Pallet Layout Design in Warehouse Using the Activity Relationship Chart (ARC): Case Study of PT Bimaruna Jaya

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Abstract—This study discusses the pallet layout design, specifically pallets in PT Bimaruna Jaya Warehouse, using the Activity Relationship Chart (ARC). This study aims to improve the warehouse's operational activities by determining the pallet layout. The data obtained were mapped out using the ARC to determine the optimal activity relationship in the warehouse. Three alternative layout solutions are generated through Blocplan Sofware based on three indicators: Adjacency score, R-score, and Rel-Dist score. The best alternative layout is alternative 3 because it has the largest Adjacency score of 0.57, the largest R-score value of 0.74, and the smallest Rel-Dist score value of 14,196. Implementing the new layout is expected to reduce the time needed to pick up goods and smoothen the flow of goods in the warehouse.

Keywords—Activity Relationship Chart (ARC): Material Handling: Pallet Layout: Warehouse.

I. INTRODUCTION

Considering the warehouse's operation, designing the warehouse is one alternative to increasing throughput and productivity by reducing the traveling distance, traveling time, and the determined locations while maximizing space utilization [1]. However, different storage types have different warehouse design problems. For example, the classic storage system has space requirements and throughput capacity. In contrast, a very compact storage system minimizes space, which requires reshuffling the storage system to reduce the throughput capacity [2]. Thus, a good warehouse layout will improve operational efficiency and overall performance. This can be achieved if all components in the warehouse are well organized and structured.

A portable platform known as a pallet plays a vital role in handling, storing, or moving goods during transportation and transit in the supply chain [3]. Pallets can be constructed using different materials, but they are most commonly made of wood and plastic [4]. Since pallets are closely related to warehouse operations, locating the pallet storage location close to the inbound and outbound locations of goods will make the operational process easier and faster.

PT Bimaruna Jaya is a logistics transportation company with four main business processes: container yard, warehouse, trucking, and forwarding. The problem occurs in the warehouse department, specifically in the Freezone warehouse. A Freezone warehouse is a storage facility specifically designated for storing imported goods without import duties or other taxes on the condition that the goods do not enter the country's domestic market. Freezone warehouses are usually located in declared free zones, i.e., ports or airports, as temporary stores of goods that will be further processed or imported to other countries.

The problem in the Freezone warehouse is the long handling time because the pallets required for handling goods are stored in various locations with no track record. The operators used to look for any available pallets and find empty locations to store pallets after using them. Moreover, unclear pallet locations took over the areas where customer goods were stored. Although the pallets are rented from a third party, no track record has caused higher rent costs to compromise many damaged and lost pallets. Thus, this study determines the pallet storage location to speed up the handling process in the warehouse area.

II. LITERATURE REVIEW

A. Warehouse

The warehouse is a vital component of any supply chain. Its primary responsibilities include adding value through value-added processing, such as kitting, pricing, labeling, and product customization; consolidating products from multiple suppliers for a single delivery to customers; and buffering the material flow along the supply chain to account for variability brought on by elements such as product seasonality and batching in production and transportation [5]. Thus, it can be concluded that the smooth handling of goods from supplier to customer in the supply chain can be achieved with the warehouse role.

B. Designing Facility Layout in Warehouse

Warehouse layout is the location placement determined based on the function of the location so that the warehouse can run effectively. The five stages to determine the appropriate layout for a warehouse are as follows [6]:
1. Determine the total space needed in the warehousing process.
2. Determine the flow of material.
3. Determine the location of each warehouse function based on proximity to each other.
4. Determine storage with high demand in an easily accessible location while storage with low demand is in the opposite area.
5. Expand the warehouse process.

In addition, several essential things need to be considered in warehouse design are as follows [6]:
1. Understanding the industry to be run.
2. Commodity goods managed.
3. The area of the existing warehouse.
4. Types of activities carried out in the warehouse.

5.   Non-operational facilities must be available.

C. Pallet Storage

Storage equipment is used to support finished products for a certain period. One of the tools to store and stack products is a pallet. A storage system using pallets is known as pallet storage. The following are pallet storage systems often used in warehouses [6]:

1. Block Stacking

Block stacking is a method of stacking blocks on the floor. It usually consists of two blocks based on the safe stacking limit according to policy.

