Enhancing Storage Efficiency: Class-Based Warehouse Layout Design of Indonesian Manufacturing Company

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Abstract

PT XYZ, a service firm focused on marine and offshore projects, encountered inefficient warehouse storage and the lack of an item code system. This made it harder to find and store items. The purpose of this study is to create a more efficient warehouse plan by utilizing the class-based storage strategy. The ABC analysis was used to classify 45 different sorts of items as fast, medium, or slow moving. The results revealed that this strategy boosted warehouse utility by 15.87%, reduced material movement distance by 19,586 meters, and saved cost by Rp49,454,650. Furthermore, picking and arranging things became more efficient, increasing by 0.38% and 0.22%, respectively.

Keywords: Storage Layout, Class-Based Storage, Storage of Goods, ABC Class

1. Introduction

The logistics sector includes transportation and warehousing. Various aspects help run an industry. One of them is storage, which has an important function to keep the production process running smoothly. This contributes to ensuring products reach customers in a timely and cost-effective manner in the process from production to delivery. Warehouse layout is a factor that affects the efficiency and effectiveness of the warehouse. The design of the warehouse layout will contribute to improving the efficiency of the company's production and business activities. Stored goods range from raw materials, semi-finished materials, spare parts, as well as finished materials [1].

PT. XYZ was founded in 2016 and is based at Komplek Bintang Industrial Park II, Tj. Uncang, Batam City. The company specializes in turnkey installation accommodation, and HVAC ducting for the marine and oil gas industries. A good warehouse layout improves both operational efficiency and worker safety. Given the complexity of its projects, improving warehouse layout can be the key to increasing competitiveness and ensuring the company's operational continuity.

Based on direct observation at PT. XYZ warehouse in **Figure 1**, the problem discovered is that the lack of item codes leads things to be kept inefficiently. This situation hinders the process of recognizing and arranging products, resulting in a reduction in warehouse operational productivity. Furthermore, certain things, such as helmets and bags, should not be kept in the warehouse since they interfere with space efficiency and the accessibility of necessary instruments.

Figure 1. Inefficient Storage

Helmets are regarded a burden in the warehouse since they take up space that could be used to store more vital or related work equipment. Storage of equipment required for warehouse operations should be prioritized, especially if warehouse capacity is restricted. Nitrogen storage must meet the practicality and safety standards for chemicals or other hazardous gases.

Figure 2. Disorganization in Storage

Another issue that develops at the warehouse of PT. XYZ in **Figure 2** is the inefficient storage system. In this circumstance, commodities are placed haphazardly in empty spaces without concern for grouping or the frequency of incoming and outgoing goods, which might reduce the company's operational efficiency. This makes the process of arranging products irregular, resulting in warehouse capacity that cannot be properly utilized and may diminish warehouse capacity [2].

In warehouse management, the choice of storage solutions is critical for optimizing space, improving storage efficiency, and ensuring simple access to goods. The goal of this study is to optimize storage capacity and compare the efficiency of the architecture before and after improvements. Hopefully, the results of this study can make a significant contribution to increasing the efficiency of storing items in the warehouse.

2. Literature Review

A warehouse is defined as a place to store various products with various storage units, both on a large and small scale, along with the stages of production in the factory and demand from consumers. The warehouse has an important role as a storage facility for various goods, including raw materials that will be processed into finished products that are ready to be marketed [3].

Storage space strategic layout planning aims to ensure the consistent smooth running of the production process. The purpose of this layout design is to manage the work area and all production facilities in an optimized way by considering the material budget and other budgets related to storage space so that the production process runs efficiently [4].

The class-based storage system groups goods according to specific classes or categories, such as demand level, frequency of collection, or physical qualities. Items in great demand are placed in more convenient areas. The advantage of this strategy is that it increases picking efficiency by placing frequently picked objects in more accessible spots. However, the application of this system necessitates extensive study to establish the classification of products and their storage locations.

In designing warehouse layouts, distance measures play an important role in optimizing operational efficiency and minimizing the time and cost required to pick, store, and move goods. Distance measurements used to design warehouse layouts are rectilinear, euclidean, and squared euclidean distance measurements [5]. Rectilinear distance is the distance between two points that can be measured through the use of lines perpendicular to one another and measured along a trajectory $d_{ij} = |x - a| + |y - b|$. (1)

The application of the class-based storage method can reduce storage time by considering when products will enter and exit the warehouse [6].

3. Research Methods

This descriptive qualitative research method involves data collection, analysis, and interpretation using the class-based storage method. ABC categorization is a mechanism for grouping objects based on their relevance in warehouse operations and reducing the time spent accessing them. ABC classification classifies commodities into three major categories: A, B, and C.

Data collection techniques carried out in research at PT. XYZ can be done with various methods. Observation is done by direct observation to understand the actual conditions that occur in the company. Observations are made to evaluate the effectiveness of the current warehouse layout, identify problems that arise, and understand the workflow and methods of placing goods.

The information collected is used to develop recommendations for designing warehouse layouts to make them more efficient and organized. Interviews were conducted by communicating directly with informants related to the object of this research including Storeman, Foreman, and warehouse operational workers related to the goods storage system, the process of entering and exiting goods, the movement of goods, the causes of goods damage, and other aspects relevant to the research. By combining information from various sources, this research can develop more suitable recommendations to improve the efficiency of goods storage in the warehouse. Documentation acts as an addition or complement to the interview and observation methods because it is considered evidence that supports the results of the research.

To understand the efficiency of storing goods with the Class-Based Storage approach in-depth, careful and systematic data analysis is needed. The workflow of the Class-Based Storage method can be seen in Figure 3 below.

