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Redesign of Warehouse Layout Using Dedicated Storage Method

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Abstract

The warehouse's facility layout arrangement can positively impact the company's performance, as indicated by the efficiency of material handling activities. On the other hand, a bad layout implies that the material flow is hampered, thus reducing performance. Therefore, analyzing and improving the facility's layout is important to produce effective and efficient operational activities. Company XYZ, which is engaged in processing refined sugar, needs help with the layout of its warehouse area, which impacts the inefficiency of warehousing activities. Accordingly, this research used the dedicated storage method to propose a warehouse layout through two scenarios. This research found that the proposed layout design for scenario 1 decreased travel distance by 41.497%. Meanwhile, scenario 2 reduced travel distance by 21.484% compared to the existing layout.

Keywords
Warehouse, Facility, Layout, Dedicated Storage Method, Travel Distance.

Introduction
An efficient company facility layout positively impacts the company by minimizing costs, increasing production speed and accuracy, and reducing employee movement to save time and minimize fatigue (Albert et al. 2023). On the contrary, a poor layout harms the company because it causes obstruction of material flow, excessive employee movement, and high production costs, resulting in a decrease in the company's performance (Yener and Yazgan 2019). Therefore, an analysis of the company's facility layout needs to be carried out to find out what company facilities need to be evaluated and improved to minimize or even avoid negative impacts that will occur (Shah and Khanzode 2017). Contextually, Company XYZ is a manufacturing industry company engaged in processing to produce refined sugar. Based on the results of observations, it is known that the warehouse area (spare parts and sacks) at Company XYZ still has problems, namely First, the placement of product-type shelves that have not been arranged properly and have

not been based on the level of intensity of incoming and outgoing goods. Second, the travel distance experienced by the operator is still relatively far, so the time required for warehousing activities is relatively long. Third, the entrance and exit doors that only use one door (double door) are unsuitable, affecting the width of the door for forklift access to the buffer area. Also, there is a narrow aisle (below 91 cm) even though accessibility is still within reach.

Based on this urgency, research on warehouse layout needs to be conducted to optimize the production flow performance at Company XYZ. The relevant method for this research is the Dedicated Storage method because this method has a policy or rule that the location of one type of product is only placed on a kind of shelf or storage area so that it can facilitate the process of taking, identifying, storing, and mapping products in warehousing activities because the location of a product has been clearly defined and fixed (Dianto et al. 2020; Putro et al. 2022; Savsar et al. 2023). The Dedicated Storage method reduces travel distance when warehousing activities occur based on the product priority value obtained from comparing throughput or product activity with space requirements to store the product (Putro et al. 2022). Therefore, an analytical study using relevant scientific concepts and theories must be conducted to optimize warehouse layout properly (Hu and Chuang 2023). Accordingly, an analysis of the warehouse layout, especially in the warehouse area at Company XYZ, is needed to achieve optimal warehouse management.

1.1 Objectives

This study aims to design a facility layout using the dedicated storage method to reduce travel distance when warehousing activities occur at the PT Company XYZ warehouse.

2. Literature Review

The high business competition results in high consumer demands for quality products or services (Burinskienė and Lerher 2021). Organizations can develop or improve operational activities to achieve these demands, including improving the layout of facilities that affect company productivity (Boysen and de Koster 2024). Facility layout is a method of organizing operations to achieve high company efficiency in the long term. Accordingly, facility layout can be interpreted as the arrangement of physical facilities in a company that significantly impacts the smooth flow of company production (Adeodu et al. 2023). One of the company facility layouts that need to be analyzed and reviewed is the warehouse facility, be it a material warehouse, finished product warehouse, or spare parts warehouse, and company supporting needs (Kłodawski et al. 2017; Mohamud et al. 2023).

