

# Improving warehouse efficiency of sparepart storage through comparison of dedicated and class-based storage methods

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## Article Info

### Article history:

Received Feb 15, 2025

Revised Feb 26, 2026

Accepted Apr 22, 2026

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### Keywords:

Class based storage

Dedicated storage

Layout optimization

Material-handling

Warehouse efficiency

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## ABSTRACT

Warehouses play a crucial role in supporting the efficiency of supply chain operations, especially in material management and goods movement. However, in a company engaged in the paper printing and recycling industry, inefficiency in searching and retrieving goods in the spare parts warehouse is a major challenge, with a sub-optimal layout hampering smooth operations. This research offers a new perspective by evaluating the effectiveness of two storage methods, namely class-based storage and dedicated storage, in the context of spare parts warehouses that have different layout characteristics. This study aims to compare the two methods in improving material-handling efficiency and optimizing warehouse layout. The results show that the class-based storage method is more effective in reducing travel distance and material-handling time than dedicated storage. In addition, this method can improve operational efficiency and support the smooth production process through the arrangement of goods based on picking frequency. The theoretical implications of this research contribute to the development of warehousing management literature, while practically, the results of this study can serve as a guide for industries in implementing more efficient warehouse layout strategies.

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## 1. INTRODUCTION

The warehouse is a place where activities related to the storage of goods take place [1]. A warehouse is a company's logistics system that plays an essential role in maintaining products and other production equipment and providing products for processing [2]. In addition, warehouse designs that ensure optimal layout and effective material-handling systems are instrumental in supporting accurate, structured product allocation [3]. The location of products in the warehouse affects the distance traveled during the order-picking process and the time to pick up the order. Distance and travel time affect the efficiency of order-picking operations [4]. This leads to factors to be considered, such as the picking process and the material delivery system [5]. The next step to optimize the warehousing function is to design an effective storage layout, which is expected to have a significant impact on the running activities [6]. The efficiency of the order-picking process is highly dependent on the storage policy used, namely the product's location in the warehouse [7]. Therefore, determining the location assignment policy for storing goods is essential for warehouse management [8]. In addition, a well-designed storage strategy or warehouse layout can help reduce the travel distance between entering and exiting the warehouse, shorten operation time, and fully utilize storage space [9].

Furthermore, using a strategy based on the existence of stock demonstrates effective warehouse management. Warehouse management then acts as a control center in the supply chain [10]. However, the effectiveness of warehouse management is often hampered by various problems, such as difficulties in moving goods, accumulation of goods, time-consuming searches for goods, and capacity constraints [11]. Similar issues are also found in a company engaged in the printing and paper recycling industry. The company produces recycled paper, such as medium linear, medium fluting, and corrugating medium paper, with three types of warehouses: raw material warehouse, chemical warehouse, and spare parts warehouse. Particularly in the spare parts warehouse, the messy layout with various types of goods not neatly arranged causes inefficiencies in searching and retrieving goods, makes it difficult for operators, and hampers the production process. Therefore, good facility layout planning is essential for more efficient space utilization. One approach that can address the problem is a class-based storage and a dedicated storage policy.

The class-based storage policy is a general joint between random and specialized policies [12]. This method is applied to optimize the distance and retrieval time factors [13]. This policy reduces travel distance by keeping frequently picked items close to the input/output (I/O) points [14]. Whereas dedicated storage, also known as fixed storage location (fixed slot storage), uses a specific location or storage area for each item [15]. A dedicated storage policy places materials in predetermined locations based on storage and throughput requirements [16]. Dedicated storage rules determine the location of classes [17]. Therefore, this study aims to compare the results of the two methods to determine the more efficient approach to improving the spare parts warehouse layout. Applying the correct method is expected to increase warehousing efficiency, facilitate production, and make it easier for operators to find goods.

Various studies have been conducted to identify effective strategies for improving warehouse efficiency and management through class-based and dedicated storage approaches. These findings show a variety of methods, technologies, and applications that can be adapted to operational needs. As one of the main focuses in improving operational efficiency, warehouse layout optimization has been conducted in [1], [16]–[19]. Furthermore, the efficiency of manually picking goods in the warehouse to optimize operations and productivity in [4], [7], [20]. In contrast to the increasing efficiency achieved through technology and automated systems carried out in [21]–[23].

