Enhancing Storage Efficiency with Class-Based Storage Design: A Lubricant Drum Warehouse Study at PT Patra Logistik

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ABSTRACT

Efficient storage is a critical aspect of warehouse management, particularly in industries constrained by limited space, such as lubricant drum storage. PT Patra Logistik, a third-party logistics (3PL) provider for PT Pertamina Lubricants, has faced inefficiencies in its warehouse operations due to an unstructured storage system. The current use of a random storage method has led to increased travel distances for goods movement, difficulty in locating products, and overall layout disorganization. This study aims to redesign the warehouse layout using the Class-Based Storage (CBS) method to minimize the travel distance involved in the picking and storing of goods. The research employed field observations, interviews, and analysis of historical goods movement data from the April-June 2024 period. ABC Analysis was utilized to classify products based on the frequency of inbound and outbound movements. These classifications served as the foundation for developing a more efficient warehouse layout. The results indicate that implementing the CBS method significantly reduced the total travel distance from 164,625 meters to 78,609 meters, a reduction of 86,015 meters. This improvement enhanced operational efficiency by decreasing retrieval time, increasing labor productivity, and optimizing storage space utilization. Furthermore, validation of the new layout design revealed strong support from respondents, with the majority agreeing or strongly agreeing with the proposed system.

1. INTRODUCTION

Storage efficiency is a critical aspect of warehouse management, especially in industries with limited storage capacity, such as lubricant drum warehouses. Warehouses play a key role in logistics operations by storing raw materials, semi-finished goods, and finished products before distribution. Effective warehouse management enhances operational performance through optimal use of space, equipment, and labor. Additionally, a well-planned warehouse layout improves accessibility, protects materials, and minimizes travel distances within the facility [1], [2].

For warehouses operating under constrained capacity, implementing an optimal storage strategy is essential to maximize space utilization and operational efficiency. Strategically placing each item in its most suitable location not only conserves valuable space but also enhances the speed and accuracy of picking and replenishment activities [3]. This improved flow of goods directly contributes to faster order processing and reduced labor costs. As market demands continue to rise, driven by expectations for rapid delivery and precise order fulfillment, that is the need for efficient storage and distribution processes becomes even more critical. Adopting data-driven placement strategies, such as ABC analysis or slotting optimization, can further support high-performance warehouse operations by aligning inventory positioning with demand frequency and handling characteristics [4], [5].

This research was conducted at DSP Plumpang, specifically within the Storage section of PT Patra Logistik. PT Patra Logistik is a logistics service provider specializing in truck transportation, warehousing and distribution, customs clearance, value-added services, and a range of other integrated logistics solutions. One of its key operations involves managing a lubricant warehouse owned by PT Pertamina Lubricants, where PT Patra Logistik serves as a third-party logistics (3PL) provider. The warehouse handles a variety of lubricant products including oils and greases derived from petroleum, synthetic compounds, and recycled materials, prior to their distribution to customers. PT Patra Logistik operates two main types of warehouses within this facility: lithos warehouses and drum warehouses. Lithos warehouses are enclosed with storage spaces used to store lubricants in boxes or stacks. In contrast, the drum warehouses are organized into 23 individual shelter units: 18 designated for local drum products, 1 for Intermediate Bulk Container (IBC) products, and 4 reserved for non-conforming goods that do not meet standard quality requirements.

Currently, the company employs a Dedicated Storage system, where each product type is assigned a fixed storage location. While this method offers simplicity and ease of organization, it has led to several operational inefficiencies. When a designated shelter reaches full capacity, excess inventory is redirected to alternate shelters. This overflow disrupts the intended storage flow, increases retrieval times, and complicates inventory tracking, ultimately reducing the overall efficiency of warehouse operations. These challenges highlight the need to reassess and potentially optimize the existing storage strategy to accommodate fluctuating inventory volumes more effectively.

This problem is primarily driven by the high volume of daily inbound goods and the fluctuating nature of customer demand. Although the Dedicated Storage method was originally adopted to streamline warehouse layout, group similar goods systematically, reduce travel time, and maximize space utilization, its effectiveness diminishes under dynamic and variable operational conditions. In practice, the fixed allocation of space restricts flexibility, leading to overflow issues and inefficient storage when shelters reach capacity. As a result, the intended benefits are not fully realized, particularly in high-turnover environments such as PT Patra Logistik's lubricant drum warehouse. Figure 1 below presents a comparative diagram that illustrates the limitations of the Dedicated Storage system as currently implemented, highlighting inefficiencies in space usage, item accessibility, and adaptability to volume fluctuations.

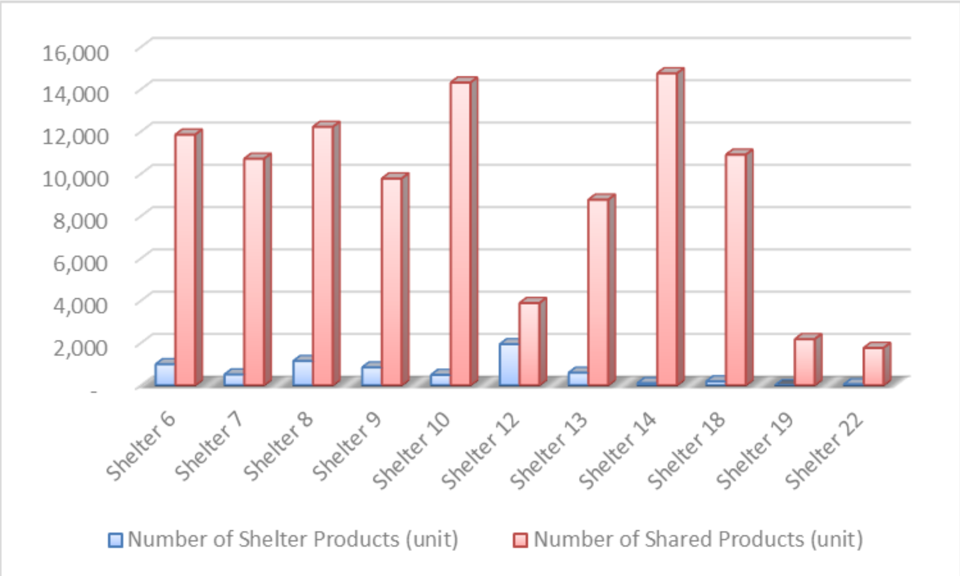

Fig. 1. Monthly comparison of dedicated and non-dedicated goods in the shelter warehouse (Jan-July 2024)

Figure 1 illustrates the comparison between the number of drums stored using the dedicated storage method and items temporarily placed in other shelters (not dedicated) over the past six months. The data shows that the number of items allocated to dedicated storage only reached 8,356 drums, which is significantly less than the 14,751 drums placed temporarily (shared). This disparity is particularly evident in Shelter 14, which recorded the highest number of non-dedicated items. This indicates that the implementation of the dedicated storage method, which is intended to assign each item a fixed and unchanging location in the warehouse [6], is not functioning as intended. Products that are supposed to be dedicated do not have fixed storage locations. Field surveys and interviews with warehouse supervisors revealed that dedicated storage is not effectively applied because some warehouses lack the capacity to accommodate all the products. As a result, the excess products are moved to other warehouses.

