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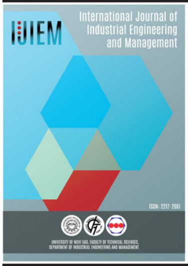

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Operations Engineering for Food Warehousing Improvement: A case study from the Navy

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ABSTRACT

Global competition and public awareness drive organizations to improve their management processes, including those related to logistics and warehousing. With the aim of improving the efficiency and safety of the food warehousing processes, an analysis of the warehouse layouts and storage areas layouts was carried out. Through the reorganization of the space and the review of storage policy, a practical proposal was made. To obtain more efficiency, an improved equation for the calculation of the distances travelled within the warehouse was defined. The implementation of the proposed improvements provides efficiency to warehousing, taking the Navy food central warehouse as a real case study.

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1. Introduction

The existence of global markets and the present economic and social environment require efficient and sustainable management of the available resources. In the search for competitiveness or justification of the spent resources, private and public organizations feel the need to implement improvements in their organizational procedures and work processes.

Warehouses, as part of the logistical system responsible for making material flows more flexible between the point of origin and consumption, plays an essential role in the continuity of the production process or the satisfaction of customers. It can also be a tool for minimizing costs related to the acquisition of resources by contracting larger quantities. The efficiency of the warehousing, as a whole, depends on the performance of its different components.

The movement of cargo and the coexistence of people and equipment in a confined space involves risks to the safety of people and goods. To analyze the warehousing activity, it is not enough to meet the economic efficiency criteria, safety and protection of workers and materials handled as well as the protection of the environment must be taken into consideration.

Food Supply Chains and warehousing have increased challenges and risks, like rapid decay of food

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items or cross-contaminations on its handling [1]. New technologies can help to prevent some risks, but not all warehouses have the business size or financial capacity to implement them, like power Warehouse Management Systems or smart packaging [2].

The Armed Forces, for the fulfilment of their strictly military missions or to support civilian populations emergency needs, should have a logistic structure that ensures the continuity of their operational capability. Food is a critical factor for maintaining the personnel physical and mental condition, and is therefore essential to ensure the continuity of its supply. The Portuguese Navy is under a process of updating its central food warehouse facilities, with the construction of new cold rooms, which poses an opportunity for improvement [3].

This work aims to recognize opportunities for improvement on the handling of food items within the Navy food central warehouse facilities and, propose the best layout solutions for the spaces under construction. To achieve this, the movement of materials within the facilities was analyzed as well as its relationship with the storage place of the different clusters of food items. Based on knowledge, some options of layout were discussed with the technicians, to understand its practical applicability.

Being a real case study, it is expected that the change on the warehouse layout and storage method will make it possible to reduce the movements of materials, and consequently, minimize the use of workers and cargo handling equipment. The achieved findings can be generalized to other similar food distribution centers

This document comprises seven sections. Besides this introduction, section two presents the relevant theoretical background concerning the warehouse activities; section three identifies the chosen methodology; section four presents the facilities under study; section five presents the proposed improvement solution; section six, the improvement quantification process and the discussion of the achieved results, which is followed by a conclusion.

2. Background

Nowadays, managers recognize the essential role played by logistics for the success of organizations [4]. Warehousing alone doesn't produce much value and it is indeed a source of costs for organizations. However, if seen as part of the logistical cycle, it produces an effective edge, making materials flow more agile and reducing uncertainty, while creating competitive advantage [5].

Within the warehouse operation upstream, there are several activities that may affect the entire cycle of operation, as for example the location of warehouse and the definition of their macro layouts [6], [7]. The layout establishes the location of the different areas of interest for the operation within the warehouses, such as the reception, consolidation or unbundle of cargo, shipping, support and administrative areas, as well as the material storing areas. There are a number of relevant factors that should be considered in the development of a layout: the location of the different areas of basic warehousing operations, the location of the materials within the warehouse and the definition of the different applicable storage techniques [8]. Regardless of the typology of the material to be stored, the layout should maximize the use of space, equipment and human resources, as well as ensuring accessibility and protection for all materials [9]. To obtain an efficient layout, it will be necessary to consider the different factors individually, and the analysis of the dynamics arising from their interaction.

The cost of handling an item depends on the distance travelled and volumes occupied within the warehouse. The layout, which maximizes each of the handling variables (travelling distance and storage area), can be different. therefore, to evaluate the effects of different storage strategies and handling techniques, it is necessary to specify the layout. Once the layout is defined, the cost associated to volumes becomes fixed, so the operating costs become a function of the average quantity of moved items, travelled distances and frequency of the materiel movements. The calculation of value based on these three factors can then be used to optimize the total warehouse operation expenses [10].

Three basic functions can be considered in warehousing: inbound movement, associated with the reception and storage of material; storage of material until its need by an internal or external customer; and outbound movement, related to the fulfilment of orders [9].