On the other hand, according to the authors in [12], [14], [24], in addition to improving picking efficiency, warehouse layout optimization also significantly reduces travel distance and operational costs. Optimization models and algorithms also play an essential role in improving the efficiency of class-based storage, as stated in [12], [25], [26]. The authors in [9], [27]–[29] stated that optimization can be improved by implementing appropriate routing strategies and storage policies. Meanwhile, according to Septiani *et al.* [30], simulation and tools are one of the effective approaches for evaluating and improving warehouse governance performance.

Several studies have evaluated the advantages of class-based storage and dedicated storage in supporting warehouse performance improvement, as revealed by [2], [15], [31], but they provide different findings. Thus, this research fills the evidence gap left by other findings regarding the effectiveness of the class-based and dedicated storage methods. Pratama and Dahda. [2] showed that dedicated storage is more practical and efficient in the context of a steel warehouse. At same time, Arif and Andesta [15] found that class-based storage is superior at reducing travel distance in laboratory sample warehouses. Firmansyah *et al.* [31] revealed that both methods could improve order-picking efficiency in spare parts warehouses. However, there is no consensus on which method is more optimal in different types of warehouses. Therefore, this research seeks to provide a new perspective by evaluating both methods in the context of spare parts warehouses with varying layouts.

## 2. METHOD

This research uses primary and secondary data. Primary data were obtained through observation, including the condition of the spare parts warehouse, its layout, and area, types of products stored, and product dimensions. Secondary data is collected from archives and company documents, including literature studies, company profiles, historical data on the entry and exit of spare parts, and procedures for receiving and distributing goods.

In the process of data calculation and layout design, several stages are carried out, namely:

- i) Calculating the throughput/space requirement (T/S) value and sorting the T/S value from largest to smallest. Calculation of throughput using (1).

$$Ti = \frac{Mi}{Pi} + \frac{Ki}{Pi} \quad (1)$$

Where  $M_i$  is average reception,  $K_i$  is average outgoing stock (delivery), and  $P_i$  is number of removals per transport cycle.

- ii) Calculating the space requirement of the dedicated storage. The required storage space is determined using (2).

$$S_i = \frac{\text{Maximum storage}}{\text{Block capacity size}} \quad (2)$$

Where block refers to a designated storage area where specific items are stored in the warehouse; and block capacity represents the maximum number of items accommodated within a given block.

- iii) Determine the location of the item storage area based on the throughput and space requirement values. After obtaining the calculation results of the frequency of outgoing and incoming items ( $T_i$ ) and area requirements ( $S_i$ ), the calculation of the ratio of  $T_i$  and  $S_i$  is carried out, which is used to calculate the distance from the storage area to the in/out (I/O) warehouse door point using (3).

$$\frac{T_i}{S_i} \quad (3)$$

Where  $T_i$  is throughput,  $S_i$  is storage, and  $T_i/S_i$  is throughput/space ratio.

- iv) Design a layout using the dedicated storage. This method help optimize space utilization and improve retrieval efficiency [30].  
v) Calculate the displacement distance and handling time. Calculation of displacement distance using (4), rectilinear distance.

$$D_{ij} = (X - a) + (Y - b) \quad (4)$$

Where  $D_{ij}$  is distance from item location to I/O point,  $X$  is distance from the center point of the area to the I/O on the X-axis (horizontal),  $a$  is distance of the item location point to the X axis,  $Y$  is distance from the center point of the area to the I/O on the Y axis (vertical), and  $b$  is distance of the item location point to the Y-axis

- vi) Handling time is calculated from cycle time and data collected when the operator moves the goods to the loading-unloading area, using (5).

$$\text{Handling time} = \frac{\text{Total distance from storage area to loading unloading area}}{\text{Average handling time}} \quad (5)$$