A warehouse is a space used to store company resources, whether raw, semi-finished, or finished products. The purpose of the warehouse is to help the company optimize the production process, both before, during, and after the production process. The warehouse has an important role because of the many warehousing activities that occur, such as input activities (entering/receiving goods), retention (storing goods), seeking (looking for goods), pickup (taking goods), preparing (preparing goods), and output (issuing/delivering goods) (Fernando et al. 2024). The warehouse is described as a company's logistics system because, in addition to being a place to store resources, the warehouse also functions as an information medium for workers regarding the situation and condition of the products stored in the warehouse. It affects the internal supply chain for those concerned (Hu and Chuang 2023; Tiwari 2023).

Theoretically, warehouses have rules for shelf placement so that warehousing activities can run optimally according to their layout type (Ramaa et al. 2012; Richards 2014). Warehouses significantly impact process time and travel distance in the material handling process (Zhang et al. 2021). Long times and long distances can have negative effects. Therefore, analyzing the warehouse layout with relevant concepts and theories is necessary to optimize its arrangement (Richards 2018). The benefits of arranging the design are to increase the productivity of the flow of raw materials, work methods, and information. Based on this, a warehouse layout analysis must be carried out to ensure that the management and administration of warehouse elements at Company XYZ run optimally.

3. Methods

3.1. Dedicated Storage Method

The dedicated storage method is proper for organizing the layout in the warehouse area. It organizes product placement based on warehousing activities that occur on the product in one storage location. In this method, the products stored and allocated space in the warehouse already have an identity, such as part number sequence and throughput-based dedicated storage, so that it can optimize the quantity of product storage in the warehouse area (Dianto et al. 2020;

Putro et al. 2022; Savsar et al. 2023). The following is a sequence of procedures for using the Dedicated Storage method to organize warehouse layout.

a. Calculation of the ratio of demand and product quantity.
b. Calculation of space requirements.

$$S = \frac{\text{Average Product Inbound (storage)}}{\text{Block or Slot Capacity}} \quad (1)$$

c. Calculation of product throughput.

$$T = \frac{\text{Average Product Inbound (storage)}}{\text{Material Handling Capacity}} + \frac{\text{Average Product Outbound (retrieval)}}{\text{Material Handling Capacity}} \quad (2)$$

d. Priority ratio calculation.

$$\text{Priority Ratio} = \frac{T}{S} \quad (3)$$

e. Calculation of travel distance using rectilinear distance.

$$d_{ij} = |x_i - x_j| + |y_i - y_j| \quad (4)$$

Where:
x_i = The x coordinate of the center point of facility i
x_j = The x coordinate of the center point of facility j
y_i = The y coordinate of the center point of facility i
y_j = The y coordinate of the center point of facility j
d_{ij}= the distance between the center points of facilities i and j

f. Determination of the proposed layout design based on the lowest travel distance.

3.2. Scenario of Analysis

The analysis design uses two scenarios, namely scenario 1, marked by the absence of a buffer area, and scenario 2, marked by the presence of a buffer area. In scenario 1, the proposed layout does not have a buffer area, as suggested by the warehouse manager's plan to eliminate the buffer area to expand the warehouse area. Meanwhile, scenario 2 proposes a layout with a buffer area, as the actual condition of the warehouse regarding the buffer area cannot be eliminated. Both proposals are designed to adjust to field conditions in the existing layout with several changes, such as the position of the shelf placement, applicable rules/procedures, and priority data for goods. In addition to the proposed design with two scenarios, there are other outputs, namely additional rules. These rules are used to optimize the design of the proposed warehouse layout and solve problems in the existing layout regarding the procedure for receiving and picking goods in the warehouse. Table 1 shows the differences between each proposal and scenario, with the comparison being the existing layout.

Table 1. Scenario of Analysis

No	Facilities	Existing Layout	Scenario 1	Scenario 2
1.	Buffer Area	✓	-	✓
2.	Office	✓	✓	✓
3.	Door shape (I/O)	Swing	Sliding	Sliding
4.	Connecting door	✓	-	✓
5.	Shelf/Rack position	Vertical-Horizontal (Mix)	Vertical	Vertical-Horizontal (Mix)

4. Data Collection

4.1. Data Collection Procedure

The data collection method for this study was to go directly to the research location to observe and obtain the desired data. The technical data that we want to get through observation are the number of shelves, the initial shelf position, the aisles between the shelves, the overall warehouse layout, the procedure for placing products on the shelves, the material handling used, and the procedures for warehouse activities, such as input, retention, seeking, pickup, preparing, and output activities.