Considering outbound movement, order picking is an extremely expensive activity and directly contributes to the quality of service provided to clients, hence, it is often considered the main warehousing activity. Automated order picking systems require high capital investment, but a manual system is a labor-intensive operation and may represent the main cost within the total warehouse operational costs. Order picking costs arise mostly from time travelling and suboptimal layout designs [11].

Order picking refers to the transport of the correct materials, in the right quantity, from its storage area, in order to satisfy the order from a client, be it internal or external to the organization. For the time needed to pick an order, three main components can be considered: (1) Routing – which refers to the movement of an agent, a worker or machine, who arranges the orders, from one place to another, to retrieve the items; (2) Picking of items – which consists of a series of actions that goes from the worker positioning near the location of the stored item to the actual collection of the intended items; (3) Remaining activities – which includes the collection and return of support equipment to be used in the collection and movement of the material or the acquisition of information [12]. Order picking activity is critical because of the costs and loss of productivity, in case of failure, and for keeping the level and quality of customer service [5]. This relevance is self-evident in the literature review led by Staudt et al. [13], regarding the performance measurement within warehousing, which suggests that inbound activities have received less attention than outbound activities. The inbound performance was measured in terms of time and productivity, while the outbound was evaluated in terms of time, quality and productivity. No study was identified to assess the cost of both activities as a way to evaluate warehousing performance.

To improve the efficiency of order picking, different approaches can be taken, and these can be clustered into three groups of operating policies: (1) Batching - put several orders or parts of orders together to create one or more movements of picking. When several different orders are combined, the products can be gathered without losing the integrity of the orders, either during the picking (sort-while-pick) or after the picking is complete (pick-and-sort). When several workers work on a single order, each worker is allocated to a specific storage area; (2) Storage assignment - focuses on establishing rules for assigning products to storage locations. Existing rules range from random, where new sites are randomly assigned to products, to full-turnover storage, where products with the highest frequency of movement are assigned to easily accessible positions. There are also intermediate forms, such as ABC-storage; (3) Routing - the methods used range from simple heuristics to optimization schemes using dynamic programming [12].

Routing optimization is a relevant factor for minimizing warehousing costs [14]. The optimization of order-pikers routing can reduce the traveling distance in a very effective way [15], [16]. Often, to minimize the time/distance of material movement, the Traveling Salesman Problem (TSP) or an equivalent model is used. However, the problem needs to be presented as NP-hard TSP only when the warehouse layout is not a standard one- or two-block rectangular. For simpler operations, where most movements inside only have one point of origin and destination, a simpler model may be used [9]. For the calculation of these distances, Carvalho et al. [8] proposes the use of Equation 1, where the variable T refers to the number of movements and D to the distance; the index I refers to the place of origin, j to the place of destination, and n to the different number of existing areas.

$$\sum_{i=1}^{n}\sum_{j=1}^{n} T_{ij} \times D_{ij} \quad (1)$$

Warehousing improvement is greatly influenced by reducing time spend on movements, and they are easier to influence because they account to about 50% of worker's time in the order picking operations. The time needed for the pickup of items, which accounts to about 20%, and remaining activities, are influenced by factors such as shelf type or staff training [5], [12].

According to Emmett [17] and Çelk & Süral [18], one of the most relevant factors in order picking operations is the location of the items. The closer to the pick-up/drop-off point the items are stored, the shorter the handling time. Similarly, Stock & Lambert [19] suggest that the most popular materials, which have a higher turnover or demand rates, should be located in areas closer to the receiving and shipping areas, hence minimizing movements within the warehouse.

The movement of materials involve the movement of people and often the use of cargo handling equipment, making it critical for the inclusion of safety and security issues. In order to minimize the occurrence of incidents with consequences for workers and moving loads, in compliance with national and international legislation, safety plans must be developed. These plans, in addition to the general rules, should take specific rules into consideration regarding the materials movement, facilities features or operators' procedures. As far as their scope is concerned, these should include the warehousing of material, due handling and the risk of fire [20].

3. Methodology

In order to achieve the objective of identifying improvements in the warehousing under study, the layout of the different facilities, existing or under construction, and the layouts of the storage areas were analyzed. By redesigning the layout, specifically the work areas and storage places, one is changing the distances to be covered for the inbound and outbound activities.

Therefore, to carry out this study, the following steps were taken: (1) analysis of the existing layouts and the flows associated with inbound and outbound movements, in terms of efficiency and security; (2) go back literature and technical expertise; (3) identification of potential improvement measures; (4) cluster food items, simplifying the task of location assignment and, while maintaining storage flexibility; (5) computing of inbound and outbound distances for each class of food items and movement rate; (6) performing an ABC analysis in terms of movement rate; (7) proposing class-based storage where the item classes with the highest handling rate are located depending on the minimization of the distance needed to fulfil inbound and outbound activities; (8) verification of proposed amendments in terms of security and food cross contamination; (9) quantification of the impact of changes in terms of cargo handling and financial impacts; (10) validation with experts concerning the validity of the suggested proposals. The followed steps can be summarized into the ten-stage methodology that is shown in Table 1.

