OPTIMIZATION OF MATERIAL STORAGE LAYOUT USING THE CLASS-BASED STORAGE METHOD AT PT PLN (PERSERO) UP3 SURAKARTA

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ABSTRACT

This study aims to optimize the material storage layout at the Jajar Warehouse of the Logistics Section of PT PLN (Persero) UP3 Surakarta by applying the Class-Based Storage (CBS) method based on ABC Analysis. The existing warehouse layout was not organized according to material movement frequency, resulting in long picking distances, inefficient retrieval processes, and increased operational time. The research employed a quantitative descriptive approach using material movement data collected from January to December 2024. Initially, ABC Analysis was conducted to classify 129 material types into three categories based on movement frequency. The classification results were then used as the basis for designing a new storage layout using the Class-Based Storage method, where fast-moving materials were placed closer to the warehouse input/output area. The effectiveness of the proposed layout was evaluated by comparing the total picking distance before and after implementation. The results indicate that the proposed layout reduced the total picking distance from 41,074,213 meters to 25,199,026 meters, representing a reduction of 15,875,193 meters (38.65%). These findings demonstrate that the integration of ABC Analysis and Class-Based Storage significantly improves warehouse operational efficiency by minimizing material travel distance and enhancing the material retrieval process.

KEYWORDS

Warehouse Layout Optimization, ABC Analysis, Class Based Storage, Picking Distance, Warehouse Management

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INTRODUCTION

Developments in the industrial and service sectors during the era of globalization require companies to enhance the efficiency and effectiveness of their operations. A warehouse management system plays a crucial role in ensuring smooth operational activities. Warehouses serve as hubs for the storage, control, and distribution of materials; therefore, effective management is essential to facilitate the flow of materials and boost company productivity. According to Frazelle (2020), the warehouse is a vital component of the supply chain system, responsible for the efficient storage, control, and distribution of goods. Meanwhile, Richards (2021) notes that disorganized storage layouts can lead to increased item retrieval times, longer material movement distances, and poor utilization of storage space.

PT PLN (Persero) UP3 Surakarta is a service unit responsible for electricity supply and the management of operational support materials in the Surakarta area and its surroundings. A key department within this unit is the Logistics Section, which manages various electrical materials at the Jajar Warehouse. These materials support activities such as new installations, network maintenance, power capacity adjustments, and customer service. Consequently, effective material storage management is a critical factor in ensuring the smooth distribution of materials and the reliability of electricity services. Observations indicate that the material storage layout at the Jajar Warehouse has not been organized based on the frequency of material usage. High-turnover items—such as singlephase MCBs, kWh meters, and medium-voltage overhead line (SUTM) accessories—are currently stored in locations that do not account for travel distance efficiency. Furthermore, the scattered placement of materials forces warehouse staff to move between multiple areas to locate required items. The warehouse layout, comprising indoor, semi-outdoor, and outdoor zones with a large total storage area, further exacerbates travel distances when material placement lacks a systematic approach.

These issues result in low efficiency in warehousing operations. Observations show that retrieving specific materials can take over 25 minutes due to long picking distances and manual search processes. Additionally, the disorganized storage system increases the risk of material damage or loss; for instance, stacking kWh meters beyond capacity creates a potential for damage, thereby raising the company's operational costs.

To address these issues, a method is required to group materials based on activity levels, enabling a more systematic storage layout. ABC Analysis is employed to classify materials into groups A, B, and C based on movement frequency. According to Heizer et al. (2020), ABC Analysis is an inventory classification method used to prioritize material control based on importance. This classification serves as the basis for implementing ClassBased Storage (CBS), a method that assigns storage locations according to material activity levels. Category A materials are placed closest to the Input/Output (I/O) points, while Category B and C materials are stored in more distant areas; this approach aims to reduce travel distances and accelerate the material retrieval process. According to Roodbergen and Vis (2020), implementing Class-Based Storage can enhance warehousing efficiency by minimizing material travel distances.

