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Jurnal Manajemen Industri dan Logistik

| ISSN (Print) 2622-528X | ISSN (Online) 2598-5795 |

article category: Logistic Management

Improving Storage Capacity and Space Utilization through COI Dedicated Storage and Rack Based Layout Redesign of a Bottled Drinking Water Warehouse

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ARTICLE INFORMATION

Article history:

Received: January 22, 2026
Revised: February 20, 2026
Accepted: August, 12, 2026

Keywords:

Case Study
COI-Dedicated Storage Policy
Rack Storage
Layout and Storage Space
Warehouse Re-layout Facility

ABSTRACT

The main problem in the Danone bottled drinking water (DBDW) warehouse is the narrow aisles resulting from efforts to maximize warehouse space capacity. Other problems include excessive pallet stacking height, the use of non-standard pallets, and the random storage policy applied in the warehouse. The purpose of this case study is to redesign the layout of the DBDW facility by first analyzing the layout of goods storage in the warehouse. Reassigning products with the Cube per Order Index (COI)-dedicated storage policy reduced the total travel distance by only about 4%, so the warehouse layout was redesigned and two storage media, a rack system and a block-stacking system, were compared. The results of the comparison show that the layout with rack storage media is more feasible to use than block stacking storage media in terms of warehouse utility and the number of goods stored. The new warehouse can store 1156 more items and secure pallet stacking.

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INTRODUCTION

Danone's bottled water warehouse currently stores five types of products: Aqua mineral water in 220 ml, Aqua in 600 ml, Aqua in 1500 ml, Vit in 600 ml, and Mizone in 500 ml. The warehouse measures 6.5 meters high, 29.5 meters long, and 18.5 meters wide. The warehouse currently applies a random storage policy combined with the First-In First-Out (FIFO) procedure, in which goods are placed in any available area without specific placement rules. A random storage policy arranges goods randomly in empty areas without further consideration, while FIFO arranges goods according to their time of arrival. The handling system for storing goods in the warehouse is done manually using trolleys. The storage media uses 80x220 cm pallets arranged in 12 stacks as depicted in Figure 1(a). The number of pallets used is 229 pallets/storage area in the warehouse. The current warehouse utilization is high considering the limited warehouse space. This indicates that the utilization of storage space in the warehouse has been maximized. However, the high warehouse utilization causes several problems. First, operators have difficulty storing and removing goods due to the narrow aisles and crowded storage space and the random storage policy as depicted in Figure 1(a), (b) and (c).

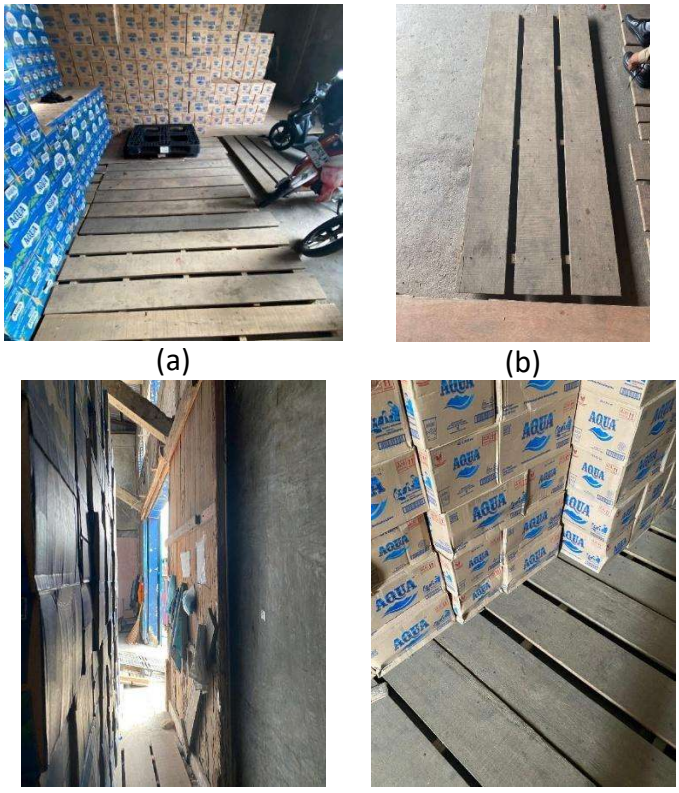


Figure 1. Problem occurs, (a) Crowded warehouse (b) Non-standard pallet (c) Narrow aisle and (d) Damaged goods

Second, there's the risk of damage to goods due to excessive stacking on pallets as depicted in Figure 1(d). Third, there's the long distances involved in storage and removal due to random storage policy. Therefore, a re-evaluation of the storage policy and warehouse layout at Danone's bottled water warehouse is necessary. Considerations such as the material handling system are crucial factors within the warehouse. Currently, Danone's warehouse still utilizes manual

http://doi.org/10.30988/jmil.v10i2.1795

handling for its operations. From the arrival of goods, to their unloading, storage, picking, and even reloading onto trucks, manual labor is still used.

Warehouses play a vital role in supporting business activities within the supply chain and are an essential element in supporting the production system [1], [2]. Therefore, proper placement and condition of storage areas are essential to minimize operational costs and improve service speed within the warehouse [1]. Warehouse design has three levels in decision-making, namely strategic, tactical, and operational [3], [4]. At the strategic level, warehouse design decisions have long-term impacts and involve significant investments. Two types of strategic-level decision-making groups are process flow design and design for selecting an appropriate warehouse system [1], [5], [6], [7], [8], [9]. At the tactical level, decisions taken have a medium-term impact of two years. At this level, the focus of the study is on warehouse layout and dimensions of several aspects such as the number of receiving and shipping docks, the type and number of functional areas, and others [2], [10], [11], [12], [13], [14], [15], [16], [17]. At the operational level, it focuses on the assignment and control of resources in the warehouse, such as the assignment of warehouse operators, the assignment of goods replacement activities in the warehouse, the assignment of picking operators, improving picking routes, storage planning, and others [3], [18], [19], [20], [21], [22], [23], [24].