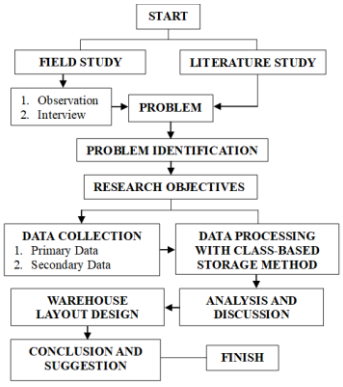

Figure 3. Research Flow Chart

The processes of data processing utilizing the class-based storage technique are as follows:

1. Calculation of Space Requirement

$$SR = \frac{\text{Maximum Storage Quantity}}{\text{Storage Capacity}} \quad (2)$$

2. Throughput Calculation

$$\text{Throughput} = \frac{\text{Frequency of Entry and Exit of Goods per Type of Goods}}{\text{Total Frequency of Entry and Exit of All Goods}} \quad (3)$$

3. Aisle Area

$$\text{Aisle Area} = \sqrt{(\text{Length})^2 + (\text{Width})^2} \quad (4)$$

4. Formation of Goods Category
5. Calculation of Product Placement

Assignment = T/S (5)

6. Calculation of Moving Distance

$$\text{Moving Distance} = |X1 - X2| + |Y1 - Y2| \quad (6)$$

7. Warehouse Utility Calculation

$$\text{Warehouse Utility} = \frac{\text{Utilized Space } (m^2)}{\text{Available Space } (m^2)} \times 100\% \quad (7)$$

8. Warehouse Layout Design

(**Source:** Ifa Saidatuningtyas, 2021)

4. Results and Discussion

Types of Goods

PT. XYZ maintains a well-organized goods management system. The organization divides inventories into two categories: raw materials and work tools.

Table 1. Raw Material Data

No	Raw Material
1	3/4" Mild Steel Bolt
2	Aluminum Foil Tape 2" x 48mm
3	No. 11 Welding Glass
4	Concrete Nails 2"
5	Welding Cable 200a
6	PVC Pipe 4"
7	PVC Elbow 45° 2"
8	Silicone Sealant
9	Thinner Kangaroo 3.5L
10	Super Best 3.5mm SS Drill Bit
11	Blind Rivet Kledy 1/8" x 5/8"
12	Cutting Disc 4" WD
13	Welding Wire RB-26 2.6mm
14	Ceiling Screw 6 x 5/8"
15	Grinding Eye End Brush 3"

The following is data on raw materials used by PT XYZ, including items such as 3/4" mild steel bolts, 2" x 48mm aluminum foil tape, No. 11 welding glass, and various others that include welding cables, PVC pipes, and solvent materials. Each item is identified with clear specifications to ensure efficient stock management. With detailed grouping and strategic placement, PT. XYZ can ensure that each raw material is easily accessible when needed, thus improving operational efficiency in the production process.

Table 2. Work Tool Data

No.	Work Tool
1	Heat Gun / Pipe Welding
2	Yamato Cutting Torch
3	F Claimp 10"
4	Scissors
5	Hammer
6	Ring Wrench
7	Spana Wrench
8	Wrench
9	5m meter
10	Screwdriver
11	Tubing Cutter
12	M10 Rivet Pliers
13	Black Big Elbow
14	Crocodile Pliers
15	M10 Press Pliers
16	5ft Ladder
17	I Meite Nail Gun 7116BL
18	Water Pass
19	Bosch Drill
20	Makita Baby Grinder
21	Circular Saw
22	Hacksaw
23	Tolsen Seated Drilling Machine
24	Fixtec Sandpaper Machine
25	Fujiyama Welding Travo
26	Jig Saw
27	Cutting Pliers
28	Electric Solder
29	Ampere Pliers
30	500A Welding Stang

PT XYZ also has a diverse and well-organized category of work tools, covering a wide range of essential tools for the production process. Some of the tools recorded include Heat Gun/Pipe Welding, Yamato Cutting Torch, various types of clamps and cutters, and tools such as hammers, ring wrenches, wrenches, and screwdrivers. In addition, other specific tools such as tubing cutters, various types of pliers, drilling machines, and gauges are also listed. The grouping and storage of these work tools is done neatly and efficiently, allowing quick and easy access by workers, which contributes to smooth operations and increased productivity at PT XYZ.

Storage and Dispensing System

Commodities are stored on storage racks by type, and work tools are placed in appropriate locations such as shelves, pallets, or directly on the warehouse floor. The goods dispensing system collects things in the loading area and has warehouse personnel double-check them. Following verification, the goods are loaded onto delivery vehicles and transported to the appointed project sites.

Material Handling

The most significant material handling tools at PT XYZ are hand pallets and trolleys. Hand pallets are used to lift and transport pallets of items, saving time and lowering the danger of harm. Trolleys, with their wheeled platforms and ergonomic handles, make it simple to transport objects of varied sizes and weights while increasing operating efficiency. These two instruments are critical to PT XYZ's operations because they improve job efficiency, reduce the risk of injury, and maximize production.

Goods Request Data

To optimize inventory and supply chain management, PT. XYZ collected thorough data on product demand from January 2023 to March 2024.

Table 3. Raw Material Demand Data

No	Raw Material	Goods Demand Data (Jan 2023 - Mar 2024)	Average Demand (Jan 2023 - Mar 2024)
1	3/4" Mild Steel Bolt	3.750	250
2	Aluminum Foil Tape 2" x 48mm	556	37
3	No. 11 Welding Glass	78	5
4	Concrete Nails 2"	2.740	183
5	Welding Cable 200a	75	5
6	PVC Pipe 4"	790	53
7	PVC Elbow 45° 2"	483	32
8	Silicone Sealant	412	27
9	Thinner Kangaroo 3.5L	249	17
10	Super Best 3.5mm SS Drill Bit	4.450	297
11	Blind Rivet Kledy 1/8" x 5/8"	13.050	870
12	Cutting Disc 4" WD	1.315	88
13	Welding Wire RB-26 2.6mm	3.822	255
14	Ceiling Screw 6 x 5/8"	3.600	240
15	Grinding Eye End Brush 3"	2.274	152

The raw material item Blind Rivet Kledy 1/8” x 5/8” is the most frequently requested raw material with a total demand of 13.050 units during the period. In contrast, Welding Glass No. 11 is the item with the lowest frequency of demand, only 78 units over 15 months.