Consequently, incoming items are often placed randomly in available empty spaces, without any fixed storage locations. Moreover, the picking process focuses only on items that are visible or placed at the front, without considering stock rotation or systematic placement. This is further exacerbated by the absence of a Warehouse Management System (WMS), as inventory is still recorded manually. As a result, the actual storage practice is not dedicated storage, but rather random storage. This leads to several negative consequences, such as incorrect item shipments, accumulation of expired products, and damage to items due to poor organization, such as leaks, dents, or breakage. In addition, the lack of clear zoning in the storage system causes difficulties in stock management, especially in the identification and retrieval processes. This increases the risk of errors in drum selection and prolongs operational time, as workers must search for items manually.

Another issue identified is the overcrowded arrangement of drums, which are placed too closely together and stacked all the way to the back of the warehouse. As a result, forklifts can only access the drums located at the front. This makes it difficult to reach drums stored at the back, especially when a specific drum is urgently needed. Consequently, the retrieval process becomes inefficient because workers must first move the front drums to access those in the back. If the drums are not properly sorted, the process of retrieving items with a forklift can take up to one hour. Moreover, excessive storage density without proper access pathways can hinder air circulation inside the warehouse, potentially affecting the physical condition of the drums in the long term.

In this study, the selection of Shelter 14 as the primary observation site is strongly justified. Shelter 14 has the highest number of shared (borrowed) products, totaling 14,751 units, while its own shelter products account for only 97 units. This stark difference indicates that Shelter 14 experiences a significant accumulation of shared products, which can lead to disorganized storage and difficulties in accessing items. The high number of shared products also negatively impacts space management, where products belonging to the shelter that should have priority are displaced by others. This may result in bottlenecks in the distribution process, increase the risk of stock retrieval errors, and hinder overall warehouse operational efficiency.

The Class-Based Storage (CBS) method is considered the most appropriate for use in this study. The selection of CBS is one of the strategies employed to optimize warehouse storage layout. Class-Based Storage groups items based on specific characteristics such as turnover rate, size, and picking frequency [7]. By categorizing items in this way, the warehouse can place high-frequency products closer to picking points or main operational areas. This enables warehouse operators to reduce travel time and effort in handling frequently accessed items, thereby improving overall warehouse operational efficiency [8]. By organizing goods based on their usage frequency and patterns, space within the warehouse can be managed more efficiently, maximizing capacity without requiring physical expansion. The use of CBS is expected to reduce item accumulation in inappropriate areas, maintain orderly storage, and ease access to frequently picked goods [9].

Additionally, more structured item arrangements simplify inventory management and minimize the risk of picking errors. Beyond item categorization, the CBS method also takes accessibility into account to minimize operational disruptions. Frequently picked items are placed near doors or main pathways, while items with lower usage frequency are stored in more distant areas. This arrangement reduces congestion in picking areas, speeding up distribution processes and enhancing warehouse worker productivity [10]. It also supports workplace safety by lowering the risk of accidents within the warehouse. Class-Based Storage is also advantageous in terms of storage efficiency. In a competitive industry, a warehouse's ability to respond quickly to demand is a crucial advantage. CBS allows companies to accelerate order processing without significant investment in physical warehouse expansion. With strategic item placement, companies can fulfill customer orders faster, ultimately increasing their competitiveness [11].

2. METHOD

This study employs a systematic research methodology combining both qualitative and quantitative approaches to develop a comprehensive understanding of the challenges and opportunities in optimizing warehouse storage at PT Patra Logistik. The research methodology is structured into several key phases, each designed to support the formulation of effective storage solutions, as can be seen in Figure 2.

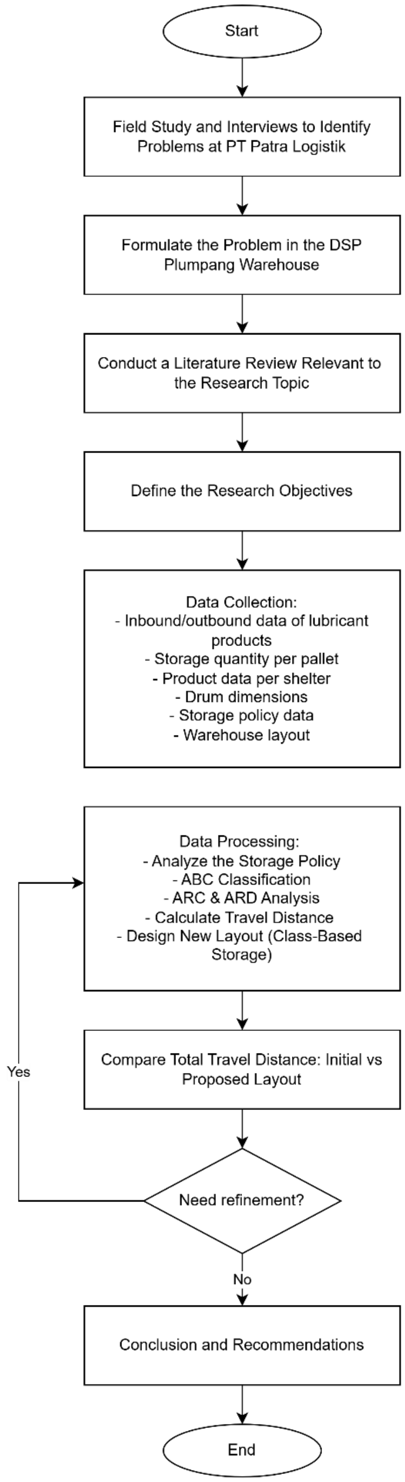

Fig. 2. Research methodology

The first stage involves field observation and interviews to identify real-world issues within the lubricant drum warehouse. Direct engagement whose mailny in charge of the site and staff allowed the researchers to uncover inefficiencies, such as overstocking, poor shelter management, and ineffective storage systems. Systematic interview was arranged according to main activities in a warehouse revolve around the efficient handling, storage, and movement of goods to support the supply chain. These activities ensure that products are received, stored, managed, and dispatched accurately and on time.