While extensive research has been conducted on the implementation of ClassBased Storage, most studies have focused on the manufacturing and general distribution sectors. Research regarding the application of ABC Analysis and Class-Based Storage in material warehouses within the electricity sector specifically at PT PLN (Persero) UP3 Surakarta remains relatively limited. Therefore, this study aims to propose improvements to the material storage layout using ABC Analysis and Class-Based Storage

methods to minimize picking distances and enhance the efficiency of warehousing operations at the Jajar Warehouse of PT PLN (Persero) UP3 Surakarta.

RESEARCH METHOD

This research was conducted at the material warehouse of the Logistics Section of PT PLN (Persero) UP3 Surakarta, located at Jl. Duku No. 14, Jajar, Laweyan District, Surakarta City. The study focused on the Jajar Warehouse, which serves as a storage facility for various electrical materials—such as MCBs, kWh meters, jointing kits, transformers, cables, metering enclosures, and polymer insulators—as well as other supporting materials. The research and data collection were carried out from March to May 2026.

Preliminary observations revealed that the material storage layout was suboptimal, characterized by unstructured placement that failed to account for usage frequency. This resulted in placement mismatches, where high-turnover materials were not situated in strategic locations. Furthermore, excessive material retrieval times (picking times) negatively impacted warehouse operational efficiency. Retrieval processes were prolonged due to long travel distances and the absence of a well-organized storage system, indicating that the existing layout failed to optimally support smooth warehouse operations.

To address these issues, the study began with a problem identification phase aimed at understanding the existing storage layout and operational constraints. Following identification, an ABC Analysis was conducted to categorize materials based on usage frequency or turnover rates, distinguishing between fast-moving, slow-moving, and nonmoving items. This analysis yielded classifications (Categories A, B, and C) that served as the basis for prioritizing material placement.

The subsequent phase involved designing the storage layout using the Class-Based Storage method. Here, the ABC classification results guided the determination of storage locations within the warehouse. Category A materials (high usage frequency) were positioned near warehouse entry and exit points, while Category B and C materials were placed further away, corresponding to their respective demand levels. This approach aimed to minimize material travel distances, thereby accelerating and enhancing the efficiency of the retrieval process.The study yielded two primary outputs: the classification of materials into Categories A, B, and C, and a new, more structured, and efficient warehouse layout design. The proposed layout is expected to resolve the issues inherent in the existing setup, particularly regarding material placement and picking process efficiency. Subsequently, a comparative analysis was conducted between the existing layout and the proposed layout to determine the resulting improvement in efficiency. This comparison is based on changes in picking distances and material retrieval times. The analysis results then served as the basis for formulating recommendations to improve the material storage system.

RESULT AND DISCUSSION

Based on the obtained material movement data, the first step in data processing is to conduct an ABC analysis. This analysis aims to categorize 129 types of materials based on their movement frequency, thereby establishing storage priorities to serve as the basis for implementing the Class-Based Storage (CBS) method.

The ABC analysis method is used to classify materials according to requirements. Classification is performed by dividing inventory items into three categories (A, B, and C) based on annual consumption value. This method is employed to prioritize inventory control, allowing the company to focus on items that have the greatest impact. The formula used to determine the ABC classification is as follows:

Material Frequency

Material frequency refers to the movement or transfer of each material, calculated based on the total number of items entering and leaving the warehouse. The movement frequency for each material is determined using the following formula:

Movement Frequency = Inbound Frequency + Outbound Frequency

Material Percentage

The material percentage represents the result of the movement frequency calculation for each material. Based on the aggregated data, the percentage is calculated using the following formula:

$$\text{Movement Percentage} = = \frac{Movement\ Frequency}{total\ Movement\ Frequency} \text{ X } 100\%$$

After calculating the movement of each warehouse material, the cumulative percentages are sorted from highest to lowest until the total reaches 100%. Subsequently, materials are grouped based on movement percentage using the ABC classification system. In this classification, each material is assigned to a specific category; Category A consists of high-movement (fast-moving) products, accounting for approximately 75%–80% of the total. Meanwhile, Category B comprises products with a moderate movement rate (slowmoving) of approximately 10%–15%, while Category C consists of the slowest-moving products (non-moving) at 5%–10%. This categorization aims to improve time efficiency during the material retrieval process by positioning products according to their movement frequency. The ABC classification results for each material are presented in the following table.