In real-world situations, optimizing warehouse layout and allocation is always a key issue in finding optimal solutions due to numerous factors. 90% of warehouses worldwide still utilize manual handling in their operations [25]. Important factors in warehouse layout design include determining the warehouse structure, measuring the dimensions of each facility within the warehouse, determining the layout details within each facility, selecting handling equipment, and selecting operational strategies [5]. In warehouse structure design, material flow patterns within the warehouse, departments or functional areas within the warehouse, and the relationships between functional areas are identified and designed. Warehouse dimension measurement involves measuring the dimensions of each functional area within the warehouse, including the allocation of space requirements for each functional area. In determining the layout details within the warehouse, detailed configuration of the aisles and functional areas of the warehouse is carried out. In determining handling equipment, the tools and technological level of handling equipment to be used within the warehouse for each functional area are selected. For operational strategies, storage placement policy, such as random storage policy or others, are selected.

In addition, evaluating warehouse operational performance is necessary to assess the selected alternative design decisions. Indicators for evaluating warehouse layout design performance can be seen from costs, throughput, utilities, and/or comparisons between several other types of assessment indicators. Evaluation of warehouse operational performance can be done through an analytical approach, a simulation approach, or benchmarking [5]. In this study, decisions were taken at the tactical and operational levels using an analytical approach that took into account the handling paths and equipment as well as the storage media used in the warehouse. Performance evaluation indicators were determined based on throughput, space requirements, total distance traveled, warehouse utilities, number of aisles, and storage area depth. The following shows the

state of the art of previous research in the area of warehouse facility layout design.

Based on previous research from Table 1, no analysis of warehouse layout design or warehouse storage layout analysis has combined them. These studies are still analyzed separately. In this study, a warehouse storage layout analysis was conducted first using a dedicated COI storage policy. The COI storage policy is based on the frequency of storage and removal of goods from various entry and exit points, where the number of entry and exit points is more than one [4].

The proportion of each item passing through each entry and exit point is the same. If the results found do not meet expectations, a redesign of the new warehouse facility layout is carried out. The redesign takes into account the storage media and handling equipment used. However, the redesign has not considered factors such as handling activity frequency, travel distance, and costs. The purpose of this study is to redesign the layout of the bottled drinking water warehouse to increase its storage capacity and space utilization and to reduce the risk of product damage.

Table 1. State of the Art

Researcher	Topic	Method	Objective	Gap
[26]	Warehouse layout design with pallet rack system	Pallet rack system design	Inventory control	Not yet focused on storage layout and placement policies
[23]	Warehouse layout design with class-based storage policy	Class-bases storage policy	Increase order picking productivity	Have not considered designing a new warehouse layout
[19]	Warehouse layout design with class-based storage policy	Class-bases storage policy	Estimating ordering time	Have not considered designing a new warehouse layout
[10]	Design of a new warehouse layout using block stacking storage media	Block stacking design	Maximizing space utility and minimizing material handling costs	Not considering the storage policy for goods in the warehouse
[13]	Block stacked layout problem	Queuing Theory and Bi-optimization	Minimizing total space and waiting time	Not considering the storage policy for goods in the warehouse
[27]	Redesigning the storage layout with a dedicated storage policy	Dedicated storage policy	Minimizing total traveled distance	Have not considered designing a new warehouse layout

RESEARCH METHOD

The research was conducted from March to August 2025 in Padang City, West Sumatera, starting with problem identification, field observations, literature review, collecting relevant data, processing data, conducting analysis, and drawing conclusions and

recommendations. In the initial stage, the research focused on analyzing the storage layout. Currently, the storage policy in the Danone warehouse still uses a random storage policy and the FIFO (First In-First Out) method. At this stage, the total initial travel distance using the random storage policy was compared with alternative storage policies, namely the COI storage policy. If the results of the analysis are unsatisfactory, the next stage will be to comprehensively improve the warehouse layout. The warehouse layout improvements will take into account the storage media to be used. Figure 2 shows the research stages and research methodology used in this study. This study has not considered the cost aspect due to time constraints and the privatization aspect of the Company. Furthermore, the methodology used to obtain the optimal solution does not use a heuristic analytical approach or simulation.