4.2. Variables

The variables required for data processing include the following.

- Flow process of inbound (storage) and outbound (retrieval) activities
- Types of products in the warehouse.
- Types and names of products stored in the spare parts and sack warehouses, such as bearings, valves, lift pump bushings, and other products.
- Warehouse capacity to accommodate products and placement of goods shelves
- Material handling is used for warehousing activities.
- The initial layout of the spare parts and sack warehouse is as follows:
- Data on incoming and outgoing products or goods in February 2024.
- Size of pallets, shelves, and material handling used to store and retrieve products or goods.

4.3. Validity

In the study on warehouse layout analysis using the Dedicated Storage method, the basic data collection uses interviews and observations. Therefore, the level of validity is influenced by the opinions of the interview sources, namely the General Manager (GM), supervisors, and warehouse employees. In addition, the high level of transparency and clear interview procedures in this study also influence the data's trustworthiness. The form of openness can be in the form of photos, interview recordings in the form of voice or video, interview transcripts, and others.

5. Results and Discussion

5.1 Results

Data processing is done through several steps: throughput calculation, space requirement, priority ratio, and design of the proposed layout design. The following is an explanation and calculation process of the steps mentioned earlier.

1. Throughput Calculation

Throughput calculation is accomplished by comparing the number of incoming and outgoing goods with the transport capacity using a trolley. The data used to calculate throughput are the type of goods, incoming goods data, outgoing goods data, and material handling capacity. The following are the results of the throughput calculation in February 2024.

Table 2. Throughput Calculation Results

Products Component Data (February 2024)						
No	**Component Types**	**Component Name**	**Inbound (Box)**	**Outbound (Box)**	**Material Handling Capacity**	**Throughput**
1	Bearing	Bearing 7318 BECBP	4	2	2	3
		Bearing 6306/ZZ	5	2	2	4
…	…	…	…	…	…	…
67.	Wire Mesh	40 SUS 316 P: 30 m L: 1,5 m	1	1	1	2
TOTAL			**983**	**858**		**609**

Based on Table 2 regarding throughput calculations, the total throughput in February 2024 at the spare parts warehouse of Company PT XYZ was 609, with the highest throughput on 13×8.7 plastic clips, with a nominal of 36 throughputs.

2. Space Requirement Calculation

The Space Requirement calculation compares the number of incoming goods with material handling capacity and the maximum stack. The following are the results of the space requirement calculation.

Table 3. Space Requirement Calculation Results

Products Component Data (February 2024)						
No	**Component Types**	**Component Name**	**Inbound (Box)**	**Material Handling Capacity**	**Maximum Stack**	**Space Requirement**
1	Bearing	Bearing 7318 BECBP	4	2	3	1
		Bearing 6306/ZZ	5	2	3	1
…	…	…	…	…	…	…
TOTAL						**154**

Based on Table 3, the results of the calculation showed that the total space requirement in the spare parts warehouse of Company XYZ was 154, with the largest space requirement for 3 cm roving screws with a nominal value of 8 blocks.

3. Priority Ratio Calculation

The priority ratio is calculated by comparing each item's throughput with its space requirement. The calculation is used to determine the priority level of placing goods along with the type of rack close to the door access for entry and exit or as a reference for rack placement to facilitate ongoing warehousing activities. The following are the results of calculating the priority ratio of products.

Table 4. Priority Ratio Calculation Results

Products Component Data (February 2024)					
No	**Component Types**	**Component Name**	**Throughput**	**Space Requirement**	**Priority Ratio**
1	Bearing	Bearing 7318 BECBP	3	1	3
		Bearing 6306/ZZ	4	1	4
…	…	…	…	…	…
67	Wire Mesh	40 SUS 316 P: 30 m L: 1,5 m	2	1	2

Referring to Table 4, the highest product placement priority ratio is 6. The following is the ranking from the highest to the lowest ratio of Company XYZ's spare parts warehouse products.