Table 1. Summary of ABC Analysis
(Source: Author's calculations)

Class	Quantity Material	Percentage	Characteristics
A	29	20%	Fast Moving
B	36	30%	SlowMoving
C	64	50%	Non Moving

Following the material grouping based on ABC analysis, the Class-Based Storage (CBS) method was applied to formulate a proposed material storage layout. At this stage, materials were categorized into storage classes according to their movement frequency, ensuring that their placement would support efficient storage and retrieval processes.
The material classification derived from the ABC method revealed varying activity levels across material groups, based on movement frequency and usage intensity during the study period. These differing characteristics served as the basis for designing the proposed storage layout using the Class-Based Storage (CBS) method. This method aims to group materials into specific storage classes, allowing their placement to align with the activity level of each material type. Consequently, each material group is assigned a storage location that supports smooth warehouse operations.

In the Class-Based Storage (CBS) method, each material group is allocated to a specific storage area based on its movement frequency characteristics. "Fast-moving" materials are placed closest to the warehouse entry and exit points due to their high demand and movement frequency. This placement strategy facilitates material retrieval and storage, thereby minimizing the time and travel distance required by operators. Meanwhile, "slowmoving" materials are placed in the central storage area, whereas "non-moving" materials are allocated to areas further from the entry and exit points, reflecting their

relatively lower movement frequency. This class-based storage arrangement is expected to create a more organized and efficient material flow. The classification results serve as the foundation for applying the Class-Based Storage (CBS) method to determine storage locations suited to the characteristics of each material group.

As shown in Table 1, materials were categorized into three classes—Class A, Class B, and Class C, based on the ABC analysis results. The subsequent step involves determining the storage area requirements for each class to serve as the basis for developing the proposed layout. At the PT PLN (Persero) UP3 Surakarta Jajar Warehouse, the storage area comprises three sections: indoor, semi-outdoor, and outdoor storage. Consequently, a proposed layout was developed for each storage area, taking into account material characteristics and existing warehouse conditions. Material placement was determined not only by ABC classification results but also by material type, size, dimensions, and storage space requirements to ensure smooth warehouse operations. The proposed layout is expected to provide a more effective material flow compared to the existing setup. In addition to facilitating the process of locating and retrieving materials, the proposed layout is also expected to reduce the total picking distance, thereby increasing the efficiency of warehouse operations. The proposed layouts for each storage area are shown in the following figures.

a. Indoor warehouse

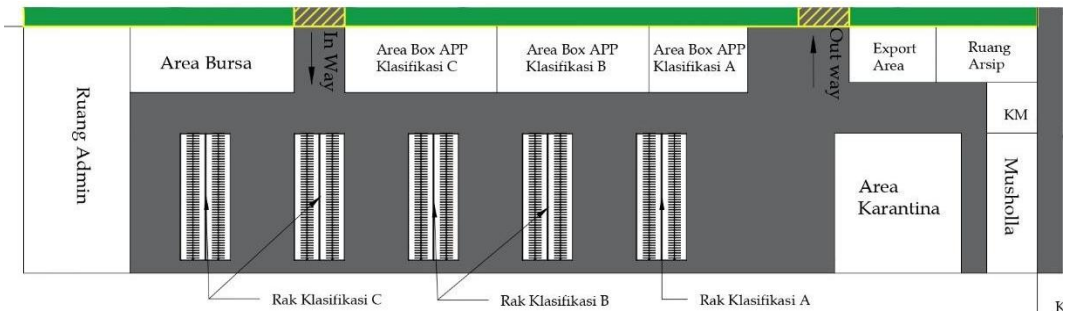


Figure 1. Indoor Warehouse Layout

Based on Figure 1, the proposed layout indicates a relocation of certain materials in accordance with the ABC classification results. Class A materials are placed on racks with the easiest access to the warehouse entrance and exit to minimize the distance operators must travel during the picking process. Meanwhile, Class B materials are situated in the central storage area, and Class C materials are placed in more distant areas due to their relatively low movement frequency. This arrangement creates a more organized material flow, which is expected to enhance the efficiency of both material storage and retrieval processes.

b. Semi-outdoor warehouse

Based on the material classification results obtained using the ABC Analysis method, a proposed layout for the semi-outdoor area was subsequently developed by applying the Class-Based Storage (CBS) method.