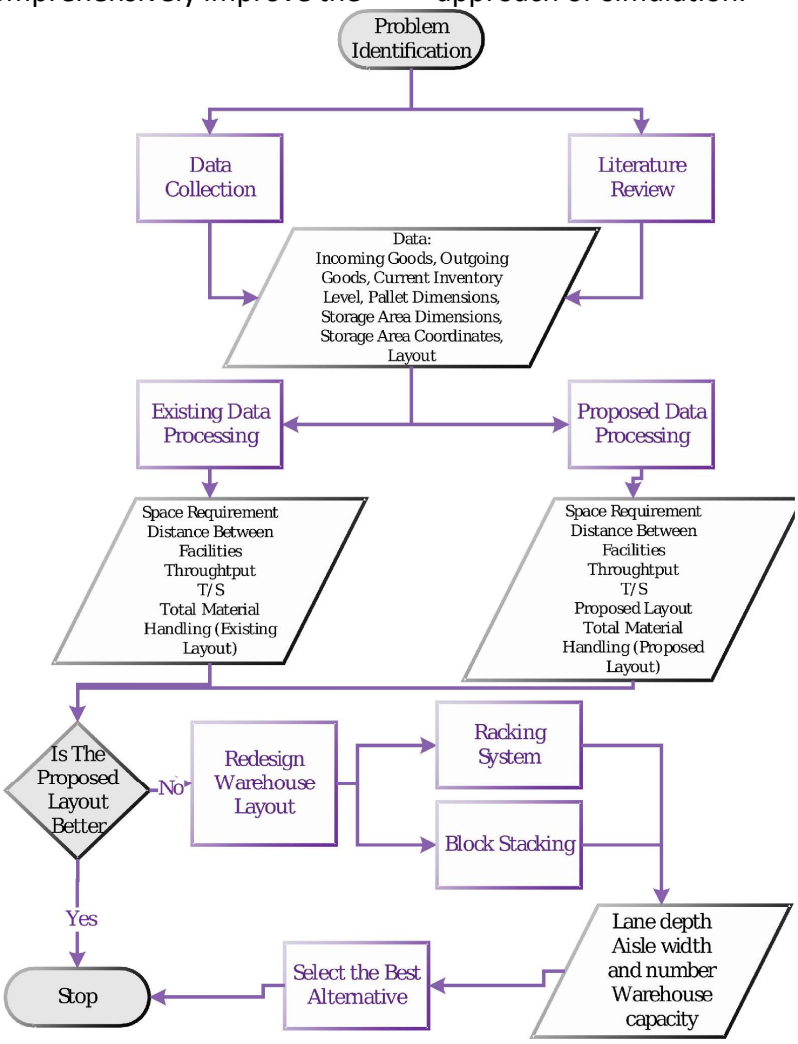


Figure 2. Research Methodology

The first step is to identify the problems within Danone's warehouse. Next, data collection and a literature review are conducted on the identified problems. The collected data is then processed using the selected storage placement policy methodology for both existing and proposed conditions. The two conditions are then compared. If significant changes are found, the storage area is changed and the process is stopped. If no changes are found, the process proceeds to the next step, which is selecting storage media for the proposed warehouse layout. Data processing is carried

out based on measurement parameters for both types of storage media and comparisons. The proposed warehouse layout is then selected to provide better indicator performance.

In the data collection stage, several data must be collected for research purposes. These data include incoming goods data, outgoing goods data, final stock, pallet dimensions, storage area dimensions, storage area coordinates, and initial layout. The pallet currently used has a size of 80 x 200 cm which is also used as a storage area. The pallet does not comply with the standards set by the American Society of Mechanical Engineers (ASME). The arrangement of goods on the pallet uses a row pattern with 12 levels. The policy for placing goods in the warehouse uses a random storage policy and there is no policy regarding aisles in the warehouse. Currently, Danone's warehouse stores five types of products, namely Aqua 220 ml, Aqua 600 ml, Aqua 1.5 l, Vit 600 ml, and Mizone 500 ml. The incoming goods, outgoing goods, and final stock data collected over the 14-day observation period are presented in Table 2, Table 3, and Table 4, respectively.

Table 2. Received Goods for 14 Days (cartons)

Days	Aqua 220 ml	Aqua 600 ml	Aqua 1,5 l	Vit	Mizone
1	2040	2040	1176	1500	2400
2	2040	2040	1176		
3	2040	2040	1176		
4	2040	2040	1176		
5	2040	2040	1176		
6	2040	2040	1176		
7	2040	2040	1176		
8	2040	2040	1176		
9	2040	2040	1176		
10	2040	2040	1176		
11	2040	2040	1176		
12	2040	2040	1176		
13	2040	2040	1176		
14	2040	2040	1176		
Total	28560	28560	16464	1500	2400

Table 2 above shows the number of items received during the 14-day observation period. All Aqua products are received four times a day, while Vit and Mizone products are received only once every two weeks. The outgoing goods over the same period are presented in Table 3 below.

Table 3. Shipped Goods in 14 Days (cartons)

Days	Aqua 220 ml	Aqua 600 ml	Aqua 1,5 l	Vit	Mizone
1	2040	2040	1176	107	171
2	2040	2040	1176	107	171
3	2040	2040	1176	107	171
4	2040	2040	1176	107	171
5	2040	2040	1176	107	171
6	2040	2040	1176	107	171

http://doi.org/10.30988/jmil.v10i2.1795

Days	Aqua 220 ml	Aqua 600 ml	Aqua 1,5 l	Vit	Mizone
7	2040	2040	1176	107	171
8	2040	2040	1176	107	171
9	2040	2040	1176	107	171
10	2040	2040	1176	107	171
11	2040	2040	1176	107	171
12	2040	2040	1176	107	171
13	2040	2040	1176	107	171
14	2040	2040	1176	107	171
Total	28560	28560	16464	1498	2394

Table 3 above provides information on the outgoing goods over the 14-day observation period. Aqua, in all sizes, leaves the warehouse four times a day, while the other products leave only once a day. The resulting final stock of each product is presented in Table 4 below.

