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The relevance of space analysis in warehouse management

C. G. S. Rebelo[a*]; M. T. Pereira[a,b,c]; F. J. G. Silva[a,b,c], L. P. Ferreira[a,b,c]; J. C. Sá[a,b,c]

[a]*ISEP – School of Engineering, Polytechnic of Porto, Rua Dr. António Bernardino de Almeida, 431, Porto 4200-072, Portugal*
[b]*Centre for Research & Development in Mechanical Engineering (CIDEM), School of Engineering, Polytechnic of Porto, 4200-072 Porto, Portugal*
[c]*INEGI – Institute of Science and Innovation in Mechanical and Industrial Engineering,, Rua Dr. Roberto Frias, Porto, Portugal 4200-072 Porto, Portugal*

*Corresponding Author. Tel.: +351910273952. E-mail address: Carolina Rebelo <carolina-rebelo@hotmail.com>

Abstract

Customers are becoming increasingly demanding and logistics is gaining more importance in order to assure customer satisfaction in terms of money, quality and time. The goal of this paper is to show that warehouses can be a source of competitive advantage and that a critical approach towards the existing available space may lead to increases in capacity with low investment. To accomplish this, a company is used as a model and suggestions for improvements are carried out. Regarding the capacity, a volume approach is taken into consideration, both in terms of the products and regarding the bins. Moreover, opportunities to achieve better space usage are presented by suggesting additional or different bins. Therefore, it is possible to reduce costs, to increase safety, to increase capacity up to 9,77%, and to help minimizing traveling distances and damages caused to the items.

Keywords: Warehousing, Layout, Action Research, Competitive Advantage, Logistics

1. Introduction

Before the industrial revolution, business took place on a local scale with small transactions between individuals and organizations [1,2]. However, with the revolution, large-scale industrial processes began to emerge, which introduced new challenges. More recently, and in the same trend, rapid globalization has brought about several transformations, fostering competitiveness [3] and increasing customer requirements. The high service level which companies have presented their customers with, has made them more demanding than ever [4]. Therefore, it is essential to develop innovative and efficient suggestions to face the challenges proposed by the market [5]. Organizations need to keep identifying their weaknesses and to think about ways to convert them into opportunities.

Although enterprises are often able to quantify the amount they spend, and even admit that they need to reduce costs, most are unable to identify what their true expenses should be, or define their potential minimum possible spending amount [6]. According to these authors, such is because companies do not have a clear methodology for determining costs. This lack of knowledge is one of the first issues that makes it difficult to identify how and in what aspects more gains can be obtained, in order to increase efficiency as well as to reduce costs [6].

The lean thinking philosophy has been largely spread all over the world being applied to enterprises and even to daily personal life [7]. The simplicity of the different strategies and the associated cost reduction, has made this way of manufacturing and living very popular, as several tools introduce small and easy tasks which boost efficiency [8,9]. One problem is that companies started using these tools because they wanted to improve something, but the starting point did not always have a quantified prediction of the outcomes. Therefore, organizations would just change things to make them better than they were, and then, quantify the

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improvements. Another issue is that managers would implement measures without understanding the true problem, and without involving the shop floor, so the outcomes were not always as good as expected [10]. In this paper, the starting point is to consider the overall picture and target the aspects that cause more entropies, making a point of involving the close participation of the workers. Then, a structured analysis is conducted, and new solutions are suggested based on quantified results.

With customers being increasingly more demanding, more attention was given to supply chain management, also known as the value chain [11]. It is important to always bear in mind that the goal of any logistic system is to create value to the client [12].

The novelty of this paper is to find a more adequate storage police based on previous improvements done at the company based on Kaizen Lean philosophy. While a storage model is a mathematical optimization model, the storage policy is a management rule. As Manzini and Goetschalckx state, though a storage policy may not generate the optimal storage plan, it is easier to implement because it does not require the solution of an optimization model [13].

