applied to boat industry

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Abstract. The industrial macroeconomic environment, where currently companies are inserted, is characterized by intense competitiveness. The success of a company depends not only on the ability to adapt to market demands, but also, on the efficiency of the practices implemented. In this way, the increase of the productivity in storage operations results on the improvement of the company´s logistical processes, giving it a competitive advantage. In this context, this study emerged to reformulate the management of the production support warehouse on a recreational boat builder company (BME), analysing the advantages and/or disadvantages of the implementation of an automated warehouse in substitution of the existing manual warehouse system. Picking times between the different warehouse types as well as the

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percentage of losses of small parts have been tested. These parts could be stored in an automatic storage system. From this study, important conclusions were drawn for the company's practical work in terms of warehouse production support and layout organization. The automatic storage system seems essential for the company to compete in a market that increasingly requires fast and error-free strategies. The results showed that investment needed to implement the automated vertical storage systems is around 45000€ and, based on the company data, considering only 8% of occupancy, the investment will be recovered on 6 years, considering only the reduction of losses. Also, the picking time reduces about 97%, from 926 seconds to 26 seconds (for the same number of pieces moved).

Keywords: Warehouse; Automated warehouse; Layout; Kardex.

1. Introduction

Warehouses are one of the parts of the supply chain that has deserved the most attention, whether for organization, efficiency, or the need to reduce costs [1]. Warehousing challenges require not only effective management, but also an innovative new strategy that considerably improves warehouse efficiency. Thus, it is required that warehouses are flexible and accessible, and that their space is properly used [2]. To improve warehouse efficiency, it is imperative to eliminate activities that do not add value to the process, eliminating waste and focusing on activities that add value to the customer.

In view of the above, BME company considered it particularly important to study the possibility of replacing a small manual warehouse of raw materials, to support production, by an automatic vertical storage system. In this way, the main objective of this study is to understand whether the existing storage system or its replacement by an automatic vertical storage system will be more advantageous. More specifically, realizing whether replacing a manual storage system for small parts with an automatic storage system brings changes in terms of optimizing warehouse space, reducing and organizing stock, and reducing scrap.

To achieve the main objective, a set of intermediate steps was defined, such as:

- Perceive the current storage system of small parts;
- Identify all small parts;
- Identify limitations in the management process of small parts;
- Register in the computer system;
- Realize the percentage of losses of small parts throughout the picking process until it reaches production;

- Relate losses to costs;
- Develop a cost analysis.

2. Literature Review

Warehouses play an increasingly important role in the supply chain. They play a key role in facilitating the movement of products as efficiently as possible between demand and its supplier and can even enable returns and customization activities. In this way, we ended the traditional view of warehouses as “dead spots”, where they were only used as storage centers, for centers where value is added to products [3].

A warehouse can be considered as a commercial building for storage of goods [4]. However, despite the globally known importance to warehouses, they still bring a negative image in terms of costs. In most cases, warehouses involve large investments in terms of land cost, building construction and, depending on the degree of automation to be implemented, in storage systems and equipment for the movement of materials, in addition to the associated operating costs themselves. However, a supply chain without stocks is a utopia [5]. In a reality where markets are increasingly unpredictable it is necessary to create small stock points between the various levels of supply chains, with warehouses having a central role in this process. In order to constitute stocks, warehouses are also responsible for enabling lower unit costs of goods and transportation; supporting the production of large lots; and allowing for accurate and timely information on existing stock [5].

Reducing picking time in a warehouse is one of the most suggested ways to improve storage system throughput. In the case of the selection of small item orders, this percentage of time spent on travel may be higher [6]. If automated warehouses are used the process can be more efficient.

Automated material storage and removal (AS/RS) systems have been in use since the 1950s, although with great growth only from the 1990s [7]. The purpose is to store raw materials, semi-finished products and final products in a production or distribution environment, in addition to rescuing the goods for the fulfillment of a withdrawal order [7].