4. Facilities

The Portuguese Navy central food warehouse facilities have a dry grocery store, eight cold rooms and several technical supporting areas, as per Figure 1.

The current facilities present some vulnerabilities, such as the fact that unloading and shipping share the same docks, although with a time lag. The reception and picking takes place in the same area, which is also a pedestrian crossing area. The reinforcement of

Table 1. General methodology

Activities	Actions taken
1. Survey of the existing situation	(1)
2. Go back to knowledge	(2)
3. Identify potential improvement measures	(3)
4. Collect and arrange data	(4)(5)(6)
5. Specify measures	(7)
6. Identify potential arising risks	(8)
7. Rectify proposal	--
8. Quantify impacts	(9)
9. Validate	(10)

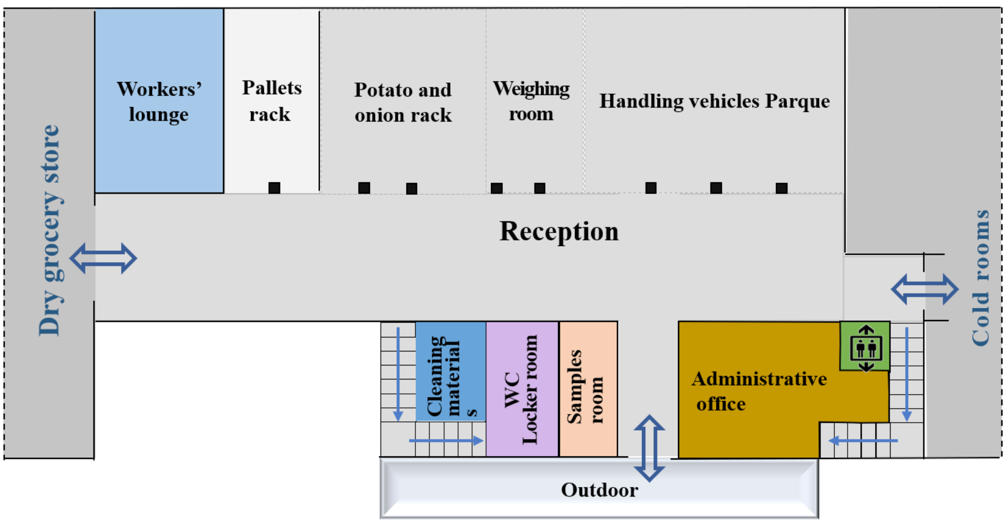

Figure 1. Facilities overview

safety signage is also ensured.

The dry grocery store has three sets of pallet racks with two levels in height. It includes an administrative office and a set of metal silos for storing liquids in bulk, as shown in Figure 2. Its main vulnerabilities are: (1) the existence of unused spaces, the metallic silos were used in the past for the storage of liquid oils in bulk, but with no use for a few years; (2) the distribution of the items on the racks do not take into account their handling rate; (3) part of the racks have difficult access due to the location of the shipment area; (4) the false ceiling has asbestos in its constitution; (5) the racks have no anti collision protection.

The storage method, in terms of allocation of spaces, is made on the basis of an opportunistic criterion and dependent on the subjective assessment of each worker. The movement of loads between the inbound and outbound docks as well as the location of the articles in the warehouse is mostly done on pallets, using hand or electric pallet trucks, forklifts or stackers.

There are eight cold rooms, half of which are refrigeration ones and the remaining are freezing ones. Each room has an associated food typology, as shown in Figure 3. The main vulnerabilities are the degradation of the facilities and energy inefficiency of the equipment; the area for the reception and picking shares the same space as is the case with the cargo handling area, without temperature control; the racks have no anti-collision protection.