Table 5. Priority Ratio Ranking

Component Name	Priority Ratio	Location
Bushing Lift Pump 1-2	6	G
…	…	…
Medical Gloves	1	Office

Based on Table 5, it can be seen that the highest priority ratio value is 6 with the products being Bushing Lift Pump 1-2, Hunger Rell Teflon, 1 Liter White HDPE Jerrycan, Noise Filter, 13×8.7 Plastic Clip, and 43 Inch TV, while the lowest value is 1 with the products, such as Flow Meter Aair 4 ”DN100BR, Packing Tombo 1000, and medical gloves. The priority ratio value will affect the placement of products in the spare parts warehouse of Company XYZ. In addition, based on direct observation, some goods or products are still placed randomly; in this case, it is not according to the type of shelf if it is based on the type of product and the type of storage shelf. Therefore, several things will be considered for processing priority ratio data towards the proposed layout design: the priority ratio value, the intensity of the types of shelves often used, shelf allocation, and operational standards for warehousing activities.

4. Proposed Layout Design

The proposed warehouse layout design is based on the results of throughput calculations, space requirements, and priority ratios. There are several adjustments from the warehouse, namely, the buffer area and the placement of shelves, which are reviewed based on the priority ratio value, the number of shelves, and the intensity of the shelves experiencing warehousing activities. In addition, the placement of the warehouse office area is kept from being changed or shifted. The aisle data in the proposed design will be adjusted to the existing layout and conditions in the field. Although in actual conditions, the aisles in the spare parts and materials warehouse are not up to standard, the aisles between shelves can still be accessed, even if only for one person.

Existing Layout

Figure 1 shows the existing layout of Company XYZ's spare parts and sack warehouse. In the existing layout, the total travel distance covering all warehouse facilities, such as shelves, offices, and buffer areas for entering and exiting the warehouse area, is 113,605.18 cm, with the furthest travel distance of 3,353.8 cm for one movement or 6,671.6 cm for two movements (in and out). The existing layout is used for data processing and as a reference to obtain the proposed layout design.