The advantage of the automated storage system is the saving of labor and storage space, as well as increased productivity and reduced errors. According to Peixoto [8] the fact that AS/RS are controlled by computer causes greater visibility of the stock, requires a smaller number of employees, and reduces operating and inventory errors. Also, according to the authors, the only disadvantage is the high cost for implementing the system.

The main automatic storage systems are the self-driving and horizontal and vertical carousels [9]. Horizontal and vertical carousels are suitable for small products. Depending on the nature of the product to be stored, horizontal carousels vary in size and height, being especially effective in areas with little free space. This mechanism is ideal for storing and collecting large quantities of an item and tend to be used to store items slightly larger than the vertical carousel as medium and large boxes [10].

The operation of the rotating shelving system is controlled by the picker through computer software and is usually assigned more than one carousel to an operator to reduce downtime.

Horizontal carousels are expensive and limited by the amount of time it takes to run. The complexity of the provisioning activity of this system and the dependence of the IT system for its operation are also inconvenient to its use [11].

The vertical carousel allows a better use of the maximum height of the building, providing a better use of space of the storage area. However, the effectiveness of this system is conditioned by the speed of movement, with a trade-off between the height of the system and, therefore, its greater storage capacity and the time that the shelves take to run [11]. The shelves circulate in any direction delivering the requested product to the operator at an appropriate height and on the shortest possible route. These shelves can also be adjusted and subdivided to handle different sizes and weights. The fact that it occupies an area smaller than the horizontal carousel and can have two or more openings, that allow employees of different levels to have access to stored products, also gives advantage to this mechanism [12].

It is an ideal storage system for small and medium-sized items that require high security whose software allows you to manage existing stock, sequence picking activity, and use the barcode scanning or pick by light system method to improve operation performance. As in the horizontal carousel, this system requires continuous maintenance and is very dependent on the computer system, and it is also recurrent the assignment of several carousels to a picker.

Self-services are storage systems that do not require warehouse operators. These have a high storage capacity, allow the movement of up to two pallets simultaneously and operate at a high speed.

3. Methodology

In this work, action-research methodology was used, in which the researcher is a participant and interventionist entity [13]. Thus, action research differs from other research strategies by the emphasis on action, promoting change within an organization [14].

In this sense, the steps of the project were as follows:

Phase 1– Diagnosis: at this stage a critical analysis of the current state of the company was performed in terms of warehouse (focusing on small parts) and the existing problems were identified to be solved in the following phases. For the development of this phase, documents from the organization were analyzed and information was collected among the actors of the production process, using tools such as the Ishikawa diagram.

Phase 2– Action planning: after identifying the existing problems in the storage process, proposals for improvement were presented to overcome the previously identified problems. This phase was developed with the involvement of all stakeholders.

Phase 3– Implementation: at this stage the planned actions defined in the planning phase were implemented.

Phase 4– Evaluation of results and discussion: after the implementation of improvement actions, the results obtained were evaluated, discussed, and compared with the current situation.

Phase 5– Learning specification: at this stage conclusions were drawn regarding the results obtained to understand whether these were in line with the expectations of the stakeholders and also the learnings were specified. At this stage, a work plan was presented to be developed in the future.

4. Case Study Analysis

In terms of storage system, BME company has the main warehouse where all production support products are stored. This warehouse, due to the small size, considering the production system, is in expansion phase, starting to occupy in the future the part now destined for carpentry. There is still some raw material that is stored in a rented warehouse.

4.1. Diagnosis

To achieve the objective proposed by the study, after the analysis of the entire production process and storage of BME, a brainstorming was carried out with the most relevant elements of the logistics process of this warehouse. This brainstorming was part of the shift heads, the warehouse operators, the warehouse chief, and the logistics director.

The main problem identified was the disorganization of the warehouse (above all due to lack of space), which consequently leads to failures in the picking process, loss of small parts and production stops.

In the causes pointed out by the collaborators and responsible for the areas related to the materials, they highlighted the lack of parts that are still often found in the reception; the lack of parts due to delay of suppliers; parts outside the location or without location.