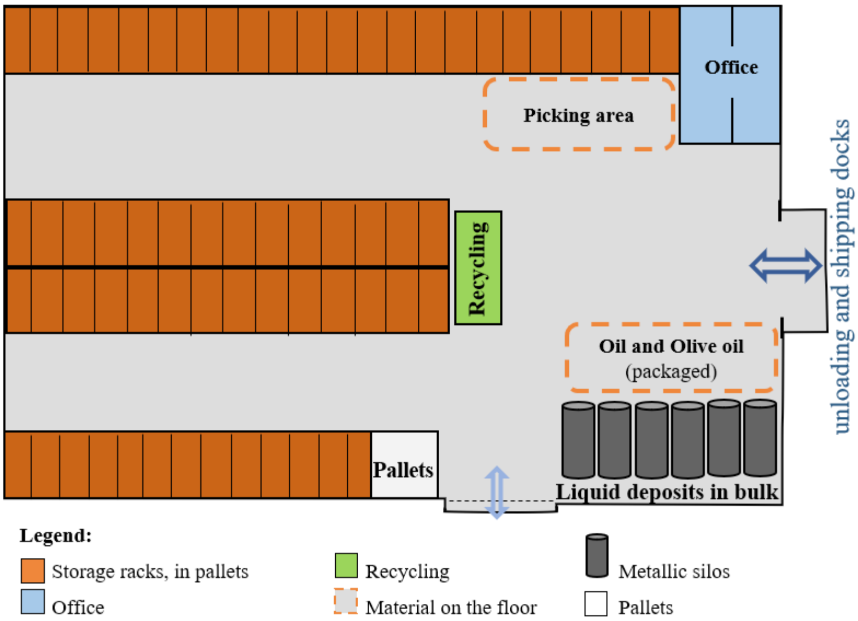

Figure 2. Dry grocery store

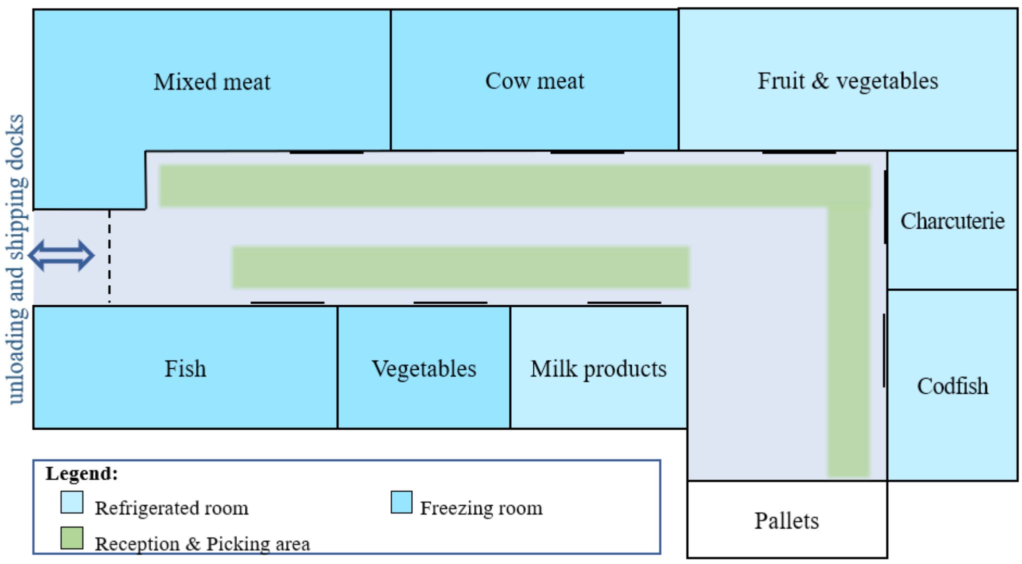

Figure 3. Current cold rooms

The current dry grocery store and the facilities under construction that will provide new cold rooms and the technical and administrative warehousing support will be the new Food Distribution Centre (FDC). The layout of the ground floor of the new facilities is shown in Figure 4.

A main innovation was the creation of separate inbound and outbound docks and technical spaces, one for cold products and one for products at normal temperature. For cold items, the new facilities will have separate reception and a picking spaces with temperature control. New cold room machinery will be more energy efficient and greater storage capacity for fresh and frozen food will be available. As a disadvantage, the smaller space for cold rooms may lead to the need to create different temperature zones inside the rooms. Because this construction project adapts existing facilities, the layout is not the most suitable for the activity in question.

5. Proposed actions

The storage location within the warehouse is a relevant factor in the definition of the layout and for the improvement of the warehousing, specifically through the reduction of the inbound and outbound movements [18]. Therefore, it is proposed to adopt a storage method based on opportunistic criterion, that place the items with the highest handling rate closer to the point of entry or exit, and the rearrangement of the working spaces, will allow the reduction of total distances of inbound and outbound movements.

Taking one year of historical data related to the activity of the Navy central food warehousing, a need is felt for clustering the food items in classes, by affinity and storage needs. With this procedure, it is possible to reduce by one-third the data to be processed, giving flexibility to the activities of assigning classes to fixed storage locations.

In order to rank the classes of items, an ABC analysis was carried out, according to their handling rate and warehouse of storage. To carry out such analysis, the following assumptions were made: (1) it was considered that the items located in different warehouses are independent, which led to separate analyses for each warehouse; (2) to estimate the number of movements between pick-up and drop-off points, the average weight per pallet for each class of items was taken into account; (3) the food items that are delivered by suppliers directly to the final clients were not considered, since they do not have physical existence at this warehouse; (4) for cold food items, the future FDC facilities were considered.