2. Stacking Frame

A stacking frame is an alternative to using shelves. It consists of stacking frames with pallets on their bases and supports that make them easier to stack.

3. Single-deep Selective Pallet Rack

The single-deep selective pallet rack is often used in warehouses because they have more accessible and faster access than others. This rack has a FIFO (First In, First Out) storage system, so using this rack will be very profitable because the time spent will not be too long. However, this type of rack takes up a lot of space, making the warehouse utilization small.

4. Double-deep Rack

A double-deep or drive-in rack is a storage media with double racks to make storage larger. This rack has a LIFO (Last In, First Out) storage system. It tends to have a large capacity but can only be accessed from one side.

5. Drive-thru Rack

A drive-thru rack is a FIFO-type rack with a larger capacity. This rack works by storing pallets on racks that are assisted by a material handling tool in the form of a forklift. This type of rack has two accesses, from the front and back. However, this type of rack requires a reliable operator because it uses a forklift.

D. Material Handling

Material handling is an essential aspect of supply chain management. It is responsible for efficiently and safely moving goods from the point of origin to the end destination. It involves using various tools and technologies to facilitate transporting, storing, and managing goods in the company's warehouse or logistics facility [7]. Material handling includes moving goods and planning, controlling, and coordinating various related activities, such as selecting appropriate equipment, designing optimal layouts, and developing effective control and monitoring systems. Efficiency in material handling benefits by resulting in increased productivity, reduced operating costs, improved service quality, and increased customer satisfaction.

Various basic types of Material Handling Devices (MHD) are used in logistics operations. The seven basic types of Material Handling Devices (MHD) are [7]:

1. Forklift

A forklift is a device for lifting, loading, and unloading goods in a warehouse or storage area. It is generally used to transport pallets or large quantities of goods.

2. Conveyor

A conveyor is a mechanical system that continuously transports goods from one location to another. It is often used to move large quantities of goods quickly and efficiently.

3. Pallet Jack (Hand Pallet)

A pallet jack or hand pallet is a simple device to move pallets or goods placed on pallets. It is usually operated manually to move goods in a warehouse.

4. Automated Guided Vehicle (AGV)

An Automated Guided Vehicle (AGV) is used to move goods in a warehouse or logistics facility. The automatic navigation technology in AGV allows it to operate without an operator's assistance.

5. Moving Goods Robots

Moving goods robots are automated robots designed to move goods in a warehouse. These robots can be programmed to perform tasks such as picking, storing, and shipping quickly and accurately.

6. Automated Storage and Retrieval System (AS/RS)

AS/RS is an automated warehouse system that stores and retrieves goods automatically. It manages inventory using automated devices such as cranes or shuttles.

7. Lift Truck

A Lift Truck, often called an Order Picker, is a device that lifts warehouse operators to a certain height so they can retrieve goods from storage shelves or high storage areas.

E. Activity Relationship Chart (ARC)

The Activity Relationship Chart (ARC) is a simple and crucial tool for expressing decision-makers' preferences regarding the degree of departmental closeness in the facility's layout design. It depicts this relationship using color symbols and letters, as shown in Table I.

TABLE I. ARC Level of Importance

No.	Importance Level	Code	Colour
1	Absolutely necessary	A	Red
2	Especially important	E	Yellow
3	Important	I	Green
4	Ordinary	O	Blue
5	Unimportant	U	White
6	Closeness desire	X	Chocolate

In addition to the code described in Table I, a reason for using the code or color is also required. The most important thing is that the reason must follow the level of activity relationship described with the code in number, i.e., 1, 2, 3.

The letter codes A, E, I, and so on indicate how the activities of each department will have a direct or close relationship with each other. These letter codes will be placed at the top of the available box of the Activity Relationship Chart, and a unique color will be given to make it easier to analyze. Furthermore, the number codes 1, 2, 3, and so on are placed at the bottom of the existing box of the ARC chart to explain the reasons for choosing or determining the degree of relationship between each department. There are two ways to create an Activity Relationship Chart: creating an Activity Template Block Diagram (ATBD) and using combinations of lines and standardized color codes for each existing activity relationship.