This is followed by the formulation of the core research problem specific to the DSP Plumpang warehouse. Identified issues include suboptimal space utilization, inefficient material flow, and difficulty accessing inventory due to a poorly designed layout. To address these issues, a literature review was conducted to explore the best practices and relevant methodologies for warehouse layout optimization. This review highlighted the suitability of methods such as Class-Based Storage (CBS) and ABC analysis, which offer structured approaches to organizing inventory based on product characteristics. Based on these insights, the objective was defined: to improve warehouse layout efficiency by increasing storage capacity, reducing travel distances, and implementing a class-based storage strategy.

The data collection phase gathered essential operational data, including three months of inbound and outbound product records, pallet-level inventory data, product dimensions, current storage policies, and the existing warehouse layout. This data was then processed and analyzed to gain insights into current storage practices, item movement patterns, and areas of inefficiency. Following data analysis, the study examined the warehouse's current storage policy to determine whether it meets efficiency standards. Where weaknesses were identified, alternative strategies were proposed. One key step was classifying lubricant products using the ABC method, which organizes inventory into Class A (high value and turnover), Class B (moderate), and Class C (low), facilitating strategic item placement based on movement and importance.

To support layout design, Activity Relationship Charts (ARC) and Activity Relationship Diagrams (ARD) were developed. These tools helped map operational interdependencies and identify high-activity zones within the warehouse. The study also calculated travel distances for material handling, using aisle-based measurement methods, to quantify the inefficiency of the current layout. Based on these insights, a new layout was proposed using the Class-Based Storage method. High-frequency items were placed in more accessible areas, while low-frequency items were assigned to less active zones. The proposed layout was then compared to the existing one by evaluating total travel distances. A reduction in movement indicated improved efficiency.

Finally, the design was validated by assessing whether the new layout significantly enhanced operational performance. If the results confirmed improvement, the proposed layout was deemed valid. If not, the layout was subject to revision. The research concluded with a summary of findings and actionable recommendations for PT Patra Logistik, offering practical steps to improve warehouse storage efficiency and support better operational outcomes.

3. DATA COLLECTION

Data for this research was gathered through direct observation and interviews with warehouse personnel at Plumpang, PT Patra Logistik. Quantitative data was collected from relevant documents, while a data-based questionnaire was used in combination with interviews conducted with key stakeholders. The study focused on a single warehouse, Shelter 14, which was selected because, under the company's dedicated storage system, this warehouse stores more products from other warehouses than its own. Additionally, the suboptimal layout design has led to random storage practices, where items are placed arbitrarily, resulting in many unused spaces. This negatively impacts the warehouse's operational efficiency, particularly in terms of item movement and storage processes.

The collected data supports the implementation of the class-based storage method, with a primary parameter being the travel distance involved in picking and storing goods. The data includes the quantity and types of products stored, the storage location of each item within the warehouse, and the movement patterns of the goods. This information enables analysis aimed at optimizing the storage system to improve space efficiency and minimize travel distance during warehouse operations.

The lubricant products stored in drum form at the shelter warehouse over a three-month period (April–June 2024) are generally uniform in type and size, with the main differences being the volume of the drum contents and the drum dimensions for grease lubricants. Most lubricant drums have a capacity of 200 liters and 209 liters, while grease lubricants come in a different size, specifically 178 kg. Lubricants in 200-liter drums include the following products: Turalik V 52, Turalik V 48, Turalik V 43, Pertamina Chain Fresh, Turalik KT 46, Turbolube 100, Turalik V 41, Translik HD 50, GC Lube SYN 150, Turalik V 69, and GC Lube MN 32. Meanwhile, lubricants in 209-liter drums include: Meditran S Min 40 CF-2/SF, Turalik 52 Min 68, Meditran SX Min 15W-40 CH4, Meditran S Min

10W CF-2/SF, Meditran S-30, Meditran SX Plus 15W-40 CI4, Meditran SXV 15W-40, Meditran SC Min 15W-40 CF4, Rored HDA Min 90 GL-5, Diloka 448 X Min 40, Rored EPA Min 80W-90 GL-4, Medipral 450 Min 40, Rored Transmission Oil 80W DMTF, and Fastron Super 20W-50 AUS API SL/CF.

The Material Handling Equipment (MHE) used by the company consists of only one type: a Toyota forklift, specifically from the Toyota 8FG/8FD series. This forklift operates on LPG fuel, as indicated by the gas cylinder mounted at the rear of the unit. This type of forklift is widely used in the logistics and warehousing industry due to its strong lifting capacity and fuel efficiency. Additionally, its compact design allows for optimal mobility within limited storage space. The use of this forklift enables faster and more efficient handling of lubricant drums, thereby supporting smooth operations at Warehouse Shelter 14.