Table 4. Work Tool Demand Data

No	Work Tool	Goods Demand Data (Jan 2023 - Mar 2024)	Average Demand (Jan 2023 - Mar 2024)
1	Heat Gun / Pipe Welding	36	2,40
2	Yamato Cutting Torch	31	2,07
3	F Claimp 10"	17	1,13
4	Scissors	158	10,53
5	Hammer	41	2,73
6	Ring Wrench	90	6,00
7	Spana Wrench	36	2,40
8	Wrench	33	2,20
9	5m meter	444	29,60
10	Screwdriver	59	3,93
11	Tubing Cutter	26	1,73
12	M10 Rivet Pliers	23	1,53
13	Black Big Elbow	235	15,67
14	Crocodile Pliers	39	2,60
15	M10 Press Pliers	11	0,73
16	5ft Ladder	31	2,07
17	I Meite Nail Gun 7116BL	11	0,73
18	Water Pass	43	2,87
19	Bosch Drill	16	1,07
20	Makita Baby Grinder	8	0,53
21	Circular Saw	7	0,47
22	Hacksaw	26	1,73
23	Tolsen Seated Drilling Machine	1	0,07
24	Fixtec Sandpaper Machine	6	0,40
25	Fujiyama Welding Travo	6	0,40
26	Jig Saw	7	0,47
27	Cutting Pliers	37	2,47
28	Electric Solder	34	2,27
29	Ampere Pliers	8	0,53
30	500A Welding Stang	22	1,47

The work tool 5M Meter was the most frequently requested equipment with total demand reaching 444 units during the period. In contrast, Tolsen Seated Drilling Machine was the tool with the lowest frequency of requests, with only 1 unit over 15 months.

Goods Entry and Exit Data

In this research, commodities movement data is used to investigate and evaluate the effectiveness of PT. XYZ's warehouse operations. Goods movement data is used from January 2023 to March 2024 to provide a full assessment of warehouse activity during a 15-month period. This study's goal is to identify the movement of items and evaluate the efficiency of the storage and retrieval process by analysing this data.

Table 5. Goods Entry and Exit Data

No	Raw Material	Enter	Exit	Frequency	Percentage (%)
1	3/4" Mild Steel Bolt	3900	3750	7650	96%
2	Aluminum Foil Tape 2" x 48mm	656	556	1212	85%
3	No. 11 Welding Glass	123	78	201	63%
4	Concrete Nails 2"	3090	2740	5830	89%
5	Welding Cable 200a	115	75	190	65%
6	PVC Pipe 4"	790	790	1580	100%
7	PVC Elbow 45° 2"	488	483	971	99%
8	Silicone Sealant	484	412	896	85%
9	Thinner Kangaroo 3.5L	295	249	544	84%
10	Super Best 3.5mm SS Drill Bit	4550	4450	9000	98%
11	Blind Rivet Kledy 1/8" x 5/8"	13350	13050	26400	98%
12	Cutting Disc 4" WD	1535	1315	2850	86%
13	Welding Wire RB-26 2.6mm	4020	3822	7842	95%
14	Ceiling Screw 6 x 5/8"	6800	3600	10400	53%
15	Grinding Eye End Brush 3"	2466	2274	4740	92%

No.	Work Tool	Enter	Exit	Frequency	Percentage (%)
1	Heat Gun / Pipe Welding	36	36	72	100%
2	Yamato Cutting Torch	31	31	62	100%
3	F Claimp 10"	17	17	34	100%
4	Scissors	168	158	326	94%
5	Hammer	41	41	82	100%
6	Ring Wrench	90	90	180	100%
7	Spana Wrench	36	36	72	100%
8	Wrench	33	33	66	100%
9	5m meter	444	444	888	100%
10	Screwdriver	74	59	133	80%
11	Tubing Cutter	26	26	52	100%
12	M10 Rivet Pliers	23	23	46	100%
13	Black Big Elbow	235	235	470	100%
14	Crocodile Pliers	39	39	78	100%
15	M10 Press Pliers	11	11	22	100%
16	5ft Ladder	31	31	62	100%
17	I Meite Nail Gun 7116BL	11	11	22	100%
18	Water Pass	43	43	86	100%
19	Bosch Drill	16	16	32	100%
20	Makita Baby Grinder	8	8	16	100%
21	Circular Saw	7	7	14	100%
22	Hacksaw	26	26	52	100%
23	Tolsen Seated Drilling Machine	1	1	2	100%
24	Fixtec Sandpaper Machine	6	6	12	100%
25	Fujiyama Welding Travo	6	6	12	100%
26	Jig Saw	7	7	14	100%
27	Cutting Pliers	37	37	74	100%
28	Electric Solder	34	34	68	100%
29	Ampere Pliers	8	8	16	100%
30	500A Welding Stang	22	22	44	100%

Some raw materials and work tools have very high usage rates, indicating their importance in daily operations. Blind Rivet Kledy 1/8” x 5/8” with the highest frequency for raw material and 5m Meter for the work tool category.

Initial Warehouse Layout

The initial layout of PT. XYZ warehouse follows the fixed and random location storage method, where each product has a fixed location. This approach aims to reduce the distance goods travel and increase productivity. The initial layout of the warehouse is carefully designed to maximize storage capacity with easy access and smooth workflow. Effective space organization is essential to ensure the efficiency of daily operations.

PT. XYZ operates a storage warehouse with an area of 750 x 500 x 300 cm. This warehouse is designed to optimally utilize the available space. The warehouse entrance and exit doors with dimensions of 215 cm high and 105 cm wide ensure efficient access in and out of goods.

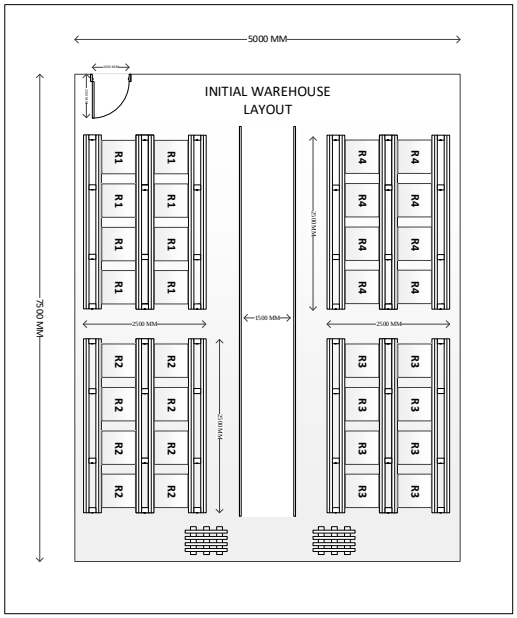

Figure 4. Initial Warehouse Layout

Space Requirement

The calculation of space requirements is used to determine the amount of space needed to store inventory efficiently by dividing the maximum storage amount by the storage capacity of the goods per slot and then multiplying by the dimensions of the material.