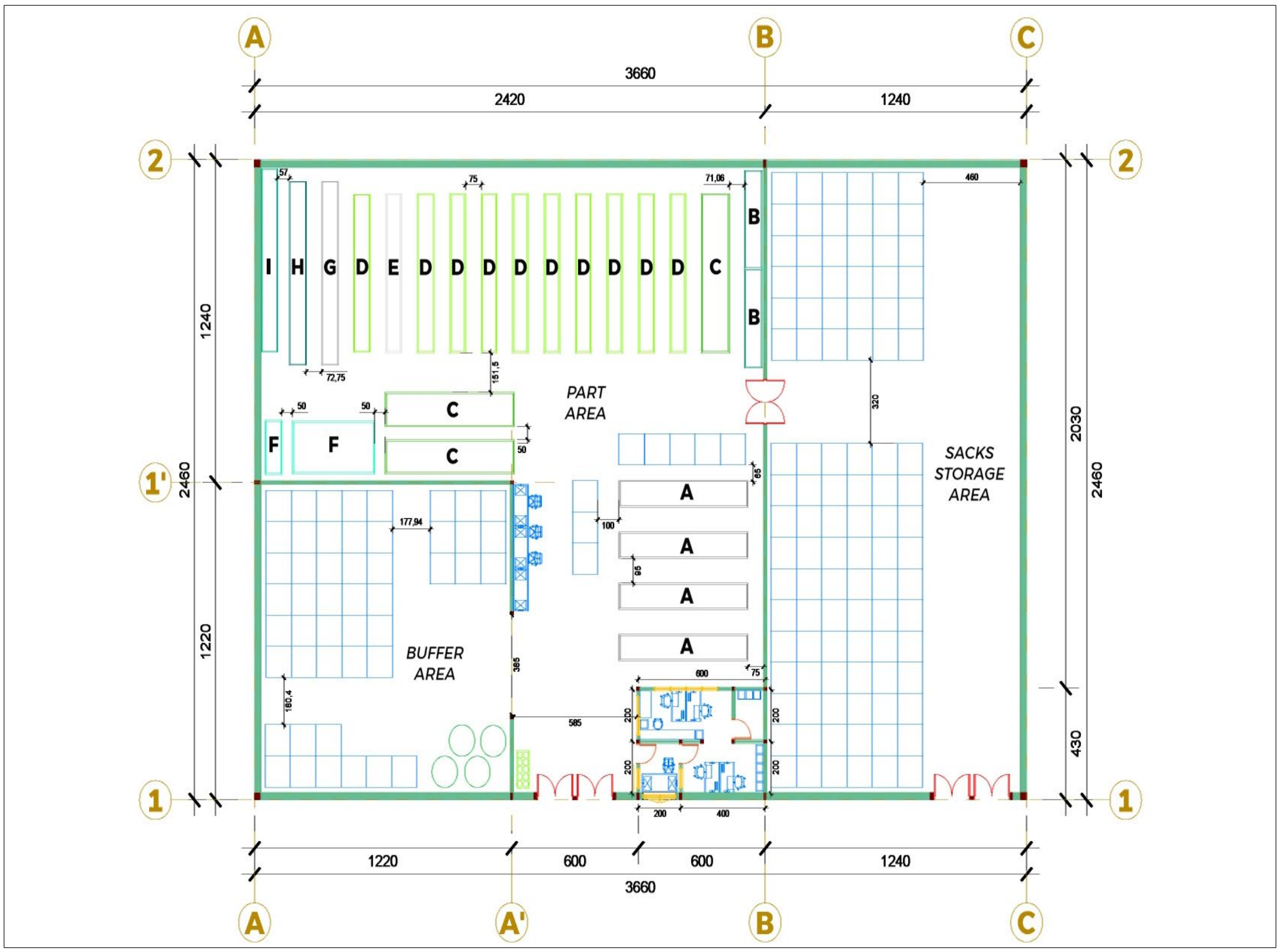

Figure 1. Existing Layout

In this research, the proposed design is determined using two scenarios (Table 1): scenario one is marked by the absence of a buffer area, and scenario two marks the presence of a buffer area. Both scenarios are based on the policy of the warehouse manager, who wants to consider a new layout if there is a significant warehouse renovation to optimize the warehouse layout.

Scenario 1

The proposed warehouse layout design scenario one is based on a modified form of the initial warehouse layout; the dominant shelf position is vertical with some adjustments. The following is the warehouse layout design scenario 1 for Company XYZ's spare parts and sack warehouse.