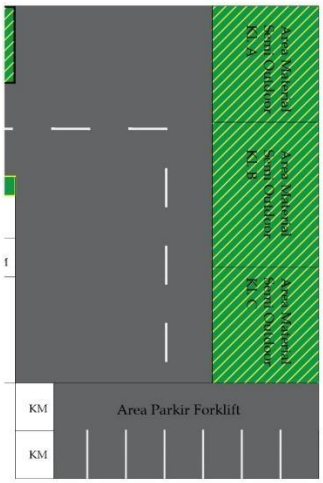


Figure 2. Semi Outdoor Warehouse Layout

Based on Figure 2, the semi-outdoor area is divided into three storage zones: Class A, Class B, and Class C semi-outdoor material areas. This zoning is based on material classification using the ABC method, ensuring that each group of materials is positioned according to its movement frequency.

c. Outdoor Warehouse

Based on the material classification results obtained using the ABC Analysis method, a proposed layout for the outdoor warehouse area was subsequently developed by applying the Class-Based Storage (CBS) method. The proposed outdoor warehouse layout utilizing the Class-Based Storage (CBS) method is shown in Figure 3.

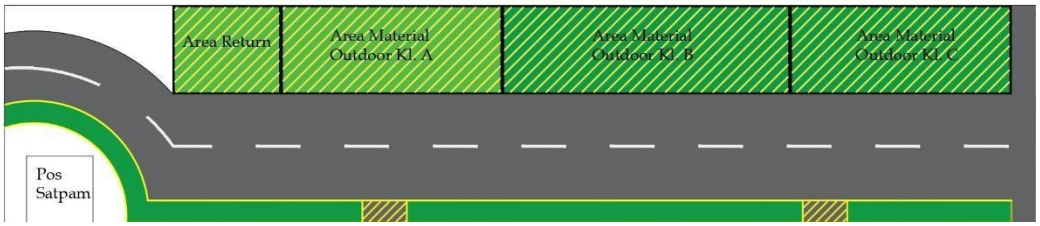


Figure 3. Outdoor Warehouse Layout

Based on Figure 3, the outdoor warehouse area is divided into several storage zones specifically the Returns Area and the Class A, Class B, and Class C Outdoor Material Areas determined through ABC analysis classification.

Following the development of the proposed layout using the Class-Based Storage (CBS) method, the next step involves calculating picking distances to assess the effectiveness of the proposed layout. This calculation entails comparing the total material movement distances under current conditions versus the proposed conditions. The results of this comparison are used to determine whether the implementation of the Class-Based Storage (CBS) method successfully reduces picking distances, thereby increasing the efficiency of material retrieval operations at the Jajar Warehouse of PT PLN (Persero) UP3 Surakarta. The formula used to calculate picking distance is as follows.

$$TJP = \sum_{i=1}^{n} (d_i \times f_i)$$

Legend:
TJP = Total Picking Distance (meters) d_i = Distance from material storage location to the I/O point (meters) f_i = Material retrieval frequency n = Number of materials

Based on this formula, the total picking distance is obtained by multiplying the distance from each material's storage location to the Input/Output (I/O) point by the material retrieval frequency during the study period. Calculations were performed for both the existing and proposed conditions to determine the change in total travel distance following the implementation of the Class-Based Storage (CBS) method. The following is an example calculation of the total picking distance for one specific material.

For the material "BOX;APPIII COMPLETE;ST PLATE 2mm" in the existing layout, the following data was obtained:

Distance from storage location to I/O point = 11 meters
Retrieval frequency = 448 times

Thus, the total picking distance is calculated as follows:
TJP = d × f
= 11 × 448
= 4,928 meters

Therefore, the total picking distance for the material "BOX;APPIII COMPLETE;ST PLATE 2mm" under the existing condition is 4,928 meters.