Table 7. Space Requirement Existing

No	Item Name	Space Requirement (m2)	Area Space Requirement (m2)
1	Aluminum Foil Tape 2" x 48mm	0,0001	1,728
2	No. 11 Welding Glass	0,0001	0,000324
3	Concrete Nails 2"	0,0004	0,000408
4	Ceiling Screw 6 x 5/8"	0,0006	0,000576
5	Grinding Eye End Brush 3"	0,0004	0,023104
6	Mild Steel Bolt 3/4"	0,0005	0,000475
7	200a Welding Cable	0,0005	0,25
8	Super Best 3.5mm SS Drill Bit	0,0006	0,00126
9	Blind Rivet Kledy 1/8" x 5/8"	0,0005	0,00024
10	4" WD Cutting Disc	0,0005	0,05202
11	RB-26 Welding Wire 2.6mm	0,0005	0,00455
12	Hammer	0,0005	0,12
13	Screwdriver	0,0005	0,0075
14	M10 Rivet Pliers	0,0005	0,0375
15	Alligator Pliers	0,0005	0,0625
16	Cutting Pliers	0,0005	0,05
17	Electric Solder	0,0005	0,025
18	Welding Stang 500A	0,0005	3
19	PVC pipe 4"	0,0005	2,9464
20	PVC Elbow 45° 2"	0,0005	0,013005
21	Silicone Sealant	0,0005	0,075
22	Thinner Kangaroo 3.5L	0,0007	0,21
23	Heat Gun / Pipe Welding	0,0005	0,1875
24	Yamato Cutting Torch	0,0005	0,3
25	F Claimp 10"	0,0006	0,12
26	Scissors	0,0005	0,08
27	Ring Wrench	0,0005	0,04
28	Spana Wrench	0,0005	0,1
29	Wrench	0,0005	0,0625
30	5m Meter	0,0004	0,01
31	Tubing Cutter	0,0005	0,05
32	Black Big Elbow	0,0005	0,3
33	M10 Press Pliers	0,0005	0,05
34	5ft Ladder	0,0003	1,875
35	Nail Gun I Meite 7116BL	0,0005	0,3
36	Water Pass	0,0005	0,1
37	Bosch Drill	0,0005	0,1
38	Makita Baby Grinder	0,0005	0,1
39	Circular Saw	0,0004	0,6
40	Hacksaw	0,0005	0,1
41	Tolsen Seated Drilling Machine	0,0002	0,39
42	Fixtec Sandpaper Machine	0,0004	0,18
43	Fujiyama Welding Travo	0,0005	0,75
44	Jig Saw	0,0002	0,05
45	Ampere Pliers	0,0005	0,064
	Total	**0,021**	**14,52**

Table 8. New Space Requirement

No	Item Name	Space Requirement (m2)	Area Space Requirement (m2)
1	Aluminum Foil Tape 2" x 48mm	0,0001	2,16
2	No. 11 Welding Glass	0,0002	0,000648
3	Concrete Nails 2"	0,0006	0,000612
4	Ceiling Screw 6 x 5/8"	0,0006	0,000576
5	Grinding Eye End Brush 3"	0,0005	0,02888
6	Mild Steel Bolt 3/4"	0,0007	0,0006175
7	200a Welding Cable	0,0008	0,4
8	Super Best 3.5mm SS Drill Bit	0,0010	0,0021
9	Blind Rivet Kledy 1/8" x 5/8"	0,0005	0,00024
10	4" WD Cutting Disc	0,0006	0,065025
11	RB-26 Welding Wire 2.6mm	0,0006	0,00546
12	Hammer	0,0010	0,375
13	Screwdriver	0,0005	0,12
14	M10 Rivet Pliers	0,0005	0,0075
15	Alligator Pliers	0,0005	0,0375
16	Cutting Pliers	0,0006	0,078125
17	Electric Solder	0,0005	0,05
18	Welding Stang 500A	0,0005	0,025
19	PVC pipe 4"	0,0005	3
20	PVC Elbow 45° 2"	0,0010	5,8928
21	Silicone Sealant	0,0010	0,02601
22	Thinner Kangaroo 3.5L	0,0007	0,1
23	Heat Gun / Pipe Welding	0,0010	0,3
24	Yamato Cutting Torch	0,0006	0,375
25	F Claimp 10"	0,0008	0,16
26	Scissors	0,0007	0,114285714
27	Ring Wrench	0,0007	0,05
28	Spana Wrench	0,0006	0,111111111
29	Wrench	0,0007	0,083333333
30	5m Meter	0,0005	0,0125
31	Tubing Cutter	0,0005	0,05
32	Black Big Elbow	0,0005	0,3
33	M10 Press Pliers	0,0005	0,05
34	5ft Ladder	0,0005	3,75
35	Nail Gun I Meite 7116BL	0,0005	0,3
36	Water Pass	0,0005	0,1
37	Bosch Drill	0,0005	0,1
38	Makita Baby Grinder	0,0005	0,1
39	Circular Saw	0,0004	0,6
40	Hacksaw	0,0005	0,1
41	Tolsen Seated Drilling Machine	0,0002	0,39
42	Fixtec Sandpaper Machine	0,0004	0,18
43	Fujiyama Welding Travo	0,0005	0,75
44	Jig Saw	0,0002	0,05
45	Ampere Pliers	0,0005	0,064
	Total	**0,026**	**20,47**

Based on the calculation of existing space requirements, the result is 14.52 m². The calculation of the proposed space requirement shows that the warehouse floor space requirement has increased to 20.47 m². The increase of 5.95 m² in space requirements in the proposed warehouse layout occurs due to a more organized arrangement of goods and more efficient use of space for each type of item

Throughput Calculation

Throughput, which is calculated by dividing the frequency of entry and exit of each type of goods by the total frequency of entry and exit of all types of goods, provides a clear picture of how much each type of goods moves in the warehouse system between January 2023 and March 2024.