This paper is organized as follows: section 1 introduces the theme. In section 2 it is possible to see a literature review on relevant topics of the paper. The research methodologies can be found in section 3. Section 4 describes the two approaches under analysis. The results are provided and discussed in section 5. Lastly, section 6 makes some concluding remarks.

2. Literature Review

Supply chain management can be defined as the effort to ensure the right product in the right place, to the right customer, at the desired time, in the right quantity and condition, while guaranteeing the adequate quality, balancing everything with controlled costs [14-17]. In this perspective usually there is a central planner who is fully informed regarding costs and a stochastic demand. This person is capable of developing optimal solutions [18,19]. This management has seen rapid developments [20] with the introduction of new concepts, technologies and methodologies that facilitate organization transformation and progress [21].

If we think about reality, even if a player has more power in a relationship, each one depends on the other. As an example, a multinational company needs suppliers to continue to produce, and these also need their suppliers to have raw material to be sold. Every part wants low prices and stock levels, and both want to have high sales volume and revenues. In this context it is possible to see that usually there are several independent decision makers [18,22]. So, the concept of supply chain is gradually being replaced by the idea of a supply network, a concept that goes beyond the first one. This approach, that is connecting more suppliers, is based on three major foundations. The first is allowing every player to be modelled more easily. The second is considering the inter-dependence of different factors that affect the whole network in order to calculate them more easily and to identify bottlenecks (so as to reduce overall costs and lead-times). The third one is to enhance the overall efficiency and to involve solutions that can be potentially computerized [23], working more as a connected network rather than a chain. Thus, there are two main differences worth being highlighted. Firstly, the idea that different parties frequently have different and conflicting goals. The second is that there may be asymmetries regarding information as different players have access to private information regarding costs and demand, and no one has the complete information on the supply chain [18]. In the perspective of a supply network, the focus should be on entailing trade-offs that bring positive benefits to the logistics system as a whole. Therefore, sometimes, a trade-off may imply an extra cost in one function but will lead to greater cost-saving in another [24]. These benefits may not be solely monetary. For instance, let us imagine a scenario where due to external motives, such as Covid, a supplier alerts their customers that they will not be able to produce the desired quantity. Or a carrier that would need 2 extra days for delivery. If the decrease in quantity, or the delay in the load, would not cause a line stoppage, it would be beneficial for both parties to agree on less quantity or a delay in shipment, promoting a flexible and long-lasting relationship. If such is the case, in the future, when the company faces an increase in demand their suppliers would be more willing to make greater effort to produce more quantity and the carrier would be more likely to put more effort in finding faster shipment alternatives/routes (such as trying to reach an earlier shuttle). On the other hand, if the company is completely strict, and always demands the exact quantity and delivery on the exact date, when they, for instance, faced an increase in demand on the short term, or when they needed a faster shipment, neither the supplier nor the carrier would be willing to put extra effort into helping.

The global logistics market was worth over 5.5 trillion euros in 2018 (Statistica). 2020 has not been such a good year. The Corona virus has caused global damages and logistics is not an exception. The impact was firstly seen in China. However, by the end of February, about 70% of large industry had already restarted operations. The pandemic has spread worldwide causing lockdowns and border closures that limited the movement of goods, leading to stock piling. In fact, the full effect of the pandemic on the overall supply network is not yet known but changes are already being felt. Other forms of demand are increasing, namely the e-commerce. On the other hand there have been some records in low fuel prices that have given some leverage to this sector. Logistics is also adapting to the circumstances, with different safety protocols, new modes of transport and contributing to the humanitarian fight, providing transportation free of charge and the material flow of goods, namely both medicine and food [25]. Indeed, the world should work as a global network with constant interaction and inter-dependence.

In an increasingly competitive reality, logistic costs are gaining more relevance in the global production expenses, as they are vital due to an increasingly wider range of products and a need for fast deliveries demanded by customers [26]. The interrelationships of the different logistic elements are interpreted in a planned manner as being part of a whole, so as to carefully identify and determine cost trade-offs. These trade-offs are positive benefits of the logistics system as a whole. These trade-offs are the core of the total logistics concept. In planning the distribution and logistics, this view of the system as a whole and its costs should be taken into consideration. Complementarily, there is the service level that is required by the customer that must be dealt with and is of extreme importance. Successful logistics may in fact be considered as the balance of total logistics cost and customer service level [23,25].