- vii) Calculate the throughput/space requirement (T/S) value and sort the T/S values from largest to smallest. Calculation of throughput using (1).  
viii) Calculate the space requirement of the class-based storage method using (2).  
ix) Determine the location of the item storage area based on the throughput and space requirement values. After obtaining the calculation results of the frequency of outgoing and incoming goods ( $T_i$ ) and area requirements ( $S_i$ ), calculate the ratio of  $T_i$  and  $S_i$ , which is used to calculate the distance from the storage area to the in/out (I/O) warehouse door point using the (3).  
x) Designing layouts using the class-based storage. Design a layout using class-based storage. This method groups products into classes to improve storage efficiency and retrieval time [23].  
xi) Calculating displacement distance and handling time. Calculation of displacement distance using (4), rectilinear distance.  
xii) Handling time is calculated using cycle time and data collected when the operator moves the goods to the loading-unloading area, using (5).  
xiii) Choosing the best layout.

### 3. RESULTS AND DISCUSSION

#### 3.1. Initial layout

The initial condition activity ratio is calculated from the average receipts ( $M_i$ ), deliveries ( $K_i$ ), and number of moves per transport ( $P_i$ ) based on data from January to May 2024. The values are then summed to obtain the activity ratio, which determines the initial layout and calculates the efficiency of material-handling time and distance [2]. The results are shown in Table 1.

Table 1. Initial layout activity ratio results [32]

No	Item type	Throughput calculation					Space requirement calculation			Activity ratio Ti/Si (times/block)	
		Pi (per month)	Mi (pcs/ month)	Ki (pcs/ month)	Mi/Pi (per month)	Ki/Pi (per month)	Ti (times)	Max stock (shelf)	Block capacity		Si (block)
1	Asdrat 1	6	9	13	2	3	5	8	10	1	5
2	Asdrat 1 ¼	7	10	14	1	2	4	8	10	1	4
3	Asdrat ½	7	12	12	2	2	4	7	10	1	4
4	Asdrat ¾	4	7	9	2	2	5	6	10	1	5
5	Asdrat 5/8	4	7	9	2	2	5	8	10	1	5
...	....	....	....	....	....	....	....	....	....	....	....
80	Vbelt 8V2000	1	2	5	2	5	7	5	10	2	4

The results of the activity ratio calculation are summarized in Table 1. This data is used to evaluate the efficiency of the initial warehouse layout. This calculation includes throughput analysis, space requirements, and activity ratios (Ti), which serve as a reference in measuring layout performance. Furthermore, the values from Table 1 are used to determine more detailed material-handling distances (Dij) and material-handling times, as shown in Table 2.

Table 2. Initial layout material handling distance and time [32]

No	Item type	X (cm)	a (cm)	Y (cm)	b (cm)	Dij (cm)	Ti/Si	Dij/(Ti/Si)	Total time	Handling time
1	Asdrat 1	450	243	300	201	306	2	184	11	16.73
2	Asdrat 1 ¼	450	241	300	204	305	2	153	12.5	12.24
3	Asdrat ½	450	324	300	210	216	1	162	12	13.50
4	Asdrat ¾	450	235	300	198	317	3	127	10	12.70
5	Asdrat 5/8	450	195	300	138	417	5	84	9	9.33
...	....	....	....	....	....	....	....	....	....	....
80	VBelt 8V2000	450	216	300	169	365	4	105	9	11.67
Total										976.02 seconds

Table 2 presents the distance from the warehouse center to the exit/entrance for each type of goods and the corresponding material-handling time, based on the activity ratio. These results provide an overview of the efficiency of material-handling management in the initial layout. The accumulated total distance and material-handling time are presented in Table 3, an essential reference in evaluating and designing improvements to the warehouse layout.

Table 3. Total distance and time results of the initial material handling layout [32]

Calculation	Total
Distance traveled	109.10 m
Handling time	976.02 seconds or 16.3 minutes

**3.2. Calculation of dedicated storage**

The activity ratio for the dedicated storage layout is calculated based on the average receipts, shipments, and single-transport moves from January to May 2024. The value is then summed to obtain the activity ratio, which serves as a reference in determining the layout and the basis for calculating the time and distance of material handling [12]. The results of this activity ratio calculation are presented in Table 4. Table 4 calculates the activity ratio for the dedicated storage layout and shows the efficiency of each item type in both storage and retrieval. Furthermore, Table 5 presents the results of calculating distance and material-handling time to evaluate the effectiveness of the dedicated storage layout.