Table 9. Raw Material Throughput

No	Raw Material	Frequency	Throughput
1	3/4" Mild Steel Bolt	7650	0,100
2	Aluminum Foil Tape 2" x 48mm	1212	0,016
3	No. 11 Welding Glass	201	0,003
4	Concrete Nails 2"	5830	0,076
5	Welding Cable 200a	190	0,002
6	PVC Pipe 4"	1580	0,021
7	PVC Elbow 45° 2"	971	0,013
8	Silicone Sealant	896	0,012
9	Thinner Kangaroo 3.5L	544	0,007
10	Super Best 3.5mm SS Drill Bit	9000	0,118
11	Blind Rivet Kledy 1/8" x 5/8"	26400	0,346
12	Cutting Disc 4" WD	2850	0,037
13	Welding Wire RB-26 2.6mm	7842	0,103
14	Ceiling Screw 6 x 5/8"	6500	0,085
15	Grinding Eye End Brush 3"	4740	0,062
	Total	**76406**	**1,000**

The highest throughput value belongs to the raw material Blind Rivet 1/8" x 5/8" with 0.346. Meanwhile, the lowest throughput in raw materials is for 200a Welding Cable with a throughput of 0.002.

Table 10. Work Tools Throughput

No.	Work Tools	Frequency	Throughput
1	Heat Gun / Pipe Welding	72	0,023
2	Yamato Cutting Torch	62	0,020
3	F Claimp 10"	34	0,011
4	Scissors	326	0,105
5	Hammer	82	0,026
6	Ring Wrench	180	0,058
7	Spana Wrench	72	0,023
8	Wrench	66	0,021
9	5m meter	888	0,286
10	Screwdriver	133	0,043
11	Tubing Cutter	52	0,017
12	M10 Rivet Pliers	46	0,015
13	Black Big Elbow	470	0,151
14	Crocodile Pliers	78	0,025
15	M10 Press Pliers	22	0,007
16	5ft Ladder	62	0,020
17	I Meite Nail Gun 7116BL	22	0,007
18	Water Pass	86	0,028
19	Bosch Drill	32	0,010
20	Makita Baby Grinder	16	0,005
21	Circular Saw	14	0,005
22	Hacksaw	52	0,017
23	Tolsen seated drilling machine	2	0,001
24	Fixtec Sandpaper Machine	12	0,004
25	Fujiyama Welding Travo	12	0,004
26	Jig Saw	14	0,005
27	Cutting Pliers	74	0,024
28	Electric Solder	68	0,022
29	Ampere Pliers	16	0,005
30	500A Welding Stang	44	0,014
	Total	**3109**	**1,000**

The highest throughput value is on the 5m Meter work tool with a total throughput of 888 units with a frequency of 0.286. On the other hand, the lowest throughput value was found for the Tolsen Seated Drilling Machine with a total throughput of 2 units with a frequency of 0.001.

Aisle Area

The aisle area is adjusted to the size and activity of the material handling equipment used to ensure the safe and efficient movement of goods. The following is the calculation of the aisle area requirements.

Trolley capasitas 300 Kg:

$$\text{Diagonal} = \sqrt{p^2 + l^2} \quad (8)$$

$$= \sqrt{0{,}9^2 + 0{,}6^2}$$

$$= 1{,}08 \text{ m}$$

$$\text{Allowance (10\%)} = 0{,}1 \times 1{,}08 = 0{,}108 \text{ m} \quad (9)$$

$$\text{Aisle Area Trolley} = 1{,}08 + 0{,}108 = 1{,}188 \text{ m} \approx 1{,}2 \text{ m} \quad (10)$$

Hand Pallet capasitas 3 Ton:

$$\text{Diagonal} = \sqrt{p^2 + l^2}$$

$$= \sqrt{1{,}15^2 + 0{,}55^2} = 1{,}27 \text{ m}$$

$$\text{Allowance (10\%)} = 0.1 \times 1.27 = 0.127 \text{ m}$$

$$\text{Aisle Area} = 1.27 + 0.127 = 1.397 \text{ m} \approx 1.4 \text{ m}$$

Based on the results of the above calculations, the aisle area required for the trolley is about 1.2 m, while for the hand pallet is about 1.4 m.

Goods Movement Distance

Determining the rectilinear displacement distance, the entrance and exit of the warehouse are set as the coordinate point (0,0). The displacement distance is calculated by determining the coordinates of each item, and then calculating the distance from each item storage point to the I/O point using the rectilinear method.

Based on the calculation of the distance of movement of goods in the initial warehouse layout with the rectilinear method, the distance of movement of all goods is 175 m, and the total frequency of movement of all goods is 79,515 times. The total workload calculated from the product of the displacement distance and frequency reaches 399,682 m.

Warehouse Layout Utilities

To calculate the warehouse utility, the block area is divided by the area of PT. XYZ has a warehouse measuring 750 x 500 x 300 cm, then the available warehouse area:

$$\text{Warehouse area} = 750 \times 500 \text{ cm} = 375.000 \text{ cm}^2$$

$$= 37.5 \text{ m}^2$$

$$Space\ Utilities = \frac{total\ blok\ area}{space\ area} \times 100\% \quad (10)$$

$$= \frac{14{,}52}{37{,}5} \times 100\%$$

$$= 38{,}71\%$$

The warehouse has been utilized at 38.71% of the total area available, indicating that there is still space that can be used for more efficient storage of goods.

Class Formation and Throughput Sort

The ABC classification method allows the formation of classes based on throughput. This method categorizes goods based on two main principles: popularity and similarity. In this study, goods are grouped into two main categories, namely raw materials and work tools.

In this research, items were grouped into two main categories, namely raw materials and tools. Next, the throughput of each item is sorted from the largest to the smallest, and the items are grouped into specific classes. To divide the goods into three classes based on throughput, class A includes 80% (fast moving), class B includes 15% (medium moving), and class C includes 5% (slow moving).