5.1 Layout proposals

Taking into account the results of the ABC analysis, the verification of potential cross contamination among different food items, and the objective of min-

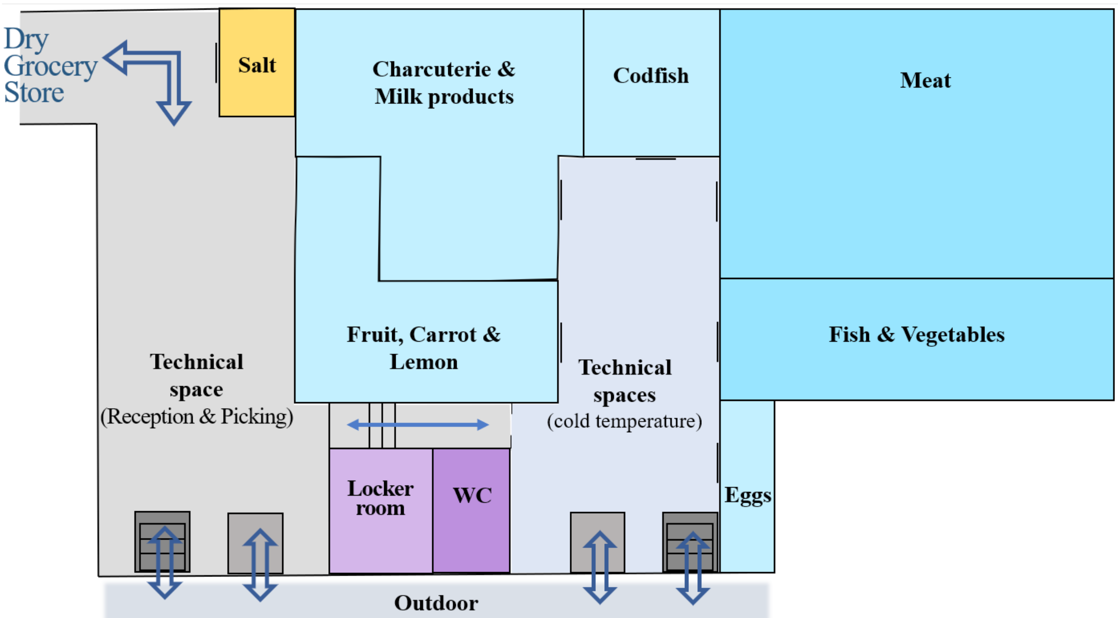

Figure 4. FDC new facilities

imizing the distance travelled by workers and cargo handling equipment in the warehouse, the following changing proposals to layouts were made.

Dry grocery store - this space will remain active with the building of the FDC. A proposal was made to move the area reserved for shipping next to the future access door, at the actual place of the first silos, hence freeing up access to all racks. This decision requires the dismantling of all metal silos. To optimize materials movement, the change of its storage localization on the racks is also required. As an example, Figure 5a) shows the current arrangement of food classes within the double racks central area, with two positions in height. Figure 5b) displays the proposed distribution. In each rack, the same class of food items take up the floor and first stage positions. Items with the highest rotation or weight go to the ground position.

FDC cold rooms - being a new space, for which there is no storage plan, it is not possible to perform a comparative analysis with the current situation. In the assignment of racks, it is considered that the quantities of food items managed by the entity remain stable. As an example, Figure 6. shows the proposed layout for the future Cold room for charcuterie and milk products. The space foresees ten racks for standardized pallets, at two levels in height.

