Effort Optimization Model in Warehouse Manual Picking. Case Study: Tusan Distribuidores

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Abstract

A recurring and expensive operation in company's warehouses is the picking. Operators who execute this activity perform repetitive physical movements and carry objects constantly, which can trigger musculoskeletal disorders. Adittionally, there is a great consumption of energy by the operators, which could have negative consequences in the long term. Health damages could reduce the quality of the company's service and productivity due to the increase in absenteeism of the personnel because of the recovery. The objective of the investigation is the application of an optimization model to reduce energy consumption during picking through the redistribution of product lines within a warehouse. The warehouse under study belongs to a Peruvian distributor with several lines of products for mass consumption. The applied model will be the one proposed by Diefenbach & Glock. The data of the current situation taken were: demand, average weights per line, efforts, distances and locations, which were coded in "A Mathematical Programming Language" (AMPL) and solved using the CPLEX solver. The results show 4.4% reduction in energy expenditure compared to the current distribution and 6.0% compared to randomly generated distributions. Finally, the optimal distribution by product lines is presented as a result of the modelling that reduces effort.

Keywords

Warehouse distribution, Picking, Musculoskeletal disorders, Optimization model, Ergonomics.

1. Introduction

The commerce and services sectors within Peru drive an important part of the economy since they together account for approximately 50% of the GDP (National Institute of Statistics and Informatics [INEI] 2021) and comprise 87% of the national active companies (INEI 2021).

In the management of commercial companies, as well as services, warehouses play an important role: first, they safeguard the quality of the products during the entire time of stay (from the moment they enter until they are retrieved to be consumed or sold) and second, they keep an updated record of materials on physical and virtual media, such as the Kardex (ESAN 2016).

One of the most important activities of the warehouse, representing 55% of the annual cost (Sánchez 2014), is picking, which is the process of preparing selected orders, in which the correct products are retrieved from their locations inside the warehouse in the exact amounts indicated in the customer's order (Nava & Quintero, 2019; Sánchez 2014).

Workers who perform manual picking in warehouses are in constant physical activity, making repetitive movements and loading goods. This repetitive motion, sometimes of a demanding nature due to an inappropriate location of the products to be dispatched, could trigger health problems. According to Mital (2017), many experts confirm that exceeding an energy expenditure of 5 kcal/min or 300 kcal/h in an 8-hour work shift could lead to significant health risks (as cited in Diefenbach and Glock, 2019). These health problems could cause musculoskeletal disorders (MSD) due to the characteristics of the movements involved in picking. For example, in the United States, in 2015, MSDs resulting from overexertion in lifting represented 31% (356,910 cases) of the total cases for all workers, who required a median of 12 days to recuperate before returning to work (Bureau of Labor Statistics [BLS] 2016). In line with the above, lower back pain accounts for 21% of all compensable work-related injuries and 33% of the cost (Pope et al. 2002). Field studies indicate that, in the world of warehouses, picking poses a high risk in the development of an MSD (Grosse et al. 2017).

Undoubtedly, this directly impacts the health of employees and the service level of companies due to employee absenteeism and the costs related to worker rehabilitation. These impacts can be reduced by taking appropriate measures in the design of workstations and operations, considering aspects related to ergonomics. Therefore, the scope of this research will be to analyze warehouse management in order to reduce the effort demanded from operators in the picking process, being the specific objective to optimize the layout of the product rows inside the warehouse. This research is aimed at all warehouses with products in different rows, that do not have loading equipment (e.g., a forklift) and have a single area for order preparation and delivery, as shown in Figure 1.