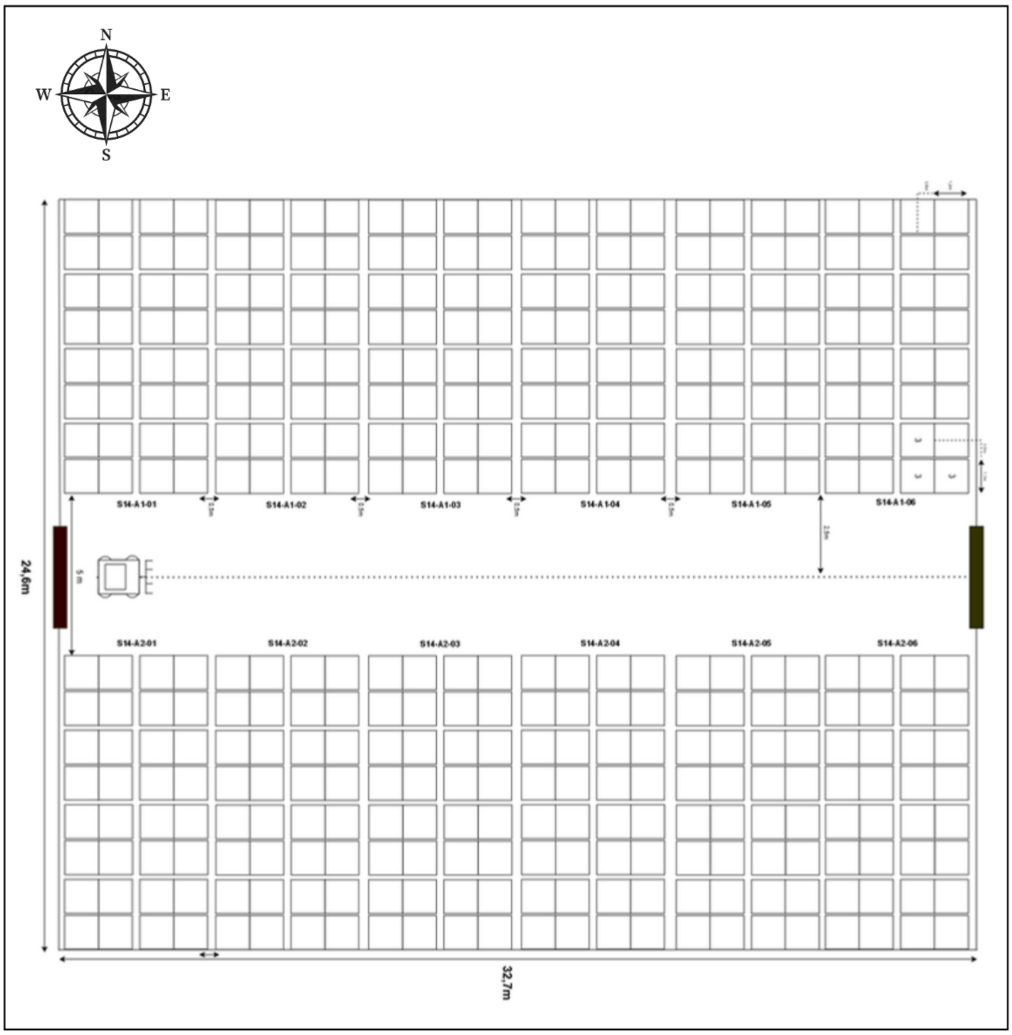

Fig. 3. Initial warehouse dimensions

The Drum Warehouse uses four-way plastic pallets as the primary storage medium, as they are considered more economical compared to wooden or metal pallets. However, there are certain cases where wooden pallets are used based on customer requests. Plastic pallets are also chosen to avoid the risk of rotting or rusting. Each pallet has dimensions of 120 cm x 100 cm and can hold up to 4 lubricant drums. Despite being made of plastic, these pallets are still capable of supporting heavy material loads effectively.

Block stacking is a commonly used storage method in warehouses for storing large quantities of goods without the need for specialized racking. In this study, block stacking is applied in the lubricant drum warehouse using an efficient storage configuration. Each pallet is designed to hold four lubricant

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drums, and the drums are stacked vertically up to three levels. Thus, a single stack consists of 12 lubricant drums (4 drums per level × 3 levels).

The data used in this study includes inbound and outbound records of lubricant drums stored in Shelter 14. The data was collected based on material receipt and usage activities over a three-month period, from April to June 2024. The focus on lubricant drum products in Shelter 14 was chosen to provide a more specific analysis of material flow at that storage location. The three-month timeframe was selected to ensure broader and more representative data coverage, capturing both regular and peak operational fluctuations. This period is considered sufficient to reflect typical warehouse activity patterns, identify storage issues, and observe trends in product movement, without introducing seasonal bias or requiring excessively long observation periods that could delay actionable insights.

The following is a visualization of the lubricant drum warehouse layout at Shelter 14 in Plumpang, as shown in Figure 3. The warehouse is used to store lubricant drums, with warehouse dimensions of 32.7 x 24.6 meters. In the layout shown above, since the storage system applied is random, the company only provides the warehouse layout when it is fully occupied, with a total of 1,152 pallet positions.

4. RESULT AND DISCUSSION

4.1. Classification Calculation Based on ABC Analysis

This analysis is based on historical data of inbound and outbound movement of spare parts during the period January to June 2024. The historical data provides an accurate picture of the frequency and volume of movement for each lubricant drum, which is then used as the basis for classifying the drums into three main categories: A, B, and C, according to the ABC Analysis method. The total percentage for each category is calculated based on the maximum percentage reference for the requirements of each class. These maximum percentage references are based on the study by [12]:

1. Total percentage for Class A: < 80%
2. Total percentage for Class B: < 15%
3. Total percentage for Class C: < 10%

To calculate the percentage of drums, the following formula (1) can be used.

$$Percentage\ value = \frac{F_i}{F_{total}} \times 100\% \quad (1)$$

In which:

F_i = Inbound and outbound frequency of drum i

F_{total} = Total overall inbound and outbound frequency of all drumsx

After calculating the percentage for each lubricant drum, the next step is to determine the class of each drum product. The results are presented in Table 1 below, showing the recapitulation of drum classification.

Table 1. Drum Classification

No.	Total Lubricant Drums	Class	Percentage
1	7	A	19%
2	5	B	14%
3	24	C	67%
Total	36	-	100%

4.2. Travel Distance Calculation

The travel distance calculation in this study aims to analyze the efficiency of material movement within the warehouse both from production to storage and from storage to the shipping area. Travel distance is measured based on the location of stored items relative to the warehouse's entry or exit points, as well as the frequency of material movement [13].