The calculations in Table 5 shows the distance and material-handling time for each item type under the dedicated storage method. This data is analyzed based on the distance of items from the X and Y axes and the frequency of picking, providing an indication of the layout for material-handling management [30]. Furthermore, the total travel distance and handling time for the dedicated storage layout are summarized in Table 6. These results provide a comprehensive evaluation of the dedicated storage’s performance in supporting warehouse operational efficiency.

Table 4. Dedicated storage activity ratio results [32]

No	Item type	Throughput calculation					Space requirement calculation			Activity ratio Ti/Si (times/block)	
		Pi (per month)	Mi (pcs/month)	Ki (pcs/month)	Mi/Pi (per month)	Ki/Pi (per month)	Ti (times)	Max stock (shelf)	Block capacity		Si (block)
1	Asdrat 1	6	9	13	2	3	5	8	10	1	5
2	Asdrat 1 ¼	7	10	14	2	2	4	8	10	1	4
3	Asdrat ½	7	12	12	2	2	4	7	10	1	4
4	Asdrat ¾	4	7	9	2	3	5	6	10	1	5
5	Asdrat 5/8	4	7	9	2	3	5	8	10	1	5
...	....	....	....	....	....	....	....	....	....	....	....
80	VBelt 8V2000	1	2	5	2	5	7	5	10	1	7

Table 5. Distance and time of material-handling: dedicated storage [32]

No	Item type	X (cm)	a (cm)	Y (cm)	b (cm)	Dij (cm)	Ti/Si	Dij/(Ti/Si)	Total time	Handling time
1	Asdrat 1	450	294	300	143	313	5	63	9.3	6.77
2	Asdrat 1 ¼	450	325	300	201	224	4	56	8.5	6.59
3	Asdrat ½	450	324	300	198	228	4	57	8.5	6.71
4	Asdrat ¾	450	297	300	139	314	5	63	8.5	7.42
5	Asdrat 5/8	450	300	300	135	315	5	63	8.5	7.41
...	....	....	....	....	....	....	....	....	....	....
80	VBelt 8V2000	450	180	300	110	460	7	66	8.5	7.76
Total									443.82 seconds	

Table 6. Total distance traveled and handling time dedicated storage [32]

Calculation	Total
Distance traveled	44.43 meters
Handling time	443.82 or 7.38 minutes

3.3. Calculation of class-based storage

In the class-based storage, the data used includes the average receipt of goods (Mi), the average delivery (Ki), and the number of removals after transport (Pi) during the period January to May 2024. This activity ratio is used to develop the layout of class-based storage and serves as the basis for calculating the efficiency of material-handling distance and time [2]. The complete results of this calculation are presented in Table 7.

Table 7. Class-based storage activity ratio [32]

No	Item type	Throughput calculation					Space requirement calculation			Activity ratio	
		Pi (per month)	Mi (Pcs/month)	Ki (Pcs/month)	Mi/Pi (per month)	Ki/Pi (per month)	Ti (times)	Max stock (shelf)	Block capacity	Si (block)	Ti/Si (times/block)
1	Asdrat 1	6	9	13	2	3	5	8	10	1	5
...	...	....	....	....	....	....	....	....	....	....	....
6	Asdrat 7/8	5	6	11	2	3	5	7	10	1	5
7	Asdrat SS M 10	7	11	14	2	2	4	6	10	1	4
...	....	....	....	....	....	....	....	....	....	....	....
9	Asdrat SS M 14	6	8	8	2	2	4	4	10	0.4	10
10	Bearing 1211	5	8	10	2	2	4	4	10	0.4	10
...	....	....	....	....	....	....	....	....	....	....	....
18	Bearing 21313 CK	8	13	15	2	2	4	4	10	0.4	10
19	Gear box WPA 70 (1:40)	8	11	15	2	2	4	3	10	0.5	8
...	....	....	....	....	....	....	....	....	....	....	....
25	Gearbox WPA 70 (1:60)	9	10	12	2	2	4	3	10	0.5	8
...	....	....	....	....	....	....	....	....	....	....	....
26-64	....	....	....	....	....	....	....	....	....	....	....
65	VBelt 5V 1060	12	5	7	1	1	2	5	10	0.5	4
...	....	....	....	....	....	....	....	....	....	....	....
80	VBelt 8V 2000	1	2	5	2	5	7	5	10	0.5	14