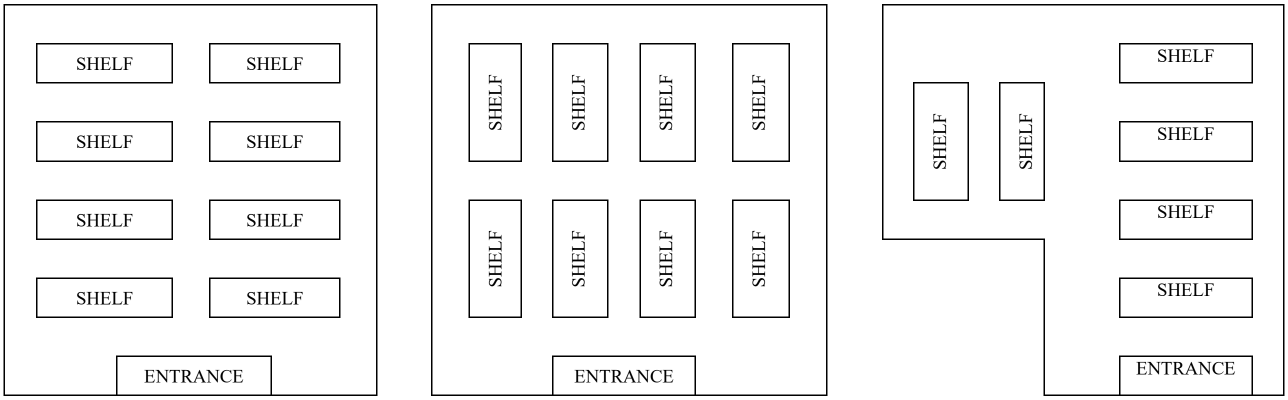

Figure 1. Typical layouts for the application of the model

1.1 Objectives

The objective of this research is to reduce the effort of workers in picking activities in warehouses by applying an optimization model. This reduction could prevent the development of musculoskeletal disorders in workers.

2. Literature Review

This research will be supported by literature related to warehouse management, ergonomics framework, and tools of operations research to meet the objectives.

Warehouse Management

According to Matusiak and de Kotser, regarding warehouse operation, the activities of order picking, arrangement and retrieval could represent between 55% and 65% of the total costs (as cited in Duque et al. 2020); therefore, significant savings could be generated for the company by improving these processes. Likewise, Sánchez-Comas (2019) states that “picking, routing, layout and slotting operations are inevitably related to each other to achieve an optimal warehouse management and even beyond this link.”

Picking, as previously mentioned, consists in receiving the order in the warehouse, then the person or system in charge, either an automated system or a picking operator, goes to the block of shelves where the requested SKU is located, retrieves it and analyzes if the order is complete; if so, he goes to the drop-off point; if not, he assesses his capacity to transport the different SKUs and goes to the next SKU until the order is fulfilled, which is then taken to the collection point (Duque et al. 2020). On the other hand, routing is the path that the person in charge of the warehouse must follow to complete the picking (Shetty et al. 2020). Finally, the layout “is a sketch that helps to project the best location for the inventory in the warehouse, ensuring a proper flow, safety of people and inventories, and improvement in times and movement while preparing and dispatching of the same” (Mejía et al. 2016). This concept is rooted in slotting, which consists in distributing items among the warehouses, if there are several, and inside them. The distribution of SKUs must be the most appropriate to minimize travel time and spaces for use (Duque et al. 2020).

Several techniques are used in warehouse management to reduce travel times and distance. One of them is the ABC model, which allows the classification of products based on their demand (Cornejo and León 2017). In this way, products with the highest rotation will be placed in a position closer to the warehouse exit and those with low rotation in a further position. This model is also used in the work of Távara (2014) to optimize the logistics management of a commercial company. By having the products with the highest rotation close to the dispatch area, the time and distance traveled to carry out the task can be reduced. Another frequently used method of managing the warehouse is grouping the products into product categories. According to Cornejo and León (2017), “[grouping into product categories] is one of the most efficient types of storage, [since] it allows better location of products and prevents cross contamination.”

Ergonomics

One aspect in which all these authors agree is that ergonomics must be considered when proposing any improvement in warehouses. This research is based on physical ergonomics, which is a science that studies the interaction between humans and their work environment, aiming at designing optimal working conditions, which implies reducing the physical load, improving posture and reducing movement effort, in such a way that efficiency, safety and well-being of employees and users are ensured (Fachal and Motti 2016; Díaz Garay and Noriega 2017).

As mentioned before, picking is a repetitive task, being one of the most critical processes with respect to service time and costs in the world of warehouses (Grosse et al. 2017). In addition, entrepreneurs must bear in mind that picking requires considerable effort to carry the goods, often involving incorrect postures when lifting heavy objects, which translates into a high risk of developing MSDs (Grosse et al. 2017).

Work-related MSDs are physical injuries caused by work-related tasks such as lifting, pushing, and pulling objects (National Institute for Occupational Safety and Health [NIOSH] 2010). Likewise, as mentioned by Luttmann et al. (2004), musculoskeletal disorders represent a main cause for absence from work, in which the main associated risks are carrying heavy loads, use of excessive force, forced postures, repetitive motion, extended efforts, and inappropriate environmental conditions.

Optimization Models

There are several authors who work on warehouse optimization models. Such is the case of Jarvis and McDowell (1991), whose main objective is to reduce the distance traveled by employees to carry out picking. They categorize the products according to their demand and propose an optimization model taking into account a symmetric distribution of the aisles. Finally, they manage to reduce the distance traveled by up to 66% for high-rotation products. Another related work is that of Kasemset and Meesuk (2014), where they aim to formulate a model that minimizes the total distance traveled using both horizontal and vertical distances. The model also assumes a symmetric warehouse layout and would have a defined number of storage blocks. In the same way, there would be a single entrance and exit route. It mentions that the horizontal distance would be the distance traveled by the operator always through the midpoints and the vertical distance taken by the height of the shelf (Kasemset and Meesuk 2014).