Table 11. Class Formation Raw Material

No	Raw Material	Throughput Percentage (%)	Cumulatif Throughput (%)	ABC Class
1	3/4" Mild Steel Bolt	34,6%	34,6%	A
2	Aluminum Foil Tape 2" x 48mm	11,8%	46,3%	
3	No. 11 Welding Glass	10,3%	56,6%	
4	Concrete Nails 2"	10,0%	66,6%	
5	Welding Cable 200a	8,5%	75,1%	
6	PVC Pipe 4"	7,6%	82,7%	B
7	PVC Elbow 45° 2"	6,2%	88,9%	
8	Silicone Sealant	3,7%	92,7%	
9	Thinner Kangaroo 3.5L	2,1%	94,7%	
10	Super Best 3.5mm SS Drill Bit	1,6%	96,3%	
11	Blind Rivet Kledy 1/8" x 5/8"	1,3%	97,6%	
12	Cutting Disc 4" WD	1,2%	98,8%	C
13	Welding Wire RB-26 2.6mm	0,7%	99,5%	
14	Ceiling Screw 6 x 5/8"	0,3%	99,8%	
15	Grinding Eye End Brush 3"	0,2%	100,0%	

Table 12. Raw Material Percentage

No	Type Class	Quantity	Percentage (%)
1	A	6	40%
2	B	4	27%
3	C	5	33%
	Total	**15**	**100%**

Based on **Table 12**, the results of ABC analysis based on throughput values can be identified as follows:

1. Class A has a value of 80% of the total throughput, which consists of 6 items and is equivalent to 40% of the total raw material items.
2. Class B has a value of 15% of the total throughput, which consists of 4 items and is equivalent to 27% of the total raw material items.
3. Class C has a value of 5% of the total throughput, which consists of 5 items and is equivalent to 33% of the total raw material items.

Table 13. Class Formation Work Tool

No.	Work Tool	Throughput Percentage (%)	Cumulatif Throughput (%)	ABC Class
1	Heat Gun / Pipe Welding	28,6%	28,6%	A
2	Yamato Cutting Torch	15,1%	43,7%	
3	F Claimp 10"	10,5%	54,2%	
4	Scissors	5,8%	60,0%	
5	Hammer	4,3%	64,2%	
6	Ring Wrench	2,8%	67,0%	
7	Spana Wrench	2,6%	69,6%	
8	Wrench	2,5%	72,1%	
9	5m meter	2,4%	74,5%	
10	Screwdriver	2,3%	76,8%	
11	Tubing Cutter	2,3%	79,2%	
12	M10 Rivet Pliers	2,2%	81,3%	
13	Black Big Elbow	2,1%	83,5%	
14	Crocodile Pliers	2,0%	85,5%	
15	M10 Press Pliers	2,0%	87,5%	B
16	5ft Ladder	1,7%	89,1%	
17	I Meite Nail Gun 7116BL	1,7%	90,8%	
18	Water Pass	1,5%	92,3%	
19	Bosch Drill	1,4%	93,7%	
20	Makita Baby Grinder	1,1%	94,8%	
21	Circular Saw	1,0%	95,8%	
22	Hacksaw	0,7%	96,5%	
23	Tolsen Seated Drilling Machine	0,7%	97,2%	
24	Fixtec Sandpaper Machine	0,5%	97,7%	C
25	Fujiyama Welding Travo	0,5%	98,3%	
26	Jig Saw	0,5%	98,7%	
27	Cutting Pliers	0,5%	99,2%	
28	Electric Solder	0,4%	99,5%	
29	Ampere Pliers	0,4%	99,9%	
30	500A Welding Stang	0,1%	100,0%	

Table 14. Work Tools Percentage

No	Type Class	Quantity	Percentage (%)
1	A	11	37%
2	B	10	33%
3	C	9	30%
	Total	**30**	**100%**

Based on **Table 14**, the results of ABC analysis based on throughput values can be identified as follows:

1. Class A has a value of 80% of the total throughput, which consists of 11 items and is equivalent to 37% of the total work tool items.
2. Class B has a value of 15% of the total throughput, which consists of 10 items and is equivalent to 33% of the total work tool items.
3. Class C has a value of 5% of the total throughput, which consists of 9 items and is equivalent to 30% of the total work tool items.

Displacement Distance of Proposed Warehouse Location

Based on the calculation of the distance of goods movement with the rectilinear method, it is obtained that the overall displacement distance of goods is 126 m, and the total displacement frequency of all goods is 79,515 times. The total workload calculated from the product of the displacement distance and frequency reaches 380,096 m.

Calculation and Analysis of Goods Movement Costs

1. Calculation of Current Goods Movement Costs

   The calculation of the cost of moving goods for each type of material is carried out on the existing storage layout and the proposed layout.

Table 15. Calculation of Existing Goods Movement Cost

No	Name of Goods	TFMK (/month)	Total Distance (meters)	Cost/meter		Cost of Movement	
1	Aluminum Foil Tape 2" x 48mm	510	68850	Rp	2.525	Rp	173.846.250
2	No. 11 Welding Glass	81	13332	Rp	2.525	Rp	33.663.300
3	Concrete Nails 2"	13	1608	Rp	2.525	Rp	4.060.200
4	Ceiling Screw 6 x 5/8"	389	46640	Rp	2.525	Rp	117.766.000
5	Grinding Eye End Brush 3"	13	1710	Rp	2.525	Rp	4.317.750
6	Mild Steel Bolt 3/4"	105	6320	Rp	2.525	Rp	15.958.000
7	200a Welding Cable	65	7768	Rp	2.525	Rp	19.614.200
8	Super Best 3.5mm SS Drill Bit	60	5376	Rp	2.525	Rp	13.574.400
9	Blind Rivet Kledy 1/8" x 5/8"	36	2176	Rp	2.525	Rp	5.494.400
10	4" WD Cutting Disc	600	90000	Rp	2.525	Rp	227.250.000
11	RB-26 Welding Wire 2.6mm	1760	105600	Rp	2.525	Rp	266.640.000
12	Hammer	190	8550	Rp	2.525	Rp	21.588.750
13	Screwdriver	523	15684	Rp	2.525	Rp	39.602.100
14	M10 Rivet Pliers	433	13000	Rp	2.525	Rp	32.825.000
15	Alligator Pliers	316	0	Rp	2.525	Rp	-
16	Cutting Pliers	5	144	Rp	2.525	Rp	363.600
17	Electric Solder	4	62	Rp	2.525	Rp	156.550
18	Welding Stang 500A	2	0	Rp	2.525	Rp	-
19	PVC pipe 4"	22	326	Rp	2.525	Rp	823.150
20	PVC Elbow 45° 2"	5	0	Rp	2.525	Rp	-
21	Silicone Sealant	12	540	Rp	2.525	Rp	1.363.500
22	Thinner Kangaroo 3.5L	5	288	Rp	2.525	Rp	727.200
23	Heat Gun / Pipe Welding	4	330	Rp	2.525	Rp	833.250
24	Yamato Cutting Torch	59	5328	Rp	2.525	Rp	13.453.200
25	F Claimp 10"	9	931	Rp	2.525	Rp	2.350.775
26	Scissors	3	416	Rp	2.525	Rp	1.050.400
27	Ring Wrench	3	230	Rp	2.525	Rp	580.750
28	Spana Wrench	31	2820	Rp	2.525	Rp	7.120.500
29	Wrench	5,2	390	Rp	2.525	Rp	984.750
30	5m Meter	1,5	176	Rp	2.525	Rp	444.400
31	Tubing Cutter	4,1	124	Rp	2.525	Rp	313.100
32	Black Big Elbow	1,5	88	Rp	2.525	Rp	222.200
33	M10 Press Pliers	5,7	258	Rp	2.525	Rp	651.450
34	5ft Ladder	2,1	32	Rp	2.525	Rp	80.800
35	Nail Gun I Meite 7116BL	1,1	32	Rp	2.525	Rp	80.800
36	Water Pass	0,9	0	Rp	2.525	Rp	-
37	Bosch Drill	3,5	156	Rp	2.525	Rp	393.900
38	Makita Baby Grinder	0,1	3	Rp	2.525	Rp	7.575
39	Circular Saw	0,8	0	Rp	2.525	Rp	-
40	Hacksaw	0,8	0	Rp	2.525	Rp	-
41	Tolsen seated drilling machine	0,9	14	Rp	2.525	Rp	35.350
42	Fixtec Sandpaper Machine	4,9	148	Rp	2.525	Rp	373.700
43	Fujiyama Welding Travo	4,5	68	Rp	2.525	Rp	171.700
44	Jig Saw	1,1	32	Rp	2.525	Rp	80.800
45	Ampere Pliers	2,9	132	Rp	2.525	Rp	333.300
	Total	**5301**	**399682**	**113625**		**Rp**	**1.009.197.050**
	Total Distance Moved		**399682**	**Total Cost**		**Rp**	**1.009.197.050**