Table 4. Stored Goods in 14 Days (cartons)

Days	Aqua 220	Aqua 600	Aqua 1,5	Vit	Mizone
1	8160	8160	4704	4500	7200
2	8160	8160	4704	4393	7029
3	8160	8160	4704	4286	6858
4	8160	8160	4704	4179	6687
5	8160	8160	4704	4072	6516
6	8160	8160	4704	3965	6345
7	8160	8160	4704	3858	6174
8	8160	8160	4704	3751	6003
9	8160	8160	4704	3644	5832
10	8160	8160	4704	3537	5661
11	8160	8160	4704	3430	5490
12	8160	8160	4704	3323	5319
13	8160	8160	4704	3216	5148
14	8160	8160	4704	3109	4977
Max	8160	8160	4704	4500	7200

Based on Table 2 and Table 3 above, the ending stock of goods stored in the internal warehouse is calculated as shown in Table 4. These three tables were used to determine the space requirement (S) and throughput (T) values for each product type. After S and T are determined, the next step is to determine the ratio between T/S. The formulas for S and T are as follows [4], [27], [28].

$$S = \frac{maximumcapacity}{storageareacapacity} \quad (1)$$

$$T = average \in \frac{averagein}{n} + \frac{averageout}{n} \quad (2)$$

n = single load capacity

In Equation (1), the maximum capacity is the highest number of cartons of each product stored during the observation period (the Max row of Table 4), whereas the storage area capacity is the number of cartons that one storage area (pallet) can hold (144 cartons). Therefore, *S* expresses the number of storage areas required by each product. In Equation (2), the average in and average out are the average numbers of cartons received and shipped, obtained from Table 2 and Table 3, while *n* is the single load capacity, namely the number of cartons moved in one handling trip (9 cartons). Thus, *T* represents the number of storage and retrieval trips generated by each product. The *T/S* ratio

shows how often a product is handled relative to the space it occupies; the higher the *T/S* value, the closer the product should be stored to the Input/Output Point.

Based on Figure 3(a), a layout is created by dividing it into four storage blocks. Block A consists of 48 pallets, block B consists of 33 pallets, block C consists of 120 pallets, and block D consists of 28 pallets. Each block will be filled with each type of product randomly and the goods that come in first will be placed in an empty space. Figure 3(b) illustrates the x and y coordinate points of each storage area which will be used to determine the distance between the Input/Output Point to each storage area. Figure 3(c) provides an overview of the initial position of all products stored in Danone's warehouse. Based on these coordinates, the initial or existing total travel distance is determined and presented in Table 9.

From Figure 3, it is known that the existing warehouse layout has three main facilities, namely the storage area, office area, and aisle. The coordinate points in the existing layout are determined based on the third quadrant [27]. In the third quadrant, the Vertical Reference Line (VRL) is located on the top side of the layout and the Horizontal Reference Line (HRL) is located on the right side of the layout. VRL and HRL are the sides/reference lines to determine the x and y coordinate points for each storage area/facility. The x and y coordinate points will be used to determine the distance from the entrance to each storage area and the distance from the exit to each storage area. The coordinate points of each facility in Danone's warehouse are presented in Table 5, which shows an excerpt of the coordinates of storage block B as a representative sample of the 229 storage areas.

There are several types of distance measurement methods between facilities, including rectilinear distance, Euclidean distance, squared Euclidean distance, Chebyshev distance, and adjacent [4], [27]. In this study, the distance measurement method used is rectilinear distance. This measurement method was chosen because the handling system in Danone's warehouse is still manual. The following is the rectilinear distance formula.

$$d = |x_j - x_i| + y_j - y_i \vee \quad (3)$$

d = distance from each storage area to input output poin (m)
x_i y_i = coordinates for each storage area (m)
x_j y_j = coordinates for each input output point (m)

Once the T/S ratio is obtained and the distance between each storage area and the Input/Output Point is calculated, the next step is to calculate the total travel distance.

The formula used to calculate the total travel distance (D) is as follows.

$$D = \frac{1}{k} x \frac{T}{S} x d \quad (4)$$

D = Total traveled Distance (m)
k = the number of I/O point
T = Throughput
S = Space requirement
d = distance traveled for each area and product from/to input output point (m)

If the total traveled distance for the existing layout conditions has been found, the next step is to rearrange the proposed layout using a dedicated-COI storage policy, where 1/k is the entry and exit coefficient. The k value is determined from the number of entry and exit in the warehouse, where the number of entry and exit in the warehouse is two. In this proposed layout, products are stored based on the T/S value and the distance from each storage area to the Input/Output Point. The largest T/S value will be placed in the storage area with the

closest distance to the Input/Output Point. After the arrangement is successful, a recalculation of D is carried out after which the existing D value is compared with the proposed D. If there are no significant changes, a complete improvement will be made to Danone's warehouse layout.