Viveros et al. (2021) present an optimization model for the slotting process with the added value of considering a warehouse with divisible first-level accommodation locations. The work was divided into two stages: first determine the optimal location for each SKU on a planning horizon and then define the best of two scenarios to reduce travel distance and costs. The model considered a peak day within the period where demand is high. In sum, the combination of storage locations (racks and locations on the ground) is, as mentioned, the added value given to this research, in addition to the four exits of the warehouse. The improvements achieved by this work were reduction of the distance traveled by 5%, improvement in the use of the warehouse, reduction of operating costs, and maximization of manpower utilization and use of vehicles in the process (Viveros et al. 2021).

A fourth optimization model for product placement is that of Li et al. (2010), whose objective is to reduce energy expenditure, thereby minimizing unnecessary movements, as well as the distance. It also seeks to reduce the time to reach the products to be dispatched. This model uses five principles: Partitioning the inventory space, based on the frequency and characteristics of the products; the principle of uniform distribution, where products with specifications are stored evenly on the different shelves; the principle of proximity, where location points should be selected close to the dispatch point to reduce the time and distance when locating the products; the principle of “First In, First Out” (FIFO), which indicates that the products that enter the warehouse first are also the ones to be disposed of first to avoid expiration, deformation or other damage; finally, the principle that indicates that the heaviest products should be placed in the lower shelves to avoid deformation.

Glock et al. (2019), for their part, develop a model that, in addition to optimizing the travel time or distance, minimizes the total load of the operator in a warehouse that has loading equipment but still requires manual effort to carry out the picking. The special feature here is that they propose the implementation of a rotating pallet system that, according to the authors, reduces the total effort of the workers. In addition, they mention that they use the time necessary to complete all orders as a measure of economic performance, while the measure of ergonomic performance is the total maximum load per operator that prepares the orders, and they reduce the total time by 15% on average and the operator load between 5.3% and 8.56% (Glock et al. 2019).

Finally, Diefenbach and Glock (2019) propose a model for the ergonomic and economic optimization of the design and item allocation in a U-shaped order picking area. Their research has two objectives: to find the optimal layout according to the number of products to be stored and to assign the products in the most economical (time or distance) and the most ergonomic way possible (effort), relying on the energy expenditure equations developed by Garg et al. (1978). In addition, they consider some physical parameters for the warehouse operators, namely male gender, 1.78 m of height, 75 kg and walking speed of 1.4 m/s, since these parameters match different ergonomic studies (Diefenbach and Glock 2019). Additionally, some parameters must be considered that said model does not take into account, as it does not present a third level that requires the use of a ladder. These parameters were taken after observing the warehouse of the research Case Study and are the following: 75° inclination angle of the ladder, speed of ladder ascent of 0.4 m/s and speed of descent of 0.1 m/s. The authors manage to reduce between 33% and 50% the total distance traveled and between 18% and 34% the total ergonomic effort compared to randomly generated warehouse layouts, also concluding that the most important variable is the frequency of picking (demand) (Diefenbach and Glock 2019).

3. Methods

To meet the objective of analyzing warehouse management to reduce the effort of operators in the picking process, an optimization model was used. This is an operations research tool, known as management science, which is a scientific approach to decision making that seeks to better design and operate a system (warehouse picking), generally under conditions that require the allocation of scarce resources. This approach generally involves the use of one or more mathematical models, which is a mathematical representation of a real situation that can be used to make better decisions or simply to better understand the real situation. An optimization model “prescribes” the behavior of an organization that will allow it to better achieve its objective. The components of a prescriptive or optimization model include objective functions, decision variables, and constraints that collectively seek to find values for decision variables that optimize (maximize or minimize) the objective functions that satisfy the proposed constraints (Winston 1971).

This tool was chosen because of the possibility of obtaining concrete results using real historical information and previous successful work with its application can be used as references. Also, these models are coded in complex programming languages such as C#, Java, among others, that, thanks to technological advance, produce quick and accurate results. For this research, the A Mathematical Programming Language (AMPL) will be used, which has the advantage that its syntax is very similar to the mathematical notation used when posing a problem of this nature.

Similarly, it offers solver compatibility depending on the characteristics of the model: linear, non-linear, quadratic, convex, among others (in this case the CPLEX solver will be used as it offers solutions for linear models with integer variables).

For this research, the model proposed by Diefenbach and Glock (2019) will be applied due to the similarity to our objectives, such as minimizing the effort of operators and optimizing the warehouse layout, with the difference that said model is designed for U-shaped warehouses. However, it is not a limitation, since the shape of the warehouse would only affect the distance values, which would be data to feed the model.