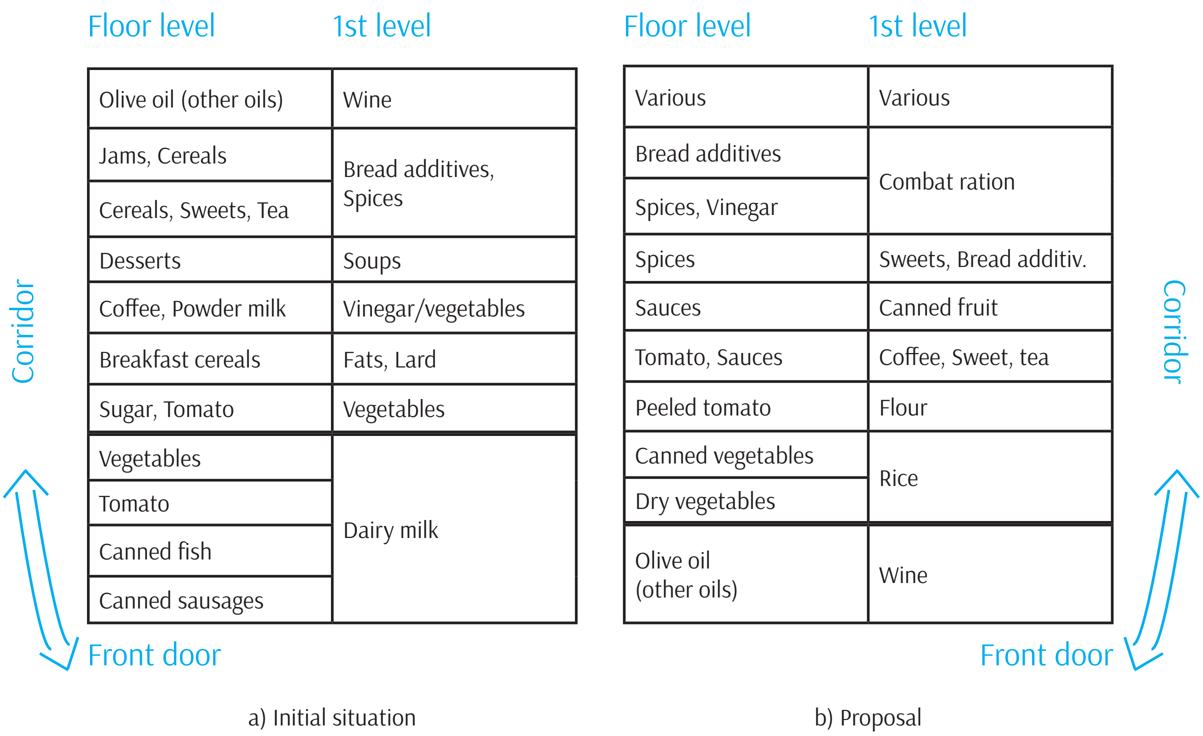

Figure 5. Central set of racks

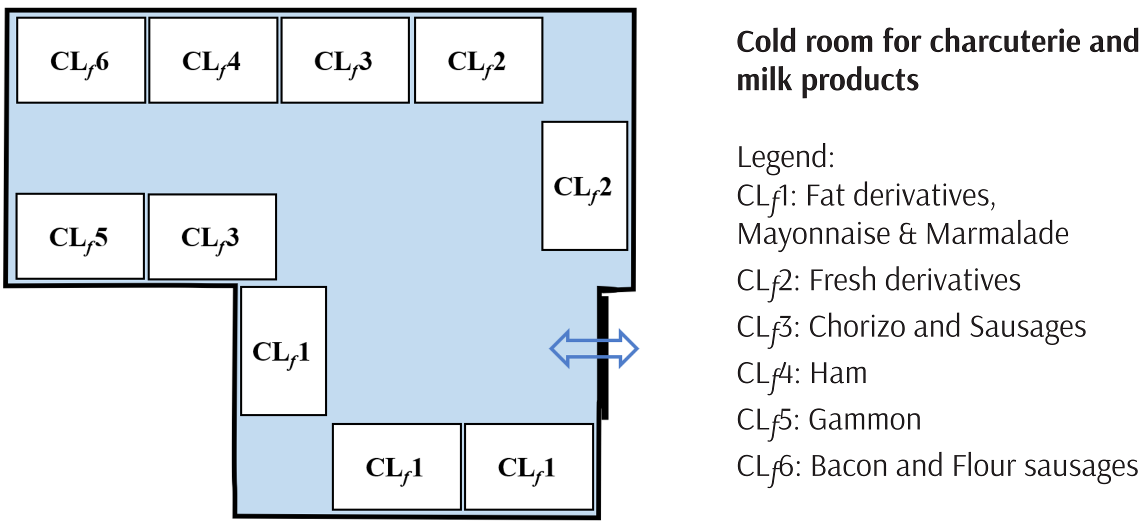

Figure 6. Proposed layout for a cold room. Source: adapted from Delaunay [3]

5.2 Safety solution

With the aim of ensuring workers' safety, food hygiene and safety practices, several proposals were made: (1) training of workers in the areas of food hygiene, safety practices and safety at work; (2) placing shock protection structures at the base of the rack supports; (3) implementing a preventive maintenance plan for cargo handling equipment; (4) marking the warehouse floor, defining pedestrian zones and direction of movement; (5) placing concave mirrors or a traffic lights system, activated by motion sensors, at increased risk areas; (6) reinforcing safety signage; and (7) replacing the false ceiling of the dry grocery store.

6. Proposals quantification and due discussion

To measure the efficiency of a system, it is necessary to be able to measure it correctly by selecting the appropriate factors [21]. In order to quantify the efficiency of the proposed solution, in terms of the total distance of cargo handling within the warehouse, equation 1 was adapted to the specific case resulting on Equation 2.

$$\sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{p} T_{kij} \times D_{ij} \qquad (2)$$

Where the variable T refers to the sum of cargo handling made for each k movement typology, between points i and j; D indicates the distance, in meters, between the location of points i and j, measured over the used paths. The index i names the physical locations of loading and unloading cargo docks; j indicates the central physical locations of the storage spaces assigned to each class of food items; k identifies the different types of load and mean of transportation adopted, e.g. box carried in hand, on pallet using a manual forklift or electric forklift, conveyor belt. This differentiation is due to the different time spend and costs associated with. Parameters m, n and p represent the upper index limit of the index i, j and k, in the same order. Variable $D \in \mathbb{Q}+$, and variable T and index $i, j, k, \in \mathbb{N}$.