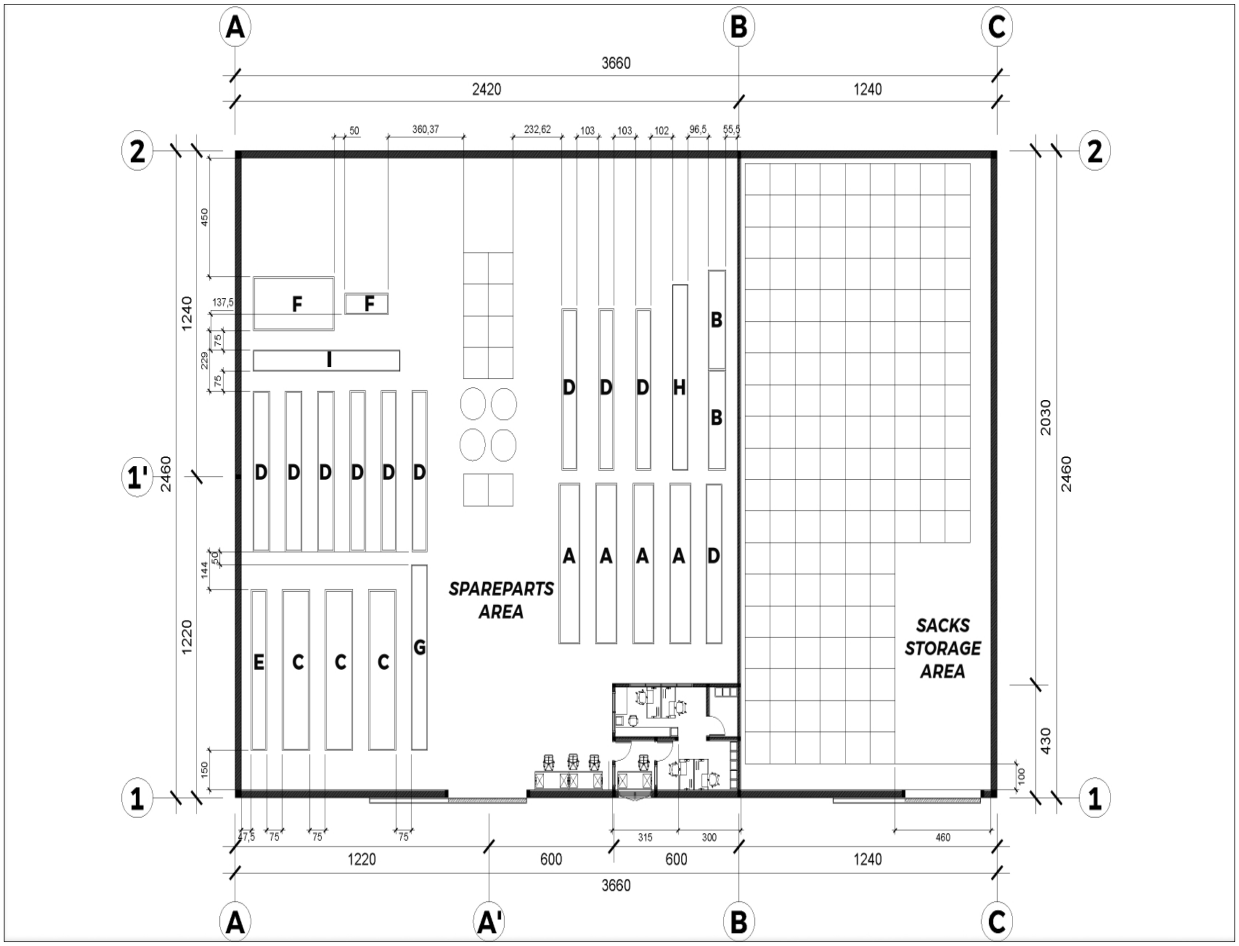

Figure 2. Layout Design of Scenario 1

Figure 2 shows the layout design that has changed when compared to the existing layout design, namely, the position of the rack position physical. In addition, the rack placement is also based on the priority ratio value, with the note that the type of rack is directly allocated as a whole. The following is the distance from the input/output point to the kind of rack or facility from the layout design of the spare part and sack warehouse scenario 1 Company XYZ.

Table 6. Travel Distance of Scenario 1

No	Location	Distance from I/O Point (Cm)	No	Location	Distance from I/O Point (Cm)
1.	Office	534,45	15.	Shelf D5	1.141,68
…	…	…	…	…	…
-	-	-	29.	Palette 2	1.562,28
Total					**33.233,06**
Total (Inbound-Outbound)					**66.466,12**

As reflected in Table 6, the shortest travel distance for one movement is 276.38 cm from the input/output point to rack G, and the farthest travel distance for one movement is 1,967.57 cm from the input/output point to rack F2. The total distance is 33,233.06 cm for one movement and 66,466.12 cm for two movements (inbound-outbound).

Scenario 2

The warehouse layout design of scenario two is based on a modified form of horizontal and vertical rack positions, with buffer areas still taken into account and rack placement based on the results of priority values with some adjustments. The following is a warehouse layout design of scenario 2 for the spare parts and sack warehouse of Company XYZ.