Furthermore, in relation to overexertion, studies such as those made by Garg et al. (1978) and Taboun and Dutta (1989) experiment and model equations to predict the energy cost of combined manual loading and transportation activities by measuring the net rate of metabolic energy expenditure from oxygen consumption (Vo2, l/min) and heart rate (HR, beats/min). These studies consider that an activity can be divided into simple tasks, for instance, lifting an object from the floor, holding the object at waist height, among others; and thanks to the equations that Garg et al. (1978) propose, the energy expenditure of simple tasks involved in the picking process in warehouses can be predicted, and they were used to build the optimization model of Diefenbach and Glock.

The company Tusan Distribuidores will be taken as a case study. It is a retailing company with different product lines such as groceries, cleaning products, beverages, sweets, among others. Its facility has a warehouse where the products are stored in groups of categories with an entrance and exit door, which is next to the order preparation area. The model will be applied in the picking operation at the Tusan Distribuidores warehouse. The starting point will be the entrance of the warehouse, from where the operator will go to the different shelves to pick up a product, and later return to the starting point. This activity is currently being carried out by two operators in the warehouse.

It is important to mention that it is intended that the heaviest products with a higher rotation are closer to the starting point (the warehouse door). The necessary constraints should also be considered so that it is as close to reality as possible. We will work with product lines which will be ordered on the warehouse shelves.

Phase 1: Determination of Parameters

We will begin by defining the parameters. (Table 1) These operate on the objective function that may well be specific to the product line (dimension i), the location in the warehouse (dimension j), the level (dimension k), or a combination of them (for example, dimension ijk).

Table 1. Determination of Parameters

Parameter	Description
I	set of Lines i.
J	set of Locations j.
K	set of Levels k.
d_{jk}	Distance in the horizontal plane from the base to location j level k.
$w_i^{w,\,c}$	Effort to walk without load + effort to walk with product i (Kcal/m).
w_i^b	Effort to carry product i located on the lower level.
w_i^m	Effort to carry product i located at the middle level.
w_i^t	Effort to climb the ladder without weight + effort to carry product i located on the upper level + effort to go down the ladder with product i.
w_{ik}	Effort to carry product i from level k.
w_i^o	Effort to leave product i on the base.
f_i	Product i picking frequency.
e_i	Number of locations occupied by product i.
p_i	Average product i weight

Phase 2: Defining the decision variable

The decision variable to decide the location of certain product categories in the warehouse will be determined below. This is how the following binary variable is obtained:

x_{ijk}: *Binary: 1, if Line i is placed in location j of level k, if not 0.*
Example result: "Yes, place the ALCOHOLIC BEVERAGES line in location 28 of level 2".

It is worth mentioning that some locations jk do not necessarily exist, as the warehouse does not have shelves in certain quadrants j, i.e., some locations jk have only one level (k=1), while other locations have up to three levels (k=1, 2 or 3).

Phase 3: Structuring the objective function and its constraints

Once the decision variable has been determined, the objective function (in this case also called effort function) will be determined. The objective function will include the two previously developed aspects: ergonomics and supply. Therefore, physical factors related to the space and products (weight and distance) will be considered, as well as demand factors (picking frequency). That said, if all the parameters had the same value, the formula would be as simple as the multiplication between them, as follows:

Effort= $\sum_{i\in I} \sum_{j\in J} \sum_{k\in K} d_{jk} * f_j * p_i * x_{ijk}$

However, if we analyze the above function, it will be essential to answer the following question: Which combination generates less effort?

Table 2. Calculation of effort with no energy expenditure

Distance (*djk*)	Weight (*pi*)	Frequency (*fi*)	Effort
10	8	5	400
4	12.5	8	400
8	10	5	400
2	25	8	400
8	5	10	400
400	1	1	400
1	400	1	400
1	1	400	400

As shown in the previous Table 2, there are infinite combinations that result in the same effort according to the simple formula, the 3 last extreme cases clearly evidence the need to weigh the parameters according to the research in ergonomics. As mentioned above, the equations developed by Garg et al. (1978) will allow a correct formulation of the objective functions by calculating the energy expenditure used for each picking task. Thus, the objective function is as follows, where the calculation of each parameter w is based on the abovementioned equations.

Minimizing effort:

$$\sum_{i\in I} \sum_{j\in J} \sum_{k\in K} f_j * ((d_{jk} * w_i^{w,c} * x_{ijk}) + (w_{ik} * x_{ijk}) + w_i^o) \qquad (1)$$

Subject to:

$$\sum_{j\in J} \sum_{k\in K} x_{ijk} = e_i \qquad \forall i \in I \qquad (2)$$

$$\sum_{i\in I} x_{ijk} = 1 \qquad \forall j \in J;\ \forall k \in K \qquad (3)$$

$$x_{ijk} \in \{0; 1\} \qquad (4)$$

The picking process in the warehouse of Tusan Distribuidores is described below to have a clear view of the algebraic notation of the objective function with respect to reality:

- The operator walks from the order preparation area to the location j, where the required product is located ($w_i^w * d_{jk}$).