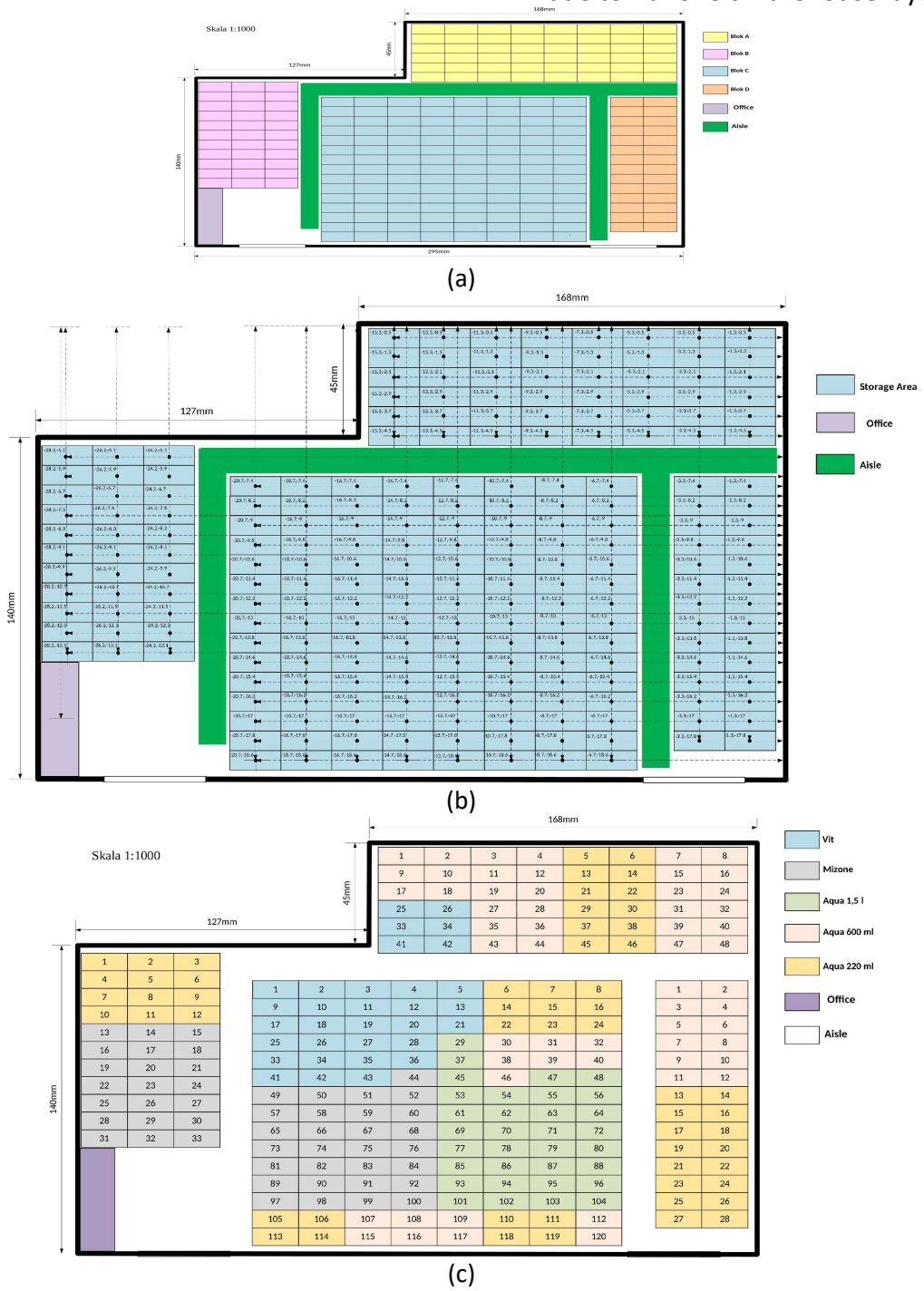


Figure 3. Existing warehouse layout (a) storage area block (b) *x* and *y* coordinates for each storage area (c) position for each product

Table 5. *x and y* Value for Each Storage Area and Input Output Point for Block B

Facilities	*X*	*Y*
Input/output point 1	-3.5	-18.4
Input/output point 2	-26	-18.4
Office	-28.75	-16.07
B1	-28.2	-5.1
B2	-26.2	-5.1
B3	-24.2	-5.1
B4	-28.2	-5.9
B5	-26.2	-5.9
B6	-24.2	-5.9
B7	-28.2	-6.7
B8	-26.2	-6.7
⋮	⋮	⋮

The improvement of the new Danone's warehouse layout will be based on the handling equipment and storage media to be used. The selection of Material Handling Equipment (MHE) and storage media is not based on a specific method and does not consider cost or financial factors. Factors considered in the redesign of the new warehouse layout include block depth, aisle width, number of rows, and stack height [29], [30]. Aisle width, block depth, shelf width, shelf depth, and shelf height are determined using formulas while the number of rows and stack height are adjusted to the conditions of the warehouse. The following is the formula for aisle width (w) and line depth (b).

$$w = \sqrt{(MHEL)^2} + \sqrt{(MHEW)^2} \quad (5)$$

$w = aislewidth$ (m)
$MHEL = MHElength$ (m)
$MHEW = MHEwidth$ (m)

$$b_{front} = \frac{WhsLength}{(L_p.rownumber)+w} \quad (6)$$

$L_p = palletlength$ (m)

$$b_{rear} = \frac{WhsWidth}{(W_p.coulomnumber)+w} \quad (7)$$

$W_p = palletwidth$ (m)

$$H = nxH_p + ((n-1)xH_c + (2xH_b) + H_{base} \quad (8)$$

H = rack total height (m)
$H_p = height\ of pallet\ \&\ goods$ (m)
$n = pallet$
$H_c = verticalclearence\ betweenpallet(0.1m)$
$H_b = heightbeam(0.1m)$
$H_{base} = distancefloor$ (m) $bottomrack\ (0.15m, opsional)$

$$W = (n_p x W_p) + ((n_p + 1) x C_v) \quad (9)$$

$W = rackwidth$ (m)
$n_p = numberofpalletpercell$
$C_v = cleareancebetweenpallet\ \&\ pole$ (m)
$W_p = palletwidth$ (m)

$$R = L_p + C_d \quad (10)$$

$R = rackdepth$ (m)
$L_p = palletlength$ (m)
$C_d = rearclearence(0.05 - 0.1m)$

RESULTS AND DISCUSSION

In this section, the results of data processing for managing the storage layout using dedicated COI are analyzed. If the results of the data processing analysis of the storage layout in Danone's warehouse do not show

significant results, the warehouse facility layout will be redesigned.

Space Requirement (S), Throughput (T), and T/S

S and T are calculated using the formulas in Equations 1 and 2. The results of the S and T calculations are presented in Tables 6 and 7 below.