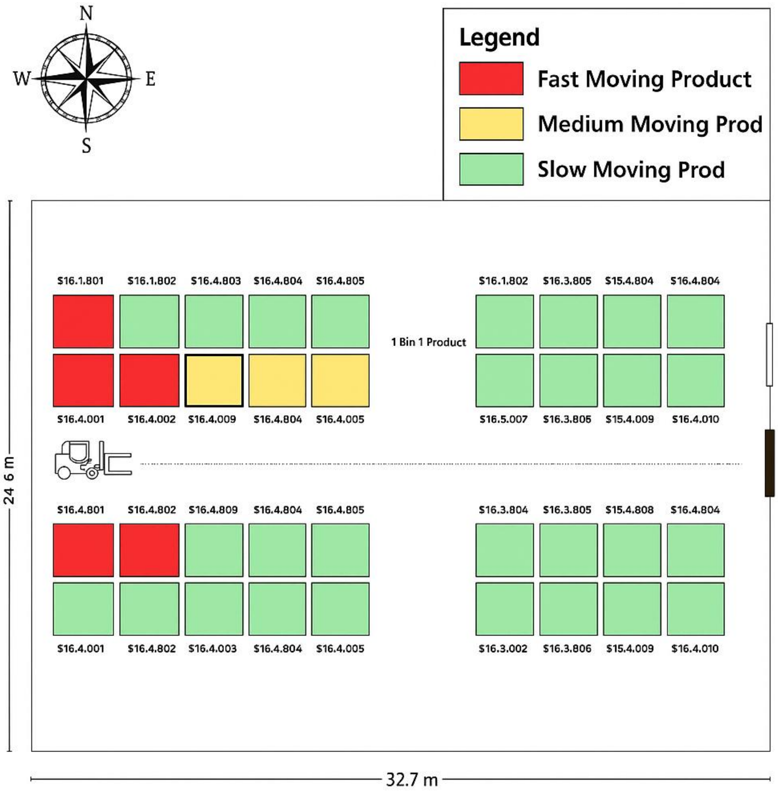

Fig. 4. Warehouse layout after classification

4.3. Calculation of Degree of Closeness Between Areas

The Activity Relationship Chart (ARC) analysis requires a closeness rating between areas to determine the optimal layout configuration. In this study, five key areas are analyzed: fast-moving storage, medium-moving storage, slow-moving storage, staging area (for goods placement), and the exit door. The importance of the relationships between these areas was assessed based on interviews and questionnaires conducted with three individuals directly involved in warehouse operations.

These respondents were selected due to their direct roles and responsibilities related to the management and storage of lubricant drums in the warehouse. The Assistant Supervisor of the Lubricant Drum Warehouse oversees all operational activities within the warehouse. He has been working in the warehouse for 25 years. His role gives him a comprehensive understanding of storage management, distribution processes, and safety procedures involved in handling lubricant drums. The Inventory Administrator oversees recording, monitoring, and managing inventory data related to the lubricant drums. His responsibility in maintaining data accuracy makes him a key source for understanding how inventory flows and is controlled within the facility. Meanwhile, Checker in Drum Shelter 14, is responsible for inspecting and verifying the physical condition and quantity of drums entering and leaving the warehouse. His position provides valuable insights into quality control and safety practices during storage and handling.

The results from these interviews are presented in Tables 2, 3, and 4. To assign closeness ratings between areas, a numerical scale from 1 to 6 was used, with each number representing a specific level of relationship:

- 1: the two areas must be far apart
- 2: the two areas can be far apart (no preference)
- 3: acceptable if not too close
- 4: better if located close together
- 5: should be close if possible
- 6: must be close

The scores provided by each respondent were then averaged to produce the final ARC code, which categorizes area relationships using the following classifications:

- A (Absolutely Necessary): must be located together
- E (Especially Important): very important to be close
- I (Important): preferable to be close
- O (Ordinary): ordinary closeness is acceptable
- U (Unimportant): not necessary to be close
- X (Undesirable): should be kept apart

These final ARC codes are presented in Table 5 and serve as the foundation for developing an efficient warehouse layout that supports operational efficiency and safety.

Table 2. Assistant Supervisor of the Lubricant Drum Warehouse

Area	Storage Fast-Moving	Storage Medium-Moving	Storage Slow-Moving	Staging Area (Goods Placement)	Exit Door
Storage Fast-Moving	X	5	5	6	6
Storage Medium-Moving	5	X	6	3	5
Storage Slow-Moving	5	6	X	2	2
Staging Area (Goods Placement)	6	3	2	X	6
Exit Door	6	5	2	6	X

Table 3. Inventory Administrator of the Lubricant Drum Warehouse

Area	Storage Fast-Moving	Storage Medium-Moving	Storage Slow-Moving	Staging Area (Goods Placement)	Exit Door
Storage Fast-Moving	X	5	4	6	5
Storage Medium-Moving	5	X	6	3	2
Storage Slow-Moving	4	6	X	3	2
Staging Area (Goods Placement)	6	3	3	X	6
Exit Door	5	2	2	6	X

Table 4. Warehouse Checker for Drum Shelter 14

Area	Storage Fast-Moving	Storage Medium-Moving	Storage Slow-Moving	Staging Area (Goods Placement)	Exit Door
Storage Fast-Moving	X	6	5	6	6
Storage Medium-Moving	6	X	6	3	5
Storage Slow-Moving	5	6	X	2	2

Staging Area (Goods Placement)	6	3	2	X	6
Exit Door	6	5	2	6	X

Table 5. Average Value of Closeness Ratings

Area	Storage Fast-Moving	Storage Medium-Moving	Storage Slow-Moving	Staging Area (Goods Placement)	Exit Door
Storage Fast-Moving	X	5	5	6	6
Storage Medium-Moving	5	X	6	3	5
Storage Slow-Moving	5	6	X	2	2
Staging Area (Goods Placement)	6	3	2	X	6
Exit Door	6	5	2	6	X

4.4. Analysis and Calculation of the Activity Relationship Chart and Activity Relationship Diagram

The analysis of the Activity Relationship Chart (ARC) and Activity Relationship Diagram (ARD) is used to determine the optimal layout based on the degree of interrelationship between activities, which include storage areas (fast-moving, medium-moving, and slow-moving), staging, and the exit door. The ARC is used to identify degree of closeness relationships based on factors such as transfer frequency, safety, and operational efficiency, while the ARD visualizes these relationships to facilitate the development of an optimal layout. The closeness degree values in the Activity Relationship Chart (ARC) are assigned based on specific considerations. Each level of interrelationship is determined by factors that influence warehouse efficiency and safety. The codes and corresponding justification used in the ARC analysis are presented in Table 6, which outlines the rationale for determining the degree of closeness between activities in the warehouse layout.

Table 6. Justification Codes for Assigning Closeness Ratings Between Areas

Code	Reason Description
1	Sequence of Workflow
2	Facilitates Material Movement
3	Uses the Same Employees
4	Shares the Same Equipment
5	Shares the Same Work Records
6	Uses the Same Space
7	Work Efficiency

Source: [14], [15]

The values obtained in the ARC analysis were derived from interviews conducted with 3 respondents in the previous stage. Based on the analysis of the justifications provided and ratings, the result of the ARC analysis is illustrated in Figure 5. The results of the Activity Relationship Chart (ARC) analysis will serve as a reference for the Activity Relationship Diagram (ARD) analysis, which aims to provide a more detailed overview of the layout of each area based on the level of closeness. The visualization of the ARD analysis results related to the proposed layout of the lubricant drum warehouse at Shelter 14 can be seen in Figure 6.