- Depending on the level k, the operator must make an effort to take any product (w_{ik}):
    - Level 1: The operator will take the product from an initial height of 0.64m (average measure of the warehouse used in this research) and lower it at waist height (0.81m).
    - Level 2: The operator must take the product down from an initial height of 1.95m to and lower it at waist height (0.81m).
    - Level 3: The operator must climb a ladder (already placed in location j), and take the product down, lower it at waist height and go down the ladder. The ladder angle must be 75°.
- The operator must walk from location j to the order preparation area carrying the product with both arms at waist height ($w_i^c * d_{jk}$).
- Once the operator is in the order preparation area, he must crouch down and leave the product on the floor (w_i^o).

4. Data Collection

Application Case

The application case is the Tusan Distribuidores warehouse. To do this, we need information such as the product demand, the average weight per product line, determination of efforts, and the distances along with the current location of the products.

Data Collection of Tusan Distribuidores

Phase 1: Product demand

Historical sales were obtained from the integrated management system of Tusan Distribuidores. Based on this information, we calculated how many times a worker carries out picking per each product line. In addition, the model assumes that picking frequency will be evenly distributed between shelf-spaces per product line.

For evaluating the current situation of the warehouse, we will consider the sale values of the month with the highest demand since January 2019 because the pandemic has altered the values. We will take the highest value, as we propose an ideal design for situations that demand the greatest effort.

Phase 2: Definition of average weights per product line

To obtain the weigh per product line, we used the sales record system of Tusan Distribuidores and obtained a weighted average.

Phase 3: Determination of effort

To determine the efforts required for the activities, we used the formulas developed by Garg et al. (1978). They calculate the energy expenditure of humans when they perform simple tasks such as picking an object, lifting an object, walking, among others. Picking activities involve various simple tasks; therefore, retrieving a product from a warehouse will represent the sum of the energy expenditure from each activity.

The information of the three first phases is exclusive for each line (subindex i) and can be summarized as shown in Table 3:

Table 3. Parameter per product line

Dimension i	Weight (kg)	Shelf-spaces	Frequency (times/hour)	Energy expenditure (kcal/times)				
i	w_i	e_i	f_i	w_i^b	w_i^m	w_i^t	$w_i^{w,c}$	w_i^o
Groceries	0.980	15	2.31	0.0702	0.0950	1.4288	0.1053	0.3160
Beverages	3.110	16	2.53	0.0804	0.1288	1.4578	0.1102	0.3281
Cleaning	2.400	30	0.45	0.0770	0.1175	1.4481	0.1086	0.3241
Alcoholic Beverages	1.460	38	0.72	0.0725	0.1027	1.4353	0.1064	0.3187
Plastics	3.268	1	4.70	0.0811	0.1313	1.4599	0.1106	0.3290
Stationery	0.272	18	0.40	0.0668	0.0838	1.4192	0.1037	0.3120
Canned Food	0.562	4	2.12	0.0682	0.0884	1.4231	0.1044	0.3136
Disposable	0.346	3	0.06	0.0672	0.0850	1.4202	0.1039	0.3124
Others	0.250	2	8.75	0.0667	0.0835	1.4189	0.1036	0.3119

Phase 4: Definition of distance and location of product lines

To determine the distance to each shelf-space (j), a tape measure was used to measure the distance from the order preparation area (located next to the entrance). The current layout of the warehouse was drafted, and a letter j was assigned to each available shelf-space, as shown in Figure 2.