With the global market, it is even more important to optimize resources, which involves eliminating waste, making the best use of time, looking for continuous improvement and using technologies in order to achieve cost savings [27]. Thus, it is preponderant to overcome obsolete costing methods, to be able to respond to the competitive reality. In an increasingly demanding society [4], where efficiency and effectiveness are key concepts, it is vital to understand the best resources to explore [28]. To this end, it is very important to ensure that companies are able to truly identify and understand their costs which is not always the case [29,30].

One aspect that has, for long, been critical is warehousing [31,37]. Data reveal that 39% of the logistics costs in Europe are due to activities regarding the warehouse [31]. In fact, all over the world warehouse activities represent around €300 billion every year, with more than 85% involving operating costs - such as space, picking, storage, sorting, labour, equipment, packaging and dispatching [38]. This value tends to increase, as there is a growth and prevalence of e-commerce and global supply networks, which add even more complexity to the processes [6].

Despite all the costs, this activity is crucial. Warehouses are vital for any institution as they boost the usefulness of goods by increasing the time they are available to potential customers [39]. This is the basic and primordial function of warehouses - saving goods for them to be available when needed.

However, in operational terms, a warehouse seems to be much more than a place to store things: it can be an opportunity for competitive advantage [40]. Adequate management can lead to a great minimization of the total cost of the warehouse operations and help meet the expectations of the service level for the business, thus optimizing the warehouse and acquiring a competitive advantage [41]. Bearing in mind the increased velocity with which customers demand their goods to be available, the faster the retrieval of goods a company can present, the quicker these products will be made available for customers. This helps outperforming its competitors and boosting the success of the company by making it easier to deliver the right products to the right clients, in the right place, at the right time, and under the right price [42,43].

As warehouse activities are numerous and done on a daily basis, small changes can lead to great improvements and enable major savings [42,44].

3. Research methodology

An investigation methodology can be understood as a systematic way to solve research problems, or as the science that studies the way that research is carried out scientifically [45].

This project emerged as an attempt to deal with a real problem: the lack of space in a warehouse. For a better way of working, a clean process of investigation should be followed. It was essential to firstly understand the context of the company under study and afterwards, to identify opportunities for improvements. These findings should be clearly listed so that other companies that face similar situations could be able to implement a similar strategy.

Therefore, the most adequate methodology identified was the action research. This type of investigation allows a systematic approach that makes it possible to find effective solutions to everyday problems, addressing the complex dynamics in a concrete social environment [46], in this case, the daily interactions of the warehouse of the company under study. For this methodology to work, co-operation among the team and researchers must exist [47], which was indeed of extreme importance as several aspects of the project required the knowledge of the team in the field. This kind of methodology favours a principle of "learning by doing" [48] .

The analysis and diagnosis resulted in a set of possible actions taking into account the proposed objective – to help the company to improve the flow of materials in the warehouse. In fact, an action research methodology can be seen as set of 7 actions: (1) choosing the aim of the study (2) analyzing and deciding on theories, (3) raising research questions, (4) gathering data, (5) examining data, (6) reporting outcomes and (7) acting upon the results [49].

A descriptive methodology was adopted to understand the status of the situation: for example data such as the number of products, their dimensions, the dimensions of the bins, the percentage of occupation among others, were collected and calculated [48]. In order to study the reasons that led to these results, the analytic method was applied [50].

During the development of the project, a combination of theoretical knowledge and practical observation was carried out, in order to create and verify the description of procedures. Therefore a hypothetical-deductive methodology was conducted [51].

4. Analysing methodologies

In this chapter firstly, the current status of a company is presented, and afterwards further improvements are suggested, leading to the proposal of a new methodology.