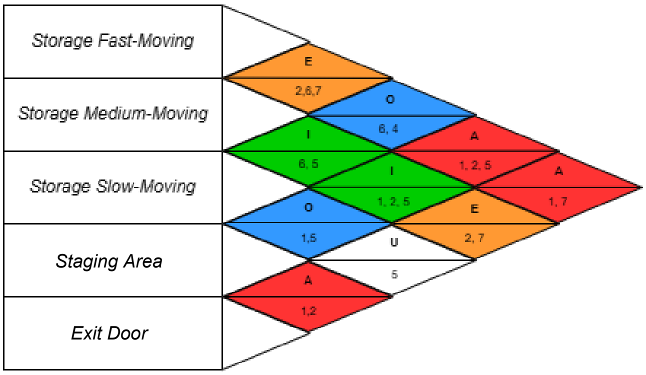

Fig. 5. Activity Relationship Chart (ARC)

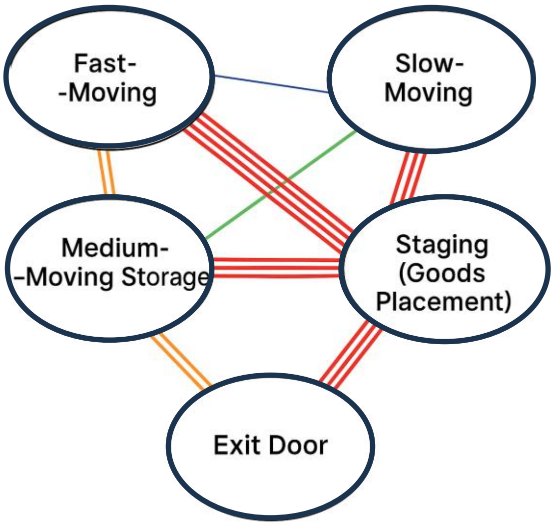

Fig. 6. Activity Relationship Diagram (ARD)

The layout illustrated in Figure 7 represents the warehouse of PT Patra Logistik, which has been visualized using the class-based storage method by considering the highest frequency of material movement. As shown, the initial warehouse layout has been reorganized into three product classes: A, B, and C. Class A consists of fast-moving items with the highest frequency of movement, Class B includes medium-moving items with moderate movement frequency, and Class C represents slow-moving items with the lowest frequency of movement. The warehouse stores a total of 36 different products, each allocated to a specific bin. Each bin has a capacity of 96 pallets and can store up to 384 drums. This change in warehouse layout is aimed at improving the efficiency of product retrieval and has been adjusted based on warehouse data collected over a three-month period, from April to June 2024.

4.5. Validation of the Proposed Warehouse Layout

The validation of the proposed layout design was conducted to ensure that the suggested configuration can solve the existing issues in the Shelter 14 warehouse. This validation process was carried out through a survey using a questionnaire. The respondents selected for this survey were 3 individuals directly involved in warehouse operations, thus able to provide relevant and insightful feedback.

The selection of respondents was based on their roles in material management and storage in the warehouse. The inventory administration, supervision, and inspection divisions hold direct responsibility over the flow of goods and the optimization of the storage layout. Therefore, their opinions are a crucial aspect in ensuring that the proposed layout design can be implemented effectively. The list of questions used in the questionnaire is shown in Table 7.

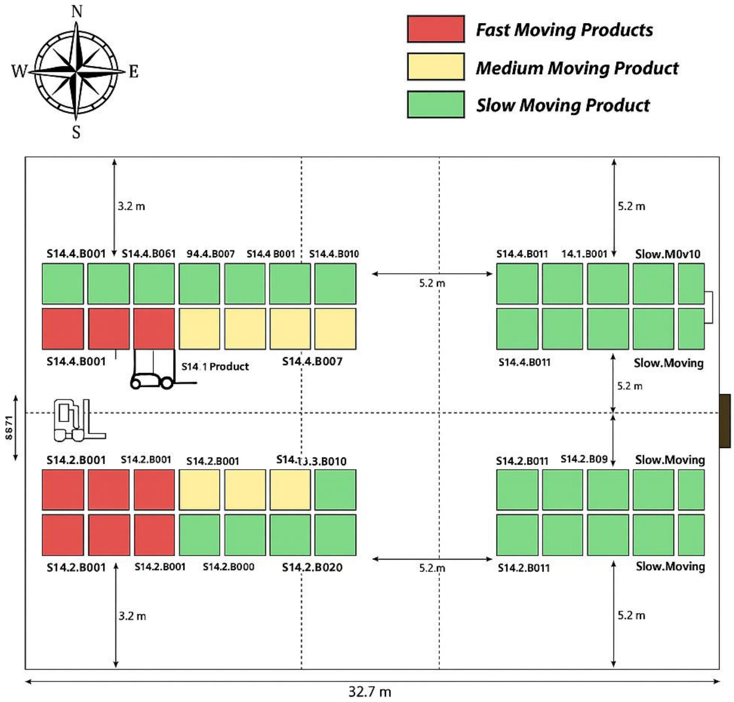

Fig. 7. Visualization of the proposed warehouse layout for Shelter 14

Table 7. List of Questions for the Validation of the Proposed Layout of Shelter 14 Warehouse

No.	List of Questions
1	The change from random storage to class-based storage will improve warehouse efficiency.
2	The warehouse layout change will reduce errors in item picking.
3	I agree that products should be grouped based on demand levels (ABC Analysis).
4	With the new layout, the travel distance for item picking will be faster.
5	Do you agree that Fast-Moving products (Class A) should be placed closer to the door?
6	Do you agree that Medium-Moving products (Class B) should be placed near the Fast-Moving items, but slightly farther from the door?
7	Do you agree that Slow-Moving products (Class C) should be placed farther from the door?
8	Do you agree that each bin should contain only one type of product?

The questionnaire was developed using a Likert scale to evaluate the level of agreement of respondents regarding the proposed warehouse layout design. The Likert scale is a widely used method for measuring individual opinions and perceptions toward specific statements. In this study, respondents were asked to respond to each statement based on their level of agreement, using a scale ranging from 1 to 5. A score of 1 indicates strong disagreement, while a score of 5 represents strong agreement. This approach enables the collection of quantifiable data reflecting respondent perceptions, which can then be used to assess the feasibility and effectiveness of the proposed layout.

Based on the survey results presented in the table, it can be concluded that most respondents gave positive feedback toward the proposed warehouse layout design. This is evidenced by the absence of any responses in the "Strongly Disagree" (SD) or "Disagree" (D) categories for all five questions asked. Accordingly, all respondents showed an overall tendency to respond between neutral and strongly agree. The distribution of answers indicates a high level of acceptance of the proposed layout, with most respondents selecting the "Agree" (A) and "Strongly Agree" (SA) categories. These results reflect the respondents' confidence that the new layout design will bring significant benefits to warehouse management.