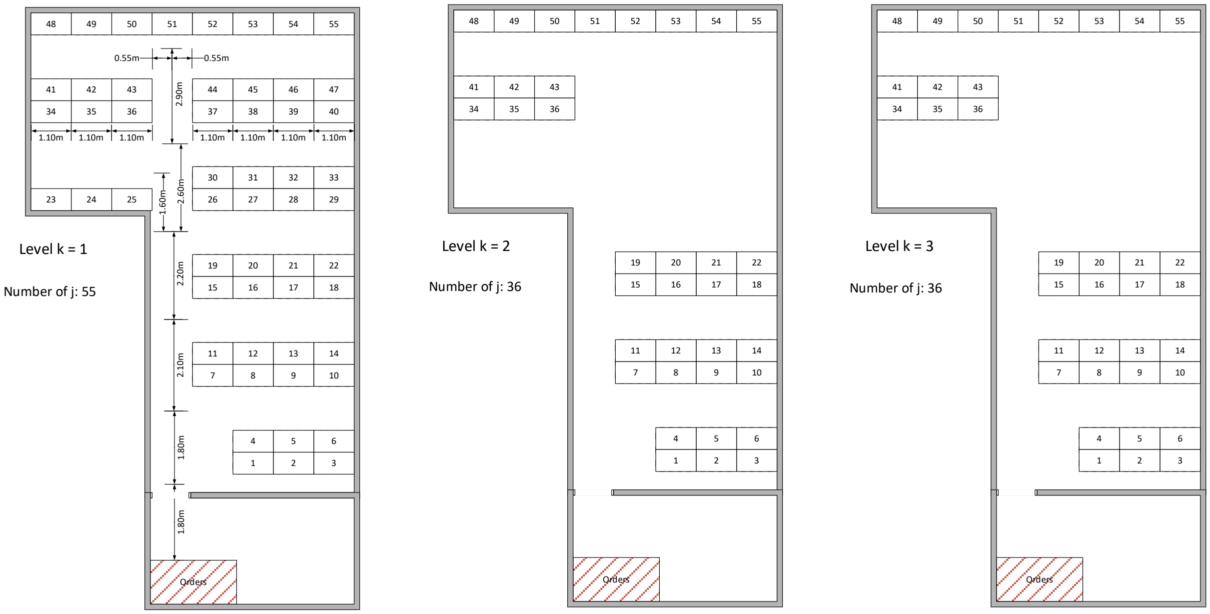

Figure 2. Allocation of locations (jk) in the warehouse and measurement – Horizontal View

To determine the location of the product lines in the warehouse, we went round the premises and organized the plan by levels (k). Figure 3 shows in detail the distance and current location of the product lines inside the warehouse. This is the current location that the company has, which will be later compared to the resulting optimal location produced by the optimization model.

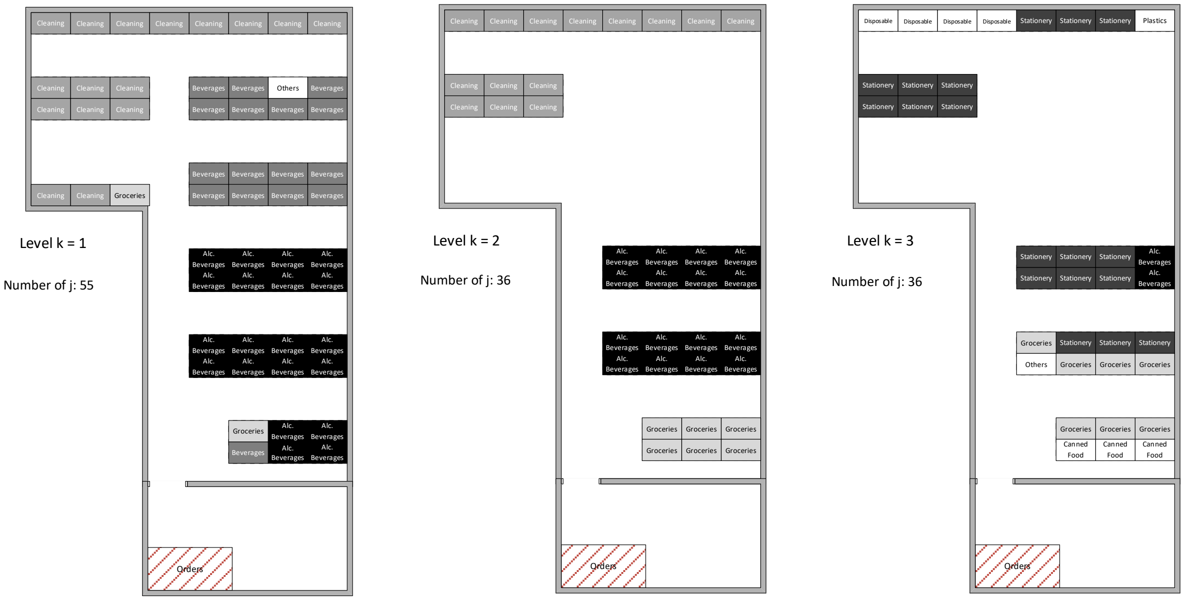

Figure 3. Current layout of product lines (ijk) – Horizontal view

5. Results and Discussion

After recording the warehouse parameters, such as distance to each location j, weight, frequency, and spaces occupied by each line i and loading and unloading heights for each level k, it was decided to use the effort optimization model. In this sense, the optimal layout for each line was determined, as shown in Figure 4 that highlights the five most important categories for comparison purposes with Figure 3 (groceries, beverages, cleaning, alcoholic beverages, and stationery).

It is worth mentioning that a total of 20 other different random layouts were generated, showing an average of 261.97 kcal/h. In addition, the current energy expenditure of a Tusan warehouse operator was calculated, resulting in a total of 257.74 kcal/h. Finally, the solution of the optimization model produced an optimal energy expenditure of 246.35 kcal/h per operator, thus generating a 4.5% to 7.0% savings compared to the random layouts and 4.4% savings compared to the current energy expenditure at the Tusan warehouse.