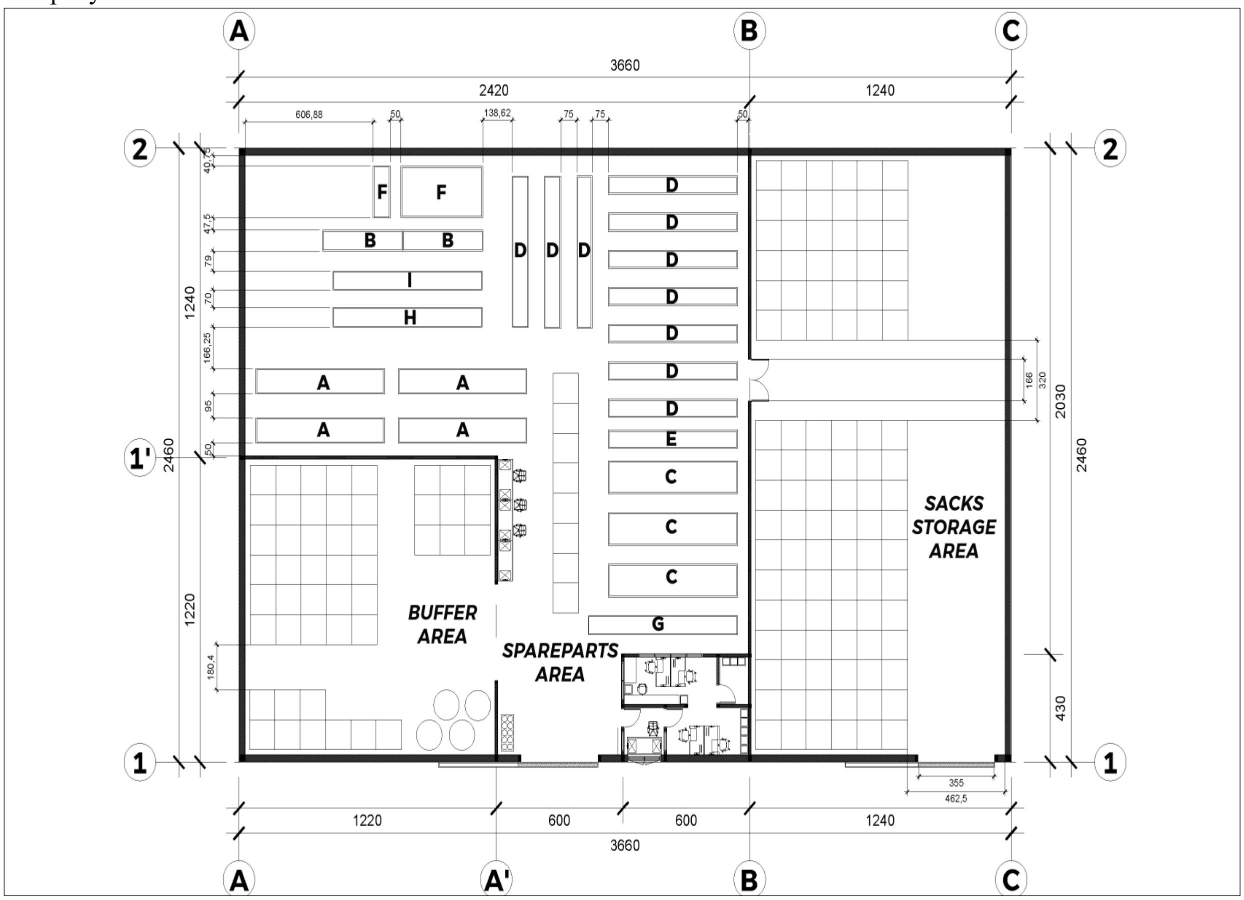

Figure 3. Layout Design of Scenario 2

Based on Figure 3, it can be seen that the warehouse layout design scenario two has changed when compared to the previously proposed design, namely, the position of the shelves changed to horizontal-vertical, the presence of a buffer area, and existing warehouse layout rules

Table 7. Travel Distance of Scenario 2

No	Location	Distance from I/O Point (Cm)	No	Location	Distance from I/O Point (Cm)
1.	Office	280,37	15.	Shelf D5	2.003,62
…	…	…	…	…	…
-	-	-	29.	Buffer Area	545,21
Total					**44.599,08**
Total (Inbound-Outbound)					**89.198,16**

.In addition, the placement of shelves is also based on the priority ratio value, noting that the type of shelf is directly allocated as a whole. Therefore, this type of warehouse is vaguely L warehouse because the location of the input and output points or doors is adjacent. The following is the travel distance from the input/output point to the type of shelf or facility from the proposed spare part and sack warehouse layout design scenario 2 Company XYZ.