Other reasons why employees wasted time searching for certain materials was related to the lack of parts in the warehouse due to the lack of updating of information in the system. The employees wasted time looking for parts that, despite having stock in the system, did not exist at that time in storage. The fact that the information was not up to date in the system could also lead to a lack of requests, because the requests were made when the safety stock was reached and if the parts that were being removed from the shelves were not updated, this generated a lack of orders due to the false existence of stock. Regarding small parts, the employees mentioned as more difficult the fact that they must be counted one by one and placed inside the bags (they often fall behind the shelves and do not recover; they are often not counted correctly because the gloves make it difficult to pick up and the manual count itself).

Since one of the biggest concerns, regarding small parts, was the number of losses, an analysis of the percentage of losses was carried out using the adjustment file for the first quarter of this year and the costs of each piece.

At the same time, the scrap sheet (Stock Requisition) was analyzed, where the missing parts and the motif are placed daily (the same process being registered in the AS 400 computer system).

The person in charge of the warehouse for this stock control mentioned that, most of the time, the AL (Misplaced Material) code is placed on the sheet when, in reality, the problem is soon in the picking process (RF – Pick List – part that was placed in the pick and disappeared*),* but as there are no barcode readings and all records are made manually, it is difficult to identify this error.

The adjustment stipend file, filled in MS Excel, identifies the part number and part description, date, quantity that was misplaced or damaged, and associated costs (Table 1).

By analyzing the results, we conclude that most losses are identified as being misplaced material in the production lines.

The small piece with the highest losses recorded is the piece “NUT” (identified in Figure 1) and each lost or lost piece has the value of 0,26 euros. It should be noted that many of the losses of these parts are not identified or reported, so this value is still higher than that recorded in the company’s adjustment file.

Table 1. Example of the Adjustment File

Part Number	Part Description	Quantity	Extension Cost	Code	Code Description
152777	NUT.HEX NYLON	4	0,17 €	AP	Material Damaged in Line
152777	NUT.HEX NYLON	2	0,09 €	AL	Lost Material
152777	NUT.HEX NYLON	6	0,26 €	AL	Lost Material

Figure 1- Small Part with Higher Percentage of Losses

To calculate the percentage of losses, the number of losses (already identified in the company's own financial adjustment file, shown in Table 1) was divided by the total amount of parts moved in the first quarter (as well as the company's movements file).

In terms of costs, in the first quarter of 2022, the references analyzed presents losses of around 2060 € (Table 2). This means losses of around 6180 € per year with only 164 referrals flagged with recorded losses. From this analysis it can be considered that this value is a minimum value because there are losses that are not accounted for and/or recorded because it is a manual registration process.

Table 2. ABC Analysis of Losses

Classification	No References	No References (%)	% Losses (Costs)	Total Costs
Class A	38	23%	80%	1 647,37 €
Class B	29	18%	15%	309,29 €
Class C	97	59%	5%	103,00 €
Total	**164**	**100%**		**2059,66 €**

According to the ABC analysis, 38 references, which correspond to 23% of the total references, are responsible for 80% of the costs (losses) and account for a value of 1647,37 € per quarter.

4.2. Improvement Proposals

From the analysis of the current situation of the BME storage process it was possible to conclude the need for change in the information systems and automation of processes. Storage activities are heavily dependent on manual processes and still subject to large errors and unaccounted wastes.

The introduction of technology in the company can design significant improvements in warehouse productivity, increase space utilization, reduce costs as well as increase employee satisfaction [15].

To enrich the analysis of the situation under study and to better achieve the objectives in question, two suppliers of automatic equipment for storage, picking and distribution of boxes, AS/RS, Automated Storage & Retrieval Systems were contacted. These suppliers, MODULA and KARDEX, in addition to offering customers a consulting service that, in essence, is based on the observation and analysis of logistics operations to optimize, provide a service for submitting commercial proposals that indicate the automatic systems that best fit the context of each company. Both suppliers considered that the number of references to be stored in the automatic storage system could be extended.