This reduction percentage is below Diefenbach and Glock (2019) results, who achieved an improvement between 17.56% and 34.33% compared to the random layouts. Let us bear in mind that this research generated scenarios with 30 to 100 different products, frequencies of 200 times per hour, weights from 5 to 25 kg, and 20-meter-long warehouses. This demonstrated that results are more favorable (between 10 to 12% higher) when the weight and frequency variables show a larger dispersion range and the warehouse area increases, as these two conditions allow a wider difference of energy expenditure from the best position to the worst possible position for the products (Diefenbach & Glock 2019).

The energy expenditure values obtained are within the recommendations of Mital (2017), who states that energy consumption should not exceed 300 kcal/h, since it may pose health risks (as cited by Diefenbach and Glock, 2019).

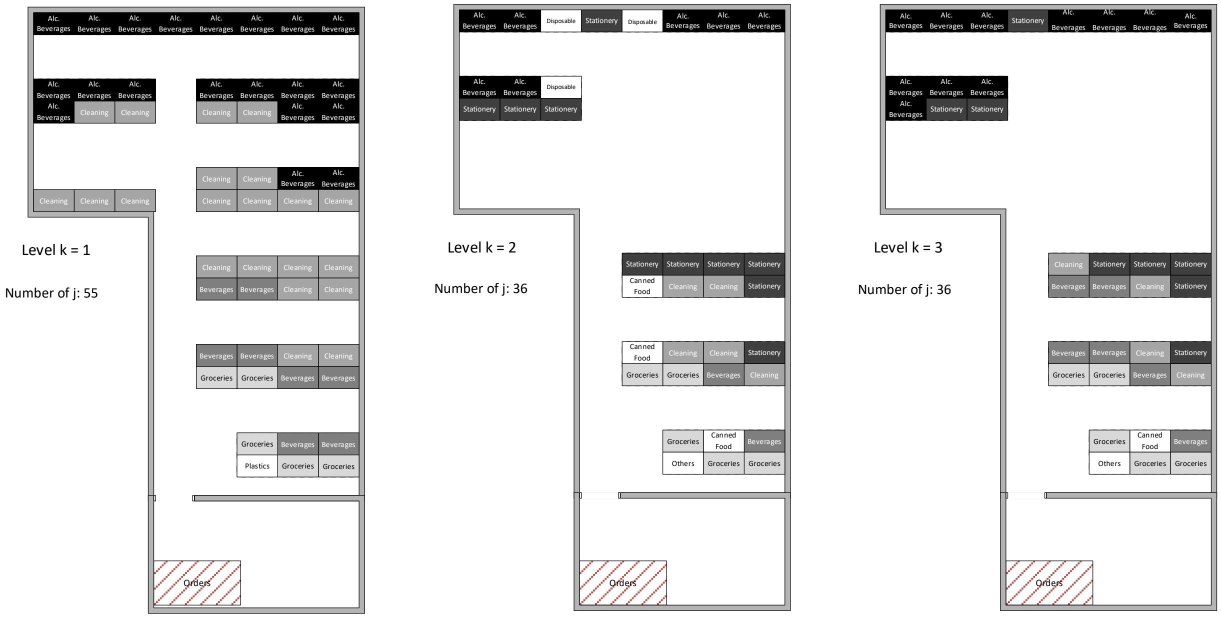

Figure 4. Optimal warehouse layout – Horizontal view

By comparing the proposed layout with the current layout, we can highlight the most relevant points:

1. The optimization model puts the alcoholic beverages in the area farthest away from the order preparation area, whereas now they are located in the middle of the warehouse.
2. Cleaning products are closer to the order preparation area.
3. Beverages are closer too but distributed among the three levels. This was different in the current layout, where beverages were placed far from the order preparation area and only in the first level.
4. Stationery is still located in the upper levels.
5. Groceries are still close to the order preparation area.

After analyzing the layout proposed by the model, the following question comes into mind: which variable in the optimization model influences the most to determine product location? For this point, we present Figures 5 and 6 that show the relation between each variable (frequency and weight) and the product location.