In this case, index i varies from n = 1 to 3, where the value 1 refers to the current unloading and shipping dock, 2 to the normal temperature FDC unloading and shipping docks and 3 to the cold temperature FDC unloading and shipping docks. The index j varies from 1 to n = 56, concerning the different food item classes. Finally, the index k varies from 1 to p=2, where the value 1 is for inbound movements and 2 for outbound movements. The first uses electric forklift or stacker (60%+40%) and the second electric stacker or manual forklift (70%+30%), according to the usual procedure.

From the application of equation 2, quantifying the improvement of introducing the layout proposals, it is obtained a total difference of handling cargo movements of about 524Km/year, corresponding to 35% of travelled distance reduction. To express the obtained improvement in terms of money value, three criteria were observed: first, the increasing in the useful life of cargo handling equipment due its lower use; next the saving in operating and maintenance costs and; finally, the increase in productivity expressed in terms of man/hour. The percentages obtained are as per Table 2.

The shown improvements do not reflect the totality of the potential benefits. Some positive effects are difficult to quantify or to observe in a simple way. As an example, one can point the simplification of the monthly and annual inventories and weekly checking of stocks and movements, or the greater flexibility in the use of human resources from other warehouses, as a result of the fixed locations policy. Worker's perception of self productivity may contribute to improve motivation. The increase in productivity and its consequence in reducing working hours, makes possible to allocate the available human resources to other tasks, increasing quality and service level or collaborate with other warehouses belonging to the same entity. The improvement of safety conditions at work, resulting from improvement proposals to ex-

Table 2. Potential improvement from implementing the layout proposals

Criterion	Improvement (%)
Increasing the service life of cargo handling equipment	5
Savings in operation and maintenance costs	7
Increasing productivity in man/hour	10

isting physical conditions impact reduction of movements within the warehouse. Being the movement of loads a critical factor for the safety of all those circulating in the warehouses, less movements and less crossing of flows means more safety.

In order to validate the relevance of the suggested proposal, a series of interviews were carried out with managers and technicians with proven experience and theoretical knowledge. The obtained answers were quite positive and allowed a fine adjustment of the proposals submitted under the case studied. The head of the responsible organization expressed the intention to implement the proposed measures of improvement in the near future.

7. Conclusions

Efficient use of resources is vital for most organizations. The public sector is not immune to this trend. The real reduction in available budgets and legal limitations to resources dictates the need to improve the use of existing resources. Warehousing, despite its importance for the proper functioning of the logistical system, represents a consumption of human, financial and material resources that may be essential for other activities. The food operations present additional challenges to the warehousing activity [2].

With the aim of improving resource usage efficiency a real case study was conducted within the Portuguese Navy's central food warehouse. Cargo handling movements within warehouses has been identified as an opportunity for improvement. Additionally, it was intended to propose a layout plan for a cold warehouse under construction. Safety at work is a legal prerogative, a motivational factor and a social obligation, so safety aspects were also analyzed in order to ensure that the proposed improvements do not represent a reduction of adequate safety standards.

The existence of random strategies in assigning storage locations, in a human based warehouse, creates subjectivity, dependence on the workers that perform the tasks and ultimately, inefficiencies. Fixing the items that have the highest rate of movement within locations, near the access and exit points of the warehouses, boosts the reduction in distance of cargo handling and the working time of workers and machines.

A specific proposal to assign food items clustered in classes to fix storage locations was made. Beyond the optimization achieved, this procedure makes possible to establish a correct storage policy within the institution. The relocation of workspaces has also been proposed, improving access to storage spaces and reducing the distances to be covered. For the facilities under construction, a detail plan was presented. The existing situation and the advanced proposals were analyzed in terms of human safety, food hygiene and safety practices.

In order to quantify the improvement achieved in the distances taken in handling cargo, an innovative formula has been defined. In addition to calculating distances according to the different possible points of origin and destination, the proposed formula considers that not all movements are equal. It allows the inclusion of different types of cargo movements, which affect the level of aggregation of loads and the necessary equipment to perform it.

The main limitation of this study is due to the fact that it is an application to a specific case and therefore the replication needs some necessary adaptations. As future lines of research, it is proposed to apply this study to other types of warehouses and organizations (different types of goods, layouts and handling methods), as well as its extension to an integrated logistical operation with several warehouses in different locations. It is also suggested to extend the study in order to quantify the impact on workers' motivation and productivity, resulting from the improvement of working methods and safety conditions within warehouses.

This work shows that changing the layout of warehouses in terms of the allocation of storage locations, taking into account the handling rate of the articles, contributes to the improvement of warehousing.

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References

[1] R. Guido, G. Mirabelli, E. Palermo, V. Solina, "A framework for food traceability: case study – Italian extra-virgin olive oil supply chain", Int. J. Ind. Eng. Manag., vol. 11, no. 1, pp. 50-60, 2020, doi: 10.24867/IJIEM-2020-1-252.