III. METHODOLOGY

The study starts by identifying the problem in a warehouse through observation and interviews with the Freezone warehouse officers. After the issue has been identified, the literature review is conducted to enrich the knowledge related to the problem and find suitable methods to solve the problem. The next step is collecting the data. The data collected included storage capacity in the Freezone warehouse, the size of each storage area, and the detailed size of the Freezone warehouse. The data obtained will be processed to determine the number of pallet locations and the pallet layout. The layout is designed according to the capacity based on the degree of relationship between the frequency of pallet usage. After processing the data, the result will be analyzed, and improvement recommendations will be given to the company. The last step in this study is to conclude based on the results by answering the previously set objectives. Suggestions for future research are provided for the extension of this research.

IV. DATA PROCESSING AND ANALYSIS

A. Freezone Warehouse Layout Before Improvement

The overall layout of the Freezone warehouse before improvement is shown in Fig. 1.
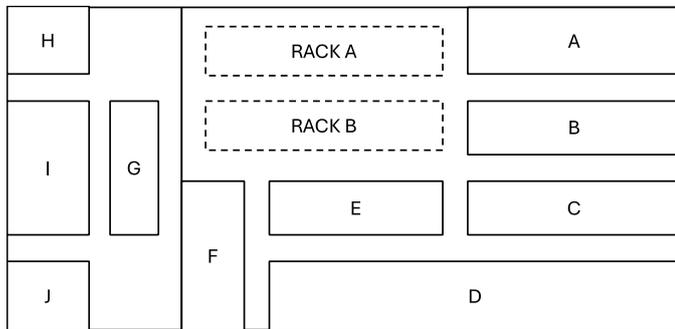

Fig. 1. The Overall Layout of The Freezone Warehouse

B. Design of Facility Area

PT Bimaruna Jaya's Freezone Warehouse area is 104 m x 50 m. This Freezone warehouse is classified into several places for storing goods. In this warehouse, two types of selective pallet racking cells have a size of 7 m x 40 m. The Freezone warehouse has 12 locations for storing goods, symbolized by the letters A, B, C, D, E, F, G, H, I, J, rack A, and rack B. In each of these classifications, there are already regular customers. The detailed information for locations in the Freezone warehouse and three different pallet types can be seen in Table II.

C. ARC and Blocplan of Freezone Warehouse

The activity relationship chart (ARC) is drawn based on the current warehouse layout and information on each location and pallet. The degree of relationship is determined using the information on the importance level in Table I. In addition, every reason given for the level of activity relationship between each item is translated into a numerical code, as shown in Table III.

TABLE II. Current Locations and Pallets in The Freezone Warehouse

No.	Item	Length (m)	Width (m)	Area (m²)
1	A	32.9	10.2	335.58
2	B	32.9	8.5	279.65
3	C	32.9	8.5	279.65
4	D	63.4	10.6	672.04
5	E	26.4	8.6	227.04
6	F	7	23.1	161.7
7	G	10	21	210
8	H	12.5	10.3	128.75
9	I	12.5	21	262.5
10	J	12.5	10.6	132.5
11	Rack A	7	40	280
12	Rack B	7	40	280
13	Pallet A	3.6	3	10.8
14	Pallet B	3.6	3	10.8
15	Pallet C	2.4	2	4.8
Total				3,275.81

TABLE III. Code and Reason Description

Code	Reason Description
1	Using the same records
2	Using the same workforce
3	Using the same space area
4	Level of relationship between workforce
5	Level of relationship between work files
6	Work file flow
7	Workflow sequence
8	Using the same equipment and facilities
9	Noise, odour, vibration, dust, dirt, etc.
10	Not in accordance with the workflow sequence

Thus, the complete Activity Relationship Chart (ARC) for the Freezone Warehouse is shown in Fig. 2.
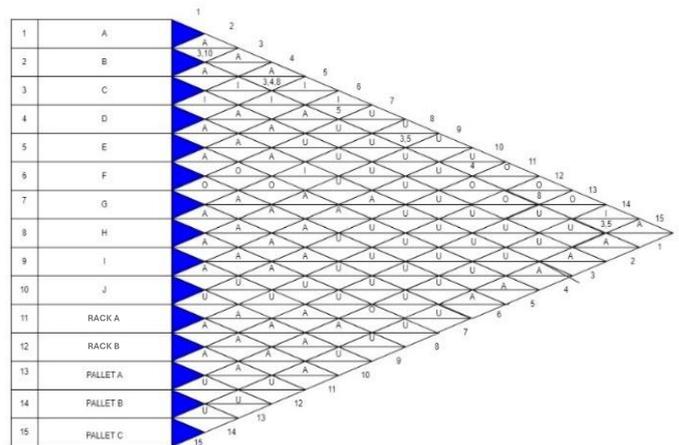