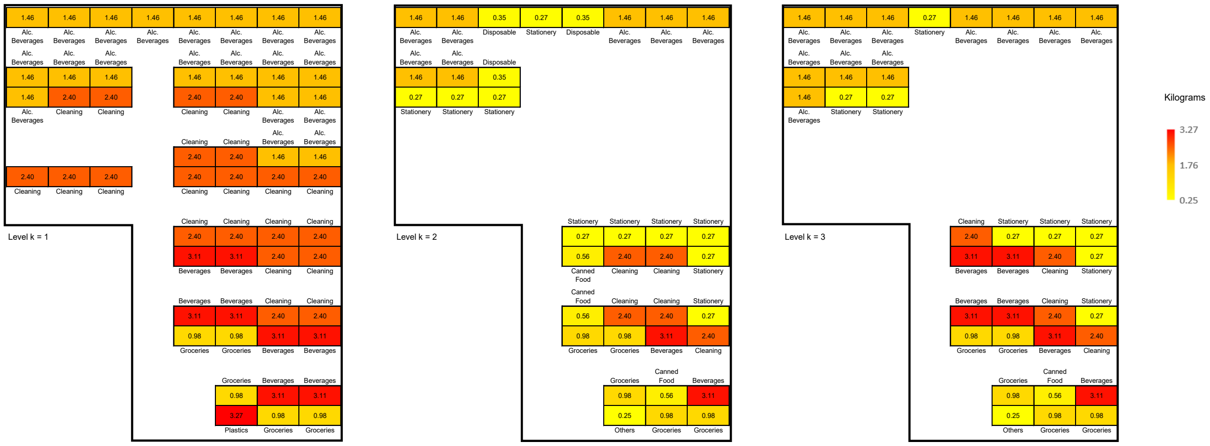

Figure 5. Weigth per location

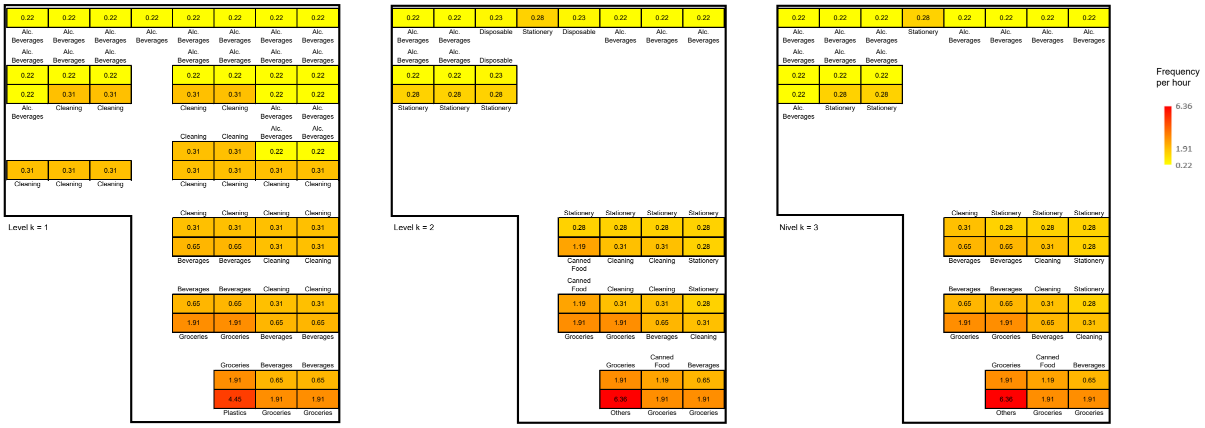

Figure 6. Frequency per location

As evidenced by the foregoing figures, the variable that influences product location the most in the three levels k is picking frequency, since the locations closest to the order preparation area show higher frequency, which decreases as products are placed further away.

Furthermore, the weight variable was found to have an important relation to the levels where products are placed, since a higher concentration of "heavy" product lines is observed in the lower levels, whereas lighter products are found in upper levels.

6. Conclusion

As picking involves repetitive motion and loading products, it may lead to the development of musculoskeletal disorders and to considerable energy expenditure, which may ultimately bring about negative effects on human health. The issue arises when we try to order the product lines in such a way as to mitigate the abovementioned problems.

Therefore, this research aimed at analyzing how warehouses manage to reduce the efforts of operators in the picking process by means of an optimization model.

In this sense, the model was applied in the warehouse of Tusan Distribuidores, a Peruvian distributor with different product lines distributed on shelves of up to three levels. We obtained the following main results of the research:

- An optimal layout manages to reduce 6% of energy expenditure compared to random layouts and 4.4% compared to the current layout of the warehouse.
- The proposed layout manages to mitigate the development of musculoskeletal disorders by reducing the effort of the operators. Likewise, this is beneficial for the operator's health for requiring less than 300 kcal/h as recommended by Mital (2017) and generates energy savings compared to the original layout.
- It is suggested to place high-demand products in the areas next to the order preparation area and balance their distribution with low rotation products.
- A direct relationship exists between the distance, weight and frequency variables and the reduction of efforts after the application of the optimization model.
- When the three variables that influence the objective function of effort show a wider range, i.e., a larger warehouse (distance), a higher variability in the demand per product line (frequency), and a higher variability in the weight per product line, there is a stronger chance that the model reduces the effort to a greater extent.

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