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Manufacturing Facility Design

Redesign of Material Storage Warehouse Layout Using Shared Storage Method (Case Study: Chemical Warehouse)

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ABSTRACT

The research was conducted in a material storage warehouse where some items were placed outside the warehouse due to space limitations. Storing items outside the warehouse can lead to a decline in product quality and financial losses. Therefore, this study aims to redesign the warehouse layout using Shared Storage method to optimize storage capacity. By analyzing storage needs and capacity, this research seeks to develop a new layout to enhance warehouse storage capacity. This study employs a quantitative approach, collecting data on material demand frequency, the existing warehouse layout, and the number of materials. Calculations were performed to determine the required aisle width and the total storage area needed for each type of material, considering forklift usage and pallet dimensions. The research findings indicate that the proposed warehouse layout increases storage capacity from 810 pallets to 1,298 pallets, representing a 60.25% increase. This improvement not only addresses space constraints but also contributes to better product management. The study provides practical implications for warehouse managers looking to implement space-saving strategies and improve operational efficiency. The Shared Storage method has proven to be a viable solution for warehouses facing similar challenges in maximizing storage space.

1. INTRODUCTION

The warehouse has a central role in the supply chain, serving as a temporary storage point for goods before they are distributed to consumers. Warehouses not only function as a storage place, but also as a regulator of the flow of goods that ensures product availability in accordance with market demand [1]. Thus, warehouse operational efficiency greatly affects customer satisfaction and business continuity.

Warehouse management is inseparable from various challenges. One of the main challenges is the limited space which is often an obstacle in storing things. In addition, unexpected fluctuations in demand can cause difficulties in inventory planning [2]. The rapid growth of the business also adds complexity in warehouse management, where companies must be able to adapt quickly to changing needs and volumes of goods that must be stored.

One of the common problems in warehouse management is a condition where the number of goods that must be stored exceeds the capacity of the available storage space. This can lead to the accumulation of goods, difficulties in retrieving goods, and an increased risk of damage to goods [3]. This is what happened to the warehouse owned by PT XYZ which is a distributor of chemical materials. At this time there is a problem where some goods are placed outside the warehouse. Based on MSDS (Material Safety Data Sheet) data of all goods, goods must be stored at a moderate temperature in a dry place with good ventilation. Items placed outside the warehouse can be exposed to excessive heat and rain. This can result in a decrease in the quality of goods. A decline in the quality of goods will cause several problems, ranging from loss of customer trust to financial losses because goods that do not meet quality standards cannot be sold, thereby reducing the company's revenue [4].

Based on the observation results, the overall area of PT XYZ's warehouse is 1,246 meters with a storage space of 570 square meters that can accommodate 810 pallets. The form of storage in a warehouse is by placing goods on pallets with dimensions of 1.2 meters x 1.2 meters. The transfer of goods is carried out using a forklift with a capacity of 3 tons. The process of picking up goods uses the FIFO (First In, First Out) principle by prioritizing first-time goods to go out first. Meanwhile, the process of determining the location of the placement of goods is carried out randomly.

Therefore, the company is working to redesign the warehouse layout to make better use of the available space, including optimizing the placement of frequently accessed goods to reduce congestion.

One of the solutions to solve this problem is to optimize the use of the existing area in the warehouse by designing an efficient storage layout model. One of the methods that can be used is the Shared Storage method. This method allows several items to be stored in the same storage area, so that the use of space can be more efficient [5]. With the Shared Storage method, warehouse management can optimize existing capacity and organize goods according to needs without requiring significant physical space additions.

So based on this background, the title of the research raised in this study is the redesign of the layout of the material storage warehouse using the Shared Storage method.

2. LITERATURE REVIEW

2.1. *Basic Theory*

2.1.1. The Role of Warehouses in Supporting Logistics Activities

A warehouse is a place used to store goods that will be used in the production, distribution, or sales process [6]. A warehouse can be a building, a room, or an area specifically designed to store items. The mission of a warehouse is to effectively deliver products to the next step in the supply chain without damaging or changing the basic shape of the product. If the warehouse is unable to process orders quickly, effectively, and accurately, then the company's supply chain optimization efforts will be disrupted [7].

The 3 basic functions of a warehouse are:

1) Storing finished products safely
2) Maintain stock of every product sold by the company
3) Preparing customer orders for shipment

2.1.2. Warehouse Layout

Warehouse layout is a system designed to manage the storage space of goods in the warehouse [8]. An effective warehouse layout can improve space use efficiency, reduce operational costs, and increase productivity.