In Table 7, the results of the class-based activity ratio calculation storage are shown in full, including throughput, space requirements, and activity ratios for each item type. This data is used as a reference when evaluating layout efficiency [15]. Furthermore, Table 8 presents the results of calculating distance and material-handling time based on the class-based storage layout, which assesses the effectiveness of storage and the goods retrieval.

Table 8 presents the detailed results of calculating distance and material-handling time for each item type based on the class-based storage layout. This data is analyzed based on the item’s position relative to the entrance and the frequency of picking, to evaluate the layout’s effectiveness [15]. Following this, Table 9 summarizes the total distance and handling time, which illustrates the overall efficiency of the layout. Figure 1 shows the initial layout, while Figure 2 shows the design based on the class-based storage.

Table 8. Results of distance and material-handling time of class-based storage [32]

No	Item type	X (cm)	a (cm)	Y (cm)	B (cm)	Dij (cm)	Ti/Si	Dij/(Ti/Si)	Total time	Handling time
1	Asdrat 1	450	370	300	267	113	5	23	11.5	2
6	Asdrat 7/8	450	390	300	271	89	5	18	11	1.64
7	Asdrat SS M 10	450	349	300	235	166	6	28	11.5	2.44
9	Asdrat SS M 14	450	356	300	240	154	6	26	11.6	2.24
10	Bearing 1211	450	195	300	154	401	11	37	8	4.63
18	Bearing 21313 CK	450	196	300	142	412	11	38	8.52	4.46
19	Gear box WPA 70 (1:40)	450	255	300	193	302	8	38	10.3	3.69
25	Gearbox WPA 70 (1:60)	450	261	300	189	300	8	38	9.4	4.04
65	VBelt 5V 1060	450	302	300	211	237	7	34	10.5	3.24
80	VBelt 8V 2000	450	318	300	209	223	7	32	10.3	3.11
Total										205.15 seconds

Table 9. Total distance traveled and total handling time class-based storage [32]

Calculation	Total
Travel distance	19.88 m
Handling time	205.15 or 3.5 minutes

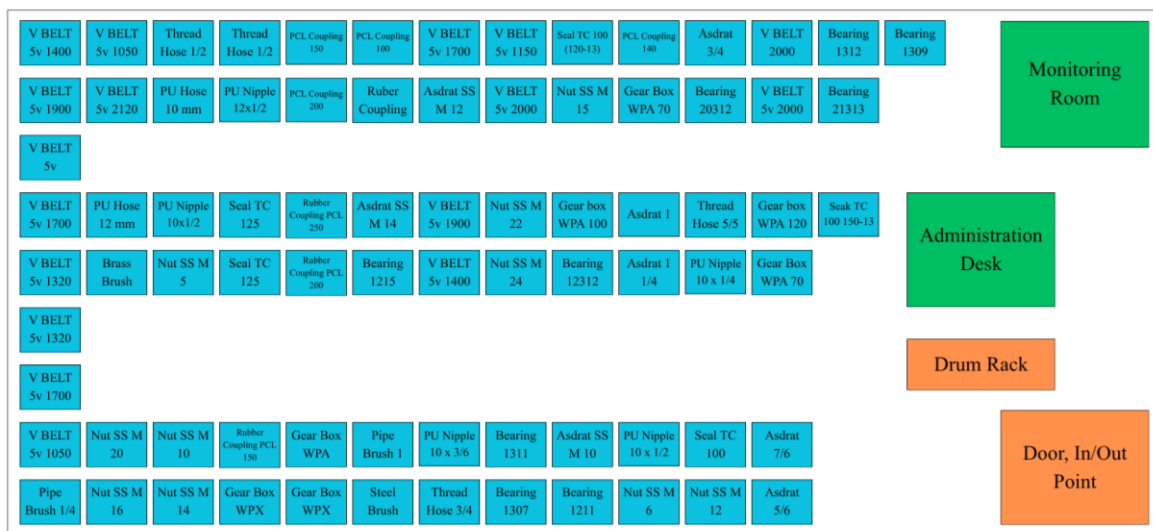


Figure 1. Initial warehouse layout [32]