4.1. The company's approach

At the company under study, a storage strategy is defined as considering the number of pallets that can fit in depth and the number of levels the bin has. In order to do so, one should go to each bin and analyse, one by one, the number of pallets that fit.

The following step is to determine the available area regarding the bins, while taking into consideration the safety space that is required. For security reasons, there must be a space of safety among different goods, and also between the goods and the structure of the bin.

In order to understand the real available area, the depth and length of each bin must be measured. From this, the dimension of the bars (both lateral and longitudinal), and the safety distance ought to be deducted.

For a clear understanding, each location is composed of a set of bins and each bin has several modules. Taking into consideration the example of Fig. 2, this would be 1 bin with 3 modules and a part of one location.

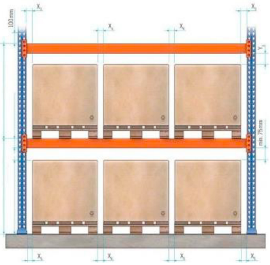

Fig. 2. Layout of bin's safety distance.

This information is then sorted by storage strategies. For each strategy, the number of modules that exists, the quantity of pallets that fit in that strategy, the number of pallets per module, the m^2 available for the strategy and, lastly, the m^2 per number of pallets are calculated.

In parallel, all goods and their respective constraints should be gathered and listed with the appropriate storage strategies and possible locations, as some goods need to be stored in a certain way due to, for example, the need of low temperature.

4.2. Know your space: a critical approach

With a clear understanding of the way the company works, a different methodology is proposed based on identified opportunities for improvement. The idea is to take into consideration a volume approach while analysing the capacity of the warehouse. With this perspective in mind, an analysis of the warehouse should be conducted in order to increase the capacity of the plant.

In the company's approach a storage strategy is analysed, for each bin, by evaluating the number of pallets that can fit in that bin. This involves going to the shop floor, seeing the number of pallets that are stored and deciding what the optimal amount should be.

However, by looking at Fig. 1, it is possible to see that, depending on the type of material, and on the way goods are packed, the same bin can have different capacities. For instance, if one places big bags in the bin, then only one pallet can be stored. However, if one thinks about smaller bags, two pallets can be allocated per level.

Therefore, it is vital to define the quantity, of each material, that could actually fit in the bins. Thus, a different approach which takes the volume into consideration is proposed. This analysis can be divided into three major tasks: 1. calculation of the available volume in the bins, 2. determination of the volume of each material, 3. understanding the number of goods that can be stored in each bin.

In order to calculate the available volume, firstly it is necessary to list all the possible locations. For each bin, the length, depth, and height should be registered. In this calculation, the dimensions of the bars (both lateral and longitudinal) and the safety distances previously mentioned, should be taken into consideration, and immediately deducted.

Fig. 1. Different capacities: area vs volume.

It is important to note that each level can have different heights. High importance should be given to safety distances as these can have a profound impact both on the infrastructures and the employees.

Regarding the volume of each pallet of goods, the dimensions of the length, depth, and height of a full pallet of each material must also be known. Therefore, a corresponding type of pallet must be registered. It should be possible to extract this information out of SAP system. As this was not made available, 170 full pallets were measured one by one and a corresponding type of pallet was registered. Since it was not possible to measure the 743 references, with the help of the workers, the measures, and types of pallets of the remaining materials were extrapolated. These dimensions should be placed in SAP for future analysis.

To understand the number of pallets of each material that can fit per level in each bin, firstly it is necessary to divide the depth of the bins by the depth of a pallet full of those materials. Then, the width of the bin by the width of a pallet full of those materials. After that, it is important to divide the height of the bins by the height of a pallet full of those materials and round down each result. Afterwards, it is necessary to divide the depth of the bins by the width of a pallet full of those materials, the width of the bins by the depth of a pallet full of those and round down each result. This is possible as the company has adapted racks that allow pallets to be stored in a horizontal or vertical way as shown in Fig. 3.

Position A – vertical pallet Position B – horizontal pallet

Fig. 3. Different ways to store a pallet.