The objectives of layout planning for storage or warehouse parts are as follows [9]:

1) Increase the effectiveness of warehouse space use
2) Ensuring efficiency in material handling
3) Minimizing storage costs while meeting the specified level of service
4) Provides maximum flexibility
5) Provides a good setup for activities in the warehouse

2.2. *Metode Shared Storage*

The Shared Storage method is one of the approaches in managing storage space in warehouses that aims to increase the efficiency of space use and simplify the process of picking goods. This method allows multiple types of items to be stored in the same storage area, thus reducing the need for separate spaces for each type of item [10]. Variables that need to be understood in the Shared Storage method include:

1) The duration of the goods is in the warehouse
2) Delivery time for each product
3) The number of products in each order
4) The frequency of demand in each period
5) The distance between each storage area and doorways
6) Space requirements

Based on the variables of the Shared Storage method above, in the process of preparing the warehouse layout there are several stages, namely:

1) Calculation of warehouse area capacity
   At this stage, an analysis of the capacity of the available warehouse area is carried out. This includes the calculation of the length of the work in process (WIP) time, delivery time, and the number of products to be stored. This data is important to determine how much space is needed to store items and how efficient the pick-up process can be.
2) Product classification based on customer
   Products are grouped based on customer needs and preferences. This classification helps in determining the optimal storage location, so that products that are frequently needed by a particular customer can be accessed more quickly.
3) Calculation of area requirements for each item
4) Determining the moving order for each area
5) Determination of the layout

3. METHODOLOGY

This research was conducted at PT XYZ in June – November 2024. Some of the stages of activities carried out to design a storage warehouse facility layout model are explained as follows:

1) Field studies
2) Studi literature
3) Alternative solutions
4) Data collection
5) Data processing
6) Data analysis
7) Discussion
8) Conclusions and suggestions

3.1. *Data Collection Techniques*

The data in this study was collected with:

1) Observation
   Observing the conditions and activities in the warehouse.
2) Literature studies
   Using references from books, scientific journals, previous research, or other academic sources with the aim of understanding theories, methods, and best practices in warehouse management.

3) Direct measurement
   Perform direct measurements.
4) Warehouse documentation
   Collect written data or records that are already available or created by the company.

3.2. *Data Analysis Techniques*

The data analysis technique in this study uses a quantitative approach. The data analysis technique in this study was carried out in 2 ways, including:

1) Descriptive analysis
   Aims to describe the data in an easy-to-understand way.
2) Comparative analysis
   To compare the initial and final data on the proposed layout model using the Shared Storage method.

The following are the steps used in the quantitative data processing process in this study:

1) Storage area calculation
   Calculate the area of storage area used before and after designing a new warehouse layout design.

$$\text{Storage area} = \text{Number of pallets x 1 pallet area} \quad (1)$$

2) Storage capacity calculation
   Measures the capacity of the warehouse in a unit of goods, including the increase in capacity achieved after the redesign. The measurement of total storage capacity can be done based on the number of pallets and the height of the stack.

$$\text{Total storage capacity} = \text{Number of pallets x Height of the stack} \quad (2)$$

3) Layout efficiency calculation
   To calculate storage efficiency, a basic formula is used that measures the number of storage slots per square meter of storage space. This efficiency is calculated by the formula:

$$\text{Efficiency (\%)} = \frac{\text{Storage capacity}}{\text{The area of storage space}} \text{ x } 100\% \quad (3)$$

   This formula is used to compare the number of storage slots with the area of space used. The higher the efficiency value, the more optimal the use of space in storing slots.
4) Calculation of storage capacity increase
   Determine how much the storage capacity increases after the implementation of the new layout.

$$\text{Increased capacity(\%)} = \frac{\text{New capacity} - \text{Initial capacity}}{\text{Initial capacity}} \textbf{ x 100}\% \quad (4)$$

4. RESULTS AND DISCUSSION

4.1. *Initial Warehouse Data*

Based on the results of observations, the total warehouse area of PT XYZ is 1,246 square meters, with a storage area of 570 square meters. Storage of goods is carried out by placing goods on pallets measuring 1.2 meters x 1.2 meters, pallets are stacked into 2 or 3 levels of stacks. The location of the storage is done randomly. A total of 570 meters of warehouse area is used as a storage room that has a storage capacity of 810 pallets. Here is the initial layout capacity table:

Table 1. Initial layout capacity

Storage Area	Length x Width (m)	Area (m^2)	Storage Capacity (Pallet)
Area A	3 x 5	15	20
Area B	17 x 5	85	144
Area C	18 x 5	90	124
Area D	38 x 5	190	262
Area E	4 x 5	20	26
Area F	5 x 5	25	34
Area G	29 x 5	145	200
Total		570	810

(Source: PT XYZ)

Based on the table below, it is known that the number of goods is 1,296 pallets, while the storage capacity of the warehouse is only 810 pallets, so as many as 486 pallets of goods are placed outside the warehouse.