Table 6. S for Each Item

No	Item	Max stored	S Theoretical	S
1	Aqua 220	8160	56.67	57
2	Aqua 600	8160	56.67	57
3	Aqua 1,5	4704	32.67	33
4	Vit	4500	31.25	32
5	Mizone	7200	50	50

Table 6 above presents the space requirement (S) of each product, which is obtained from the ratio between the maximum quantity stored and the capacity of a single storage area. Aqua 220 ml and Aqua 600 ml require the largest storage space, namely 57 storage areas each, while Vit requires the smallest, namely 32 storage areas. The throughput (T) of each product is presented in Table 7 below.

Table 7. T for Each Item

No	Item	Average in	N	Average out	n	*T*
1	Aqua 220	2040	9	2040	9	454
2	Aqua 600	2040	9	2040	9	454
3	Aqua 1,5	1176	9	1176	9	262
4	Vit	1500	9	107	9	179
5	Mizone	2400	9	117	9	286

Based on Tables 6 and 7, it is known that Aqua 220 ml and Aqua 600 ml require the most storage space and have the fastest turnover. This indicates that both types of products should be placed in areas close to the Input/Output Point. The next step is to rank the products in order to place each of them in the appropriate storage area, which is done by first determining the T/S ratio for each product type. The results of the T/S calculation are presented in Table 8 below.

Table 8. T/S for Each Item

No	Item	*S*	*T*	*T/S*	*1/k*
1	Aqua 220	57	454	7,96	½
2	Aqua 600	57	454	7,96	½
3	Aqua 1,5	33	262	7,94	½
4	Vit	32	179	5,59	½
5	Mizone	50	286	5,72	½

The T/S will be used as a ranking to place each product type in the storage area closest to the Input/Output Point. The number of entrances and exits that exceed one will result in a new coefficient that follows the formula 1/k, where k is the number of entrances and exits. The coefficient 1/k becomes 1/2. The results of Table 8 explain that the number of storage areas required to store goods in Danone's warehouse is 229 storage areas.

Distance to each storage area to I/O points (d)

Equation 3 is used to calculate the distance from each storage area to the Input/Output Point. A summary of the results of these distance calculations can be seen in Table 9 below.

Table 9. d from I/O Points to Each Storage Area (m)

Storage area	To I/O point 1	To I/O point 2	Total
A1	29.7	28.6	58.3
A2	27.7	30.6	58.3
A3	25.7	32.6	58.3
A4	23.7	34.6	58.3
A5	21.7	36.6	58.3
A6	19.7	38.6	58.3
A7	18.1	40.6	58.7
A8	20.1	42.6	62.7
A9	28.9	27.8	56.7
A10	26.9	29.8	56.7
⋮	⋮	⋮	⋮

In Danone's warehouse, the input/output points are separated, so there are two doors designated as entrances and exits. This results in different distances between each storage area and each input/output points. Table 9 only shows 10 of the 229 storage areas in the warehouse as a representative sample. Data on the distance between each storage area and input/output points will be used to determine the total distance traveled by the trolley during warehouse operations.

Distance Traveled (D)

The next step is to determine the total distance traveled using Equation 4 for each product type in each storage area. The total distance traveled is summarized in Table 10, which presents an excerpt of the storage areas occupied by the VIT product type, with a total travel distance of 3,844.80 meters. The total initial travel distance for each product type in each storage area is 32,539.18 meters. The Proportion column in the table is taken from the 1/k value presented in Table 8. The next step is to change the placement of the storage area for each product type with a dedicated COI storage policy. Placement is based on the T/S value and the distance proportion with the following provisions:

a. Products with the largest T/S value will be placed in the storage area with the smallest proportion
b. Products with the smallest T/S value will be placed in the storage area with the largest proportion

http://doi.org/10.30988/jmil.v10i2.1795

Based on these provisions, the proposed storage layout of the warehouse can be determined, as shown in Figure 4. The next step is to calculate the total proposed travel distance and to compare it with the existing or initial total travel distance presented in Table 10. Table 11 shows the total proposed travel distance for the VIT product.

Table 10. Initial Distance Traveled (D) for VIT Type (m)

Storage area	Proportion	T/S	D	Item
A25	26.75		149.53	
A26	26.75		149.53	
A33	25.95		145.06	
A34	25.95		145.06	
A41	25.15		140.59	
A42	25.15	5,59	140.59	VIT
C1	22.25		124.38	
C2	22.25		124.38	
C3	22.25		124.38	
C4	22.25		124.38	
⋮	⋮		⋮	
Total distances traveled			3844,80	

Table 10 above presents the initial travel distance of the VIT product for every storage area it currently occupies, with a total of 3,844.80 meters. The same calculation was then repeated for the proposed layout, and an excerpt of the result is presented in Table 11 below.

Table 11. Proposed Distance Traveled (D) for VIT Type (m)

Storage area	Proportion	T/S	D	Item
A28	26.75		149.53	
A29	26.75		149.53	
A30	26.75		149.53	
B1	26.75		149.53	
A31	26.95		150.65	
A48	27.35	5,59	152.88	VIT
A17	27.55		154.01	
A18	27.55		154.01	
A19	27.55		154.01	
A20	27.55		154.01	
A21	27.55		154.01	
A22	27.55		154.01	
⋮	⋮		⋮	
Total traveled distance			5064.58	