MODULA supplier presented as a proposal the supply of an automatic vertical warehouse "Modula Model LIFT MC25" with 7500 mm high and 61 drawers, which allows storing up to 130,54 square meters of materials in an occupied area on the floor of 9,23 square meters, as well as a software system connected to the company's software (AS-400). This proposal can store about 2300 references and, thus, the 170 references that were analyzed would occupy a maximum of 5 drawers (machine occupancy rate only 8%). This confirms that the number of parts to be stored could be expanded. The investment in this storage system is around 45000 €.

KARDEX supplier, in turn, for prior analysis of the situation requested an inquiry that was answered in conjunction with the director of the logistics department and after viewing the movement file, made an analysis of the daily movements (considering all references) and made a visit to the warehouse. In this visit considered that there is enough potential to have a more comprehensive solution than only the approximately 170 references mentioned initially. In this way it did not present an initial budget or the most suitable type of machine.

4.3. Results Discussion

After realizing that the option for a vertical storage system allows to extend the storage of small parts initially identified (about 170 pieces), medium-sized parts and cables were also identified to be stored on the automated warehouse.

Therefore, the possibility of vertical storage can extend up to at least 937 references. This allows to release large parts of the shelves with location (00, 01 and 05 in some cases) and monetize the occupancy rate of the vertical storage machine.

In the case of the proposal submitted by MODULA, which was the reference of analysis, the occupancy rate would increase from 8% to the order of 41%.

It should be noted that by increasing the occupancy rate of the machine, the company can monetize in picking times, losses and recover investment in a smaller number of years. An investment of 45000 €, with only a machine occupancy rate of 8%, and considering the costs of losses in the order of 7000 € per year, would be recovered after approximately 6/7 years. If we expand the stored parts, with a machine occupancy rate in the order of 41%, the recovery of the investment will be in just 1/2 years.

In terms of layout of the new warehouse, already contemplating the vertical warehouse, since the zone for implementation is next to the exit of the warehouse for the production section, these parts could be the last to collect (minimizing time and distances). The distance from the vertical warehouse to the outlet for production is minimal (about 14 meters) and takes about 15 seconds to travel.

The automatic vertical warehouse operates according to the principle that there is no need for the operator to move to the location of the material (picking "goods-to-person"). The operator only tells the code he wants, when typing in the panel or by reading barcode, the warehouse management software reads and tells the operator how many items to collect.

In terms of picking time, MODULA proposal presents indicative values. The average time to access a drawer, with full load, is a maximum of 26 seconds. If the drawers are fully charged, in a picking time of 15 seconds, 61 drawers per hour will be delivered (which corresponds to about 4 drawers in 15 seconds of picking).

Comparing with previous studies in terms of picking times if we use an automatic storage system, and contemplating only small and medium-sized parts, we can monetize on average about 900 seconds. The picking time goes from 926 seconds to 26 seconds (for the same number of pieces moved).

5. Conclusions

The main objective of this work was to analyse the viability of implementing a vertical warehouse for small-sized parts in the BME company, to optimise the storage systems, increase the efficiency of the storage processes and reduce losses. Once the analysis was performed in terms of turnover of small parts, losses and cost of losses, and although it is not yet possible to quantify the savings obtained (mainly in terms of losses), the implementation of this vertical storage process will increase the physical space of the warehouse, the quality of operations, as well as reduce the probability of human error, which is currently evident, and also promote better use of human resources.

It is anticipated that the allocation of raw materials defined with this proposal of vertical storage, will in the future provide benefits in terms of storage activity, since it allows a better use of the storage space, as already mentioned, but also an increase in safety and reduction of losses of the components. In terms of picking activity, benefits are also expected as it will lead to a reduction in the number of locations on the picking list, which will therefore lead to a reduction in travel time and collection time.

It should be noted that this reorganization and profitability can still be extended to the kanban production support screws, which in a future proposal can also be stored automatically, allowing to avoid losses and control stocks.

In short, it is considered that the objective of analyzing the feasibility of implementing a vertical warehouse has been fulfilled, being a proposal to be implemented by BME because the investment will be recovered in terms of decreased losses, profitability of space and human resources, although the analysis needs to be extended also to medium-sized parts.

The automatic storage system seems essential for the company to compete in a market that increasingly requires fast and error-free strategies.

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