[2] I. Beker, M. Delić, S. Milisavljević, D. Gošnik, G. Ostojić, S. Stankovski, "Can IoT be Used to Mitigate Food Supply Chain Risk?", Int. J. Ind. Eng. Manag., vol. 7, no. 1, pp. 43-48, 2016.

[3] R. Delaunay, Otimização da Cadeia Logística da área da alimentação da Marinha Portuguesa: Os fluxos de armazém. Almada, Portugal: Escola Naval, 2020, http://hdl.handle.net/10400.26/33691.

[4] A. Rushton, P. Croucher, P. Baker, The handbook of logistics and distribution management: understanding the supply chain. 5th ed., London, UK: Kogan Page Ltd. 2014.

[5] M. T. Pereira, J. M. Sousa, L. P. Ferreira, J. Sá, F. J. Silva, "Localization System for Optimization of Picking in a Manual Warehouse", Procedia Manuf., vol. 38, 2019, pp. 1220 1227, doi: 10.1016/j.promfg.2020.01.213.

[6] J. A. Tompkins, J. A. White, Y. A. Bozer, J. M. Tanchoco, Facilities Planning. 4th ed., Hoboken, New Jersey, JWS, 2010.

[7] A. Frias, J. Cabral, "Facility Localization: Strategic Decision on Insular Territory", Asian J. Bus. Manag., vol. 1, no. 5, pp. 217-225, 2013, http://repositorio.uac.pt/handle/10400.3/2493.

[8] J. C. Carvalho, A. P. Guedes, A. J. Arantes, A. L. Martins, C.A. Luís, E. B. Dias, . . ., T. Ramos, Logística e Gestão da Cadeia de Abastecimento. Lisboa, Portugal: Ed. Sílabo, 2012.

[9] T. N. Larson, H. March, A. Kusiak, "A heuristic approach to warehouse layout with class based storage", IIE Trans., vol. 29, no. 4, pp. 337-348, 1997, doi: 10.1080/07408179708966339.

[10] J. R. Berry, "Elements of Warehouse Layout", Int. J. Prod. Res., vol. 7, no. 2, pp. 105-121, 1968, doi: 10.1080/00207546808929801.

[11] A. Gialos, V. Zeimpekis, "Testing vision picking technology in warehouse operations: Evidence from laboratory experiments", Int. J. Ind. Eng. Manag., vol. 11, no. 1, pp. 19-30, 2020, doi: 10.24867/IJIEM-2020-1-249.

[12] K. J. Roodbergen, I. F. Vis, "A model for warehouse layout", IIE Trans., vol. 38, no. 10, pp. 799-811, 2006, doi: 10.1080/07408170500494566.

[13] F. H. Staudt, G. Alpan, M. D. Mascolo, C. M. Rodriguez, "Warehouse performance measurement: a literature review", Int. J. Prod. Res., vol. 53, no. 18, pp. 5524-5544, 2015, doi: 10.1080/00207543.2015.1030466.

[14] I. Beker, V. Jevtić, D. Dobrilović, "Shortest-path algorithms as a tools for inner transportation optimization", Int. J. Ind. Eng. Manag., vol. 3, no. 1, pp. 39-45, 2012.

[15] R. de Koster R., E. van der Poort, K. J. Roodbergen (1998) "When to apply optimal or heuristic routing of orderpickers", in Advances in Distribution Logistics. Lecture Notes in Economics and Mathematical Systems, B. Fleischmann, J.A.E.E. van Nunen, M.G. Speranza, P. Stähly. Eds., Berlin, Heidelberg, Springer, 1998, vol. 460, doi: 10.1007/978-3-642-46865-0_16.

[16] R. de Koster, K. J. Roodbergen, R. Voorden, "Reduction of walking time in the distribution center of De Bijenkorf", in New Trends in Distribution Logistics. Lecture Notes in Economics and Mathematical Systems, M. G. Speranza, P. Stähly, Eds., Berlin, Heidelberg, Springer, 1999, vol. 480, doi: 10.1007/978-3-642-58568-5_11.

[17] S. Emmett, Excellence in Warehouse Management: How to Minimise Costs and Maximise Value. West Sussex, England: JWS, 2005.

[18] M. Çelk, H. Süral, "Order picking under random and turnover-based storage policies in fishbone aisle warehouses", IIE Trans., vol. 46, no. 3, pp. 283-300, 2014, doi: 10.1080/0740817X.2013.768871.

[19] J. Stock, D. Lambert, Strategic Logistics Management. Int. 4th ed., Singapore: McGraw-Hill/Irwin, 2001.

[20] G. Swartz, Warehouse Safety: A Practical Guide to Preventing Warehouse Incidents and Injuries. Oxford, England: Gov. Inst., 1999.

[21] I. Beker, S. Čerepnalkovska, D. Šević, B. Kamberović, "Procedure for KPI definition", IS'17, 2017, pp. 288-291. http://www.iim.ftn.uns.ac.rs/is17/papers/52.pdf