Tables 10 and 11 show a change in the total travel distance. In the initial layout, the total travel distance of VIT products is 3844.80, while in the proposed layout it is 5064.58. This is because VIT products have the smallest T/S value of all existing product types, so VIT products in the proposed layout are placed in the furthest storage area with the largest proportion. Figure 4 shows that each product is currently placed in its respective area according to the COI provisions or the calculated proportion and T/S. This makes the initial travel distance of VIT products lower than the proposed one, although the overall total is lower in the proposed layout. The total travel distance proposed overall is 31262.39, while in the initial layout the total travel distance is 32539.18. The difference between the initial total travel distance and the total travel distance proposed is insignificant, namely 4%. This indicates that reassigning products alone yields only a small improvement. The reduction of 1276.79 m is small because the COI-dedicated policy only changes the location of each product within the existing block stacking layout, while the number of storage areas, the stacking height, and the aisle width remain the same. However, the main problems mentioned earlier cannot be resolved. The warehouse capacity is still limited to 229 storage areas, and the narrow aisles continue to restrict the movement of the material handling equipment. Therefore, it is necessary to propose a better warehouse layout. This new layout should change not only the storage policy but also the storage media, namely by replacing block stacking with a rack-based system so that the vertical space can be utilized optimally.

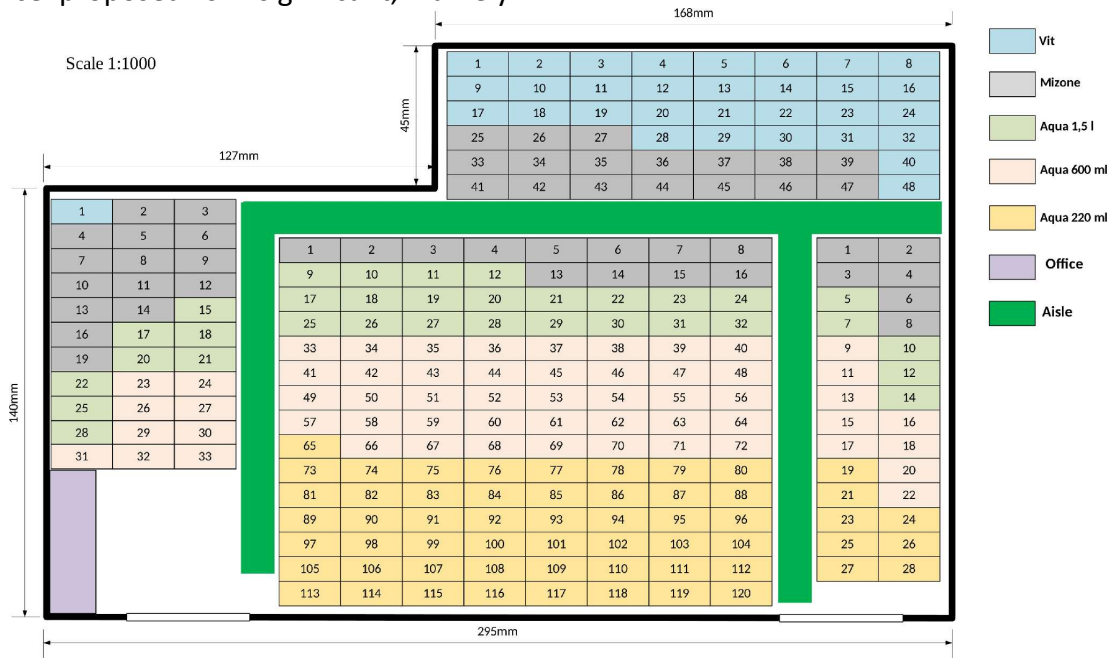
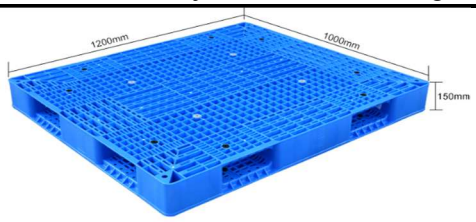


Figure 4. Proposed layout using the dedicated-COI storage policy

Proposed Warehouse Layout

The next step is to determine the standard pallet size, media, and handling equipment to be used in the proposed warehouse layout. The pallet size used is 1x1.2 m, the storage medium is single-deep pallet racks or block pallets, and and the handling equipment is an electric pallet jack or a narrow-aisle forklift, as shown in Figure 5. The rack dimensions are adjusted to the pallet size, and the rack height is adjusted to the existing warehouse height.

http://doi.org/10.30988/jmil.v10i2.1795



(a)



(b)



Flexi®
15VN / 1000

The Flexi® 15VN offers 230° Over-rotation™ in a narrow 40" TrueRadius™ Chassis. Its 2,850lb capacity operates in the most narrow aisles. A pioneer of articulated forklift trucks, lifts to 25ft.



(c)

Source: Flexi-Solution-Brochure.pdf

Figure 5. Illustration (a) Pallet (b) Single-deep rack (c) MHE

The height of the shelves is also determined by the stacking of goods on the pallets, which will determine the number of stacks on the shelves. The stacking of goods is determined by the dimensions and weight of the goods, thus addressing the problem of damage caused by over stacking. The proposed layout will also transform aisles, initially narrow due to manual handling, into wider ones due to the use of machine handling. Everything will ultimately depend on the depth of the shelf blocks or pallets, which will be determined in the proposed layout.

The dimensions of each product carton are 39x26x25 cm (Aqua 220), 39x26x25 cm (Aqua 600), and 35x27x32 cm (Aqua 1.5). The weight of each carton is 11 kg, 15 kg, and 19 kg, respectively. In addition, there are also Vit 600 ml and Mizone 500 ml products with carton sizes of 39x26x25 cm and 40x25x25 cm, respectively, with a weight approximately equal to the 600 ml Aqua carton. The weight of the 500 ml Mizone carton is 12 kg. The cartons are arranged in a row or brick pattern to ensure a strong and sturdy structure. The pallets used are standard plastic pallets with dimensions of 100x120x15 cm. The pallet type is single-face flush wing.