Table 2. Number of materials in November 2024

Material Type	Number of Materials (Unit)	Storage Type	Capacity per pallet (Unit)	Number of pallets
Material PAC	5,200	Pallet 1,2 x 1,2	40	130
Material HCL	14	Pallet 1,2 x 1,2	1	14
Material SH	32	Pallet 1,2 x 1,2	1	32
Material SA	116	Pallet 1,2 x 1,2	1	116
Material CH	264	Pallet 1,2 x 1,2	1	264
Material CC	740	Pallet 1,2 x 1,2	1	740
Total				1,296

(Source: PT XYZ)

4.2. *Implementation of the Shared Storage Method*

4.2.1. Calculation of Space Requirements and Storage Capacity

Table 3. Space requirements

Material Type	Number of pallets	Pallet capacity per slot (2 levels)	Number of slots required
Material PAC	130	2	65
Material PAC	14	2	7
Material SH	32	2	16
Material SA	116	2	58
Material CH	264	2	132
Material CC	740	2	370
Total			648

(Source: PT XYZ)

The data on the storage space needs of the materials are listed in Table 3. Each type of material has different characteristics, including the number of pallets and pallet capacity per slot (2 levels). The total number of slots needed is calculated by dividing the number of pallets by the pallet capacity per slot. The result is a total of 648 slots needed to store all materials safely and efficiently.

The storage space requirement is calculated based on the base area required for each slot. With the standard size of a wooden pallet being 1.2 meters x 1.2 meters, the base area of one storage slot is calculated as follows:

Base area per pallet = 1.2 m x 1.2 m = 1.44 m^2

Figure 1. Wooden Pallets

Since one storage slot holds two pallets vertically, the base area used remains at 1.44 m^2 per slot. The total storage space requirement is calculated by multiplying the number of slots by the base area per slot:

Total storage area = 648 x 1.44 m^2 = 933.12 m^2

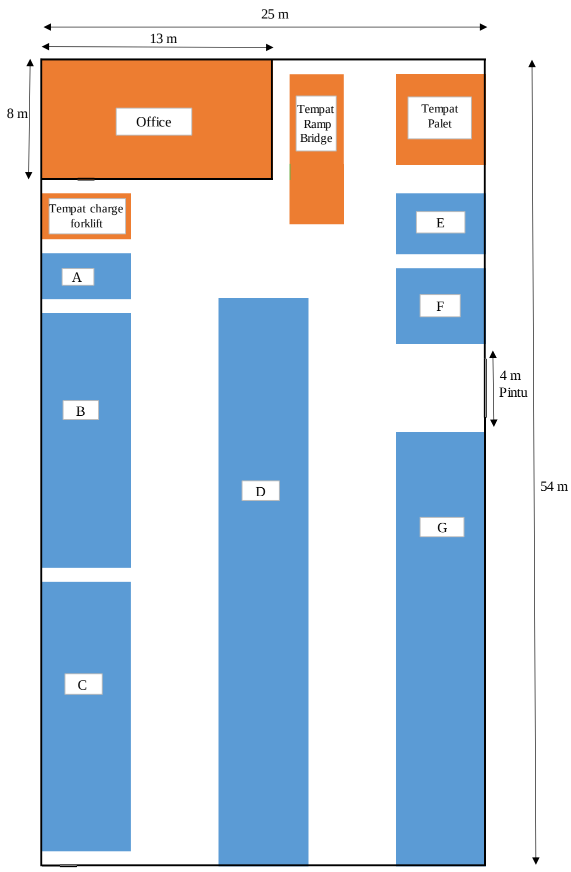

Figure 2. Initial layout design

4.2.2. *Calculation of the Required Aisle Width*

The width of the aisle is the space required for the forklift to move freely and perform maneuvers, such as transporting and moving pallets within the warehouse. The width of the aisle is influenced by several important factors, including the size of the forklift, the size of the pallet, and the need for space for the forklift turnover. To perform this calculation, some of the data used are as follows:

- Forklift with a width of 1.23 meters, and a turning radius (minimum turning angle) of 2 meters.
- Wooden pallets with a standard size of 1.2 meters x 1.2 meters used to store goods in the warehouse.