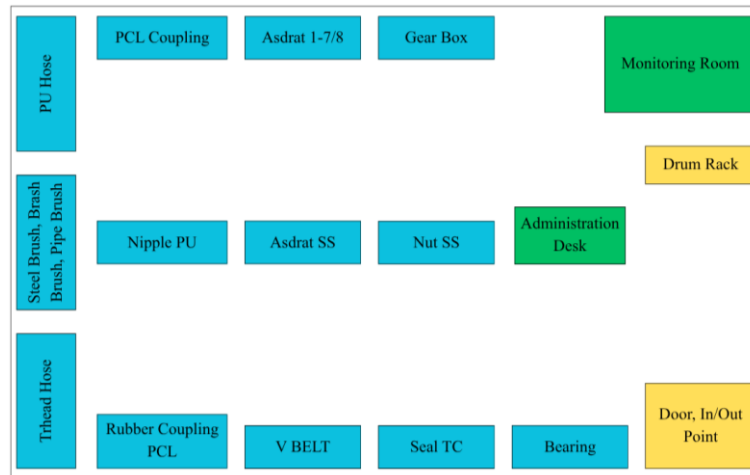


Figure 2. Layout based on class-based storage [32]

**4. CONCLUSION**

Based on the evaluation of the warehouse layout, the application of class-based storage shows advantages in reducing travel distance and material-handling time over the dedicated storage. Grouping goods by picking frequency allows low-frequency goods to be placed closer to the entry/exit point if they share characteristics with frequently picked goods, thereby improving material-handling efficiency and simplifying operator search for goods. This method's application significantly optimizes the warehouse layout, improving operational efficiency and the overall smoothness of the production process. Theoretically, this research contributes to the understanding of warehouse layout optimization by analyzing the impact of various storage methods on operational efficiency. The findings highlight how class-based storage can reduce travel distances and material-handling time compared to dedicated storage. Practically, the results guide companies in overcoming warehouse layout inefficiencies to improve operational efficiency and productivity. However, this study has limitations due to its limited scale to one company and a specific type of warehouse (spare parts), thus limiting the generalization of the results to other industries. Future research could explore using advanced technologies such as internet of things (IoT), warehouse management systems (WMS), or artificial intelligence (AI)-based algorithms to create more adaptive and efficient warehouse layouts.

**ACKNOWLEDGMENTS**

We thank the Department of Industrial Engineering, Faculty of Industrial Technology, Universitas Islam Indonesia, for supporting the publication of this research.

**FUNDING INFORMATION**

Authors state no funding involved.

**AUTHOR CONTRIBUTIONS STATEMENT**

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Prayoga Prima		✓	✓		✓	✓	✓	✓	✓		✓			
Hermawan														
Qurtubi	✓			✓	✓					✓		✓	✓	✓

C : **C**onceptualization

M : **M**ethodology

So : **S**oftware

Va : **V**alidation

Fo : **F**ormal analysis

I : **I**nvestigation

R : **R**esources

D : **D**ata Curation

O : **O** Writing - **O**riginal Draft

E : **E** Writing - **R**eview & **E**ditng

Vi : **V**isualization

Su : **S**upervision

P : **P**roject administration

Fu : **F**unding acquisition

**CONFLICT OF INTEREST STATEMENT**

Authors state no conflict of interest.

**INFORMED CONSENT**

We have obtained informed consent from all individuals included in this study.

**DATA AVAILABILITY**

Data availability does not apply to this paper as no new data were created or analyzed in this study.




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