Afterwards, it is necessary to multiply, for both options, and for each level, the capacity in depth by the capacity in width and by the capacity in height of the level under analysis. By choosing the highest value between the two options, the capacity of each product in each location is determined.

5. Results

In this chapter the results of both methodologies are presented.

5.1. The company's current status

According to the current data, the company's warehouse has the capacity to store 5.137 pallets in the 668 modules, organized in 73 sets of bins distributed in 24 locations. To find out this information, it was necessary to go to the warehouse, to understand how it was organized and to register, for each set of bins, the number of pallets that could fit in depth as well as the number of levels that each set of bins had.

According to the information extracted from SAP, in 2019, a variety of 743 different products entered the warehouse with an average of 5.261 pallets per month. Currently there is an overall occupation of 103,06% with bins that are very saturated, reaching 630,58% of occupation.

The warehouse under study stores raw and packaging materials. The warehouse is mainly organized with block stacking and drive-in bins that ensure that the last products entering the bins are the first ones to exit.

For a clear understanding of the way the company was organized, the layout and organization of the warehouse was divided, as can be seen in Fig. 4. The light green arrows represent the entrance of goods. The darker green one symbolizes the exit of materials which feed the production lines. Goods can enter from the supplier's trucks (as seen on the right), and they can also enter the warehouse from the factory, as leftovers from production (arrow on the left).

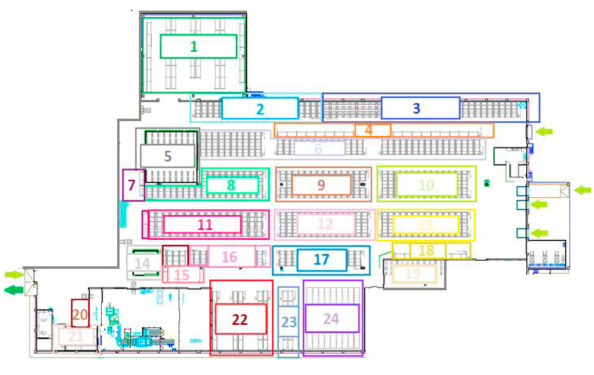

Fig. 4. Company's layout.

5.2. The improvement process

Bearing this in mind, in order to quantify the capacity of the warehouse, instead of taking into consideration the available area, or capacity in terms of pallets, it was decided to take the volume into consideration. To do so, it was necessary to find out the volume of the materials, of the bins and then, to calculate their capacity. This study led to the conclusion that there was a need of 8.618,150 m^3 per month to store the goods. Moreover, the total calculated available volume of the warehouse is 11.015,42 m^3.

In this analysis, high importance was given to the safety factor. Much more than simply taking into consideration these measures, it was very important to make it easier for the warehouse team to perceive the maximum height up to which the goods could safely be stored. In an attempt to make this very visual, and easy to respect, a red ribbon was placed on the bins, highlighting the maximum height permitted, as can be seen in Fig. 1.

In this manner, it was possible to analyse the capacity of the warehouse per product by building a tool in MS Excel®.

Table 1 shows an excerpt of the comparison between the depth, width and height of the bins with the depth width and height of each material correspondingly: scenario 1. In Table 2 it is possible to see an excerpt of the comparison between the depth of the bins with the width of the materials, the width of the bins with the depth of the materials and their heights: scenario 2. In these two options, comparisons are made by dividing the dimensions of the bins by the dimensions of the products.

Table 3 analyses the multiplication of depth, width, and height of the bins with the depth, width and height of the products (correspondingly). Table 4 analyses the multiplication of depth, width and height of the bins with the width, depth and height of the products (correspondingly).

Table 1. Excerpt of the comparison between depth, width and height (H) correspondingly for level 1.

Material	Depth (mm)	Width (mm)	Height (mm)	Capacity in depth	Capacity in width	Height level 1
				3.710	1.370	2.134,8
27731630	1200	800	565	3	1	3
43858521	1344	1000	574.5	2	1	3
43891436	1252	1205	622	2	1	3
43891460	1252	1205	622	2	1	3

Table 2. Excerpt of the comparison between depth width and height (H) not correspondingly for level 1.