To determine the minimum width of the aisle, the following formula is used:

Aisle width = Forklift width + Swivel radius + Pallet width

Aisle width = 1.23 m + 2 m + 1.2 m

Aisle width = 4.43 m

So, the minimum aisle width required for the forklift to move and rotate freely is 4.43 meters.

4.2.3. *Determination of Location of Goods*

The determination of the location of the placement of goods aims to optimize the warehouse layout so as to speed up the process of picking up goods, reduce operating time, and increase the efficiency of the use of storage space. The method used in the placement of goods in this study is classification based on popularity (fast-moving and slow-moving). Goods are grouped based on their total frequency of demand as calculated in Table 4.

Table 4. Frequency of demand

Material Type	Frequency of demand					Total
	Jul	Aug	Sept	Oct	Nov	
Material CH	3	11	10	7	6	37
Material CC	3	8	7	7	8	33
Material PAC	2	7	7	5	1	22
Material SA	2	3	5	3	5	18
Material SH	0	5	0	2	3	10
Material HCL	1	4	0	1	1	7

(Source: PT XYZ)

Based on this analysis, the goods with the highest demand get priority to be placed in strategic locations. The results of the classification based on total demand are as follows:

a) Fast-Moving:
   - Material CH (37 demand)
   - Material CC (33 demand)
   - Material PAC (22 demand)

b) Slow-Moving:
   - Material SA (15 demand)
   - Material SH (10 demand)
   - Material HCL (7 demand)

Based on the above classification, the placement of goods is designed on the principle of zone storage, where goods with a high level of demand are placed in a zone closer to the door, while goods with a low level of demand are placed in a more distant zone.

4.2.4. *Designing a New Layout Proposal*

This warehouse layout is designed to optimize storage and operational efficiency based on data on the frequency of demand for goods. With dimensions of 25 m x 54 m, the storage area is adapted for each type of material. The calculation of storage slots is obtained by dividing the available storage area by the area per slot:

$$\text{Number of slots} = \frac{\text{Width x length of material storage}}{\text{Area per slot}} \quad (5)$$

- Material CH (Green)

$$\text{Area CH 1} = \frac{5.5 \text{ m x } 8.5 \text{ m}}{1.44 \text{ m}^2} = 32.46 \approx 32 \text{ Slots}$$

$$\text{Area CH 2} = \frac{29 \text{ m x } 5 \text{ m}}{1.44 \text{ m}^2} = 100.69 \approx 100 \text{ Slots}$$

- Material CC (Blue)

$$\text{Area CC 1} = \frac{37.5 \text{ m x } 10 \text{ m}}{1.44 \text{ m}^2} = 260 \text{ Slots}$$

$$\text{Area CC 2} = \frac{29 \text{ m x } 5.5 \text{ m}}{1.44 \text{ m}^2} = 110 \text{ Slots}$$

- Material PAC (Yellow)

$$\text{Area PAC} = \frac{19 \text{ m x } 5 \text{ m}}{1.44 \text{ m}^2} = 65.97 \approx 65 \text{ Slots}$$

- Material SA (Red)

$$\text{Area SA} = \frac{12 \text{ m x } 7 \text{ m}}{1.44 \text{ m}^2} = 58.3 \approx 58 \text{ Slots}$$

- Material SH (Dark Blue)

$$\text{Area SH} = \frac{4 \text{ m x } 6 \text{ m}}{1.44 \text{ m}^2} = 16.66 \approx 16 \text{ Slots}$$

- Material HCL (Purple)

$$\text{Area HCL} = \frac{4 \text{ m x } 3 \text{ m}}{1.44\text{m}^2} = 8.33 \approx 8 \text{ Slots}$$

The following is a proposed new layout design with the Shared Storage method:

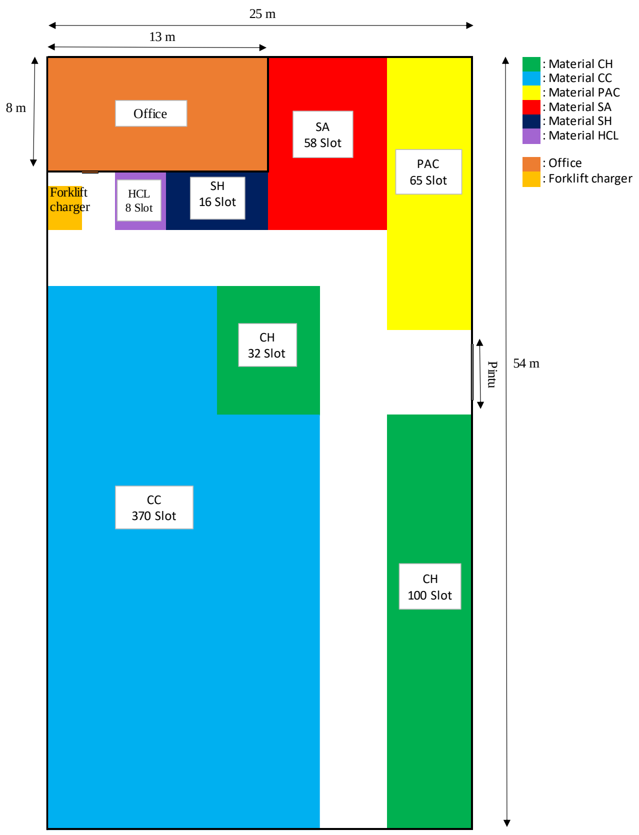

Figure 3. Proposed New Layout Design

Table 5. Size and capacity of new layout design

Storage Area	Length (m)	Width (m)	Area (m^2)	Number of storage slots (1.44 m^2 / slot)	Storage capacity (Units)
CH 1	5.5	8.5	46.75	32	64
CH 2	29	5	145	100	200
CC	37.5	10	375	260	520
	29	5.5	159.5	110	220
PAC	19	5	95	65	130
SA	12	7	84	58	116
SH	4	6	24	16	32
HCL	4	3	12	8	16
Total			603.75	649	1,298

4.3. *Discussion*

4.3.1. *Capacity Comparison*

The total storage capacity is calculated based on the total number of pallets that can be accommodated in the entire slots. By calculating the number of pallets that can be stored in all slots, companies can find out the maximum capacity of the warehouse to store goods. Here is the calculation of the total storage capacity:

Total Initial Layout Storage Capacity

$$= 20 + 144 + 386 + 26 + 34 + 200$$
$$= 810 \text{ Pallets}$$

Total New Layout Storage Capacity

$$= 740 + 64 + 200 + 130 + 116 + 32 + 16 = 1{,}298 \text{ Pallets}$$

Table 6. Comparison table

Layout	Storage space (m2)	Storage capacity (slots)	Storage Capacity (pallet)
Initial layout	570	405	810
New layout design	603.75	649	1,298

The storage capacity on the initial layout was 810 pallets, while on the new layout it increased to 1,298 pallets. There was a 60.25% increase in capacity, which shows that the proposed new layout design is more efficient in utilizing space, allowing for the storage of more pallets than the previous layout. The following is the calculation of the capacity increase:

Increased Capacity (%)

$$= \frac{\text{New Layout Capacity} - \text{Initial Layout Capacity}}{\text{Initial Layout Capacity}} \text{x}100\%$$

$$= \frac{1298 - 810}{810} \text{x}100\% = 60.25\%$$

4.3.2. *Efficiency Level Comparison*

Storage efficiency is calculated by comparing the slot capacity with the area of storage space. In the initial layout, the storage efficiency is 0.7105 slots/m², while in the new layout, the efficiency increases to 1.0751 slots/m². This increase in efficiency is 51.31%. This means that the new layout allows for more storage slots per square meter of warehouse space. Here are the calculations:

$$\text{Initial layout efficiency} = \frac{\text{Initial Layout Slot Capacity}}{\text{Initial layout storage space}} = \frac{405}{570}$$
$$= 0.7105 \left(\frac{\text{slot}}{\text{m}^2}\right)$$
$$\text{New layout efficiency} = \frac{\text{New Layout Slot Capacity}}{\text{New layout storage space}} = \frac{649}{603.75}$$
$$= 1.0751 \left(\frac{\text{slot}}{\text{m}^2}\right)$$

5. CONCLUSION

Based on the results of research and analysis of warehouse layouts that have been carried out, it can be concluded that there has been an increase in storage capacity in the new warehouse layout model. The calculation results show that the new layout proposal has succeeded in increasing storage capacity. The area of the new layout (Figure 3) reaches 603.75 m^2 which is able to accommodate as many as 649 slots. This number is up from the original 405 slots in the initial layout. The increase in pallet storage capacity was also significant, from 810 pallets to 1,298 pallets, indicating that the methods applied were effective in maximizing storage space.

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