From the calculation of the placement of the existing layout of goods, the total cost of moving goods is IDR 1,009,197,050 with a total distance of 399,682 meters.

2. Calculation of Class-Based Storage Goods Movement Cost

Table 16. Calculation of Class-Based Storage Goods Movement Cost

No	Name of Goods	TFMK (/month)	Total Distance (meters)	Cost/meter	Cost of Movement
1	Blind Rivet Kledy 1/8" x 5/8"	510	0	Rp 2.525	Rp -
2	5m Meter	4,8	72	Rp 2.525	Rp 181.800
3	Super Best SS 3.5mm Drill Bit	80,8	0	Rp 2.525	Rp -
4	RB-26 Welding Wire 2.6mm	13,4	201	Rp 2.525	Rp 507.525
5	Mild Steel Bolt 3/4"	388,7	11660	Rp 2.525	Rp 29.441.500
6	Ceiling Screw 6 x 5/8"	12,67	190	Rp 2.525	Rp 479.750
7	Concrete Nails 2"	105,3	3160	Rp 2.525	Rp 7.979.000
8	Black Big Elbow	4,13	186	Rp 2.525	Rp 469.650
9	Scissors	2,27	136	Rp 2.525	Rp 343.400
10	Ring Wrench	21,73	978	Rp 2.525	Rp 2.469.450
11	Screwdriver	5,47	164	Rp 2.525	Rp 414.100
12	Water Pass	12	540	Rp 2.525	Rp 1.363.500
13	Hammer	4,8	288	Rp 2.525	Rp 727.200
14	Alligator Pliers	4,4	330	Rp 2.525	Rp 833.250
15	Cutting Pliers	59,2	5328	Rp 2.525	Rp 13.453.200
16	Heat Gun / Pipe Welding	8,87	665	Rp 2.525	Rp 1.679.125
17	Spana Key	3,47	208	Rp 2.525	Rp 525.200
18	Grinding Eye End Brush 3"	64,7	0	Rp 2.525	Rp -
19	Cutting Disc 4" WD	59,7	896	Rp 2.525	Rp 2.262.400
20	PVC Pipe 4"	36,3	1088	Rp 2.525	Rp 2.747.200
21	Aluminum Foil Tape 2" x 48mm	600	27000	Rp 2.525	Rp 68.175.000
22	Electric Solder	3,07	0	Rp 2.525	Rp -
23	Wrench	31,3	470	Rp 2.525	Rp 1.186.750
24	Yamato Cutting Torch	5,2	156	Rp 2.525	Rp 393.900
25	5ft Ladder	1,5	22	Rp 2.525	Rp 55.550
26	Tubing Cutter	4,1	0	Rp 2.525	Rp -
27	Hacksaw	1,5	22	Rp 2.525	Rp 55.550
28	M10 Rivet Pliers	5,7	172	Rp 2.525	Rp 434.300
29	Handlebar Welding 500A	2,1	32	Rp 2.525	Rp 80.800
30	F Claimp 10"	1,1	0	Rp 2.525	Rp -
31	Bosch Drill	0,9	42	Rp 2.525	Rp 106.050
32	PVC Elbow 45° 2"	1760	184800	Rp 2.525	Rp 466.620.000
33	Silicone Sealant	190	22800	Rp 2.525	Rp 57.570.000
34	Thinner Kangaroo 3.5L	522,8	54894	Rp 2.525	Rp 138.607.350
35	Welding Glass No. 11	433,3	39000	Rp 2.525	Rp 98.475.000
36	Welding Cable 200a	316	23700	Rp 2.525	Rp 59.842.500
37	M10 Press Pliers	3,5	312	Rp 2.525	Rp 787.800
38	Meite 7116BL Nail Gun I	0,1	10	Rp 2.525	Rp 25.250
39	Makita Baby Grinding	0,8	48	Rp 2.525	Rp 121.200
40	Ampere Pliers	0,8	36	Rp 2.525	Rp 90.900
41	Circular Saw	0,9	56	Rp 2.525	Rp 141.400
42	Jig Saw	4,9	222	Rp 2.525	Rp 560.550
43	Fixtec Sandpaper Machine	4,5	136	Rp 2.525	Rp 343.400
44	Fujiyama Welding Travo	1,1	32	Rp 2.525	Rp 80.800
45	Tolsen Seated Drilling Machine	2,9	44	Rp 2.525	Rp 111.100
	Total	**5301**	**380096**	**113625**	**Rp 959.742.400**
	Total Distance Moved		**380096**	**Total Cost**	**Rp 959.742.400**

After calculating the placement layout before and after the application of the class-based storage method, it was found that there was a significant improvement in the operational efficiency of the warehouse. The distance of goods movement was reduced from 399,682 meters to 380,096 meters. In addition, the cost of moving goods also decreased from Rp1,009,197,050 to Rp959,742,400. This shows that the application of the class-based storage method has successfully improved the efficiency of storing and retrieving goods in the warehouse.