4.6. Warehouse Layout Analysis

The implementation of the Class-Based Storage (CBS) system at PT Patra Logistik followed a structured and data-driven approach designed to improve warehouse efficiency. The process involved several critical stages: data extraction and cleaning, classification of inventory based on historical turnover rates, warehouse zoning, and reallocation of storage space. The warehouse under study measures 32.7 by 24.6 meters and features a designated input/output (I/O) point for the movement of goods. Based on CBS principles, items were grouped into three classes: Class A (Fast Moving), Class B (Medium Moving), and Class C (Slow Moving). These groupings were strategically placed within the warehouse, with Class A items located nearest to the I/O point to minimize travel time and optimize picking efficiency. This layout adjustment was aimed at reducing the total travel distance for order pickers and forklifts during material handling operations.

Throughout the implementation process, several challenges emerged. One of the most significant was ensuring the accuracy of historical inventory transaction data, which required extensive preprocessing to eliminate inconsistencies and outliers. Additionally, integrating the CBS methodology with the company's existing warehouse management system posed operational constraints, particularly in adjusting to new routing patterns and training personnel on the revised layout. Despite these obstacles, the project delivered compelling results. A comparative analysis of travel distances revealed that under the original layout, the total material handling distance was 164,625 meters, while under the CBS layout, this figure was reduced to 78,609 meters. This reflects a reduction of 86,015 meters, approximately 52% demonstrating a dramatic improvement in internal material flow. These results translate directly to operational benefits such as reduced order fulfillment time, lower energy consumption for forklift operations, and decreased labor fatigue.

Beyond these quantitative benefits, the CBS layout also improved space utilization and inventory accessibility. The transition from a random storage system to a more organized, demand-driven model allowed for easier tracking of goods, fewer picking errors, and more predictable traffic patterns within the warehouse. The placement of fast-moving goods near the I/O point minimized congestion and bottlenecks, particularly during peak hours. These improvements contribute to smoother warehouse operations and lay a foundation for scaling logistics capacity in the future.

These empirical findings are strongly supported by recent academic literature, which emphasizes the effectiveness of CBS in optimizing warehouse performance. For example, [16] Pan et al. (2020) stress that CBS, when combined with intelligent layout planning, leads to measurable reductions in travel distances and labor requirements. [17] further demonstrate that CBS policies significantly enhance order picking efficiency in e-commerce and high-volume fulfillment centers, where time is a critical factor. Moreover, the study by [18] provides evidence that real-time data integration with CBS policies can dynamically adjust storage assignments, further amplifying efficiency gains. These studies, drawn from a variety of industrial contexts, consistently report similar trends to those observed at PT Patra Logistik: decreased travel time, improved picking accuracy, and optimized space utilization.

The consistency between this case study and recent literature reinforces the generalizability of CBS as a best practice in warehouse management. It also suggests that CBS can be adapted and scaled across various types of warehouse environments, including traditional, automated, and hybrid systems. For PT Patra Logistik, the success of this implementation provides a strong argument for further digitalization and integration of data analytics into storage strategies. In broader terms, this study contributes to the growing body of evidence that warehouse layout optimization when guided by structured methodologies like CBS can deliver significant operational and economic benefits. Future studies may explore hybrid approaches, integrating CBS with technologies such as warehouse drones or automated guided vehicles (AGVs), to push the boundaries of warehouse efficiency even further.

5. CONCLUSION

The study conducted at PT Patra Logistik reveals that the previous random storage system in Shelter 14 led to several operational inefficiencies, including disorganized item placement, excessive forklift travel distances, and difficulty in locating goods. These issues not only prolonged retrieval times but also increased the likelihood of errors during storage and picking activities. Items were often stacked without a systematic order, leading to underutilized space and challenges in inventory control. To address these problems, the Class-Based Storage (CBS) method was introduced as a structured alternative for warehouse management. This system classifies items based on their movement frequency: Class A (Fast Moving) items are placed in easily accessible locations near the I/O point, while Class B (Medium Moving) and Class C (Slow Moving) items are stored progressively farther away.

The CBS implementation at PT Patra Logistik followed a systematic and data-driven process that included data cleaning, item classification, zoning, and reallocation within the 32.7 by 24.6-meter warehouse. The layout redesign centered around repositioning high-turnover inventory to minimize travel distance and optimize picking efficiency. Despite some challenges particularly in processing historical transaction data and integrating the new system with existing warehouse operations, the implementation was successful. The total material handling distance was reduced from 164,625 meters to 78,609 meters, achieving a distance savings of 86,015 meters, or roughly 52%. This significant reduction contributed to faster order fulfillment, shorter retrieval times, lower forklift energy consumption, and improved workforce productivity.

The benefits extended beyond efficiency metrics. The shift to a class-based system resulted in a more organized and intuitive warehouse layout, decreasing picking errors and improving space utilization. The structured placement of goods made it easier for staff to locate and handle items, enhancing both accuracy and speed. Validation through a respondent survey further confirmed these improvements. Most warehouse workers reported that the changes made their tasks easier and more efficient, expressing strong support for the new layout. Their positive feedback demonstrates that the CBS system is not only effective in theory but also well accepted in practice by operational personnel.

Based on these outcomes, several practical recommendations can be proposed for PT Patra Logistik. First, the company should consider investing in a more robust warehouse management system (WMS) capable of supporting dynamic ABC classification and real-time inventory updates. This would further improve operational visibility and allow the warehouse to respond flexibly to changing demand patterns. Second, it is essential to provide regular training and orientation for warehouse staff to ensure consistent application of the CBS principles and minimize human error during picking and storage. Third, PT Patra Logistik should establish a routine process—perhaps quarterly—for reviewing and updating item classifications based on the latest movement data, ensuring that the CBS model remains aligned with actual inventory behavior. Finally, integrating technology enhancements such as barcode scanning, pick-to-light systems, or mobile handheld devices could further improve picking accuracy and operational speed.

In summary, the implementation of the Class-Based Storage method at PT Patra Logistik has led to demonstrable improvements in warehouse efficiency, accuracy, and staff satisfaction. By combining structured layout design with data-driven classification, the company has addressed key inefficiencies of its previous random storage system. The alignment of these results with contemporary research further supports the scalability and relevance of CBS in modern warehouse environments. Continued refinement and investment in supporting technologies will allow PT Patra Logistik to maintain and expand these operational gains in the future.