Fig. 2. ARC for Freezone Warehouse

Based on the ARC for Freezone Warehouse, alternative layouts are generated using Blocplan Software. There are three alternative layouts obtained as follows:

- Alternative 1
  Fig. 3 shows the alternative Freezone warehouse layout 1 obtained from the output of Blocplan Software. Alternative Layout 1 has an Adjacency score of 0.44, an R-score of 0.69, and a Rel-Dist score of 15,403.
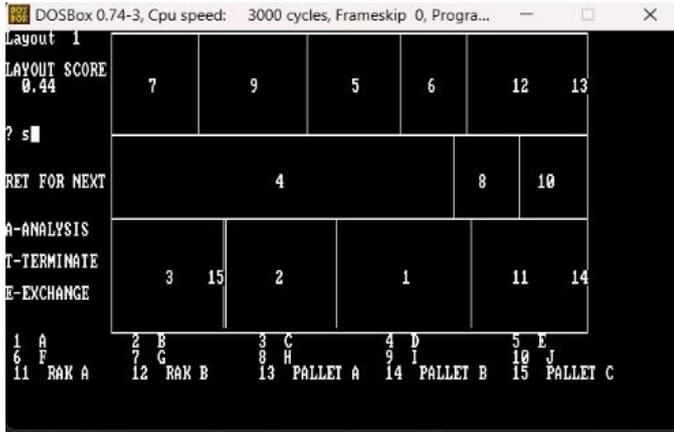
Fig. 3. Alternative 1 for Freezone Warehouse

- Alternative 2
  Fig. 4 shows the alternative Freezone warehouse layout 2 obtained from Blocplan Software's output. Alternative Layout 2 has an Adjacency score of 0.55, an R-score value of 0.62, and a Rel-Dist score of 14,961.
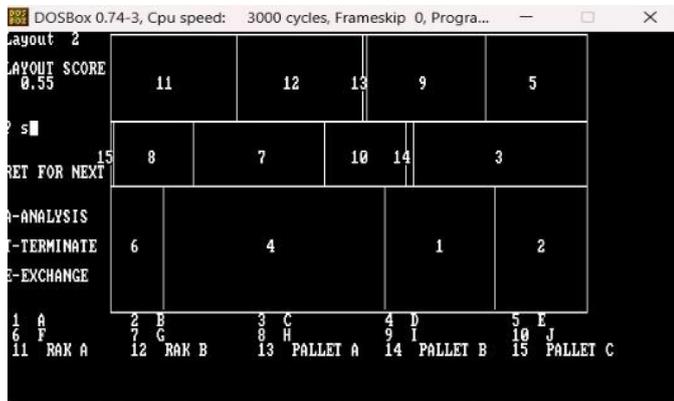

Fig. 4. Alternative 2 for Freezone Warehouse

- Alternative 3
  Fig. 5 shows the alternative Freezone warehouse layout 3 obtained from the output of Blocplan Software. Alternative Layout 3 has an Adjacency score of 0.57, an R-score of 0.74, and a Rel-Dist score of 14,196.
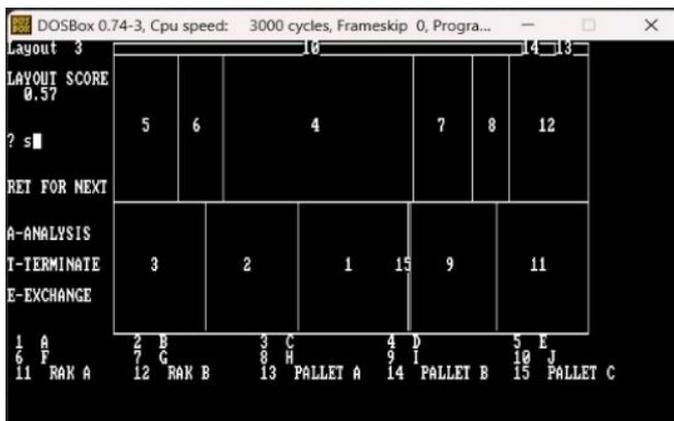