New Warehouse Layout Utility

Warehouse dimensions of 750 x 500 x 300 cm and a 1.5m wide center aisle.

Warehouse area = 37.5 m²

The new warehouse layout has utilized 54.58% of the total available area, indicating that there has been a significant improvement in the efficient use of storage space.

Warehouse Layout Comparison

Calculation of warehouse layout comparison using the formula:

$$\frac{x - y}{x} \; x \; 100\% \qquad (11)$$

Description:

x = Product picking time in the old layout

y = Product retrieval time in the new layout

The results of the analysis after the design of the goods storage layout are as follows:

1. Product Retrieval
   The results of the calculation of product retrieval efficiency show a decrease in the average efficiency level of 0.38% with a standard deviation of 0.08%. This shows that there is an improvement with the application of the ABC method to product picking in the warehouse and brings significant improvements in terms of product picking efficiency.
2. Product Placement
   The results of the calculation of product placement efficiency show a decrease in the average efficiency level of 0.22% with a standard deviation of 0.07%. This shows that there is an improvement with the application of the ABC method to the placement of goods in the warehouse and brings significant improvements in terms of product placement efficiency.

Warehouse Layout Design

The results of the warehouse layout design using the class-based storage method can improve the efficiency of storing goods by grouping goods based on certain classifications so that the storage process becomes easier. Raw materials and frequently used work tools are placed in easily accessible locations, while items with lower demand are placed in more distant areas. This method can overall reduce the time required for searching and retrieving items.

Table 17. Placement of Goods Based on Class-Based Storage Method

No	Name of Goods	Classification	Displacement Distance	Frequency
1	Blind Rivet Kledy 1/8" x 5/8"		0	7650
2	5m Meter		1	72
3	Super Best SS 3.5mm Drill Bit		0	1212
4	RB-26 Welding Wire 2.6mm		1	201
5	Mild Steel Bolt 3/4"		2	5830
6	Ceiling Screw 6 x 5/8"		1	190
7	Concrete Nails 2"		2	1580
8	Black Big Elbow		3	62
9	Scissors	Fast Moving	4	34
10	Ring Wrench		3	326
11	Screwdriver		2	82
12	Water Pass		3	180
13	Hammer		4	72
14	Alligator Pliers		5	66
15	Cutting Pliers		6	888
16	Heat Gun / Pipe Welding		5	133
17	Spana Key		4	52
18	3" End Brush Grinding Eye		0	971
19	Cutting Disc 4" WD		1	896
20	4" PVC Pipe		2	544
21	Aluminum Foil Tape 2" x 48mm		3	9000
22	Electric Solder		0	46
23	Wrench		1	470
24	Yamato Cutting Torch	Medium	2	78
25	5ft Ladder	Moving	1	22
26	Tubing Cutter		0	62
27	Hacksaw		1	22
28	M10 Rivet Pliers		2	86
29	Handlebar Welding 500A		1	32
30	F Claimp 10"		0	16
31	Bosch Drill		3	14

32	PVC Elbow 45° 2”	Slow Moving	7	26400
33	Silicone Sealant		8	2850
34	Thinner Kangaroo 3.5L		7	7842
35	Welding Glass No. 11		6	6500
36	Welding Cable 200a		5	4740
37	M10 Press Pliers		6	52
38	Meite 7116BL Nail Gun I		5	2
39	Makita Baby Grinding		4	12
40	Ampere Pliers		3	12
41	Circular Saw		4	14
42	Jig Saw		3	74
43	Fixtec Sandpaper Machine		2	68
44	Fujiyama Welding Travo		2	16
45	Tolsen Seated Drilling Machine		1	44
Total			**126**	**79515**

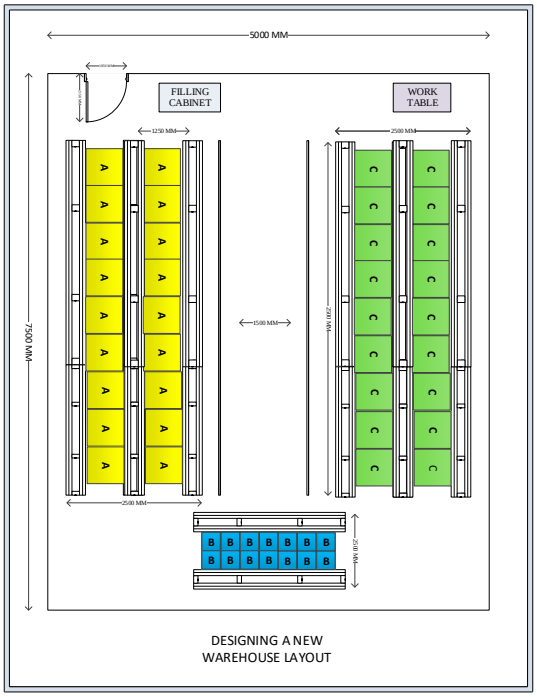

Figure 5. Proposed Warehouse Layout

5. Conclusions

The research results of designing the warehouse layout of PT XYZ with the class-based storage method to improve the efficiency of goods storage show a significant increase in warehouse operational efficiency. The proposed design with ABC classification shows that for raw materials, class A includes 6 items, class B consists of 4 items, and class C includes 5 items. For work tools, class A includes 11 items, class B consists of 10 items, and class C includes 9 items. The design of the class-based storage method can increase warehouse utility by optimizing the existing warehouse area by 15.87%. Placement based on ABC class can shorten the distance of material movement by 19,586 meters and save the cost of material movement by Rp49,454,650.00. In addition, the design of the warehouse layout also provides some efficiency, namely for picking goods to reduce efficiency by 0.38% while for placing goods by 0.22%.

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