While the findings of this study provide valuable insights into the effectiveness of Class-Based Storage (CBS) in improving warehouse efficiency, several limitations should be acknowledged. First, the study was conducted in a single warehouse facility (Shelter 14) within PT Patra Logistik, limiting the generalizability of the results. Different warehouses may have varying layouts, product types, operational constraints, and levels of automation that could affect the implementation and impact of CBS. As such, the outcomes observed in this context may not directly apply to other facilities or industries without adjustment.

Second, the implementation and data collection were carried out within a specific time frame, focusing primarily on historical movement data over a limited period. This snapshot approach may not fully capture seasonal fluctuations, long-term inventory trends, or the evolving nature of demand patterns, which could influence the stability of class assignments over time. Third, the study primarily focused on physical travel distance as the main performance indicator for operational improvement. Although reduced travel distance implies time and energy savings, a comprehensive cost-benefit analysis including factors such as implementation cost, labor productivity, system maintenance, and training, was beyond the scope of this research. Such an analysis would provide a more holistic evaluation of the economic viability of CBS.

Furthermore, the study applied a static classification model based on historical data. In rapidly changing operational environments, a dynamic storage system that continuously updates item classification and placement based on real-time movement data could offer greater flexibility and responsiveness. However, such systems require advanced warehouse management software and additional investment, which were not part of the current study's scope.

Future research should therefore explore the implementation of CBS across multiple warehouse settings to assess scalability and adaptability. Additionally, studies could focus on integrating dynamic storage algorithms supported by real-time data analytics and machine learning to further enhance warehouse responsiveness. Evaluating the financial impact of CBS adoption through detailed cost-benefit analyses would also provide deeper insights into long-term sustainability. Lastly, incorporating qualitative measures such as worker satisfaction, safety, and ergonomics could enrich the understanding of CBS's broader organizational effects.

REFERENCES

[1] I. H. Mohamud, M. A. Kafi, S. A. Shahron, N. Zainuddin, and S. Musa, "The Role of Warehouse Layout and Operations in Warehouse Efficiency: A Literature Review," *Journal Européen des Systèmes Automatisés*, vol. 56, no. 1, 2023.

[2] C. C. Okpala and O. Chukwumuanya, "Plant Layouts'Analysis and Design," *Int J Adv Engg Tech/Vol. VII/Issue III/July-Sept*, vol. 201, p. 206, 2016.

[3] J. C. Duque-Jaramillo, J. M. Cogollo-Flórez, C. G. Gómez-Marín, and A. A. Correa-Espinal, "Warehouse Management Optimization Using A Sorting-Based Slotting Approach," *Journal of Industrial Engineering and Management*, vol. 17, no. 1, pp. 133–150, 2024, doi: 10.3926/jiem.5661.

[4] H.-L. Lin and Y.-Y. Ma, "A New Method of Storage Management Based on ABC Classification: A Case Study in Chinese Supermarkets' Distribution Center," *Sage Open*, vol. 11, no. 2, p. 21582440211023190, 2021.

[5] L. F. Cardona, L. Rivera, and H. J. Martínez, "Analytical Optimization for The Warehouse Sizing Problem Under Class-based Storage Policy," *Ing Cienc*, vol. 12, no. 24, pp. 221–248, 2016.

[6] D. Meldra and H. M. Purba, "Relayout Tata Letak Gudang Barang dengan Menggunakan Metode Dedicated Storage," *Jurnal Rekayasa Sistem Industri*, vol. 4, no. 1, pp. 32–39, 2018.

[7] N. Puspita Anugrawati Hidayat, "Perancangan Tata Letak Gudang dengan Metoda Class-Based Storage Studi Kasus CV SG Bandung," 2012.

[8] A. Yue and S. L. Smith, "Minimizing Robot Digging Times to Retrieve Bins in Robotic-Based Compact Storage and Retrieval Systems," *arXiv preprint arXiv:2312.05338*, 2023.

[9] J. Gu, M. Goetschalckx, and L. F. McGinnis, "Research on Warehouse Design and Performance Evaluation: A Comprehensive Review," Jun. 16, 2010. doi: 10.1016/j.ejor.2009.07.031.

[10] J. J. Bartholdi and S. T. Hackman, "Warehouse & Distribution Science: Release 0.96," *The supply chain and logistics institute*, vol. 30332, 2014.

[11] S. K. C. Tulli, "Warehouse Layout Optimization: Techniques for Improved Order Fulfillment Efficiency," *International Journal of Acta Informatica*, vol. 2, no. 1, pp. 138–168, 2023.

[12] D. Dhoka and Y. L. Choudary, "ABC Classification for Inventory Optimization," *IOSR Journal of Business and Management*, vol. 15, no. 1, pp. 38–41, 2013.

[13] D. Irwansyah, I. Erliana, F. Fahrudin, and M. Alfian, "Measurement of Warehouse Layout at Rice Refinery Using Shared Storage Method," *International Journal of Engineering, Science and Information Technology*, no. 4, 2022, doi: 10.52088/ijesty.v1i4.307.

[14] N. M. Iskandar and I. S. Fahin, "Perancangan Tata Letak Fasilitas Ulang (Relayout) Untuk Produksi Truk Di Gedung Commercial Vehicle (CV) PT Mercedes-Benz Indonesia," *Penelitian dan Aplikasi Sistem dan Teknik Industri*, vol. 11, no. 1, pp. 66–75, 2017.

[15] A. Rachman, D. Widyaningrum, and A. W. Rizqi, "Perancangan Tata Letak Fasilitas Untuk Meminimalkan Jarak Material Handling Pada Pabrik Pupuk Organik PT Petrokopindo Cipta Selaras Dengan Metode ARC dan ARD," *J. Tek. Ind*, vol. 9, no. 1, 2023.

[16] A. Aslan *et al.*, "Smarter Facility Layout Design: Leveraging Worker Localisation Data to Minimise Travel Time and Alleviate Congestion," *Int J Prod Res*, vol. 63, no. 4, pp. 1326–1353, 2025.

[17] R. Manzini, M. Gamberi, A. Persona, and A. Regattieri, "Design of A Class Based Storage Picker to Product Order Picking System," *The International Journal of Advanced Manufacturing Technology*, vol. 32, pp. 811–821, 2007.

[18] J. F. Leon, Y. Li, X. A. Martin, L. Calvet, J. Panadero, and A. A. Juan, "A Hybrid Simulation and Reinforcement Learning Algorithm for Enhancing Efficiency in Warehouse Operations," *Algorithms*, vol. 16, no. 9, p. 408, 2023.