Fig. 5. Alternative 3 for Freezone Warehouse

D. Analysis

Blocplan Software's output provides three alternative layouts for the Freezone warehouse. The proposed layouts are evaluated based on the Adjacency score, R-score, and Rel-Dist score. The Adjacency score indicates the proximity between facilities. The R-score indicates layout efficiency. The Rel-Dist score indicates the total distance traveled by material.

The first step in determining the best layout alternative is to look at the largest R-score value. If the value is the same, look at the largest Adjacency score value. If the Adjacency score value is the same, continue by looking at the smallest Rel-Dist score value.

Unlike all layout alternatives, layout alternative 3 has the highest R-score value, 0.74. The higher the R-score value, the better the layout efficiency. Moreover, the R-score value is close to 1.0, indicating an optimal alternative layout. For other indicators, such as the Adjacency score, layout alternative 3 produces the highest score of 0.57. In addition, layout alternative 3 also has the lowest Rel-Dist score, with 14,196. This shows that layout alternative 3 is the best alternative to implement in the Freezone warehouse because it has the best score among the three indicators.

Fig. 6 shows the Freezone warehouse layout after improvement. Pallet A is best located beside Rack A. Pallet B is best suited between Rack B and the F area. The last pallet location, Pallet C, is determined between F and J.
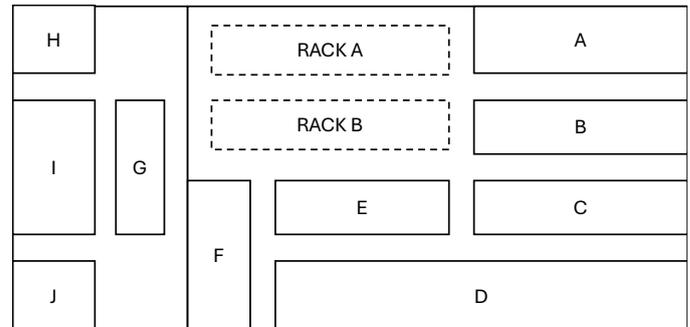

Fig. 6. The Freezone Warehouse Layout After Improvement

V. CONCLUSION

Determining the pallet location placement in the Freezone warehouse is vital for operational activities, specifically material handling processes. The methods for determining the pallet location in this study are creating the Activity Relationship Chart (ARC) based on a degree of proximity between locations in the Freezone warehouse and creating alternative Freezone warehouse layouts using Blocplan software based on three indicators, Adjacency score, R-score, and Rel-Dist score.

Three locations are allocated for pallet storage based on the Freezone warehouse's area and space availability. Two areas of 10.8 m^2 and one area of 4.8 m^2 are the options for pallet locations. The operator's space availability and ease of handling pallets determine these three locations.

According to the result of ARC and transferred to the Blocplan Software, three alternative layouts are produced. Those alternative layouts are evaluated based on three

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indicators: the Adjacency score, the R-score, and the Rel-Dist score. Among three alternative layouts, alternative layout 3 is the best solution generated from the Blocplan Software because it has the highest Adjacency score value, the highest R-score value, and the lowest Rel-Dist score value. The best-suited locations for three types of pallets are as follows: Pallet A is best located beside Rack A, Pallet B is between Rack B and the F area, and Pallet C is between F and J.

The solution proposed in this study could give the company insight into designing a warehouse layout that should include customer goods and areas for material handling tools. This study could boost operational activities because determining the specific pallet locations in the warehouse can reduce the traveling distance. Moreover, defining areas for pallets will help with the traceability of the pallets throughout the warehouse's operational activities.

This study can be extended to future research that has not been covered. Future research could consider several factors, such as the total number of pallets required for each location, specific areas for storing damaged pallets, and customer demand patterns. Implementing a simulation method to discover the best solution for determining the pallet location could also provide a comprehensive solution. It can also be analyzed whether the current customer goods locations should be changed to allocate the pallets in the warehouse.

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