Material	Depth (mm)	Width (mm)	Height (mm)	Capacity in depth	Capacity in width	Height level 1
				3.710	1.370	2.134,8
27731630	1200	800	565	4	1	3
43858521	1344	1000	574.5	3	1	3
43891436	1252	1205	622	3	1	3
43891460	1252	1205	622	3	1	3

Table 3. Excerpt of multiplication of scenario 1.

Material	Bins	Modules	Level 1	Level 2
27731630	351	27	9	9
43858521	234	18	6	6
43891436	234	18	6	6
43891460	234	18	6	6

Table 4. Excerpt of multiplication of scenario 2.

Material	Bins	Modules	Level 1	Level 2
27731630	468	36	12	12
43858521	351	27	9	9
43891436	351	27	9	9
43891460	351	27	9	9

Lastly, Table 5 compares the maximum of each result from Table 3 and Table 4, in order to find out the maximum value, that is, the maximum capacity of the bin per product.

Table 5. Excerpt of the capacity.

Material	Bin	Module	Level 1	Level 2	Level 3
43289601	156	12	6	3	3
43665770	156	12	6	3	3
43774482	156	12	6	3	3
43826067	117	9	3	3	3

Thus, it was possible to find out which materials and in what amount could fit in each bin.

Every day, there was a number of materials that were sent to an external warehouse. This represents an extra cost for the company. Unfortunately, for reasons of confidentiality, the information regarding the number of products or amount spent with this external warehouse was not made available for this research. However, it was possible to see that there was not enough capacity to store all goods.

Bearing the safety distances in mind, it was possible to see that there was a possibility to add seven more bins (highlighted with green arrows in Fig. 5). These bins (Extra bin A1.1, Extra bin A1.2 and Extra bin C), would add an extra available space of 160,16 m^3 increasing the overall capacity by 1,45%.

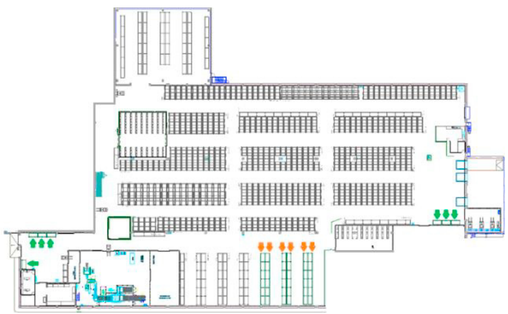

Fig. 5. A different look at the capacity: layout.

Moreover, zone 24 was a space on the floor because there were no bins with enough height to store such high height. Therefore, the acquisition of Cantilever beams, is proposed. The orange arrows in Fig. 5 highlight the simulation of these bins. With this, the available space of the location would increase from 230,40 m^3 to 1.119,74 m^3, an increase of 386% of the capacity of the location and 8,07% of the overall capacity.

Another aspect is to change zone 15, transforming the seven levels into four, reducing the height of each. If such were possible, the available volume of zone 15 would increase from 37,61 m^3 to 55,10 m^3, an increase of 46,50% of the location and 0,16% of the overall capacity.

All these changes would represent an overall increase of capacity of 9,77% (1.066,99 m^3). This, together with a change in storage techniques, led to an occupation of the bins of 71,27%

6. Conclusions

The goal of the study was to show that warehouses can be a source of competitive advantage and that a critical approach towards the existing available space may lead to increases in capacity with low investment and this was achieved.

One of the starting points in company's methodology is to analyse the number of pallets that can fit in each bin. However, depending on the type of material, a different number of pallets can be stored. Therefore, it was suggested that a volume perspective be taken into consideration, regarding both the dimensions of each location and the dimensions of the materials.