Meanwhile, for the material "BOX;APPIII COMPLETE;ST PLATE 2mm," the following data was obtained after the layout revision:

Proposed distance = 4 meters
Picking frequency = 448 times

Thus, the total picking distance after the layout revision is:
TJP = d × f
= 4 × 448
= 1,792 meters

Therefore, the total picking distance for the material "BOX;APPIII COMPLETE;ST PLATE 2mm" in the proposed layout is 1,792 meters.

The same calculation was performed for all materials included in the study, for both the existing and proposed conditions. The calculation results were then summarized to obtain the total picking distance for each condition. Finally, the total picking distances for the existing and proposed layouts were compared to determine the extent of the reduction in material travel distance following the implementation of the Class-Based Storage (CBS) method.

Table 2. CBS Calculation

No	Material Name	Picking Frequency	Existing Distance (m)	Total Existing (m)	Proposed Distance (m)	Total Proposed (m)
1	BOX;APPIII COMPLETE;ST PLATE 2mm;	448	11	4928	4	1792
2	BOX;APP TR;;6.6-41.5KVA	276	11	3036	4	1104

3	CABLE PWR;NFA2X;2X10mm2;0.6/1k V;OH	1313220	9	11818980	5	6566100
4	CABLE PWR;NFA2X;2X10mm2;0.6/1k V;OH	1313220	10	13132200	6	7879320
5	CABLE PWR;NFA2XT;3X70+1X70;0.6/1kV;OH	168004	10	1680040	6	1008024

Table 2 displays only a portion of the total picking distance calculation results to illustrate the data presentation. The calculations were performed for all 129 materials included in the study using the same procedure. The complete calculation results are presented in Appendix A, while the total picking distances obtained for all materials serve as the basis for the comparative analysis between the existing and proposed conditions. Following these calculations, the next step is to determine the percentage reduction in picking distance using the following formula:

$$Efisiensi = \frac{TJP_{existing} - TJP_{usulan}}{TJP_{existing}} \times 100\%$$

$$= \frac{41.074.213 - 25.199.026}{41.074.213} \times 100\%$$

$$= 38{,}65\%$$

Based on the calculations, the total picking distance under existing conditions was 41,074,213 meters, whereas after implementing layout improvements using the ClassBased Storage (CBS) method, it was reduced to 25,199,026 meters. This represents a reduction in total picking distance of 15,875,193 meters (or 38.65%), demonstrating that the proposed layout enhances the efficiency of the warehouse material retrieval process compared to the previous setup.

The study results indicate that applying the Class-Based Storage method reduces total picking distance because materials with high movement frequency are positioned closer to the I/O area. This placement eliminates the need for operators to travel excessive distances during retrieval, thereby making picking activities more efficient. These findings align with research on storage layout optimization using the Class-Based Storage method, which confirms that the method reduces material travel distance by positioning materials according to their activity levels.

CONCLUSION

Based on the research findings regarding the optimization of material storage layout using the Class-Based Storage method at PT PLN (Persero) UP3 Surakarta, the following conclusions can be drawn:

1. Based on the ABC analysis, the 129 types of materials studied were categorized into classes A, B, and C according to their movement frequency during the period of January–December 2024. These classification results served as the basis for

prioritizing material placement within the warehouse, allowing the layout to be aligned with the activity level of each material.

2. The application of the Class-Based Storage (CBS) method resulted in a proposed new layout for the indoor, semi-outdoor, and outdoor warehouse areas. In the proposed layout, Class A materials are placed closest to the Input/Output (I/O) area due to their high movement frequency, while Class B materials are positioned in the central area, and Class C materials are located further away. This arrangement was designed by considering both the ABC classification results and warehouse operational conditions to ensure a more organized flow of material movement.
3. Calculation results indicate that implementing the Class-Based Storage (CBS) method improves the efficiency of the material retrieval process at the Jajar Warehouse of PT PLN (Persero) UP3 Surakarta. The total retrieval distance under existing conditions was 41,074,213 meters, whereas after the layout improvement, it was reduced to 25,199,026 meters. Consequently, there was a 38.65% reduction in total retrieval distance, successfully achieving the research objective of minimizing retrieval distance through the application of the Class-Based Storage (CBS) method.

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