Based on Table 7, it can be seen that the shortest travel distance for one movement is 159.55 cm, namely from the input/output point to oxygen, and the farthest travel distance for one movement is 2,719.09 cm from the input/output point to the F2 rack. The total distance for the two movements (in-out) is 89,198.16 cm.

5.1 Discussion

Data processing reflects on the design of scenario 1 with the condition of no buffer area and scenario 2 with the condition of a buffer area. These differences are in the existence of a buffer area, the shape of the I/O door, a connecting door between the part area and the sack area, the location of user services, and the position of the dominant rack. These differences can be reviewed in detail in the proposed layout design in the Result and Discussion section. In addition to the differences in facilities, there are differences in the total travel distance between the existing and proposed layout. The following is the total travel distance data between layouts.

Table 8. Comparison of Travel Distance

No	Scenario	Travel Distance (Cm)
1.	Existing	113.605,18
2.	Scenario 1	66.466,12
3.	Scenario 2	89.198,16

Based on Table 8, there is a difference in travel distance between the existing layout and the proposed layout of scenario 1 and scenario 2. In the proposed scenario 1, the resulting design has a total travel distance of 66,466.12 cm, resulting in a travel distance reduction percentage of 41.497%. Meanwhile, in scenario 2, the design that produces a total travel distance in and out is 89,198.16 cm, resulting in a travel distance reduction percentage of 21.484%. The difference in travel distance between the proposed designs is caused by several factors, namely the position of the rack placement and the use of warehouse space area for storage, both with and without buffers. Then, in the proposed layout that is recommended for implementation, there are additional rules that function to optimize the proposed design. The following are additional rules for the proposed design of the two scenarios.

Table 9. Policy of Material Handling

No	Policy of Scenario 1	Policy of Scenario 2
1.	Users (operators) who enter and want to pick up goods in the spare parts area must report and be accompanied by a warehouse operator, even if they know where the goods, they want to pick up are stored.	Users (operators) who enter and want to pick up goods in the spare parts area must report and be accompanied by a warehouse operator, even if they know where the goods, they want to pick up are stored.
2.	Pallets in the spare parts area are only used as a base for parts or a temporary part transit area and may not be used to store sacks because the entire sack storage area is in the sack area (next to the spare parts area).	Pallets in the spare parts area are only used as a base for parts or a temporary part transit area and may not be used to store sacks because the entire sack storage area is in the sack area (next to the spare parts area).
3.	The placement of products, goods, or spare parts must be by the type of rack and recorded according to the name and specifications of the products/goods/spare parts to be stored.	The placement of products, goods, or spare parts must be by the type of rack and recorded according to the name and specifications of the products/goods/spare parts to be stored.
4.	-	The buffer area is intended for sacks, with a limit of 50 pallets or 500 sacks. In addition, the buffer area can also be used for the temporary storage of parts if the part pallet (centre pallet of the part area) can no longer be used (full).

Referring to Table 9, the rule difference between the two scenarios is in the fourth rule, where scenario 1 does not use a buffer, whereas scenario 2 places a buffer.

6. Conclusion

Based on the data processing conducted, this study found that the proposed layout design for scenario 1 has a total travel distance in and out of 66,466.12 cm with shelves arranged differently from the existing layout, namely vertically; it can have a significant effect on warehouse performance, which is 47,139.06 cm for the difference with the existing layout and produces a percentage reduction in travel distance of 41.497%. The proposed layout design based on scenario 2 has a total travel distance of 89,198.16 cm and makes a percentage reduction in travel distance of 21.484% compared to the existing layout. Furthermore, this study has the opportunity for further research development by investigating from the investment aspect or benefit-cost analysis.

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