Due to the lack of more accurate information, the width, depth and height of 170 articles were measured and the dimensions of the remaining materials were extrapolated in accordance with the grouping discussed with the warehouse team. All the safety distances were taken into consideration.

This study led to the conclusion that there was a need of 8.618,150 m^3 per month to store the goods and a capacity to store 11.015,42 m^3 (11.054,05 m^3 if zone 7 is considered, however, this is reserved for product blocked due to quality reasons and information was not made available).

The company has adapted racks that allow pallets to be stored in a horizontal or vertical way. Therefore, in order to determine the real available volume, the depth, width and height of the bins was compared with the depth, width and height of the products (dividing each correspondingly).

Afterwards, the depth, width and height of the bins was compared with the width, depth and height of the products (dividing each correspondingly). Then the product of each scenario was analysed and lastly the maximum of the two options was chosen so as to identify the maximum capacity of the bin per product. This was also done with a tool that was built with MS Excel®. With this, it was possible to better understand the maximum number of products that could fit in each bin.

On a daily basis, it was possible to see that every day, there was a number of materials that were sent to an external warehouse, due to lack of space, which represented high costs to the company.

The study suggested an addition of seven more bins in order to make the most of the space that was not used, adding 160,16 m^3 of space.

Another suggestion, which lacks the approval of competent entities, consisted of changing the design of the current bins of zone 15. These structures have many levels, but each level has very little height. The proposal of altering the number of levels of these bins from seven to four would add 17,49 m^3.

Moreover, some loads were stored on the floor as they did not fit in any bin. In this space the most expensive goods were stored, and material damages were frequent. To overcome this, the acquisition of Cantilever beams was suggested, increasing the available space in 889,34 m^3.

By proposing the acquisition of these beams, it is possible to store goods with several dimensions in more than one level and to gain an increase in safety, saving time and decreasing the number of accidents and material damages. An extra advantage of this solution is that any load would be able to be stored in more than one level and in safety conditions and easily collected. In the current status, as the materials are stored in line, if the materials needed are the ones at the end of the line, other products, either from the sides or in front, need to be removed and then, placed again. With this solution, it is possible to choose the materials that are needed and directly remove them (saving time and preventing damages). The budget for the acquisition of these structures (considered in the analysis), varies between a total of 9.936€ and 17.064€ depending on the brand and quality of the infrastructure.

Although the degree of material damages was not made available, since the materials stored in this zone are the most expensive ones, this solution would represent a decrease in costs.

These changes would result in an increase in capacity of 9,77% This, together with a change in the layout could lead to a decrease in travelling distances that would represent 2,71 hours per month, a decrease in one person for four days (and 2,52 hours). Despite not being able to exactly quantify the amount saved in external warehouses, bearing in mind the average costs charged to other companies, this could represent savings from 10.000 up to 15.000€/month (120.000 to 180.000€/year).

In the initial situation, it was possible to see that several locations were saturated, with some surpassing 200% of occupation. Moreover, the overall bin occupation was 103,06% With the proposed solution, together with a change from a dedicated-storage technique to a class-based one, where in each class goods were randomly stored, the occupation of the bins is 71,27% This is due to the possibility of storing several goods in the same bin.

It is also possible to gain an increase in safety with a better storage of goods. Despite being hard to quantify the safety level, during the six months of study there was a near accident because the height of the products was not taken into consideration. The proposed solution overcomes this both by bearing in mind the height when calculating the bin capacity and by adding a ribbon highlighting the maximum allowed height.

In short, this solution permits a decrease in costs (as less space in the external warehouse is necessary and fewer materials are damaged), an increase in the storage capacity (9,77%), a decrease in traveling time and material damages (with the Cantilever beams) and, an increase in safety (with the red ribbons highlighting the maximum height).

CRediT author statement

G. S. Rebelo: Conceptualization, Methodology, Investigation. M. T. Pereira: Formal analysis, Writing-Original Draft, Supervision. J. F.G. Silva: Writing-Review & Editing, Visualization. L. P. Ferreira, J. C. Sá: Writing-Review & Editing, Visualization.

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