Since the racking to be used is single-deep pallet racking, calculations for the rack width, depth, and height are necessary. The pallet blocks used will be adjusted to the pallet dimensions. Once the pallet rack and pallet block calculations are obtained, the next step is to design the proposed warehouse layout based on the calculations for both storage media types. The choice between the two storage media types is not based on cost but rather on the utilization of warehouse space capacity.

The following are the steps taken to obtain aisle parameters. First, determine the number of stacks on the pallet. Table 12 below provides an overview for determining the number and height of stacks on the pallet.

Table 12. Number and Height of Pallet Stack

Item	Aqua 220	Aqua 600	Aqua 1.5
Stack capacity	11.83	11.83	12.70
Stack capacity applied (cardboard)	11	11	12
Weight per cardboard (kg)	11	15	19
Total weight for stack (kg)	121	165	228
Stack number	11.07	8.12	5.88
Stack number applied	11	8	5
Total stack height (cm)	275	200	160
Rack height (cm)	300	225	185
Applied rack height (cm)	300	300	300
Total pallet capacity (cardboard)	121	88	60
Maximum storage capacity	8160	8160	4704
Number of pallet requirement	67.44	92.73	78.4
Applied number of pallet requirement	68	93	79

Based on the number and height of the stack, the aisle width, height, and depth of the rack can be determined using Equations 5 to 10. However, the aisle width used is from the technical specifications of the selected handling equipment, namely the Narrow Aisle Flexi 15VN. Table 13 below provides information on the technical specifications of the handling equipment used.

Table 13. Narrow aisle Flexi 15VN specification

Parameter	Dimension (mm)
Length	2692
Width	1219
Aisle width	1600
Reach	10338

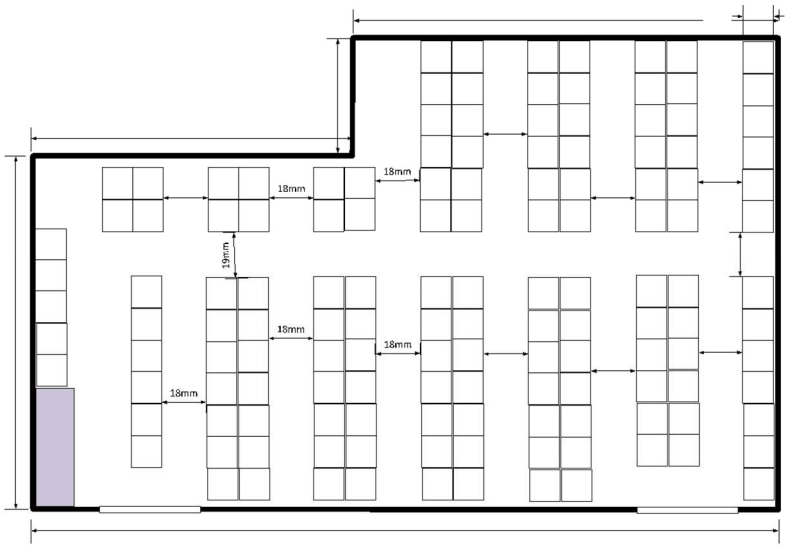


Figure 6. New proposed layout

http://doi.org/10.30988/jmil.v10i2.1795

The new warehouse layout is capable of accommodating 280 pallets, as shown in Figure 6. One pallet can accommodate a maximum of 121 boxes, so the total number of boxes that can be stored in the new warehouse is 33,880 boxes. The warehouse storage capacity has increased from 32,724 boxes to 33,880 boxes. There is a difference of 1,156 boxes more than the initial layout. In addition, the initial objective of this research was achieved because it can minimize stacking item on pallet and increase the amount of storage capacity of the warehouse. In addition, loading and unloading access and the flow of products in and out of the warehouse are smoother. This is because the new warehouse layout is neatly arranged and the aisles are wider and more numerous. In addition, a comparison of the storage capacity of the initial warehouse layout and the proposed warehouse layout is presented in Table 14 below.

Table 14. Comparison of Initial and Proposed Warehouse Utility

Variable	Initial layout	New layout
Storage capacity	32724 cartons	33880 cartons
Storage space	403040 cm^2	210000 cm^2
Warehouse area	545750 cm^2	545750 cm^2
Office area	6990 cm^2	6990 cm^2
Aisle space	135720 cm^2	328760 cm^2
Warehouse utility	75%	40%

CONCLUSION

Based on the results and discussion, it can be concluded that the warehouse layout, which changed product storage placement from a random to a fixed COI policy, has not had a significant impact. Therefore, a new warehouse layout is needed to reduce product damage due to overcrowding. The proposed new layout uses two storage alternatives: a rack system and a block system. The block system is not yet feasible due to the significantly reduced storage capacity compared to the initial layout. Therefore, a rack system was chosen to design the new warehouse layout, taking into account new handling equipment. Based on the results of the new rack system design, it can be concluded that product damage can be minimized and storage capacity can be theoretically increased. However, the actual impact has not been felt because the new layout has not yet been implemented in the Danone warehouse. Further recommendations include recalculating the total travel distance based on the storage area assignment approach using a dedicated COI storage policy. Furthermore, it is recommended that material handling equipment be selected using a scientific approach, such as an assignment model or engineering economics, before installing it in the new warehouse.

ACKNOWLEDGMENT

We would like to thank the Danone warehouse for granting permission to conduct the observations. We hope that the proposed recommendations will be implemented so that the results can be evaluated.

http://doi.org/10.30988/jmil.v10i2.1795

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